



Corticon

Rule Modeling

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Table of Contents

Introduction to Corticon rule modeling11

Build the Vocabulary.....13

- Construct a Vocabulary from scratch.....15
 - Step 1 Design the Vocabulary.....16
 - Step 2 Identify the terms16
 - Step 3 Separate the generic terms from the specific16
 - Step 4 Assemble and relate the terms16
 - Step 5 Diagram the Vocabulary.....18
 - Step 6 Model the Vocabulary in Corticon Studio.....19
- Populate a Vocabulary from a Datasource.....21
 - Step 1 How Datasources are transformed into a Corticon Vocabulary.....21
 - Step 2 The Vocabulary generation process for RDBMS sources.....22
 - Step 3 The Vocabulary generation process from REST sources.....28
 - Step 4 Verify and update the generated Vocabulary.....32
- Extend a Vocabulary.....33
 - Custom Data Types.....33
 - Domains.....50
 - Support for inheritance.....52
- TestYourself questions for Build the vocabulary.....59

Rule scope and context.....63

- Rule scope.....70
- Aliases.....73
- Scope and perspectives in the vocabulary tree.....74
 - Roles.....76
 - Technical aside.....83
- TestYourself questions for Rule scope and context.....84

Rule writing techniques.....89

- How to work with rules and filters in natural language.....89
- Filters vs conditions.....92
- Qualify rules with ranges and lists.....94
 - Ranges and lists in conditions and filters.....94
 - Ranges and value sets in condition cells.....96
- How to use standard boolean constructions.....109
- How to embed attributes in posted rule statements.....109

How to include apostrophes in strings.....111
 TestYourself questions for Rule writing techniques and logical equivalents.....111

Collections.....113

How Corticon Studio handles collections.....114
 How to visualize collections.....114
 A basic collection operator.....115
 How to filter collections.....116
 How to use aliases to represent collections.....116
 Sorted aliases.....124
 Advanced collection sorting syntax.....127
 Statement blocks.....129
 Using sorts to find the first or last in grandchild collections.....131
 Singletons.....132
 Special collection operators.....135
 Universal quantifier.....135
 Existential quantifier.....137
 Another example using the existential quantifier.....141
 Aggregations that optimize EDC database access.....147
 TestYourself questions for Collections.....148

Rules containing calculations and equations.....153

Terminology.....153
 Operator precedence and order of evaluation.....154
 Datatype compatibility and casting.....156
 Datatype of an expression.....159
 Defeating the parser.....160
 Manipulating datatypes with casting operators.....161
 Supported uses of calculation expressions.....162
 Calculation as a comparison in a precondition.....163
 Calculation as an assignment in a noncondition.....164
 Calculation as a comparison in a condition.....164
 Calculation as an assignment in an action.....166
 Unsupported uses of calculation expressions.....166
 Calculations in value sets and column cells.....166
 Calculations in rule statements.....167
 TestYourself questions for Rules containing calculations and equations.....167

Rule dependency in chaining and looping.....171

Forward chaining.....171
 Rulesheet processing modes of looping.....173
 Types of loops.....174
 Looping controls in Corticon Studio.....178

How to identify loops.....	179
Looping examples.....	182
Determine the next working day when given a date	182
Remove duplicated children in an association	186
How to use conditions as a processing threshold.....	190
TestYourself questions for Rule dependency chaining and looping.....	192
Filters and preconditions	195
What is a filter	195
Full filters.....	197
Limiting filters.....	199
Database filters.....	204
What is a precondition	207
Summary of filter and preconditions behaviors.....	210
Performance implications of the precondition behavior.....	210
How to use collection operators in a filter.....	212
Location matters.....	214
Multiple filters on collections.....	216
Filters that use OR.....	219
TestYourself questions for Filters and preconditions.....	219
How to recognize and model parameterized rules.....	223
Parameterized rule where a specific attribute is a variable or parameter within a general business rule.....	223
Parameterized rule where a specific business rule is a parameter within a generic business rule....	225
How to populate an AccountRestriction table from a sample user interface	226
TestYourself questions for Recognizing and modeling parameterized rules.....	227
How to write rules to access external data.....	229
A scope refresher.....	230
Quick steps for setting up the Cargo sample.....	230
Enable database access for rules using root-level entities.....	231
Test the Rulesheet with database access disabled	232
Test the Rulesheet with database access enabled.....	233
Optimize aggregations that extend to database.....	239
Precondition and filters as query filters.....	240
Filter query qualification criteria.....	240
Operators supported in query filters.....	241
How to use multiple filters in filter queries.....	242
Insert new records in a middle table.....	243
Integrate EDC Datasource data into rule output.....	243
TestYourself questions for how to write rules to access external data.....	244

Logical analysis and optimization.....	245
Test, validate, and optimize your rules.....	245
Scenario testing.....	246
Rulesheet analysis and optimization.....	246
Traditional means of analyzing logic.....	247
Flowcharts.....	248
Test suites.....	250
Validate and test Rulesheets in Corticon Studio.....	253
How to expand rules.....	253
The conflict checker.....	255
The completeness checker.....	259
Logical loop detection.....	265
Test rule scenarios in the Ruletest Expected panel.....	266
How to navigate in Ruletest Expected comparison results.....	266
Review test results when using the Expected panel.....	266
Techniques that refine rule testing.....	270
How to optimize Rulesheets.....	276
The compress tool.....	276
How to produce characteristic Rulesheet patterns.....	278
Compression creates sub-rule redundancy.....	281
Effect of compression on Corticon Server performance.....	281
Precise location of problem markers in editors.....	282
TestYourself questions for Logical analysis and optimization.....	282
Advanced Ruleflow techniques and tools.....	285
How to use a Ruleflow in another Ruleflow.....	285
Conditional branching in Ruleflows.....	287
Example of branching based on a Boolean.....	290
Example of branching based on an enumeration.....	295
Logical analysis of a branch container.....	299
How branches in a Ruleflow are processed.....	302
How to generate Ruleflow dependency graphs.....	303
Ruleflow versions and effective dates	309
TestYourself questions for Ruleflow versions and effective dates.....	311
Troubleshooting Corticon Studio problems.....	313
Where did the problem occur.....	314
Use Corticon Studio to reproduce the behavior.....	314
Observe constraint violations or severe errors.....	314
Analyze Ruletest results.....	315
Trace rule execution.....	316
Identify the breakpoint.....	316

At the breakpoint.....317

Partial rule firing.....318

How to initialize null attributes.....319

How to handle nulls in compare operations.....319

Studio license expiration.....321

How to compare and report on Rulesheet differences.....321

TestYourself questions for Troubleshooting rulesheets and ruleflows.....325

Appendix A: Studio properties and settings.....327

Appendix B: Answers to TestYourself questions.....333

TestYourself answers for Building the vocabulary.....334

TestYourself answers for Rule scope and context.....335

TestYourself answers for Rule writing techniques and logical equivalents.....337

TestYourself answers for Collections.....338

TestYourself answers for Rules containing calculations and equations.....339

TestYourself answers for Rule dependency and inferencing.....340

TestYourself answers for Filters and preconditions.....341

TestYourself answers for Recognizing and modeling parameterized rules.....342

TestYourself answers for Writing rules to access external data.....342

TestYourself answers for Logical analysis and optimization.....343

TestYourself answers for Ruleflow versioning and effective dating.....344

TestYourself answers for Troubleshooting rulesheets.....344

Introduction to Corticon rule modeling

This set of topics describes the core of Corticon. Here you construct the logic and patterns in vocabularies that are assembled in rows-and-columns rule sheets where the diverse operators enable spreadsheet layouts of readable rule patterns. The modeling topics are supported by guides to the modeling language and a quick reference to the user-interface's basic tooling functions.

If you are just stepping up to Corticon, you will appreciate the walkthrough pace of the basic and advanced rule modeling tutorials. You get a lot of design and testing done without writing a single line of computer code!

Build the Vocabulary

This section describes the concepts and purposes of a Corticon Vocabulary. You see how to build a Vocabulary from general business concepts and relationships.

Depending on your point of view, a Vocabulary represents different things and serves different purposes. For the rule modeler, the Vocabulary provides the basic elements of the rule language – the building blocks with which business rules are implemented in Corticon. For a systems analyst or programmer, a vocabulary is an abstracted version of a data model that contains the objects used in those business rules implemented in Corticon.

A vocabulary serves the following purposes:

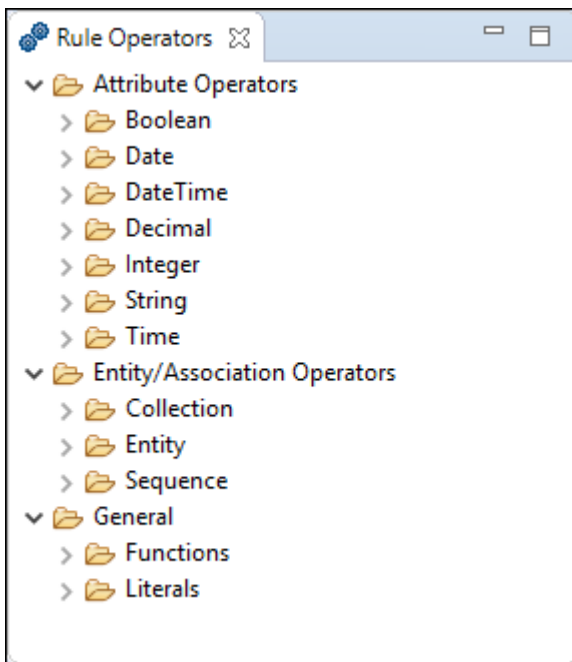
- Provides terms that represent business “things”. Throughout the product documentation, we will refer to these things as *entities*, and properties or characteristics of these things as *attributes*. Entities and their attributes in underlying data sources (such as tables in a relational database or fields in a user interface) can be represented in the Vocabulary.
- Provides terms that are used to hold temporary or *transient* values within Corticon (such as the outcome of intermediate derivations). These entities and attributes usually have a business meaning or context, but do not need to be saved (which we will also refer to as *persisting*) in a database, or communicated to other applications external to Corticon. An example of this might be the following two simple computational rules:

1. `itemSubTotal` is equal to the product of `itemCount` and `itemPrice`
2. `orderTotal` is equal to the sum of all `itemSubTotals`

In these two rules, `itemSubTotal` is the intermediate or transient term. We may never use `itemSubTotal` by itself; instead, we may only create it for purposes of subsequent derivations, as in the calculation of `orderTotal` in rule #2. Since a transient attribute may be the result of a very complicated rule, it may be convenient to create a Vocabulary term for it and use it whenever rewriting the complex rule would be awkward or unclear. Also see the note on [Transients](#).

- Provides a federated data model that consolidates entities and attributes from various enterprise data resources. This is important because a company's data may be stored in many different databases in many different physical locations. Corticon believes that rule modelers need not be concerned with where data is, only how it is used in the context of building and evaluating business rules. The decision management system should ensure that proper links are maintained between the Vocabulary and the underlying data. We often refer to this concept as *abstraction* – the complexities of an enterprise's data storage and retrieval systems have been hidden so that only the aspects relevant to rule writing are presented to the rule modeler.
- Provides a built-in library of *literal* terms and operators that can be applied to entities or attributes in the Vocabulary. This part of the Vocabulary, the lower half of the **Vocabulary** window shown in the following figure, is called the Operator Vocabulary because it provides many of the verbs (the operators) needed in our business rules. Many standard operators such as the mathematical functions { +, -, *, / } and comparator functions { <, >, = } as well as more specialized functions are contained within this portion of the Vocabulary. See the *Rule Language Guide* for descriptions and examples of all operators available, as well as detailed instructions for extending the library.

Figure 1: Operator Vocabulary



- When XML messaging is used to carry data to and from the rules for evaluation, data must be organized in a pre-defined structure that can be understood and processed by the rules. An schema supplies the contract for sending data to and from a Corticon Decision Service. An XML schema, generated directly from the Vocabulary, accomplishes this purpose. This schema is called a Vocabulary-Level service contract and details can be found in the *Deployment Guide*.

Scope

An important point about a Vocabulary: there does not need to be a one-to-one correlation between terms in the Vocabulary and terms in the enterprise data model. In other words, there may be terms in the data model that are not included in or referenced by rules – such terms need not be included in the Vocabulary. Conversely, the Vocabulary may include terms (such as transient attributes) that are used only in rules – these terms need not be present in the data model. Two guiding principles:

- If the rule modeler wants to use a particular term in a business rule, then that term must be part of the Vocabulary. This can include terms that exist only within the Vocabulary – these are the transient attributes introduced above.
- If a rule produces a value that must be retained, persisted, or otherwise saved in a database (or other means external to the rules), then that Vocabulary term must also be present in the enterprise data model. There are many methods for linking or mapping these Vocabulary terms with corresponding terms in the data model, but a discussion of these methods is technical in nature and is not included in this manual.

There are two basic starting points for building a Vocabulary: construct one from scratch, or generate one from a REST or database source.

For details, see the following topics:

- [Construct a Vocabulary from scratch](#)
- [Populate a Vocabulary from a Datasource](#)
- [Extend a Vocabulary](#)
- [TestYourself questions for Build the vocabulary](#)

Construct a Vocabulary from scratch

Investigation

The first step in creating a Vocabulary from scratch is to collect information about the specifics of the business problem you are trying to solve. This usually includes research into the more general business context in which the problem exists. Various resources may be available to you to help in this process, including:

- **Interviews** – The business users and subject matter experts are often the best source of information about how business is conducted today. They may not know how the process is *supposed* to work, or how it *could* work, but in general, no one knows better how a business process or task is performed today than those who are actually performing it.
- **Company policies and procedures** – Any written policies and procedures are an excellent source of information about how a process is *supposed* to work, and the rules that govern the process. Understanding the gaps between what is supposed to happen and what is actually happening can provide valuable insight into problems.
- **Existing systems and data sources** – Systems address specific business needs, but needs often change faster than systems can keep up. Understanding what the systems were designed to do versus how they are actually being used often provides clues about the core problems. Also, business logic contained in these legacy systems often captures business policies and procedures (the business rules!) that are not recorded anywhere else.
- **Forms and reports** – Even in heavily automated businesses, forms and reports are often used extensively. These documents can be very useful for understanding the details of a business process. Reports also illustrate the expected output from a system, and highlight the information users require.

Analyze the chosen scenario and/or existing business rules in order to identify the relevant terms and the relationships between these terms. We refer to statements expressing the relevant terms and relationships as facts and recommend developing a Fact Model to more clearly illustrate how they fit together. We will use a simple example to show the creation of a Fact Model and its subsequent development into a Vocabulary for use in Corticon Studio.

Step 1 Design the Vocabulary

Example

An air cargo company has a manual process for generating flight plans. These flight plans assign cargo shipments to specific aircraft. Each flight plan is assigned a flight number. The cargo company owns a small fleet of three airplanes -- two Boeing 747s and one McDonnell-Douglas DC-10 freighter. Each airplane type has a maximum cargo weight and volume that cannot be exceeded. Each aircraft also has a tail number which serves to identify it. A cargo shipment has characteristics like weight, volume and a manifest number to identify it.

Now let's assume the company wants to build a system that automatically checks flight plans to ensure no scheduling rules or guidelines are violated. One of the many business rules that need to be checked by this system is:

1. An aircraft must not carry a cargo shipment that exceeds its maximum cargo weight.

Step 2 Identify the terms

We identify the terms (entities and attributes) for our Vocabulary by circling or highlighting those nouns that are used in the business rules we seek to automate. The previous example is reproduced below:

An air cargo company has a manual process for generating flight plans. These flight plans assign cargo shipments to specific aircraft. Each flight plan is assigned a flight number. The cargo company owns a small fleet of three airplanes, 2 Boeing 747s and 1 McDonnell-Douglas DC-10 freighter. Each airplane type has a maximum cargo weight and volume that cannot be exceeded. Each aircraft also has a tail number which serves to identify it. A cargo shipment has characteristics like weight, volume, packaging method, and a manifest number to identify it.

Step 3 Separate the generic terms from the specific

Why did we only circle the *aircraft* term above and not the names of the aircraft in the fleet? It is because 747 and DC-10 are *specific* types of the *generic* term aircraft. The *type* of aircraft can be said to be an attribute of the generic aircraft entity. Along these same lines, we also know from the example that several cargo shipments and flight plans can exist. Like the specific aircraft, these are *instances* of their respective generic terms. For the Vocabulary, we are only interested in identifying the generic (and therefore reusable) terms. But ultimately, we also will need a way to identify specific cargo shipments and flight plans from within the set of all cargo shipments and flight plans – assigning *values* to attributes of a generic entity will accomplish this goal, as we will see later.

Step 4 Assemble and relate the terms

None of the terms we have circled exists in isolation – they all relate to each other in one or more ways. Understanding these relationships is the next step in Vocabulary construction. We begin by simply stating facts observed or inferred from the example:

- An aircraft *carries* a cargo shipment.
- A flight plan *schedules* cargo for shipment *on* an aircraft.
- A cargo shipment *has* a weight.
- A cargo shipment *has* a manifest number.
- An aircraft *has* a tail number.
- An aircraft *has* a maximum cargo weight.
- A 747 *is* a type of aircraft.

And so on...

Notice that some of these facts describe how one term relates to another term; for example, an aircraft *carries* a cargo shipment. This usually provides a clue that the terms in question, aircraft and cargo shipment, are entities and are two of the primary terms we are interested in identifying.

Also notice that some facts describe what Business Rule Solutions, LLC (BRS) calls “has a” relationships; for example, an aircraft “has a” tail number, or a cargo “has a” weight. This type of relationship usually identifies the subject (aircraft) as an entity and the object (tail number) as an attribute of that entity. By continuing the analysis, we discover that the problem reduces to a Vocabulary containing 3 main entities, each with its own set of attributes:

Entity: aircraft

Attributes: aircraft type, max cargo weight, max cargo volume, tail number

Entity: cargo shipment

Attributes: weight, volume, manifest number, packaging

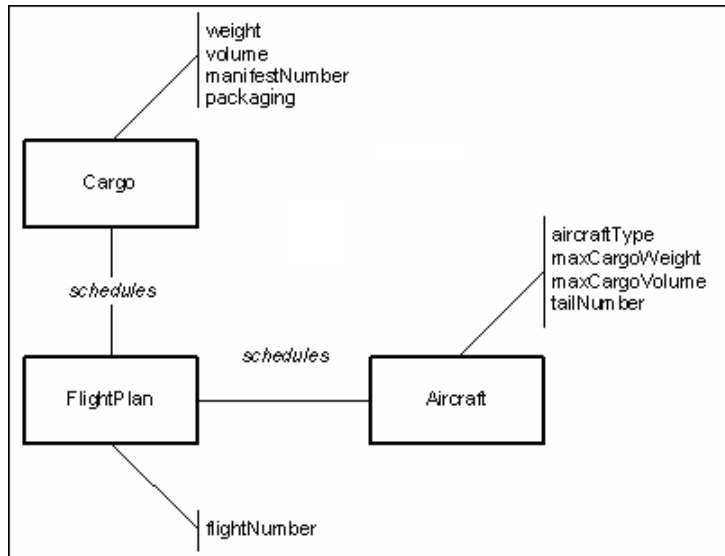
Entity: flight plan

Attributes: flight number

Step 5 Diagram the Vocabulary

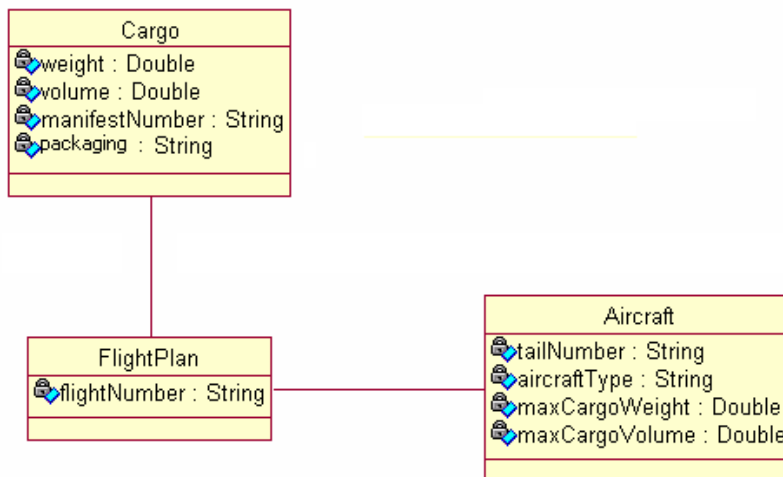
Using this breakdown, we can sketch a simple Fact Model that illustrates the entities and their relationships, or *associations*. In our Fact Model, we will represent entities as rectangular boxes, associations between entities as straight lines connecting the entity boxes, and entity-to-attribute relationships as a diagonal line from the associated entity. The resulting Fact Model appears below in the following model:

Figure 2: Fact Model



A UML Class diagram contains the same type of information, and may be more familiar to you:

Figure 3: UML Class Diagram



It is not a requirement to construct diagrams or models of the Vocabulary before building it in Corticon. But it can be very helpful in organizing and conceptualizing the structures and relationships, especially for very large and complex Vocabularies. The BRMS Fact Model and UML Class Diagram are appropriate because they remain sufficiently abstracted from lower-level data models which contain information not typically required in a Vocabulary.

Step 6 Model the Vocabulary in Corticon Studio

Our next step is to transform the diagram into our Corticon Vocabulary. This can be done in Corticon Studio using its built-in **Vocabulary Editor**.

In Corticon Studio, choose **New > Rule Project**. Click on that Rule Project, and then choose **New > Vocabulary**. Create the entities, attributes, and associations that were defined in our diagram.

Note: See "Vocabulary topics" in the Quick Reference guide for complete details on building a Vocabulary.

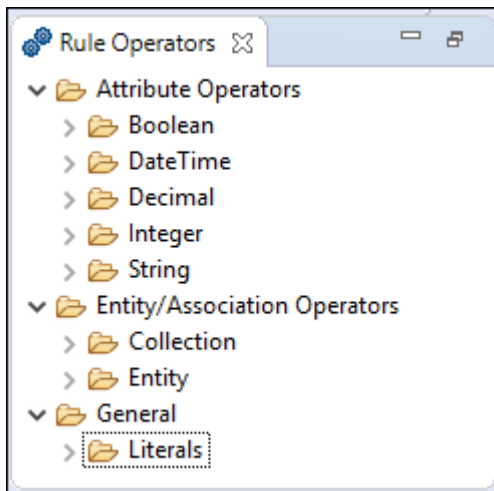
The naming conventions for entities and attributes, and the naming conventions for entities and attributes in the Fact Model will be used in the Vocabulary:

- All attributes in our Vocabulary must have a data type specified. These may be any of the following common data types: **String**, **Boolean**, **DateTime**, **Date**, **Time**, **Integer** or **Decimal**.
- Attributes are classified according to the method by which their values are assigned. They are either:
 - **Base** -- Values are obtained directly from input data or request message, or
 - **Transient** -- Created, derived, or assigned by rules in Studio.

Note:

Transient attributes carry or hold values while rules are executing within a single Rulesheet. Since XML messages returned by a Decision Service do not contain transient attributes, these attributes and their values cannot be used by external components or applications. If an attribute value is used by an external application or component, it must be a base attribute.

To show the rule modeler which attributes are base and which are transient, Corticon Studio adds an orange bar to transient attributes, as shown here for `packDate`:



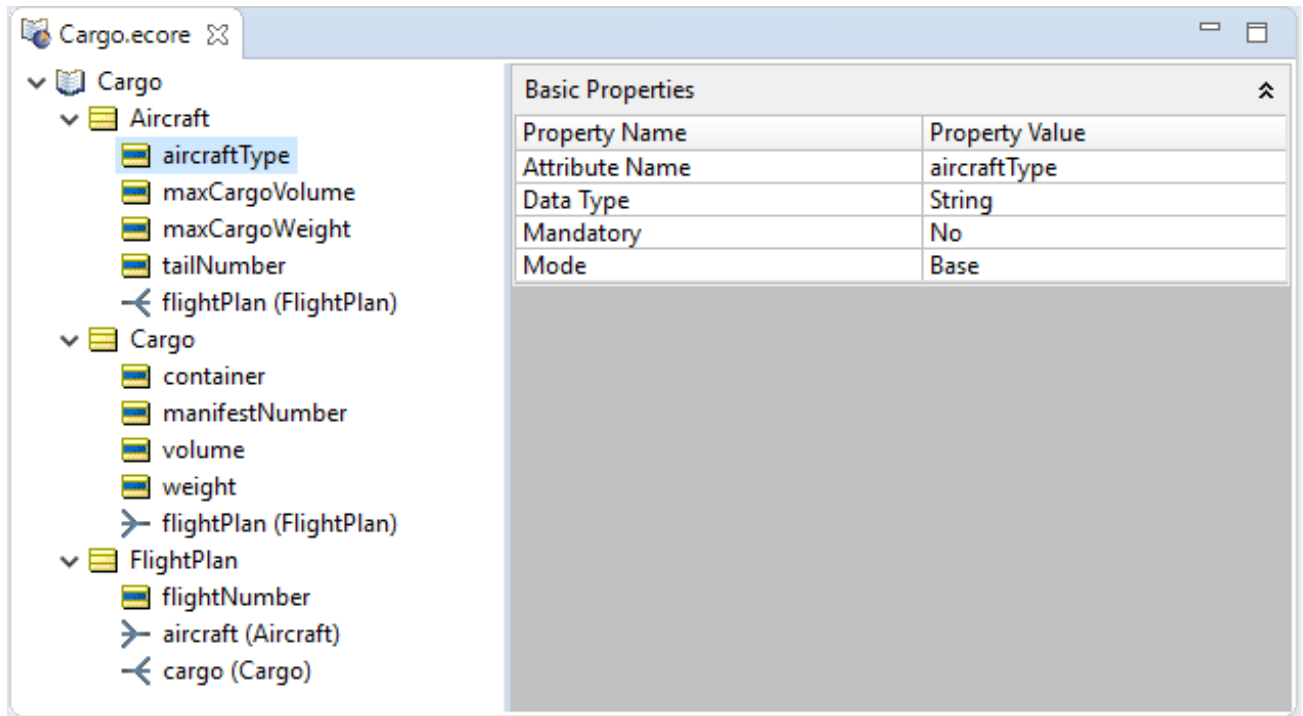
XML response messages created by Corticon Server will not contain the `packDate` attribute.

It is a good idea to use a naming convention that distinguishes transient attributes from base attributes. For example, you could start a transient attribute's name with `t_` such as `t_packDate`. We caution against modifying the names of terms so that they are cryptic. The intent is to express them in a language accessible to business users, as well as developers.

- Associations between entities have role names that are assigned when building the associations in the UML class diagram or Vocabulary Editor. Default role names simply duplicate the entity name with the first letter in lowercase. For example, the association between the `Cargo` and `FlightPlan` entities would have a role name of *flightPlan* as seen by the `Cargo` entity, and *cargo* as seen by the `FlightPlan` entity. Roles are useful in clarifying context in a rule – a topic covered in more detail within the [Scope](#) chapter.
- Associations between entities can be directional (one-way) or bi-directional (two-way). If the association between `FlightPlan` and `Aircraft` were directional (with `FlightPlan` as the *source* entity and `Aircraft` as *target*), we would only be able to write rules that traverse *from* `FlightPlan` *to* `Aircraft`, but not the other way. This means that a rule may use the Vocabulary term `flightPlan.aircraft.tailNumber` but may not use `aircraft.flightPlan.flightNumber`. Bi-directional associations allow us to traverse the association in either direction, which clearly allows us more flexibility in writing rules. Therefore, it is strongly recommended that all associations be bi-directional whenever possible. New associations are bi-directional by default.
- Associations also have cardinality, which indicates how many instances of a given entity may be associated with another entity. For example, in our air cargo scenario, each instance of `FlightPlan` will be associated with only one instance of `Aircraft`, so we can say that there is a *one-to-one* relationship between `FlightPlan` and `Aircraft`. The practice of specifying cardinality in the Vocabulary deviates from the UML Class modeling technique because the act of assigning cardinality can be viewed as defining a constraint-type rule. For example, *a flightPlan schedules exactly one aircraft and one cargo shipment* is a constraint-type business rule that can be implemented in a Corticon Studio as well as *embedded* in the associations within a Vocabulary. In practice, however, it may often be more convenient to embed these constraints in the Vocabulary, especially if they are unlikely to change in the future.
- Another consideration when creating a Vocabulary is whether derived attributes must be saved (or persisted) external to Corticon Studio, for example, in a database. It is important to note that while the structure of your Vocabulary may closely match your data model (often persisted in a relational database), the Vocabulary is *not required* to include all of the database entities/tables or attributes/columns, especially if they will not be used for writing rules. Conversely, our Vocabulary may contain attributes that are used only as transient variables in rules and that do not correspond to fields in an external database.
- Finally, the Vocabulary must contain all of the entities and attributes needed to build rules in Corticon Studio that reproduce the decision points of the business process being automated. This will most likely be an iterative process, with multiple Vocabulary changes being made as the rules are built, refined, and tested. It is very common to discover, while building rules, that the Vocabulary does not contain necessary terms.

But the flexibility of Corticon Studio permits the rule developer to update or modify the Vocabulary immediately, without programming.

Figure 4: Vocabulary Window in Corticon Studio



Note: In this figure, Corticon Studio Vocabulary is hiding its details. When changed to show Vocabulary details, the list exposes properties related to mapping.

Populate a Vocabulary from a Datasource

Often you have data sources that you want to use as the basis for your rule modeling that might have many tables each with many columns. You could transcribe each data source's schema to create a Vocabulary, yet the ability to populate the Vocabulary quickly from the schema would expedite the process dramatically.

When you use this built-in Vocabulary generation utility, Corticon makes its best effort at setting up the name patterns, and defining the data types and associations. It is important that you review the Vocabulary in contrast with the source schema to validate that the results are correct.

Step 1 How Datasources are transformed into a Corticon Vocabulary

The relationship between relational Datasources and Corticon Vocabulary elements are:

Relational Database	Corticon Vocabulary
Schema	Vocabulary
Table	Vocabulary: Entity

Relational Database	Corticon Vocabulary
Table Column or Field	Vocabulary: Attribute
Relationship between Tables	Vocabulary: Association

Once you connect to a Datasource and import its metadata, you can constrain the tables and attributes that will be evaluated. Then, the internal algorithm will make its best efforts to populate the Vocabulary.

Assuming that you are creating a new Vocabulary, these are the steps it takes:

1. For each selected Table in the Datasource, create a new Entity in the Vocabulary.
2. For each Column in the Table:
 - a. Create a new Attribute in the Entity.
 - b. Determine the best Corticon data type for the Attribute by referring to the column's data type information.
 - c. If the column is part of the Table's primary key, mark the Attribute as part of the Entity identity.
3. Once all Tables and Columns are processed, Associations are created for each foreign key for each table (if the source and target tables are both mapped in the Datasource.)

The creation process tries to be complete and accurate, but it has limited abilities:

- Columns that are referenced by foreign keys will not be added as Attributes.
- Tables that do not have any valid columns (as restricted above) will not be created (such as, Association middle tables, or Sequence tables.)
- The data type for an attribute is evaluated in this order: Datetime, Time, Date, Decimal, Integer, String, Boolean. Some Corticon data types might not get picked for attributes because of an overload of possible mappings (such as, Date and Time could always be created as Datetime). Note these decisions are derived from data when data is in a REST source that has no schema.

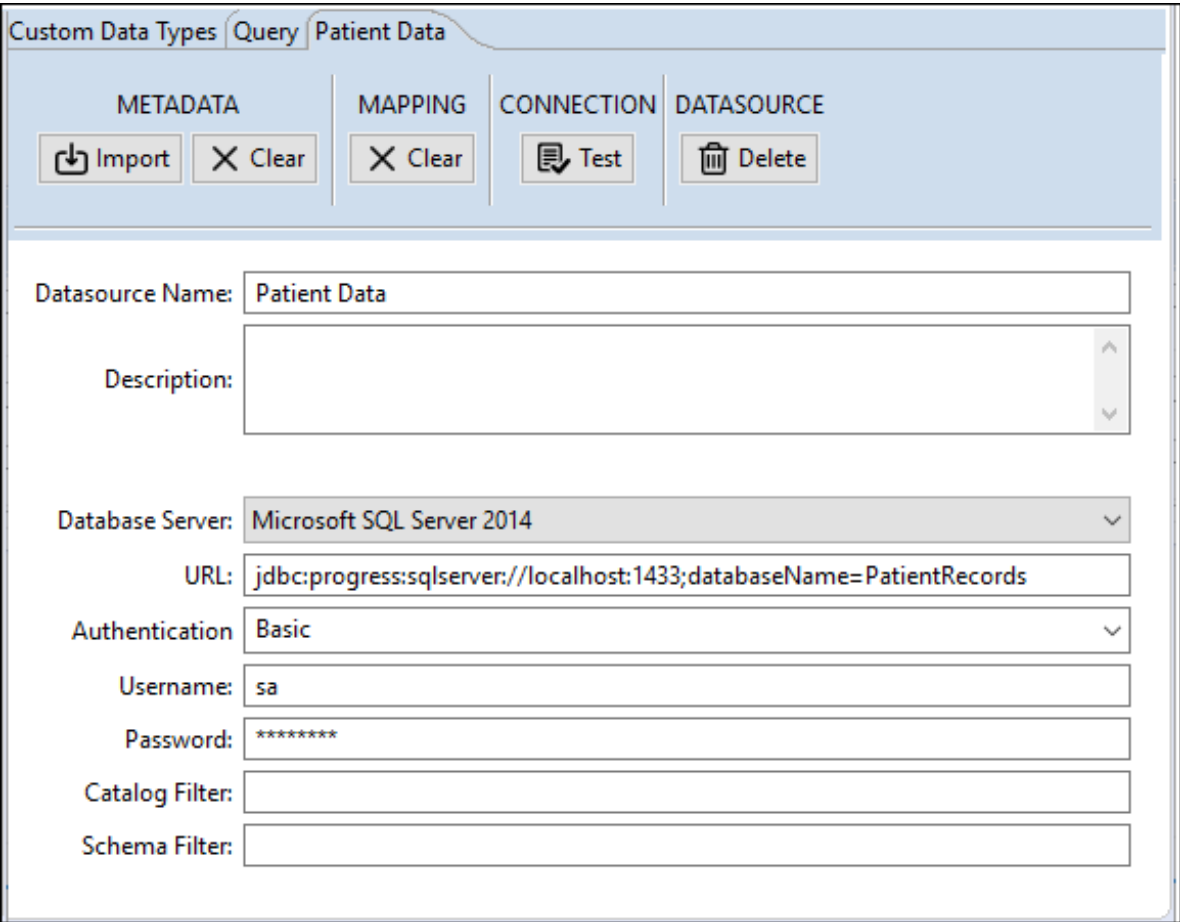
The next topic, [Step 2 The Vocabulary generation process for RDBMS sources](#) on page 22 shows the procedure for populating a new Vocabulary.

Step 2 The Vocabulary generation process for RDBMS sources

Relational databases have well-structured schema that declare every element's data type. The following steps in Corticon Studio that populate a new Vocabulary from a relational database Datasource. We'll use the Patient/Treatment schema that was created from SQL statements in the Data Integration's **ADC Connectivity** sample.

To generate a Vocabulary from a relational data source:

1. In Corticon Studio, create a new Rules Project named **GenMed**.
2. In the new project, create a Vocabulary named **GenMed**.
3. Open the Vocabulary in its editor, and then select the menu command **Vocabulary > Add Datasource** plus the source type, EDC or ADC. For this example, we'll choose **Add ADC Datasource**.
4. Define the Datasource name as **Patient Data** like the one in the Data Integration sample ADC Database Connectivity. Connect to the SQL server 2014 as the database **PatientRecords**. Enter credentials, and then click **CONNECTION Test**:



Custom Data Types Query Patient Data

METADATA MAPPING CONNECTION DATASOURCE

Import Clear Clear Test Delete

Datasource Name: Patient Data

Description:

Database Server: Microsoft SQL Server 2014

URL: jdbc:progress:sqlserver://localhost:1433;databaseName=PatientRecords

Authentication: Basic

Username: sa

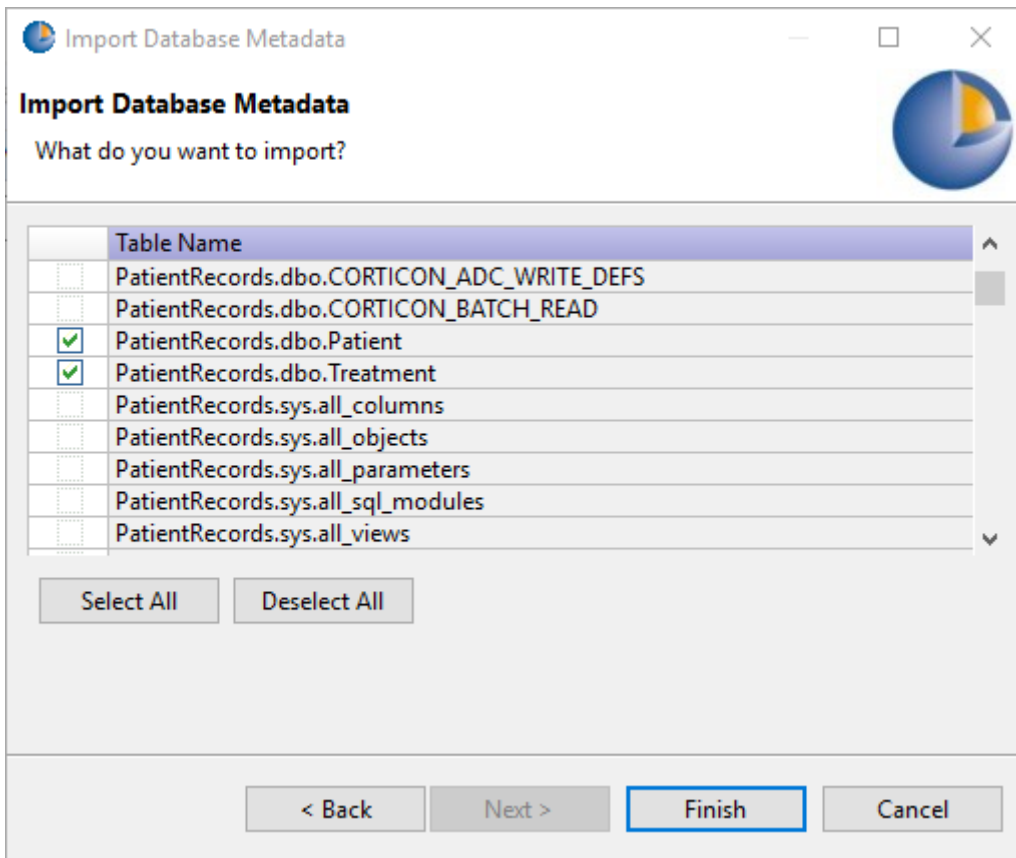
Password: *****

Catalog Filter:

Schema Filter:

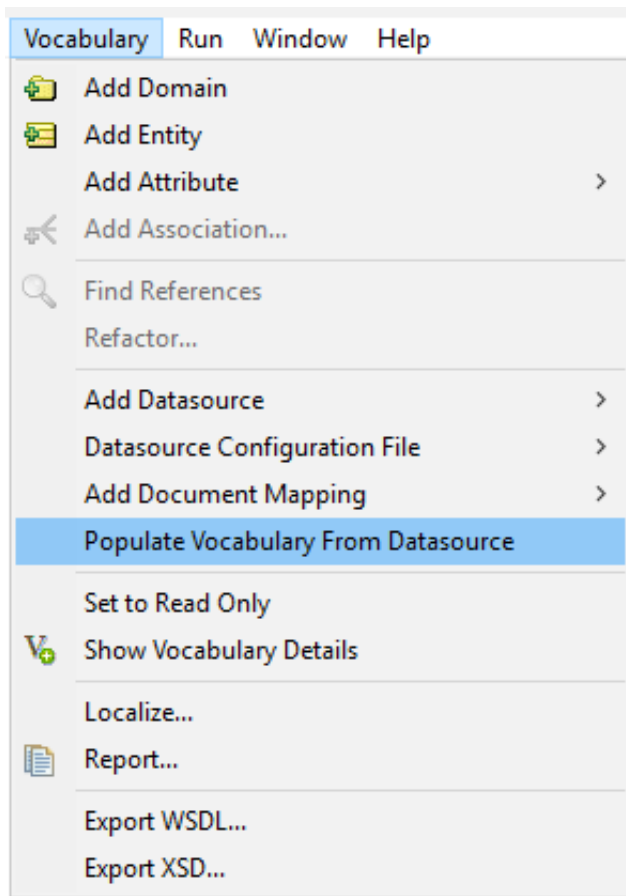
Note: You might want to add a **Schema Filter** value, such as `dbo`, to constrain the results of the next step.

- 5. Click **METADATA Import**, and then choose the option to choose tables you want to use. For this example, choose just the two `dbo` tables as shown:

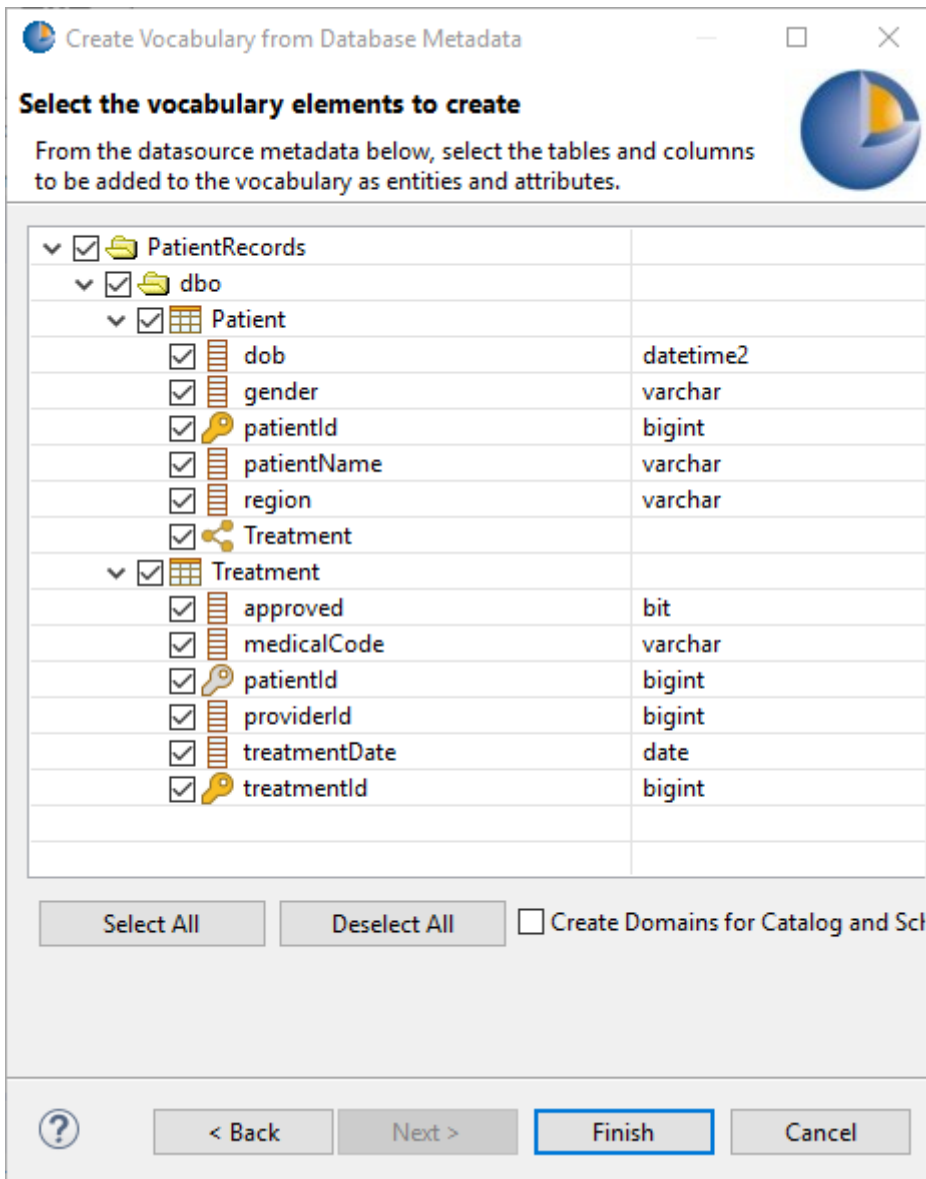


and click **Finish**.

6. Select the menu command **Vocabulary > Populate Vocabulary From Datasource**

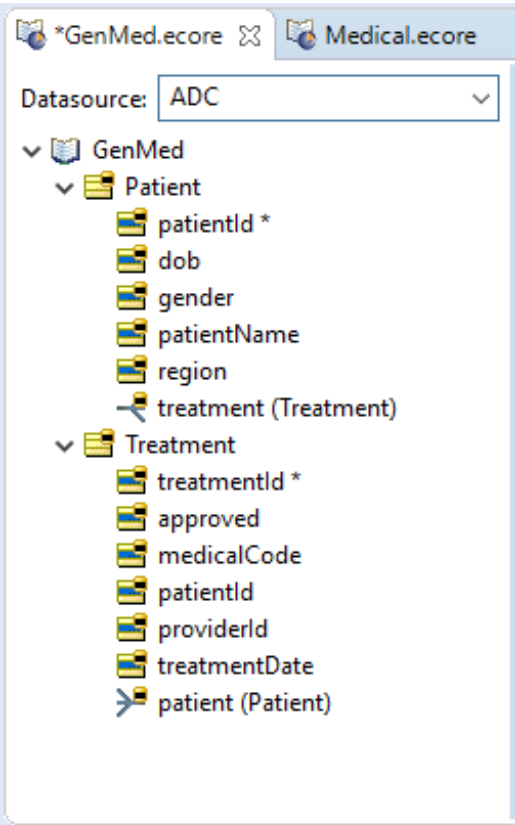


7. Choose the **Patient Data** Datasource. If there were several Datasources defined, you'd choose them one at a time for this process. In this example, there is only one. Click **Next**.
8. A wizard opens to let you review the Datasource prior to creating the Vocabulary elements, where you can select the Tables and Columns that will create Entities and Attributes. In the following image, the tree was expanded:



Click **Finish**.

9. The Vocabulary is generated, as shown:



Step 3 The Vocabulary generation process from REST sources

REST sources are generally not as clearly structured as relational databases. Some provide a schema but generally they do not. They can however conform to a relational database schema when Corticon uses the Progress® DataDirect® Autonomous Rest Connector to access REST sources. The REST connector maps the JSON in a REST source to a relational database schema, and then translates SQL statements to REST API requests. These steps in Corticon Studio populate a new Vocabulary from the REST Datasource used in the REST connectivity sample in the Data Integration guide. It has no schema. Its data looks this:

```

1 {
2   "results": [
3     {
4       "procedureCode": "B5120ZZ",
5       "rates": [
6         {
7           "startDate": "2018-1-1",
8           "endDate": "2018-6-1",
9           "rate": 0.85
10        },
11       {
12         "startDate": "2018-6-2",
13         "endDate": "2018-12-31",
14         "rate": 0.8
15       }
16     ]
17   }
18 ]
19 }
```

To generate a Vocabulary from a REST data source:

1. In Corticon Studio, create a new Rules Project named **GenRates**.
2. In the new project, create a Vocabulary named **GenRates**.
3. Open the Vocabulary in its editor, and then select the menu command **Vocabulary > Add Datasource > Add REST Datasource**.
4. Define the Datasource connection for the URL
<https://bj36i9ki66.execute-api.us-east-2.amazonaws.com/prod/ReimbursementRate?procedureCode=B5120ZZ>
as shown:

Custom Data Types REST Service

MAPPING SCHEMA CONNECTION DATASOURCE

Clear Discover Import Export Clear Test Delete

Datasource Name: REST Service

Description:

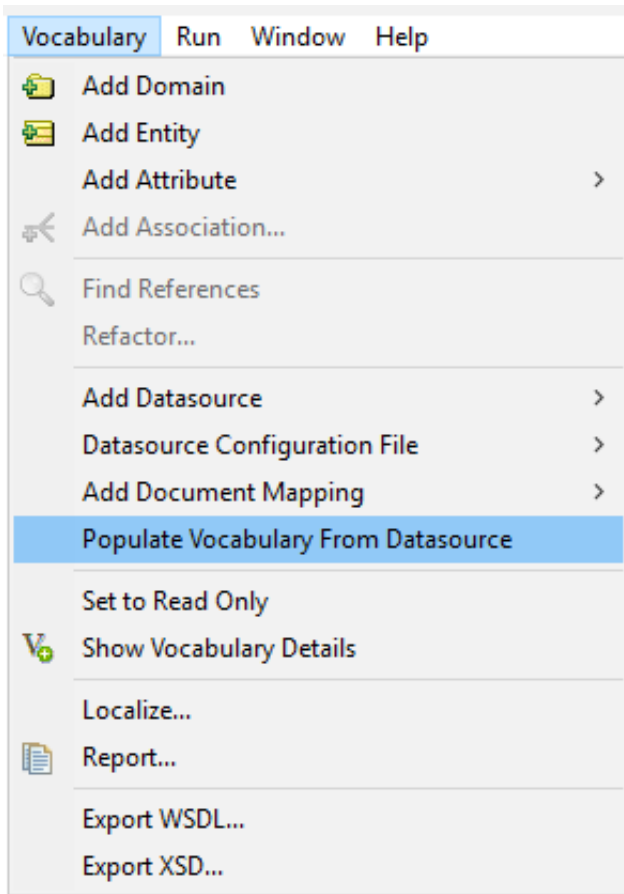
REST URL: https://bj36i9ki66.execute-api.us-east-2.amazonaws.com/prod/ReimbursementRate

Authentication: None

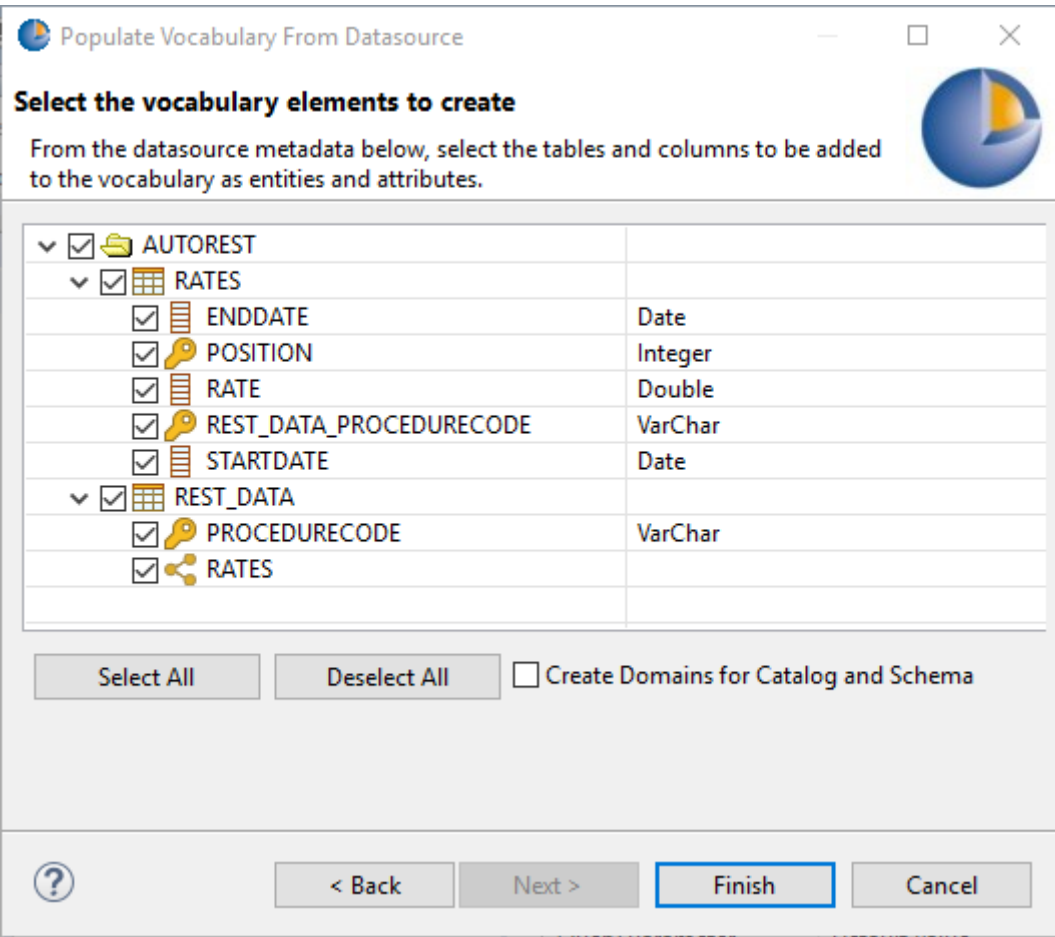
Query Parameter	Default Value	Type
procedureCode	B5120ZZ	URL
		URL

Click **CONNECTION Test**.

- 5. Click **SCHEMA Discover**. If your REST source had a schema, or one that you exported in an earlier processing of this source you could import it at this time. For this source, you need to let the Progress® DataDirect® Autonomous Rest Connector map the JSON in the REST source to a relational database schema, and then translate SQL statements to REST API requests.
- 6. Select the menu command **Vocabulary > Populate Vocabulary From Datasource**

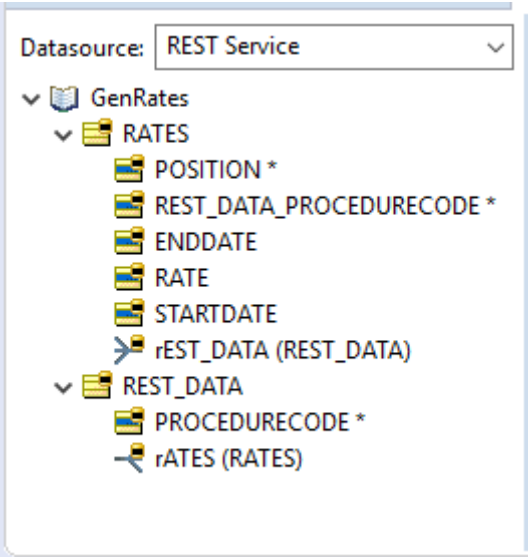


7. Choose the **REST Service** Datasource. If there were several Datasources defined, you'd choose them one at a time for this process. In this example, there is only one, **REST Service**. Click **Next**.
8. A wizard opens to let you review the Datasource prior to creating the Vocabulary elements, where you can select the Tables and Columns to create as Entities and Attributes. Here, the tree was expanded for `REST_DATA`, the primary table that was unnamed so it was given this default name. You can see links between tables at the bottom of this table to all the other tables. We'll accept everything to see how this is handled:



Click **Finish**.

9. The Vocabulary is generated, as shown:



The Primary Key in RATES is POSITION, a standard ARC uses to ensure keys are unique, plus the REST_DATA_PROCEDURECODE, the default name of the primary entity, and the REST_DATA entity's single primary key, PROCEDURECODE

10. Here is an association:

The screenshot shows the Microsoft Dynamics CRM interface. At the top, there are two tabs: 'GenRates.ecore' and 'Medical.ecore'. Below the tabs, there is a 'Datasource:' dropdown menu set to 'REST Service'. To the left is a tree view showing the 'GenRates' entity structure. Under 'GenRates', there is a 'RATES' entity with several attributes: 'POSITION *', 'REST_DATA_PROCEDURECODE *', 'ENDDATE', 'RATE', 'STARTDATE', 'rEST_DATA (REST_DATA)', and 'REST_DATA'. Under 'REST_DATA', there are 'PROCEDURECODE *' and 'rATES (RATES)'. To the right of the tree view is a 'Basic Properties' table.

Property Name	Property Value
Association Role Name	rEST_DATA
Source Entity Name	RATES
Target Entity Name	REST_DATA
Cardinalities	*-> 1
Navigability	Bidirectional
Mandatory	No

Below the 'Basic Properties' table is a section titled 'REST Service Datasource Properties'. It contains a 'Join Expression' property with the value 'AUTOREST.RATES.REST_DATA_PROCEDURECODE='.

Step 4 Verify and update the generated Vocabulary

Produce a Vocabulary Report

The import of Datasource metadata to build a Vocabulary is processed through a best-effort algorithm. You should produce a Vocabulary report to review the entity names, attribute names and data types, and the implied associations.

Adding and deleting

You can delete any entity (which will delete all its attributes) as well as any attributes and associations. You should take care not to delete primary keys. The impact of deletions in the Vocabulary are entirely local. They have no impact on the Datasource. You can add attributes and, because the metadata you imported was not deleted, you can re-add a deleted attribute and bind it to the column in the Datasource.

Doing updates from a Datasource is not a syncing operation. There is no provision for removing metadata that is no longer in the Datasource.

Refactoring names

You can rename any entity and attribute even if it is a just case change. For example, refactor `dob` with `DOB`. It is important that you *refactor*, not *rename* so that other instances of the name in the Vocabulary such as associations are correspondingly updated.

If you re-populate the Vocabulary from the Datasource, the name you entered is retained while it is still logically the Datasource column name.

Note: MS Dynamics as a Datasource - Some table names in Dynamics might map to an unexpected name. For example, a Case table might become an Incident entity by default on initial import.

Data types

The algorithm in the import makes best efforts to map the Datasource's data type to corresponding Corticon data type. The data type for an attribute is evaluated in this order: Datetime, Time, Date, Decimal, Integer, String, Boolean. Some Corticon data types might not get picked for attributes because of an overload of possible mappings (such as, Date and Time could always be created as Datetime). Note these decisions are derived from data when data is in a REST source that has no schema. After import you can revise the data type such as when you have custom data types that apply constraints, or date of birth imports as Datetime while your rules want just Date, or when `"flight_number":55` is imported an integer data type when your use is as a String,

Mandatory

Whether an attribute is mandatory is set by you. It will not be changed on a re-import.

Associations

The metadata from the Datasource often provides correct associations. When you use multiple Datasources, you need to create the associations between entities. In all cases, review your associations.

Transients

You can add transients. If you change an imported attribute to a transient, its binding to its Datasource column is dropped.

Foreign keys

When if both the source and target table are mapped in the Datasource, an association is created for each foreign key for each table.

Domains

You might have the need for multiple domains. If you use REST Datasources, you need to rename the existing domains before importing a new one.

Extend a Vocabulary

Once a Vocabulary has been defined, you can extend the design by [customizing data types to enforce certain values and constraints](#), [use multiple domains](#), and [implement inheritance](#).

Custom Data Types

Corticon uses seven basic data types: Boolean, Decimal, Integer, String, DateTime, Date, and Time. An attribute must use one of these types. Yet you also have the option of creating custom data types that “extend” any one of these basic seven.

You define and maintain Custom Data Types in a Vocabulary by selecting the Vocabulary name in the tree view.

Data Type Name

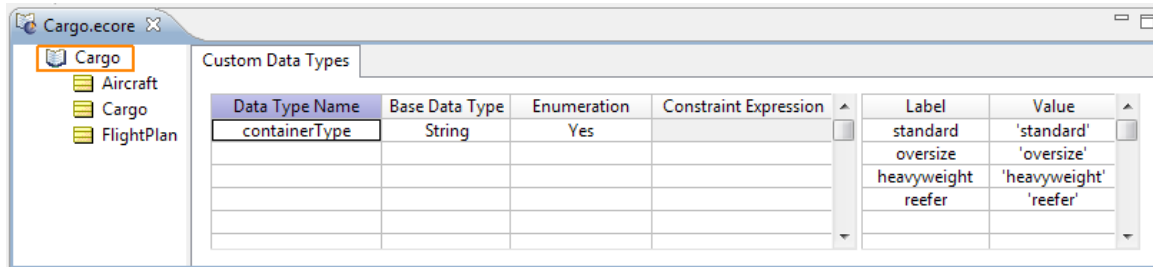
When defining a custom data type, you must give it a name with no blanks. The name must comply with standard entity naming conventions (see the *Quick Reference Guide* for details) and must not overlap (match) any of the base data types, any other custom data type names, or the names of any Vocabulary entities.

Base Data Type

The selection in this field determines which base data type the custom data type extends.

We already used this feature in the custom data type `containerType`, a `String`, in the *Basic Tutorial*. It lists its labels and values.

Figure 5: Vocabulary Editor Showing the Custom Data Type `containerType`



Enumeration Or Constraint Expression?

Enumeration - When the **Enumeration** for a Custom Data Type is set to `Yes`, as shown above, the **Constraint Expression** field is disabled, and the **Label** and **Value** columns are enabled.

Constraint Expression - When the **Enumeration** for a Custom Data Type is set to `No`, the **Constraint Expression** field is enabled and the **Label** and **Value** columns are disabled.

The following sections explore each of these features.

Constraint Expressions

When you want to prompt Rulesheet and Ruletest designers to use a specific range values for an attribute, a constraint expression will validate entries when the associated Ruletest runs.

Constraint expressions are optional for non-enumerated Custom Data Types, but if none are used then the Custom Data Type probably isn't necessary because it reduces to a base attribute with a custom name.

All **Constraint Expressions** must be `Boolean` expressions, in other words they must return or resolve to a `Boolean` value of `true` or `false`. The supported syntax is the same as Filter expressions with the following rules and exceptions:

- Use the `value` to represent the Custom Data Type value.
- Logical connectors such as `and` and `or` are supported
- Parentheses may be used to form more complex expressions
- The expression may include references to Base and Extended Operators which are compatible with the Base Data Type chosen.
- No Collection operators may be referenced in the expression.
- There should be **NO** references to `null`. This is because `null` represents a lack of value and is not a real value. The Constraint Expression is intended to constrain the value space of the data type and expressions such as `attribute expression <> null` do not belong in it. An attribute that must not have a null value can be so designated by selecting `Yes` in its **Mandatory** property value.

The following are typical Constraint Expressions:

Constraint Expression	Meaning
value > 5	Integer values greater than 5
value >= 10.2	Decimal values greater than or equal to 10.2
value in (1.1..9.9]	Decimal values between 1.1 (exclusive) and 9.9 (inclusive)
value in ['1/1/2014 12:30:00 PM'..'1/2/2019 11:00:00 AM')	DateTime values between '1/1/2014 12:30:00 PM' (inclusive) and '1/2/2019 11:00:00 AM' (exclusive)
value in ['1:00:00 PM'..'2:00:00 PM']	Time values between '1:00:00 PM' (inclusive) and '2:00:00 PM' (inclusive)
value.size >= 6 and (value.indexOf(1) > 0 or value.indexOf(2) > 0)	String values of minimum 6 characters in length that contain at least a 1 or 2

How to use non-enumerated Custom Data Types in Rulesheets and Ruletests

Non-enumerated custom data types use **Constraint Expressions** and do not cause Rulesheet drop-downs to become populated with custom sets. Also, manually entering a cell value that violates the custom data type's **Constraint Expression** is not prohibited in the Rulesheet. For example, in the example below, `weightLimit` is defined as a non-enumerated custom data type with **Base Data Type** of `Integer`.

Figure 6: Non-enumerated Custom Data Types

Custom Data Types			
Data Type Name	Base Data Type	Enumeration	Constraint Expression
weightRange	Decimal	No	value < 2000

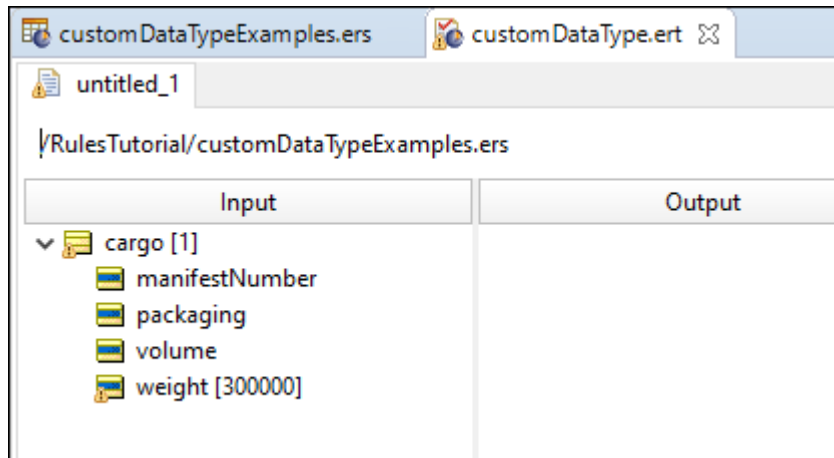
Then, after assigning it to the Vocabulary attribute `Cargo.weight`, it is used in a Rulesheet Condition row as shown below:

Figure 7: Using Custom Data Types in a Rulesheet

Conditions		1		
a	cargo.weight	300000		
b				
Actions		<		
Post Message(s)		✉		
A				
B				
Overrides				
Rule Statements				
Ref	ID	Post	Alias	Text
1		Violation	cargo	300,000 exceeds the CDT constraint

Notice in *Using Custom Data Types in a Rulesheet* that the 300000 entry violates the **Constraint Expression** of the custom data type assigned to `Cargo.weight`, but *does not turn red or otherwise indicate a problem*. The indication comes when data is entered for the attribute in a Ruletest, as shown below:

Figure 8: Violating a Custom Data Type's Constraint Expression




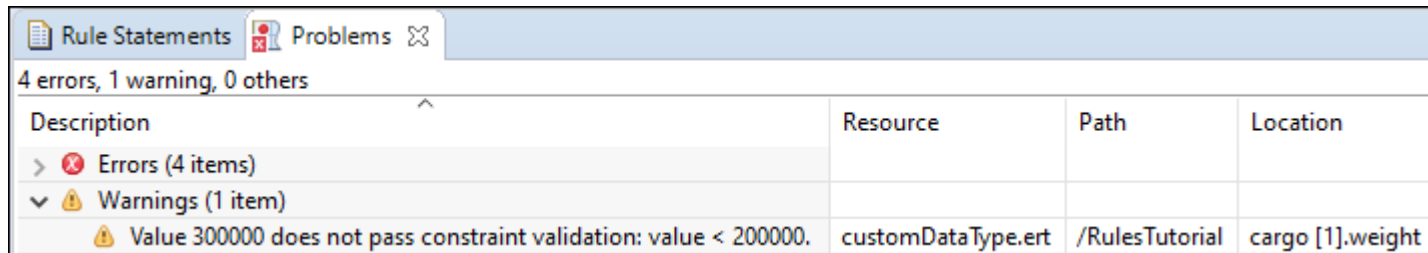

Notice that the small yellow warning icon  indicates a problem in the attribute, entity, and both Ruletest tabs. Such an error is hard to miss! Also, a Warning message will appear in the **Problems** tab (if open and visible) as shown below. If the Problems tab is closed, you can display it by selecting **Window > Show View > Problems** from the **Studio** menubar.

Figure 9: Violating the Constraint Expression of a Custom Data Type



A Warning will not prevent you from running the Ruletest. However, an Error, indicated by a small red icon , will prevent the Ruletest execution. You must fix any errors before testing.

Enumerations

Enumerations are lists of strictly typed unique values that are the valid values for each attribute that is assigned the custom data type name as its data type. These lists also prompt Rulesheet and Ruletest designers to use a specific list of values. Enumerated lists, often referred to as *enums*, can be maintained directly in the Vocabulary, or retrieved and updated from a data source.

Each item list can be partnered with a unique *label* that you select in Rulesheets and Ruletests.

How enumeration labels and values behave

Before you start setting up and using enumerations, you should get acquainted with labels and values.

Note: It is important that you determine whether you want to use labels, as changing a set of enumerations later to add or remove the labels data will impact any Rulesheets and Ruletests that use that custom data type's enumerations as you can observe in this topic.

At the Vocabulary root, we created a String enumeration with only values. The base data type can be any Corticon data type except boolean. Every line requires a unique entry of its type, and the list must have no blank lines from the top down to the last line.

The following examples are String values. They can contain spaces and pretty much any other character. It needs to be set off in plain single quote marks. If you enter or paste text with the delimiters, they are added for you. Like this:

Custom Data Types			Database Access	
Data Type Name	Base Data...	Enum...	Label	Value
colorLabeled	String	Yes		'red'
colorUnlabeled	String	Yes		'blue'

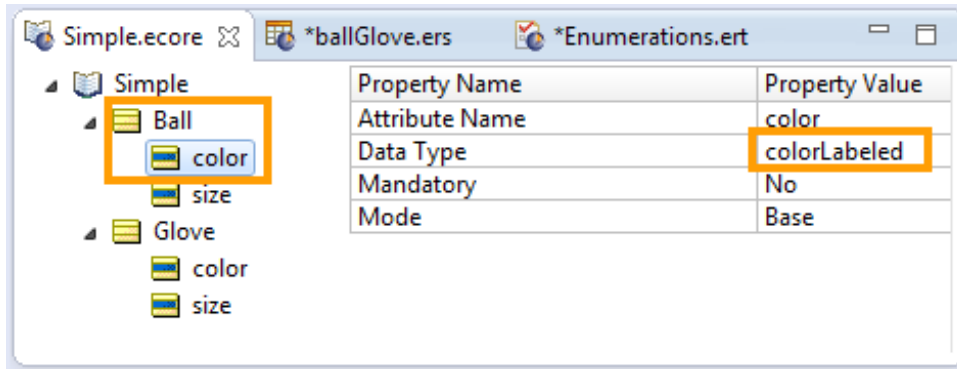
If you want to use labels, the label is always a String of any alphanumeric characters but cannot contain spaces. Each must be unique and must have a corresponding value. Even when you use labels, the values must be unique.

Custom Data Types			Database Access	
Data Type Name	Base Data...	Enum...	Label	Value
colorLabeled	String	Yes	red	'Crimson'
colorUnlabeled	String	Yes	blue	'Cerulean'

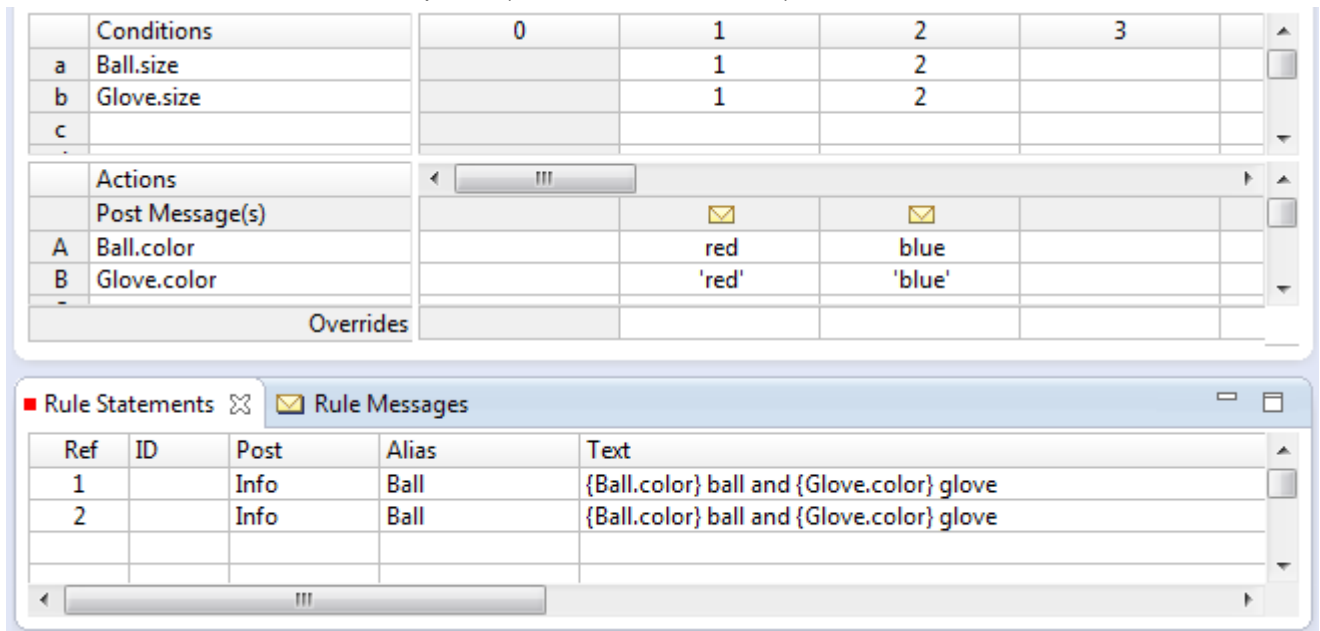
We set the `Glove.color` to use the `colorUnlabeled` data type:

Property Name	Property Value
Attribute Name	color
Data Type	colorUnlabeled
Mandatory	No
Mode	Base

We set the `Ball.color` to use the `colorLabeled` data type:



When we create a Rulesheet, the list offered at A1 contains the label (`Ball.color = red`), while the list offered at B1 contains the value in quotes (`Glove.color='red'`).



We added Rule Statements so that we can see how the labeled and unlabeled items are handled.

In a simple Ruletest, we add some size tests to see what results. As shown, the labels and values in the result Output are both unquoted. The Rule Messages display the value when the label was in use and the value of the value-only enumeration.

untitled_1

/simple/ballGlove.ers Differences: 0

Input	Output
<ul style="list-style-type: none"> Ball [1] <ul style="list-style-type: none"> size [1] Glove [1] <ul style="list-style-type: none"> size [1] Ball [2] <ul style="list-style-type: none"> size [2] Glove [2] <ul style="list-style-type: none"> size [2] 	<ul style="list-style-type: none"> Ball [1] <ul style="list-style-type: none"> color [red] size [1] Glove [1] <ul style="list-style-type: none"> color [red] size [1] Ball [2] <ul style="list-style-type: none"> color [blue] size [2] Glove [2] <ul style="list-style-type: none"> color [blue] size [2]

Rule Messages

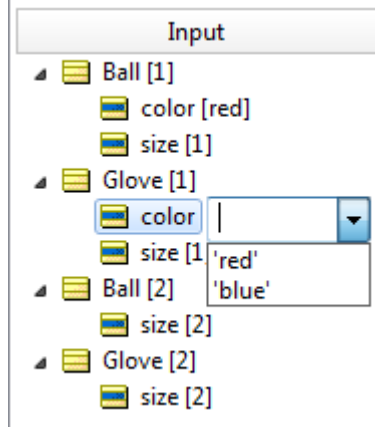
Severity	Message	Entity
Info	Crimson ball and red glove	Ball[1]
Info	Cerulean ball and blue glove	Ball[2]

Entry of test values in the Ruletest list the label+value's label...

Input

- Ball [1]
 - color [red]
 - size [1]
- Glove [1]
 - color [blue]
 - size [1]
- Ball [2]
 - size [2]
- Glove [2]
 - size [2]

... while the value-only list has quoted values...



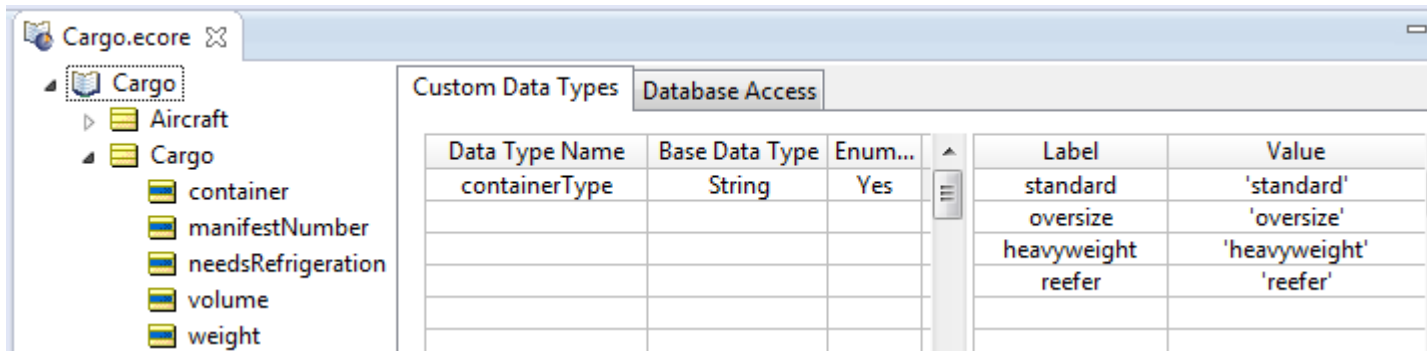
... but both are reconciled to unquoted values in the displayed Input and Output.

Severity	Message	Entity
Info	Crimson ball and red glove	Ball[1]
Info	Cerulean ball and blue glove	Ball[2]

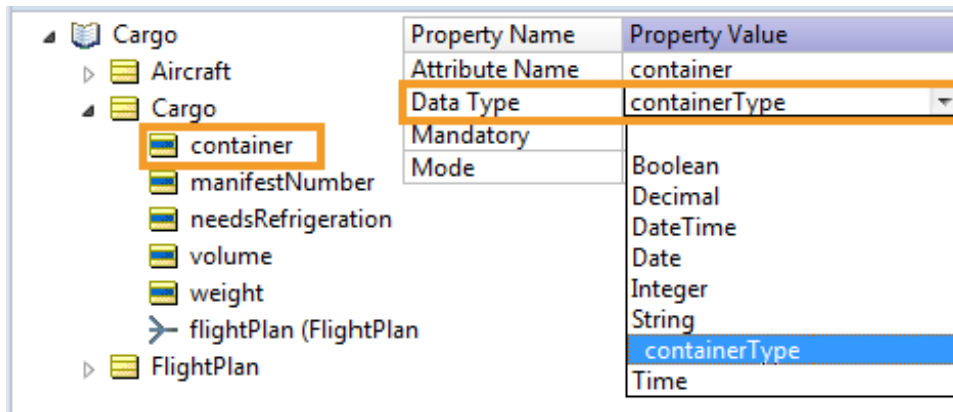
Note: It is important that you determine in each custom data type whether you want to use labels. Some enumerations can have labels while others do not. Changing a set of enumerations later to add or remove the labels data will impact any Rulesheets and Ruletests that use that custom data type's enumerations as you can observe in this topic.

Enumerations defined in the Vocabulary

To set up an Enumeration, open the project's Vocabulary, and then click on its root, Cargo in this tutorial example. Then enter a preferred unique name without spaces, and then click on the Base Data type cell of the row to choose the data type (the values are all red until you have added a successful value or label/value pair). Click on the Enumeration cell to choose Yes. Now enter a value on the first row, and a label if you want one. All the cells are validated and the red markers are cleared. Then you can add other value or label/value pairs on the next lines.



When you have completed a valid Custom Data Type, choose attributes in the Vocabulary that will be constrained to the enumeration.



If your custom data type is a local enumeration, then you enter the enumerated values of the base data type into the **Value** column, and, if you intend to use labels, enter label text into the **Labels** column.

Note: Pasting in labels and values - If you have the source data in a spreadsheet or text file, you can copy from the source and paste into the Vocabulary after you have defined the name, base data type, and chosen yes to enumeration. When you paste two columns of data, click on the first label row. If you have one column of data you want to use for both the label and the value, paste it in turn into each column. If the data type is String, Date, Time, or DateTime, the paste action will add the required single quote marks.

The **Label** column is optional: you enter **Labels** only when you want to provide an easier-to-use or more intuitive set of names for your enumerated values.

The **Value** column is mandatory: you need to enter the enumerations in as many rows of the **Value** column as necessary to complete the enumerated set. Be sure to use normal syntax, so custom data types that extend String, DateTime, Date, or Time base data types must be enclosed in single quote characters.

Here are some examples of enumerated custom data types:

Figure 10: Custom Data Type, example 1

Data Type Name	Base Data Type	Enumerati...	Constraint Expression	Label	Value
containerType	String	Yes			2
PrimeNumbers	Integer	Yes			3
USHolidays2015	Date	Yes			5
ShirtSize	Integer	Yes			7
RiskProfile	Integer	Yes			11
DevTeam	String	Yes			13

PrimeNumbers is an Integer-based, enumerated custom data type with Value-only set members.

Figure 11: Custom Data Type, example 2

Custom Data Types						
Data Type Name	Base Data Type	Enumerati...	Constraint Expression		Label	Value
containerType	String	Yes			standard	'standard'
PrimeNumbers	Integer	Yes			oversize	'oversize'
USHolidays2015	Date	Yes			heavyweight	'heavyweight'
ShirtSize	Integer	Yes			reefer	'reefer'
RiskProfile	Integer	Yes				
DevTeam	String	Yes				

packingType is a String-based, enumerated custom data type with Label/Value pairs.

Figure 12: Custom Data Type, example 3

Custom Data Types						
Data Type Name	Base Data Type	Enumerati...	Constraint Expression		Label	Value
containerType	String	Yes			New_year	'1/1/2015'
PrimeNumbers	Integer	Yes			Independen...	'7/4/2015'
USHolidays2015	Date	Yes			Labor_Day	'9/7/2015'
ShirtSize	Integer	Yes			Thanksgiving	'11/26/2015'
RiskProfile	Integer	Yes			Christmas	'12/25/2015'
DevTeam	String	Yes				

USHolidays2015 is a Date-based, enumerated custom data type with Label/Value pairs.

Figure 13: Custom Data Type, example 4

Custom Data Types						
Data Type Name	Base Data Type	Enumerati...	Constraint Expression		Label	Value
containerType	String	Yes			S	1
PrimeNumbers	Integer	Yes			M	2
USHolidays2015	Date	Yes			L	3
ShirtSize	Integer	Yes			XL	4
RiskProfile	Integer	Yes			XXL	5
DevTeam	String	Yes				

ShirtSize is an Integer-based, enumerated custom data type with Label/Value pairs.

Figure 14: Custom Data Type, example 5

Custom Data Types						
Data Type Name	Base Data Type	Enumerati...	Constraint Expression		Label	Value
containerType	String	Yes			Low	1
PrimeNumbers	Integer	Yes			Medium	2
USHolidays2015	Date	Yes			High	3
ShirtSize	Integer	Yes			VeryHigh	4
RiskProfile	Integer	Yes				
DevTeam	String	Yes				

RiskProfile is an Integer-based, enumerated custom data type with Label/Value pairs

Figure 15: Custom Data Type, example 6

Custom Data Types						
Data Type Name	Base Data Type	Enumerati...	Constraint Expression	Label	Value	
containerType	String	Yes			'Dave'	
PrimeNumbers	Integer	Yes			'John'	
USHolidays2015	Date	Yes			'Jim'	
ShirtSize	Integer	Yes			'Prashant'	
RiskProfile	Integer	Yes			'Mahesh'	
DevTeam	String	Yes			'Kendall'	
					'George'	
					'Cheryl'	
					'Amish'	
					'Eric'	
					'Marian'	

DevTeam is a String-based, enumerated custom data type with Value-only set members.

Use the **Move Up**  or **Move Down**  toolbar icons to change the order of Label/Value rows in the list.

Enumerations retrieved from a database

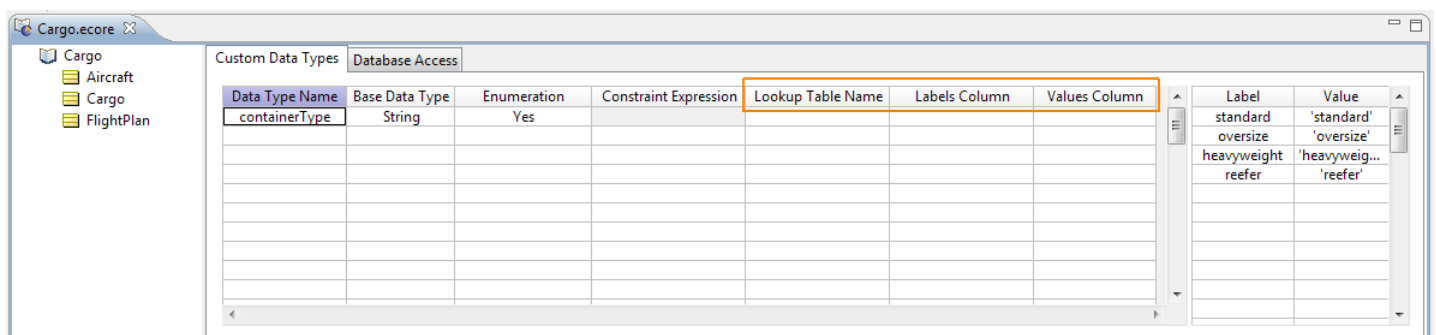
If you want your custom data type to get its enumerated labels and values from a database, then you need to define the database table and columns that will be accessed.

This topic covers the significant points of this feature in the context of the Vocabulary.

Note: This functionality uses Corticon's Enterprise Data Connector. For more information, see *"Import possible values of an attribute from database tables" in the "Advanced EDC Topics" section of the Data Integration Guide*

When your Vocabulary has a verified connection to a supported database, the **Custom Data Types** tab presents three additional columns, as shown:

Figure 16: Custom Data Type columns for defining database retrieval



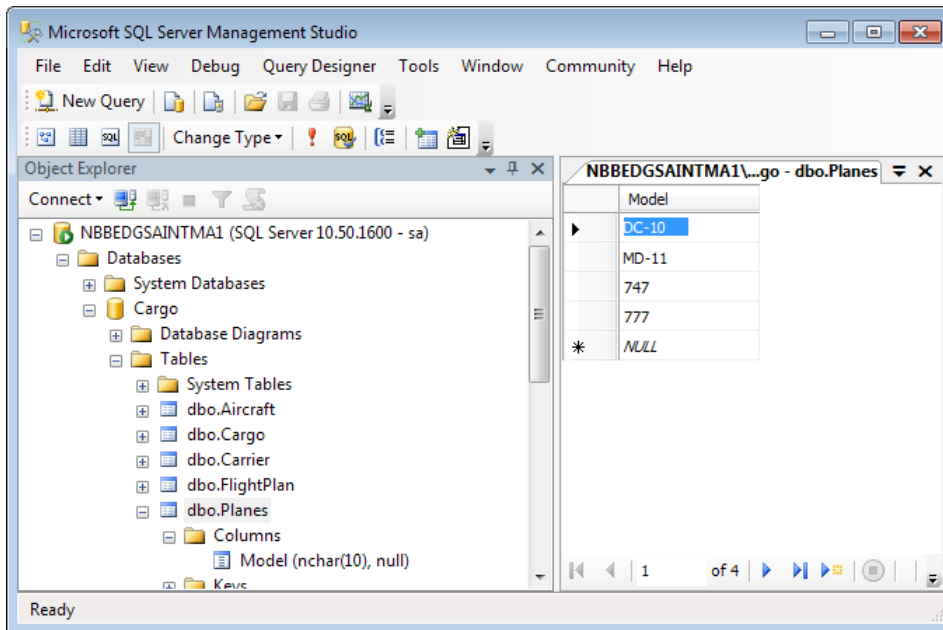
Data Type Name	Base Data Type	Enumeration	Constraint Expression	Lookup Table Name	Labels Column	Values Column	Label	Value
containerType	String	Yes					standard	'standard'
							oversize	'oversize'
							heavyweight	'heavyweig...
							reefer	'reefer'

These columns are how you specify:

- **Lookup Table Name** - The database syntax that specifies the table that has the enumerations.
- **Labels Column** - The column in the lookup table that holds the label. This is optional as you can elect to use only values.
- **Values Column** - The column in the lookup table that holds the value associated with the label, or the solitary value. This is required.

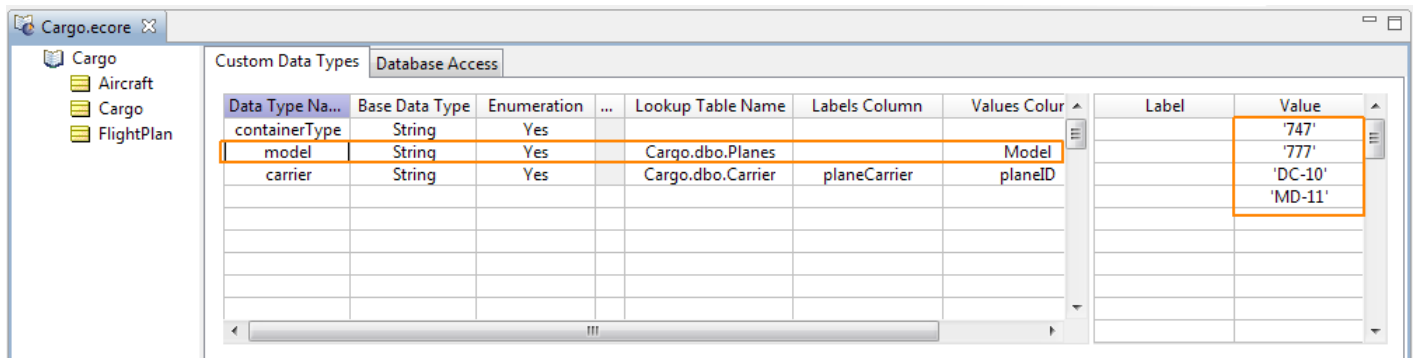
The following examples show two options:

Figure 17: SQL Server table with values to use in the Vocabulary



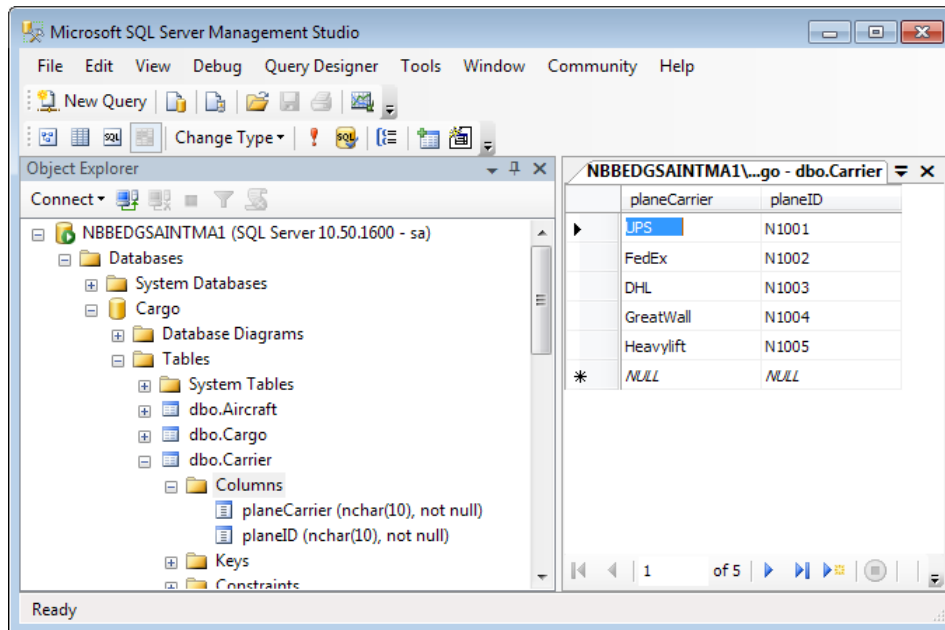
The value data is retrieved into the Vocabulary as highlighted:

Figure 18: Definition and retrieved values in the Corticon Studio



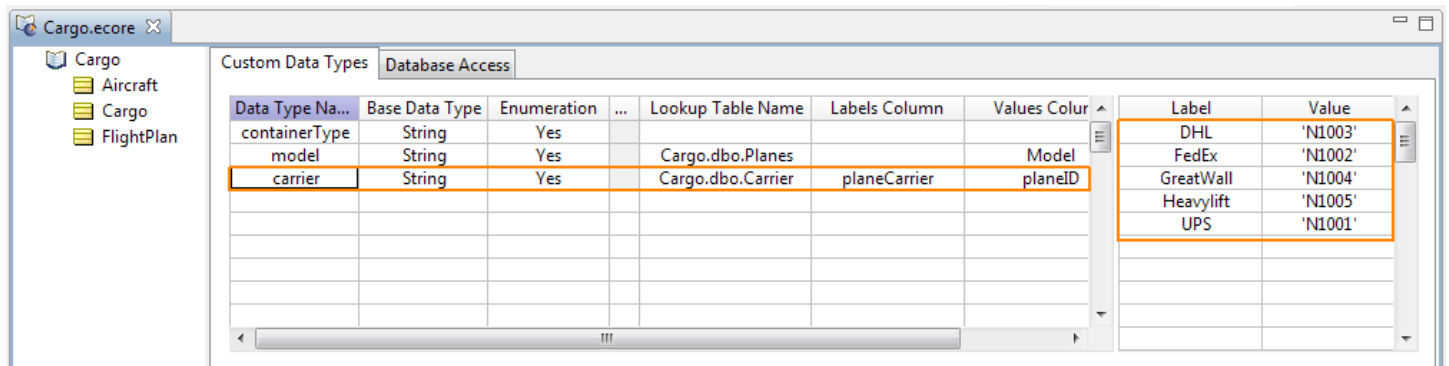
Another example retrieves name-value pairs.

Figure 19: SQL Server table with labels and values to use in the Vocabulary



The label-value data is retrieved into the Vocabulary as highlighted:

Figure 20: Definition and retrieved label-values in the Corticon Studio



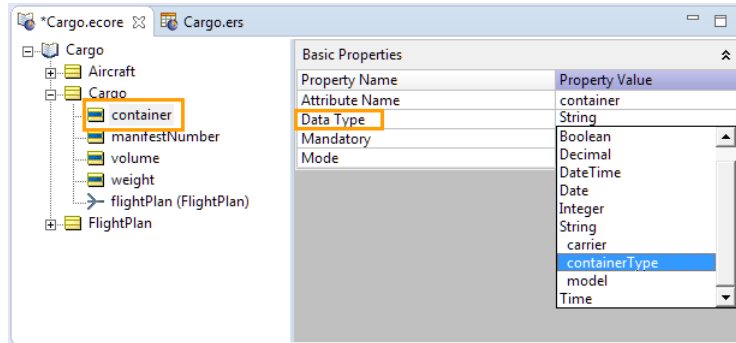
How to use Custom Data Types

Custom data types are powerful additions to your Vocabulary that propagate their effects into Rulesheets and Ruletests.

Use Custom Data Types in a Vocabulary

Once a Custom Data Type has been defined as shown above, it may be used and reused throughout the Vocabulary's attribute definitions.

Figure 21: Using Custom Data Types in the Vocabulary

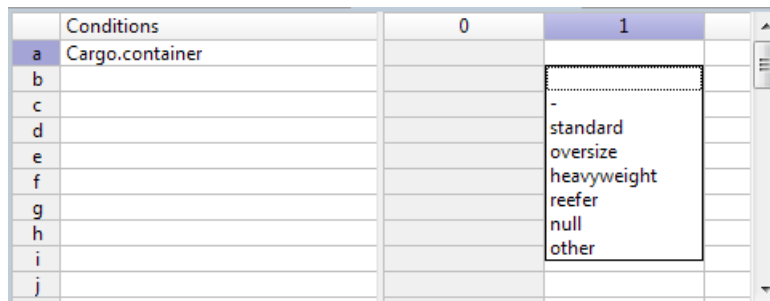


Notice in this figure that multiple attributes can use the same custom data type; the custom data type `containerType` is shown in the drop-down as a sub-category of the String-based data type. The other custom data types will be grouped with their base data types as well.

Use enumerated Custom Data Types in Rulesheets

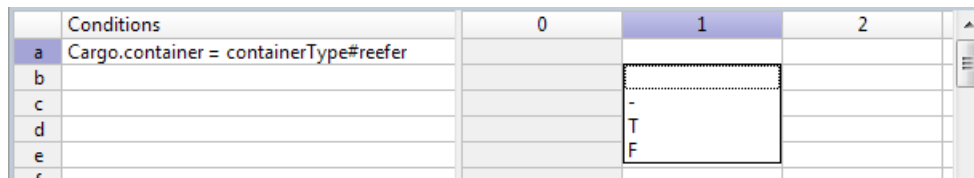
Once an enumeration has been defined and assigned to an attribute, its labels are displayed in selection drop-downs in both Conditions and Actions expressions, as shown below. If **Labels** are not available (since **Labels** are optional in an enumerated custom data type's definition), then **Values** are shown. The `null` option in the drop-down is only available if the attribute's **Mandatory** property value is set to `No`.

Figure 22: Using Custom Data Types in the Rulesheet



You can test a condition bound to an attribute by evaluating the attribute against a custom data type label using the `#` tag, as shown:

Figure 23: Using # tag to test a custom data type

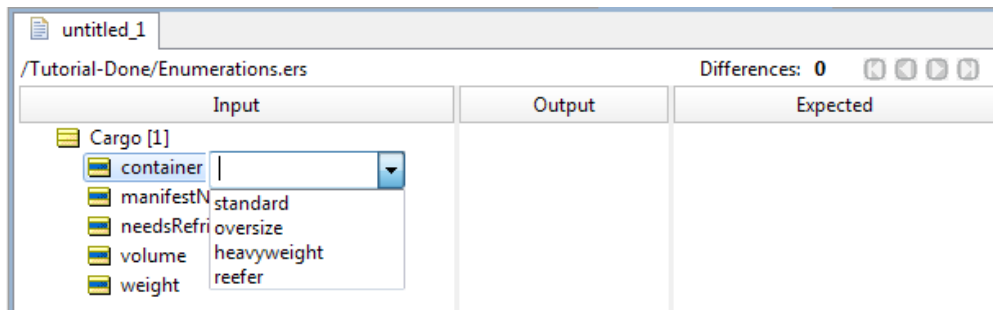


Note: Using a dot instead of a `#` tag works but, if there is custom data type with the same name as an entity, the expression will be invalid.

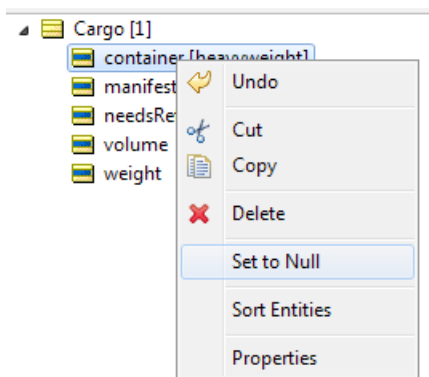
Use enumerated Custom Data Types in Ruletests

An enumeration's Values and Labels are available as selectable inputs in a Ruletest, as shown:

Figure 24: Ruletest selecting container's containerType list



If you want the attribute value to be null, right-click on the attribute and then select **Set to Null**, as shown:



Use IN operator with an enumerated list

When your rule condition or filter are not defined by a range of values, you might have tried use a series of test and logical OR operations to describe the test. For example, `entity1.attribute1='This' or entity1.attribute1='That' or entity1.attribute1='TheOther'` is long, and could evolve into a very long expression. You can eliminate the use of the long form of enumeration literals by using the `in` operator's list format to reduce that filter or condition expression to `entity1.attribute1 in {'This', 'That', 'TheOther'}`.

You can go a step further by defining enumerated lists to define even more brisk expressions, where the labels that you choose are abbreviations for the full names. For example, `Regions.state in {MA, NH, VT, CT, RI, ME}` to qualify only US New England states.

For more information about these features, see the topics in [Quality rules with ranges and lists](#) on page 94

How to relax enforcement of Custom Data Types

Using Custom Data Types lets you define general limitations of an attribute's values that are enforced on all Rulesheets and Ruletests in the project and its Decision Services. While they are valuable in focusing on what is valid in rule designs, violations of the constraints or lists cause rule processing -- Ruletests in Studio; Decision Services on Servers -- to halt at the first violation. Such exceptions indicate that values in attributes are not within numeric constraint ranges or not included in enumerated lists that have been set in the Vocabulary's Custom Data Types.

Note: It is recommended that you use relaxed enforcement of CDTs only in test environments. In production, you should enforce data constraints and lists to ensure valid processing by rules.

For Ruleflows, a rule that throws an exception in earlier Rulesheets disables processing in subsequent Rulesheets. In the following example, the Advanced Tutorial testsheet outputs the following statements:

Severity	Message	Entity
Info	[Checks,2] The customer is a Preferred Cardholder	Customer[1]
Info	[coupons,2] \$2 off next purchase when 3 or more Soda/Juice items are purchased in a single visit.	ShoppingCart[1]
Info	[coupons,3] 10% off next gas purchase when total is over \$75.	ShoppingCart[1]
Info	[coupons,B0] \$1.649800 cashBack bonus earned today, new cashBack balance is \$10.889800.	ShoppingCart[1]
Info	[use__cashBack,1] cashback.bonus has been deducted from the total. New total = \$71.600200. Today's savings = \$10.889800.	ShoppingCart[1]

Note: The rule tracing feature reveals which Rulesheets fired which rules.

By defining a Custom Data Type that specifies the `Item` attribute `price` must be greater than zero, and then entering the input value `-1.00` for an item on the testsheet, the first constraint error stops all the subsequent rules from firing:

Severity	Message
Violation	An unexpected error occurred in Input Data: com.corticon.cdo.ConstraintViolationException: constraint violation setting Item.price to value [-1]

Relaxing the enforcement of Custom Data Type constraints produces warnings instead of violations, so that development teams and pre-production testing teams can expedite their debugging of rules and error handling, as shown:

Severity	Message	Entity
Warning	constraint violation setting Item.price to value [-1]	Item[3]
Info	The customer is a Preferred Cardholder	Customer[1]
Info	\$2 off next purchase when 3 or more Soda/Juice items are purchased in a single visit.	ShoppingCart[1]
Info	\$1.379800 cashBack bonus earned today, new cashBack balance is \$10.619800.	ShoppingCart[1]
Info	cashback.bonus has been deducted from the total. New total = \$58.370200. Today's savings = \$10.619800.	ShoppingCart[1]

This example might indicate that the applications that format requests should handle the data constraint before forwarding a request into the rules engine.

Detailed Example

The following example uses the `Cargo` Vocabulary. It has two Custom Data Types, one numeric constraint (assigned to `Cargo.weight` and `Cargo.volume`) and an enumeration list (assigned to `Cargo.container`.)

Data Type Name	Base Data Type	Enumeration	Constraint Expression	Label	Value
containerType	String	Yes		standard	'standard'
positiveInteger	Integer	No	value >=1	oversize	'oversize'
				heavyweight	'heavyweight'
				reefer	'reefer'

A value that is outside the constraints (`Cargo [1] volume = -1`) is noted as violating the attribute's data type constraint on each input attribute and its entity, as well as noted on the **Problems** tab. But when the Ruletest runs, it halts on the first `Violation`, as shown:

The screenshot shows the Corticon Studio interface for a rule named 'Cargo.ers'. The 'Input' pane shows a 'Cargo [1]' entity with properties: container [secure], volume [-1], and weight [100]. The 'Output' pane shows the same entity with properties: container [secure], volume [-1], and weight [100]. The 'Expected' pane is empty. The 'Rule Messages' pane shows a 'Violation' message: 'An unexpected error occurred in Input Data: com.corticon.cdo.ConstraintViolationException: constraint violation setting Cargo.container to value [secure]'. The 'Error Log' pane shows two warnings: 'Value -1 does not pass constraint validation: value >=1.' and 'Value secure is not in defined Values List of the CustomDataType of standard, oversize, heavyweight, reefer'.

The details of that first exception are entered in the log (when the `loglevel` is `INFO` or higher, and the `logInfoFilter` does not include `VIOLATION` -- thereby accepting that type of info into the log.) No further processing occurs.

Note: See the topic "*How to change logging configuration*" in the *Using Corticon Server logs* section of *Server Guide*

By setting the property in `brms.properties` that relaxes enforcement of Custom Data Types, `com.corticon.vocabulary.cdt.relaxEnforcement=true`, and then restarting the Studio, the errors are still flagged in the data, and the **Problem** information is unchanged. However, the **Rule Messages** section flags each of the constraint breaches as a **Warning**, lets them proceed, and then fires all the other rules.

The screenshot shows the Corticon Studio interface for the same rule 'Cargo.ers'. The 'Input' pane shows 'Cargo [1]' with properties: container [secure], volume [-1], and weight [100]. The 'Output' pane shows 'Cargo [1]' with properties: container [standard], volume [-1], and weight [100]. The 'Expected' pane is empty. The 'Rule Messages' pane shows three messages: two 'Warning' messages for 'constraint violation setting Cargo.container to value [secure]' and 'constraint violation setting Cargo.volume to value [-1]', and one 'Info' message for 'Cargo weighing <= 20,000 kilos must be packaged in a standard container.'. The 'Error Log' pane shows two warnings: 'Value -1 does not pass constraint validation: value >=1.' and 'Value secure is not in defined Values List of the CustomDataType of standard, oversize, heavyweight, reefer'.

Note: It is recommended that you create or update the standard last-loaded properties file `brms.properties` to list override properties such as this for Corticon Studios and Servers. See the introductory topics in "*Server properties and settings*" in the *Server Guide* for more for information on where to locate this properties file.

Domains

Occasionally, it may be necessary to include more than one entity of the same name in a Vocabulary. This can be accomplished using *Domains*. Domains allow you to bundle one or more entities in a *subset* within the Vocabulary, thus you can reuse entity names so long as the entity names are unique within each Domain. Additional Domains, referred to as *sub-Domains*, can be defined within other Domains.

Select **Vocabulary > Add Domain** from the Studio menubar or click  from the Studio toolbar.


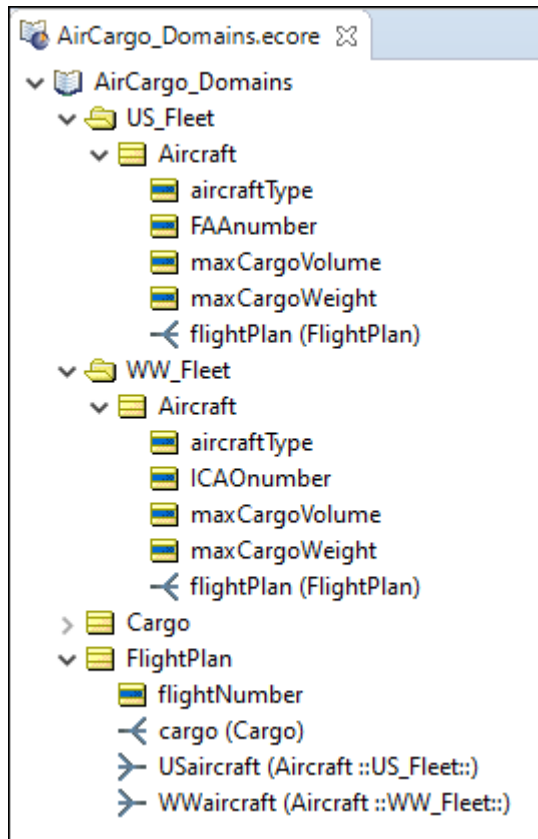
A new folder  is listed in the Vocabulary tree. Assign it a name. The example in the following figure shows a Vocabulary with two Domains, `US_Fleet` and `WW_Fleet`:

Figure 25: Using domains in the Vocabulary>

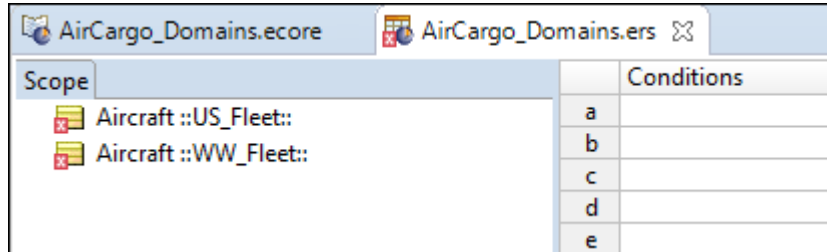



Notice that the entity `Aircraft` appears in each Domain, using the same spelling and containing slightly different attributes (`FAANumber` vs. `ICAOnumber`). Notice too that the association role names from `FlightPlan` to `Aircraft` have been named manually to ensure uniqueness: one is now `USaircraft` and the other is `WWaircraft`.

Domains in a Rulesheet

When using entities from domains in a Rulesheet, it is important to ensure uniqueness, which means aliases must be used to distinguish one entity from another.

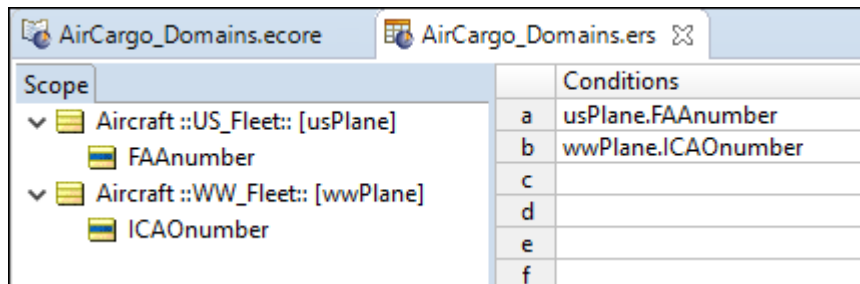
Figure 26: Non-unique Entity names prior to defining Aliases



In *Non-unique Entity names prior to defining Aliases*, both `Aircraft` entities have been dropped into the **Scope** section of the Rulesheet. But because their names are not unique, an error icon  appears. Also, the “fully qualified” domain name has been added after each to distinguish them. By fully qualified, we mean the `::US_Fleet::` designator that follows the first `Aircraft` and `::WW_Fleet::` that follows the second.

But it would be inconvenient (and ugly) to use these fully qualified names in Rulesheet expressions. So we require that you define a unique alias for each. The aliases will be used in the Rulesheet expressions, as shown in *Non-unique Entity names after defining Aliases*.

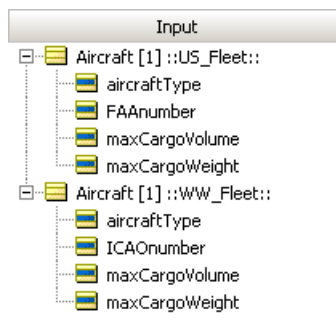
Figure 27: Non-unique Entity names after defining Aliases



Domains in a Ruletest

When using Vocabulary terms in a Ruletest, just drag and drop them as usual. You will notice that they are automatically labeled with the fully qualified name, as shown in **Domains in a Ruletest**.

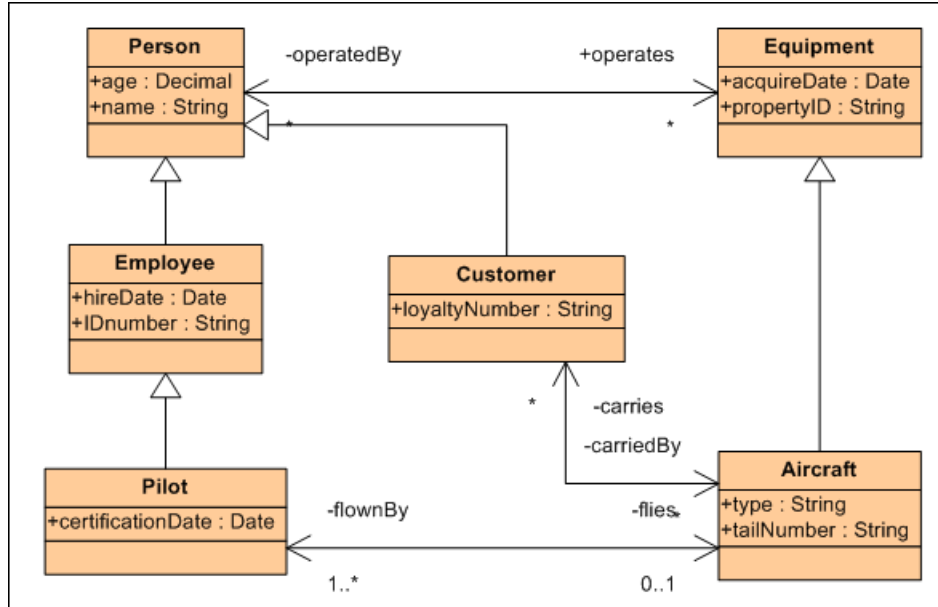
Figure 28: Domains in a Ruletest



Support for inheritance

UML Class diagrams frequently include a modeling/programming concept called inheritance, where a class may “inherit” attributes and/or associations from another class. For example:

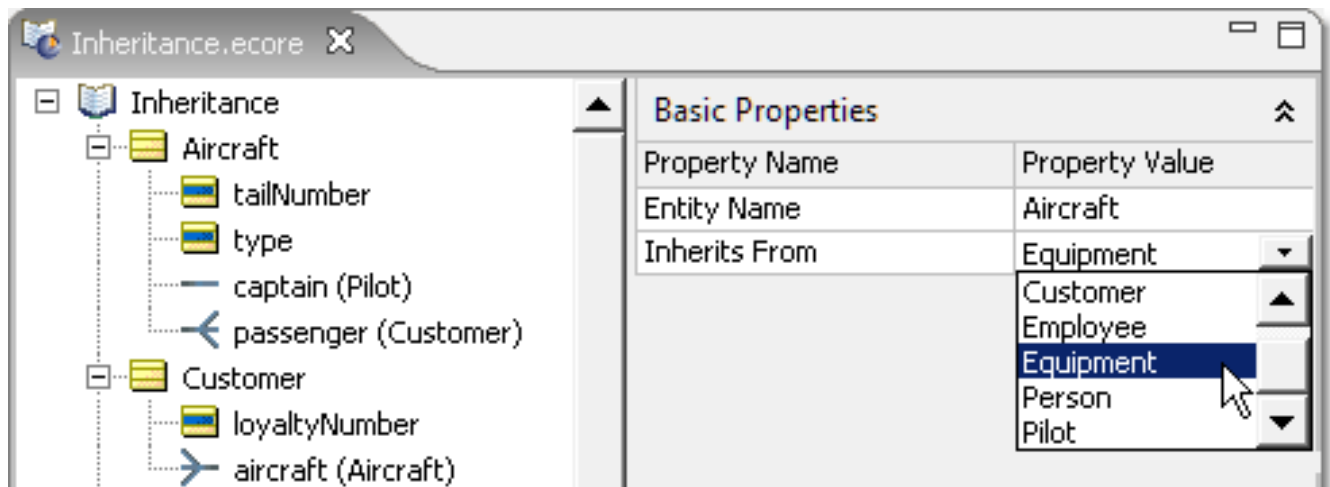
Figure 29: Rose UML Model Showing Inheritance



In this diagram, we see a UML model that includes inheritance. The solid-headed arrow symbol indicates that the `Employee` class is a descendant of the `Person` class, and therefore inherits some of its properties. Specifically, the `Employee` class inherits the `age` and `name` attributes from `Person`. In other words, `Employee` has all the same attributes of a `Person` plus two of its own, `hireDate` and `IDnumber`. Likewise, `Aircraft` inherits all of `Equipment`'s attributes (`acquireDate` and `propertyID`) plus has attributes of its own, `type` and `tailNumber`.

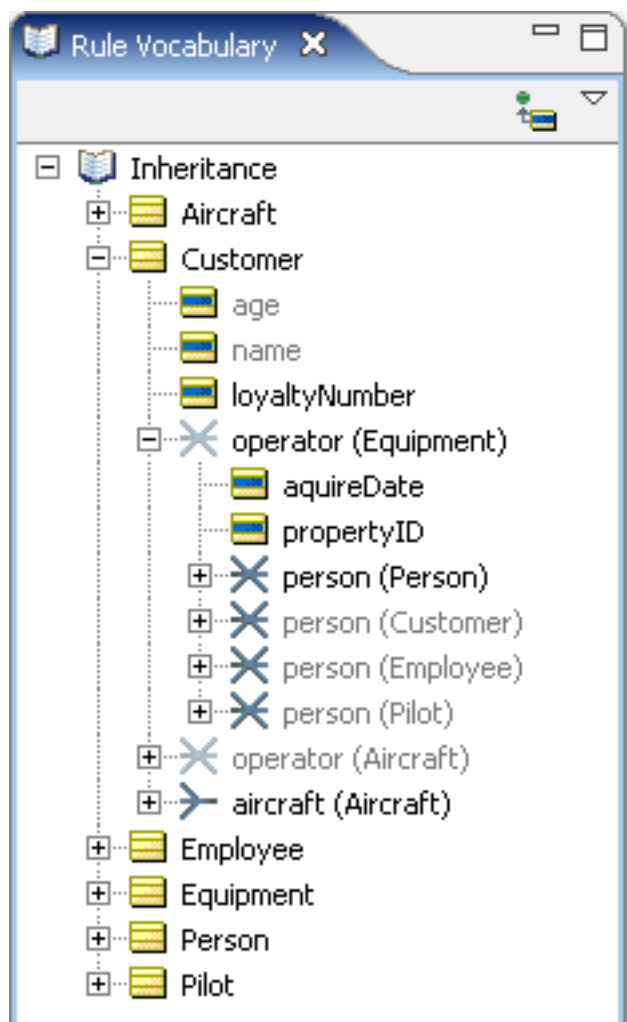
Modeling this UML Class Diagram as a Corticon Vocabulary is straightforward. All Entities, Attributes and Associations are created as per normal practice. To incorporate the elements of inheritance, we only need add one additional setting for each of the descendant entities, as shown:

Figure 30: Selecting Ancestor Entity for Descendant



Once all descendant entities have been configured to inherit from their proper ancestor entities, we can save the Vocabulary and view it in the **Rule Vocabulary** window:

Figure 31: Vocabulary with Inheritance



Notice that many of the term names and icons are varying shades of gray - these color codes help us to understand the inherited relationships that exist in the Vocabulary.

Inherited attributes

Attributes with names displayed in **solid black type**, such as `Customer.loyaltyNumber` in *Vocabulary with Inheritance*, are *native* attributes of that entity.

Attributes with names displayed in **dark gray type**, such as `Customer.age`, are inherited attributes from the ancestor entity (in the case of `Customer`, `Person`).

Inherited associations

Inherited Associations are a bit more complicated. An entity may be directly associated with another entity or that entity's descendants. An entity may also inherit an association from its ancestor.

Using the example shown in *Selecting Ancestor Entity for Descendant* and *Vocabulary with Inheritance* above, let's dissect each of these combinations.

- `Customer.aircraft` is a direct association between `Customer` and `Aircraft` entities. No inheritance is involved, so the association icon is **black** and the rolename is **black**
- `Customer.operator (Equipment)` is an association “inherited” from `Customer`'s ancestor entity `Person`, which has a direct association with `Equipment` and the rolename `operator` in our Vocabulary (the UML Class Diagram in *Selecting Ancestor Entity for Descendant* shows the rolename as `operates` because it is more conventional in UML to use verbs as rolenames, whereas nouns usually make better rolenames in a Corticon Vocabulary). Because the association is inherited from the ancestor's direct association, the icon is **dark gray** and the rolename is **black**.
- `Equipment` (which we can see equally well in the expanded `operator` rolename) has several associations with `Person`. One of these is a direct association with the `Person` entity. In this case, both association icon and rolename are **black**. But `Equipment` also has associations with descendants of the `Person` entity, specifically `Employee`, `Customer`, and `Pilot`. We call these “filtered” associations, and display their rolenames as **dark gray**.
- Finally, `Customer` has another association with `operator (Aircraft)` because `Aircraft` is a descendant of `Equipment`. So we combine the “inherited” **dark gray** icon and the “filtered” **dark gray** rolename to display this association.

How to control the tree view


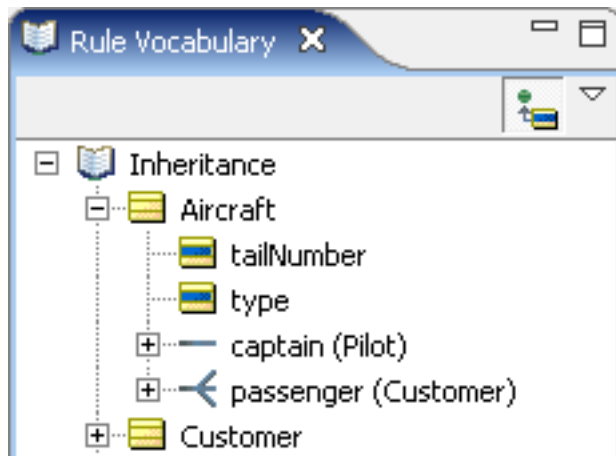
In cases where a Vocabulary contains inheritance (and includes the various icons and color schemes described above) but the modelers who use it do not intend to use inheritance in their rules, the inherited associations and filtered rolenames can be hidden from view by clicking the  icon in the upper right corner of the Rule Vocabulary window, as shown:

Figure 32: Vocabulary with Inheritance Properties Hidden



`Person` and `Equipment` are associated (using named roles), but what relationship does `Employee` have with `Equipment` or `Aircraft`, if any? This version of Corticon Studio supports inherited associations.

How to use aliases with inheritance

Any Entity, Attribute, or Association can be dragged into the Scope section for use in Rulesheets. But if two or more terms share the same name, they must be assigned unique alias names before they can be used in rules.


For example, in *Vocabulary with Inheritance*, we see that there are four `Customer.operator.person` terms in the Vocabulary due to the various forms of inheritance used by the entities and associations. If two or more of these nodes are dragged into the Scope window (as shown in *Non-Unique Nodes used in the Scope Window*), they will be assigned error icons  to indicate that their names are not unique. Without unique names, Corticon Studio does not know which one is intended in any rule that uses one of the nodes. To ensure uniqueness, aliases must be assigned and used in rules, as shown in *Uniqueness Established using an Alias*.

Figure 33: Non-Unique Nodes used in the Scope Window

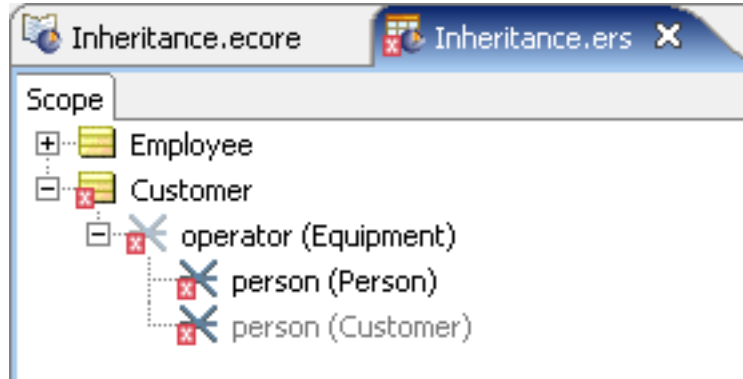
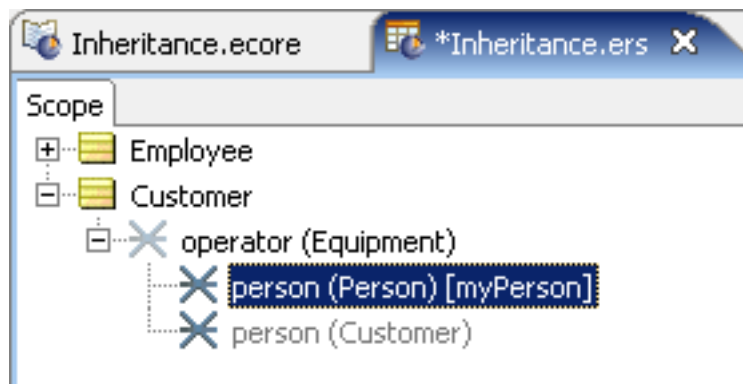


Figure 34: Uniqueness Established using an Alias





Effects of inheritance on rule execution

The point of inheritance is not to complicate the Vocabulary. The point is to be able to write rules on ancestor entities and have those rules affect descendant entities automatically. Here are simple examples:

Inherited Conditions and Actions

A very simple Rulesheet, shown in *Rules written on Employee*, contains two rules that test the `age` value of the `Employee` entity. There are no explicit Actions taken by these rules, only the posting of messages.

Figure 35: Rules written on Employee

Conditions		0	1	2
a	Employee.age < 18	-	T	F
b				
c				
Actions				
	Post Message(s)			
A				
R				
Overrides				

Rule Statements		Rule Messages		
Ref	ID	Post	Alias	Text
1		Warning	Employee	[{Employee.name}] is too young to be an employee!
2		Info	Employee	[{Employee.name}] is old enough to be an employee

A Ruletest provides an instance of `Employee` and an instance of `Pilot`. Recall from the Vocabulary that `Pilot` is a descendant of `Employee`, which means it inherits its attributes and associations. But more importantly from a rule execution perspective, a `Pilot` will also be affected by any rules that affect an `Employee`. This is shown in the following figure:

Figure 36: Inheritance in action

The screenshot displays a Ruletest interface with two main panels: 'Input' and 'Output'. Each panel shows a tree structure of objects and their attributes.

Input Panel:

- Employee [1]**
 - age [24]
 - hireDate
 - IDnumber
 - name [Joe Smith]
- Pilot [1]**
 - age [12]
 - certificationDate
 - hireDate
 - IDnumber
 - name [Mary Jones]

Output Panel:

- Employee [1]**
 - age [24.000000]
 - hireDate
 - IDnumber
 - name [Joe Smith]
- Pilot [1]**
 - age [12.000000]
 - certificationDate
 - hireDate
 - IDnumber
 - name [Mary Jones]

Below the trees is a 'Rule Messages' table with the following data:

Severity	Message	Entity
Info	[Joe Smith] is old enough to be an employee	Employee[1]
Warning	[Mary Jones] is too young to be an employee!	Pilot[1]

Using inheritance can be an efficient and powerful way to write rules on many different types of employees (such as pilots, gate agents, baggage handlers, and mechanics) without needing to write individual rules for each.

Inherited Association

A similar test demonstrates how associations are inherited during rule execution. In this case, we test `Employee.hireDate` to see who's "qualified" to operate a piece of Equipment. The `+=` syntax used by the Action row is explained in more detail in the *Rule Language Guide*.

Figure 37: Rulesheet populating the operators collection

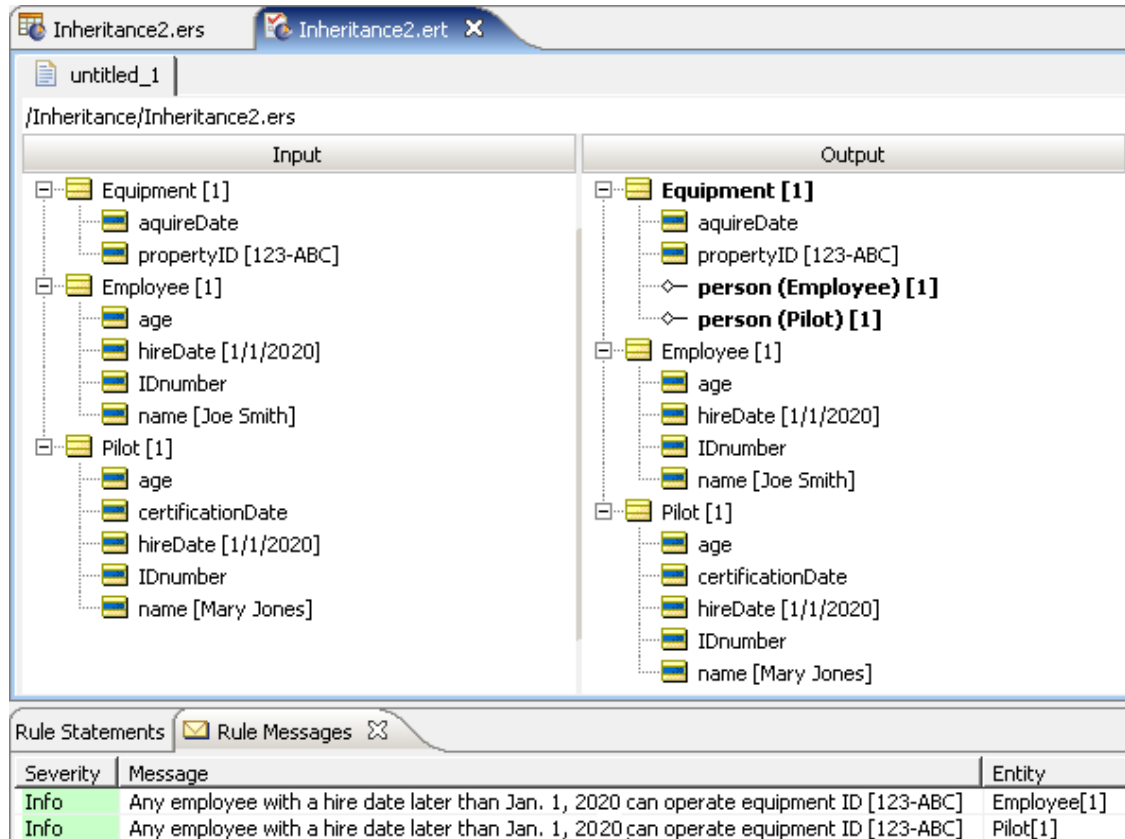
Conditions		0	1
a	Employee.hireDate > '1/1/2020'	-	T
b			
c			
d			
e			

Actions		0	1
Post Message(s)			✉
A	operators += Employee		☑
B			
C			
Overrides			

Ref	ID	Post	Alias	Text
1		Info	Employee	Any employee with a hire date later than Jan. 1, 2020 can operate equipment ID [{Equipment.propertyID}]

Now in, we provide a sample `Equipment` entity, one `Employee`, and one `Pilot`. Both `hireDates` satisfy the rule's Condition (the `Pilot` inheriting `hireDate` from its `Employee` ancestor as before). When the `Employee` is added to the `operators` collection alias, an instance of the association between `Equipment` and `Employee` is created. But what may be surprising is that the same occurs for `Pilot`, which also has an association to `Equipment` that it inherited from `Employee`!

Figure 38: Inheriting an Association



TestYourself questions for Build the vocabulary

Note: Try this test, and then go to [TestYourself answers for Building the vocabulary](#) on page 334 to correct yourself.

1. Give 3 functions of the Vocabulary.
2. True or False: All Vocabulary terms must also exist in the object or data model?
3. True or False: All terms in the object or data model must also exist in the Vocabulary?
4. True or False: In order to create the Vocabulary, an object or data model must already exist.
5. The Vocabulary is an _____ model, meaning many of the real complexities of an underlying data model are hidden so that the rule author can focus on only those terms relevant to the rules.
6. The UML model that contains the same types of information as a Vocabulary is called a _____
7. What are the three components (or nodes) of the Vocabulary?

8. Which of the following are acceptable attribute names?

Hair_color	hairColor	HairColor	hair color
------------	-----------	-----------	------------

9. Which color is used in the Entity icon?

10. Which of the three Vocabulary components can hold an actual value?

11. What are the five main data types used by Vocabulary attributes?

12. Which colors are used in the Base attribute icon?

13. Which colors are used in the Transient attribute icon?





14. What is the purpose of a Transient Vocabulary term?

15. Associations are _____ by default.





16. Association icons indicate:

optionality	singularity	cardinality	musicality
-------------	-------------	-------------	------------

17. Which of the following icons represents a one-to-many association?

			
---	---	---	---

18. Which of the following icons represents a one-to-one association?

			
---	---	---	---

19. If an association is one-directional *from* the Source entity *to* the Target entity, then which term is not available in the Vocabulary?

Target.attribute	Target.source.attribute	Source.target.attribute	Source.attribute
------------------	-------------------------	-------------------------	------------------

20. The default role name of an association *from* the Source entity to the Target entity is:

role1	source	target	theTarget
-------	--------	--------	-----------

21. Sketch a model for the following scenario:

A Purchase Order has a customer name, order date, total amount and an unlimited number of Line Items. Each Line Item has a part number, quantity, price-per-unit and total price.

22. Create a Corticon Studio Vocabulary for the model sketched in 22.

23. List the (4) steps in generating a Vocabulary from scratch.

24. Cardinality of an association determines:

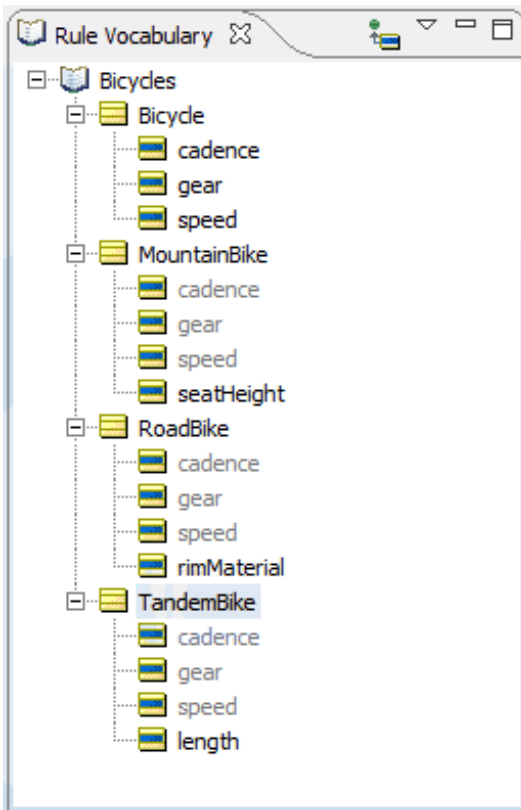
- a. The number of possible associated entities.
- b. The number of attributes for each entity.

- c. The number of associations possible within an entity.
 - d. The number of attributes for each association.
25. The Vocabulary terms are the nouns of Corticon rules. What are the verbs?
 26. What Corticon document contains the complete list of all Vocabulary Operators, descriptions of their usage, and actual examples of use in Rulesheets?
 27. True or False. In addition to the supported vocabulary data types, you can create *any* type of custom data type you want?
 28. You must name your custom data type. Which of the following are *not* custom data type naming convention requirements?
 - a. Cannot match any other vocabulary entity names
 - b. May match other Custom Data Type Names
 - c. Base Data Type names may not be re-used.
 - d. The name must comply with the standard entity naming rules.
 29. True or False. The Enumeration section of the Custom Data Types exposes the Label/Value columns and allows you to create a list of acceptable value rows.
 30. Selecting `no` in the *Enumeration* section of the Custom Data Types enables the Constraint Expression. Give an example of a Constraint Expression:

31. True or False. Constraint Expressions must be equivalent to a Boolean expression to be valid.
32. In an Enumeration, are both the **Label** and **Value** columns required?
33. When you create Enumerated Custom data Types, which of the following are acceptable entries for the Value column:

12/12/2011	"12/12/2011"	Airbus	'Airbus'
------------	--------------	--------	----------

34. Name an advantage to using Enumerated Custom Data Types when it comes to testing your rules in a Ruletest.
35. Explain what Domains do in the Vocabulary?
36. True or False. If you use a Domain, then you will be required to create an alias for each unique Entity/Domain pair?
37. True or False. Inheritance can be modeled in a Vocabulary.
38. In the following vocabulary, which Entities have native attributes and which Entities have inherited attributes?



39. Give two examples of inherited attributes from the vocabulary above:

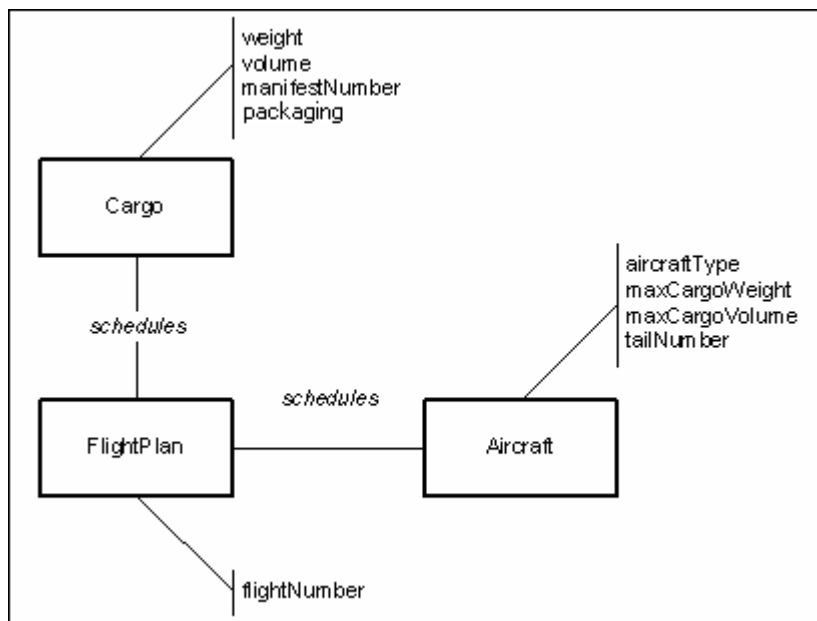
40. True or False. Using Inheritance can be a way to write efficient and powerful rules. For example, one rule could be used to modify the cadence attribute for all the entities in the Vocabulary example above.

Rule scope and context

The air cargo example that we started in the Vocabulary chapter is continued here to illustrate the important concepts of *scope* and *context* in rule design.

A quick recap of the fact model:

Figure 39: Fact Model



According to this Vocabulary, an Aircraft is related to a Cargo shipment through a FlightPlan. In other words, it is the FlightPlan that connects or relates an Aircraft to its Cargo shipment. The Aircraft, by itself, has *no direct relationship* to a Cargo shipment unless it is scheduled by a FlightPlan; or, no Aircraft may carry a Cargo shipment without a FlightPlan. Similarly, no Cargo shipment may be transported by an Aircraft without a FlightPlan. These facts constitute business rules in and of themselves and constrain creation of other rules because they define the Vocabulary we will use to build all subsequent rules in this scenario.

Also recall that the company wants to build a system that automatically checks flight plans to ensure no scheduling rules or guidelines are violated. One of the many business rules that need to be checked by this system is:

1. An Aircraft must not carry a Cargo shipment that exceeds its maximum Cargo weight

With our Vocabulary created, we can build this rule in the Studio. As with many tasks in Studio, there is often more than one way to do something. We will explore two possible ways to build this rule – one correct and one incorrect.

To begin with, we will write our rule using the “root-level” terms in the Vocabulary. In the following figure, column #1 (the **true** Condition) is the rule we are most interested in – we’ve added the **false** Condition in column #2 simply to show a logically complete Rulesheet.

Figure 40: Expressing the Rule Using “Root-Level” Vocabulary Terms

The screenshot shows the Rule Studio interface. On the left is the 'Rule Vocabulary' tree with categories like 'airCargo', 'aircraft', 'flightPlan (FlightPlan)', and 'cargo'. The main area shows a rule configuration for 'rootLevelScope.ers'. It includes a 'Conditions' table with two columns (1 and 2), an 'Actions' section with 'Post Message(s)', and a 'Rule Statements' table at the bottom.

Conditions		1	2
a	cargo.weight > aircraft.maxCargoWeight	T	F
b			
c			

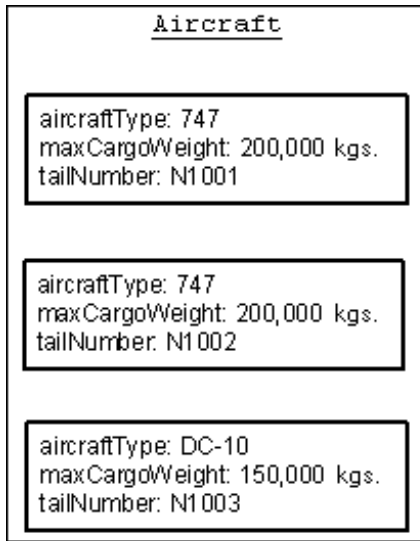
Actions			
Post Message(s)		✉	✉
A			
B			
C			

Ref	ID	Post	Alias	Text
1		Violation	cargo	Cargo [{cargo.manifestNumber}] is too heavy to be carried by Aircraft [{aircraft.tailNumber}]
2		Info	cargo	Cargo [{cargo.manifestNumber}] may be carried by Aircraft [{aircraft.tailNumber}]

We can build a Ruletest to test the rule using the Cargo company's actual data, as follows:

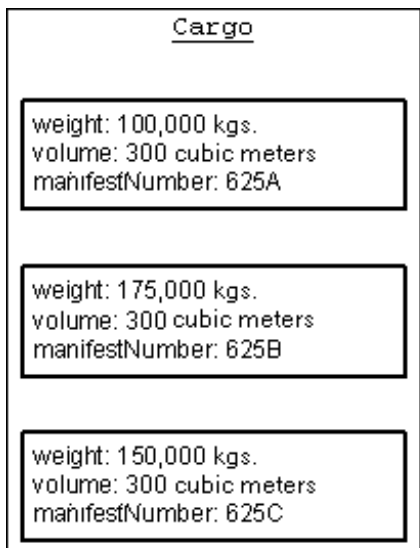
The company owns 3 Aircraft, 2 747s and a DC-10, each with different tail numbers. Each box represents a real-life example (or *instance*) of the `Aircraft` term from our Vocabulary.

Figure 41: The Cargo Company's 3 Aircraft



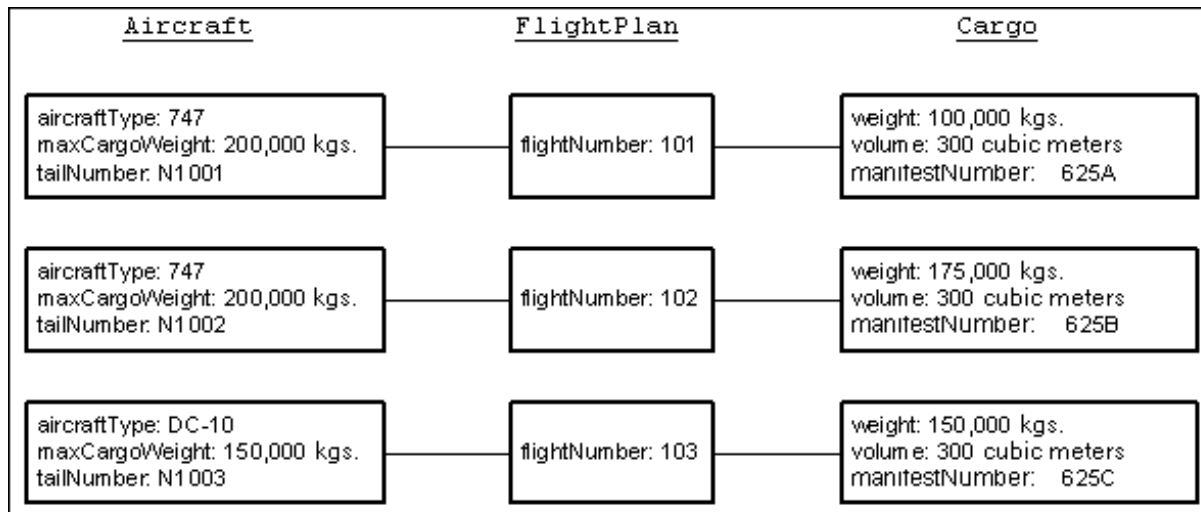
These `Aircraft` give the company the ability to schedule 3 `Cargo` shipments each night (there is another business rule implied here – “an `Aircraft` must not be scheduled for more than one flight per night”, but we won't address this now because it is not relevant to the discussion). On a given night, the `Cargo` shipments look like those shown below. Again, like the `Aircraft`, these `Cargo` shipments represent specific *instances* of the generic `Cargo` term from the Vocabulary.

Figure 42: The 3 Cargo Shipments for the Night of June 25th



Finally, our sample business process manually matches specific aircraft and cargo shipments together as three flightplans, shown below. This organization of data is consistent with the structure and constraints implicit in our Vocabulary.

Figure 43: The 3 FlightPlans with their related Aircraft and Cargo instances



We can construct a Ruletest (in the following figure) so that the company's actual data will be evaluated by the rule. Since the rule used "root-level" Vocabulary terms in its construction, we will use "root-level" terms in the Ruletest as well:

Figure 44: Test the Rule Using "Root-Level" Vocabulary Terms

The screenshot shows a software interface with a 'Rule Vocabulary' tree on the left and a 'Ruletest' window on the right. The Ruletest window displays a table with 'Input' and 'Output' columns, showing hierarchical data for aircraft, cargo, and flight plans.

Input	Output
aircraft [1] <ul style="list-style-type: none"> aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N101] 	aircraft [1] <ul style="list-style-type: none"> aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N101]
aircraft [2] <ul style="list-style-type: none"> aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N102] 	aircraft [2] <ul style="list-style-type: none"> aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N102]
aircraft [3] <ul style="list-style-type: none"> aircraftType [DC10] maxCargoWeight [150000.000000] tailNumber [N103] 	aircraft [3] <ul style="list-style-type: none"> aircraftType [DC10] maxCargoWeight [150000.000000] tailNumber [N103]
cargo [1] <ul style="list-style-type: none"> manifestNumber [625A] weight [100000] 	cargo [1] <ul style="list-style-type: none"> manifestNumber [625A] weight [100000.000000]
cargo [2] <ul style="list-style-type: none"> manifestNumber [625B] weight [175000] 	cargo [2] <ul style="list-style-type: none"> manifestNumber [625B] weight [175000.000000]
cargo [3] <ul style="list-style-type: none"> manifestNumber [625C] weight [150000] 	cargo [3] <ul style="list-style-type: none"> manifestNumber [625C] weight [150000.000000]

Running the Ruletest :

Figure 45: Results of the Ruletest

The screenshot shows a software interface with the following components:

- File Explorer:** Shows tabs for 'airCargo.ecore', 'rootLevelScope.ers', and 'rootLevelScope.ert'. The active file is 'untitled_1' located at '/RulesTutorial/rootLevelScope.ers'.
- Data Comparison:** A table comparing 'Input' and 'Output' data for three aircraft and three cargo items.

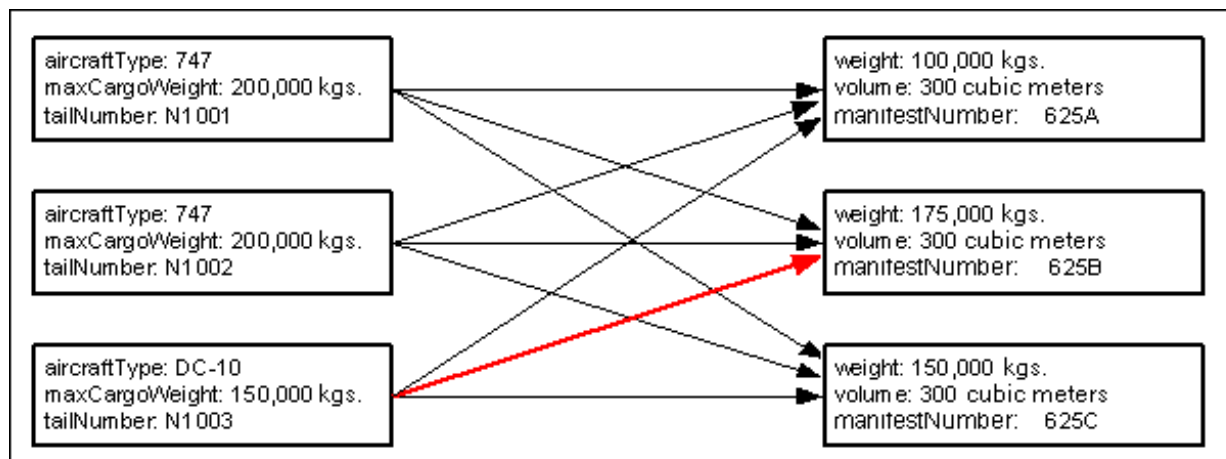
Input	Output
aircraft [1] aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N101]	aircraft [1] aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N101]
aircraft [2] aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N102]	aircraft [2] aircraftType [747] maxCargoWeight [200000.000000] tailNumber [N102]
aircraft [3] aircraftType [DC10] maxCargoWeight [150000.000000] tailNumber [N103]	aircraft [3] aircraftType [DC10] maxCargoWeight [150000.000000] tailNumber [N103]
cargo [1] manifestNumber [625A] weight [100000]	cargo [1] manifestNumber [625A] weight [100000.000000]
cargo [2] manifestNumber [625B] weight [175000]	cargo [2] manifestNumber [625B] weight [175000.000000]
cargo [3] manifestNumber [625C] weight [150000]	cargo [3] manifestNumber [625C] weight [150000.000000]
- Rule Messages Table:**

Severity	Message	Entity
Violation	Cargo [625B] is too heavy to be carried by Aircraft [N103]	cargo[2]
Info	Cargo [625B] may be carried by Aircraft [N102]	cargo[2]
Info	Cargo [625A] may be carried by Aircraft [N102]	cargo[1]
Info	Cargo [625C] may be carried by Aircraft [N102]	cargo[3]
Info	Cargo [625B] may be carried by Aircraft [N101]	cargo[2]
Info	Cargo [625A] may be carried by Aircraft [N101]	cargo[1]
Info	Cargo [625C] may be carried by Aircraft [N101]	cargo[3]
Info	Cargo [625A] may be carried by Aircraft [N103]	cargo[1]
Info	Cargo [625C] may be carried by Aircraft [N103]	cargo[3]

Note the messages returned by the Ruletest. Recall that the intent of the rule is to verify whether a given `FlightPlan` is in violation by scheduling a `Cargo` shipment that is too heavy for the assigned `Aircraft`. But we already know there are only three `FlightPlans`. And we also know, from examination of **The 3 FlightPlans with their related Aircraft and Cargo instances**, that the combination of aircraft `N1003` and cargo `625C` does not appear in any of our three `FlightPlans`. So why was this combination, one that does not actually exist, evaluated? For that matter, why has the rule fired *nine* times when only *three* sets of `Aircraft` and `Cargo` were present? The answer lies in the way we defined our rule, and in the way the Corticon Server evaluated it.

We gave the Ruletest three instances of both `Aircraft` and `Cargo`. Studio treats `Aircraft` as a “collection” or “set” of these three specific instances. When Studio encounters the term `Aircraft` in a rule, it applies all instances of `Aircraft` found in the Ruletest (all three instances in this example) to the rule. Since both `Aircraft` and `Cargo` have three instances, there are a total of nine *possible combinations* of the two terms. In the following figure, the set of these nine possible combinations is called a “cross product”, “Cartesian product”, or “tuple set” in different disciplines. We tend to use cross-product when describing this outcome.

Figure 46: All Possible Combinations of Aircraft and Cargo



One pair, the combination of manifest `625B` and plane `N1003` (shown as the red arrow in the figure above), is indeed illegal, since the plane, a `DC-10`, can only carry `150,000` kilograms, while the cargo weighs `175,000` kilograms. But this pairing does not correspond to any of the three `FlightPlans` created. Many of the other combinations evaluated (five others, to be exact) are not represented by real flight plans either. So why did Studio bother to perform three times the necessary evaluations? It is because our rule, as implemented in [Figure 40: Expressing the Rule Using Root-Level Vocabulary Terms](#) on page 64, does not capture the essential elements of **scope** and **context**.

We want our rule to express the fact that we are only interested in evaluating the `Cargo–Aircraft` pair for *each* `FlightPlan`, not for *all* possible combinations. How do we express this intention in our rule? We use the associations included in the Vocabulary.

Refer to the following figure:

Figure 47: Rule Expressed Using FlightPlan as the Rule Scope

The screenshot shows the Corticon Rulesheet Editor interface. On the left is the 'Rule Vocabulary' tree, where 'FlightPlan' is expanded to show 'aircraft' and 'cargo' sub-terms. The right pane is titled 'FlightPlanScope.ers' and contains a table for rule conditions and actions.

Conditions		1	2
a	FlightPlan.cargo.weight > FlightPlan.aircraft.maxCargoWeight	T	F
b			

Actions			
Post Message(s)		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
A			
B			
C			

Rule Statements				
Ref	ID	Post	Alias	Text
1		Violation	FlightPlan	Cargo [{{FlightPlan.cargo.manifestNumber}}] is too heavy for Aircraft [{{FlightPlan.aircraft.tailNumber}}]
2		Info	FlightPlan	Cargo [{{FlightPlan.cargo.manifestNumber}}] may not be carried by Aircraft [{{FlightPlan.aircraft.tailNumber}}]

Here, we've rewritten the rule using the `aircraft` and `cargo` terms from *inside* the `FlightPlan` term.

Note: By “inside” we mean the `aircraft` and `cargo` terms that appear when the `FlightPlan` term is opened in the Vocabulary tree, as shown by the orange circles in **Rule Expressed Using FlightPlan as the Rule Scope**.

This is significant. It means we want the rule to evaluate the `Cargo` and `Aircraft` terms *only in the context of a FlightPlan*. For example, on a different night, the `Cargo` company might have eight `Cargo` shipments assembled, but only the same three planes on which to carry them. In this scenario, three flight plans would still be created. Should the rule evaluate all eight `Cargo` shipments, or only those three associated with actual flight plans? From the original business rule, it is clear we are only interested in evaluating those `Cargo` shipments *in the context of actual flight plans*. To put it differently, the rule's application is limited to only those `Cargo` shipments assigned to a specific `Aircraft` via a specific `FlightPlan`. We express these relationships in the Rulesheet by including the `FlightPlan` term in the rule, so that `cargo.weight` is properly expressed as `FlightPlan.cargo.weight`, and `Aircraft.maxCargoWeight` is properly expressed as `FlightPlan.aircraft.maxCargoWeight`. By attaching `FlightPlan` to the terms `aircraft.maxCargoWeight` and `cargo.weight`, we have indicated mandatory *traversals* of the associations between `FlightPlan` and the other two terms, `Aircraft` and `Cargo`. This instructs Corticon Server to evaluate the rule using the intended context. In writing rules, it is extremely important to understand the context of a rule and the scope of the data to which it will be applied.

For details, see the following topics:

- [Rule scope](#)
- [Aliases](#)
- [Scope and perspectives in the vocabulary tree](#)
- [TestYourself questions for Rule scope and context](#)

Rule scope

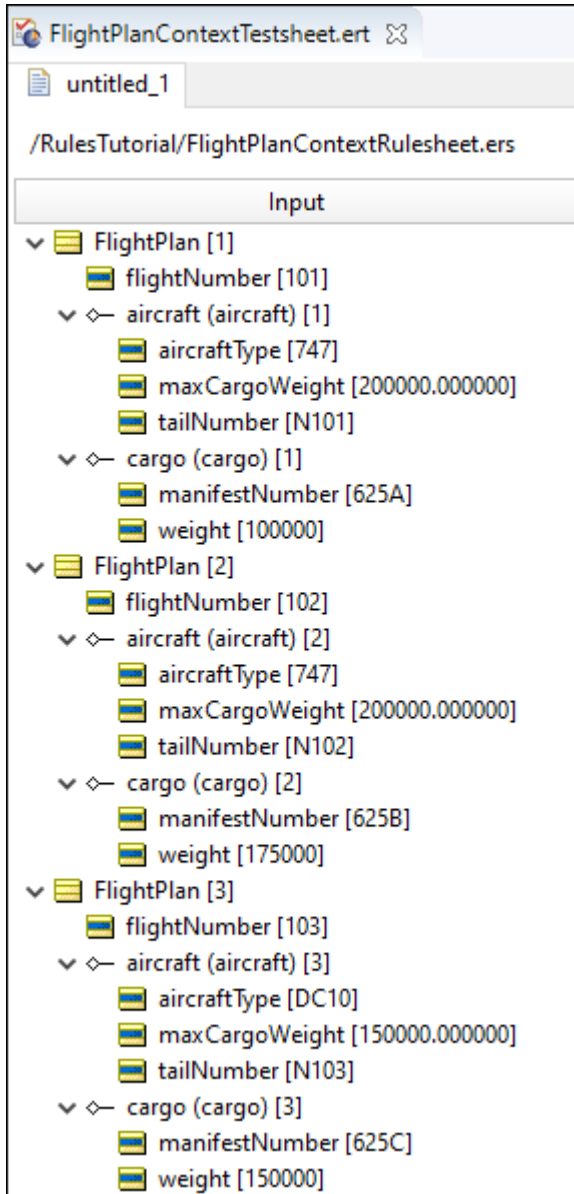
Because the rule is evaluating both `Cargo` and `Aircraft` in the context of a `FlightPlan`, we say that the rule has *scope*, which means that *the rule evaluates only that data which matches the rule's scope*. This has an interesting effect on the way the rule is evaluated. When the rule is executed, its scope ensures that the Corticon Server evaluates only those pairings that *match the same FlightPlan*. This means that a `cargo.weight` will **only** be compared to an `aircraft.maxCargoWeight` **if** both the `cargo` and the `aircraft` share the same `FlightPlan`. This simplifies rule expression greatly, because it eliminates the need for us to specify *which FlightPlan* we are talking about for each `Aircraft-Cargo` combination. When a rule has context, the system takes care of this matching automatically by sending *only* those `Aircraft - Cargo` pairs that *share the same FlightPlan* to be evaluated by the rule. And, since Corticon Studio automatically handles multiple instances as *collections*, it sends *all* pairs to the rule for evaluation.

Note: See the [Collections](#) topic for a detailed discussion of this subject.

To test this new rule, we need to structure our Ruletest differently to correspond to the new structure of our rule and reflect the rule's scope. For more information on the mechanics of creating associations in Ruletests, see "[Add and edit association nodes and their properties](#)" and "[Create associations in the test tree](#)" in the *Quick Reference Guide*.

Finally, one `FlightPlan` is created for each `Aircraft-Cargo` pair. This means a total of three `FlightPlans` are generated each night. Using the terms in our Vocabulary *and the relationships between them*, we have the possibilities shown in [Figure 43: The 3 FlightPlans with their related Aircraft and Cargo instances](#) on page 66. The rule will evaluate these combinations and identify any violations.

Figure 48: New Ruletest Using `FlightPlan` as the Rule Scope



What is the expected result from this Ruletest? If the results follow the same pattern as in the first Ruletest, we might expect the rule to fire nine times (three `Aircraft` evaluated for each of three `Cargo` shipments).

But refer to *Ruletest Results Using Scope – Note no Violations* and you will see that the rule, in fact, fired only 3 times – and only for those `Aircraft-Cargo` pairs that are related by common `FlightPlans`. This is the result we want. The Ruletest shows that there are no `FlightPlans` in violation of our rule.

Figure 49: Ruletest Results Using Scope – Note no Violations


Severity	Message	Entity
Info	Cargo [625B] may be carried by Aircraft [N102]	FlightPlan[2]
Info	Cargo [625C] may be carried by Aircraft [N103]	FlightPlan[3]
Info	Cargo [625A] may be carried by Aircraft [N101]	FlightPlan[1]

One final point about scope: it is critical that the context you choose for your rule supports the intent of the business decision you are modeling. At the very beginning of our example, we stated that the purpose of the application is to check flightplans *that have already been created*. Therefore, the context of our rule was chosen so that the rule's design was consistent with this goal – no aircraft-cargo combinations should be evaluated unless they are already matched up via a common flightplan.

But what if our business purpose had been different? What if the problem we are trying to solve was modified to: “Of all possible combinations of aircraft and cargo, determine which pairings must **not** be included in the same FlightPlan.” The difference here is subtle but important. Before, we were identifying invalid combinations of pre-existing FlightPlans. Now, we are trying to identify invalid combinations from all possible cargo-aircraft pairings. This other rule might be the first step in a screening or filtering process designed to discard all the invalid combinations. In this case, the original rule we built, root-level context, would be the appropriate way to implement our intentions, because now we are looking at all possible combinations *prior to creating new FlightPlans*.

Aliases

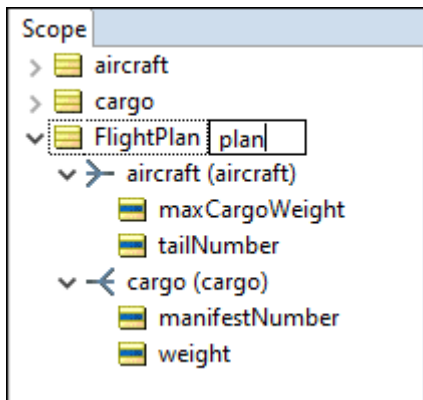
To clean up and simplify rule expression, Corticon Studio allows you to declare *aliases* in a Rulesheet Using an alias to express scope results in a less cluttered Rulesheet.

To define an alias, you need to open the **Scope** tab on the Rulesheet. Either click the toolbar button  to open the advanced view, or choose the Rulesheet menu toggle **Advanced View**.

If rules have already been modeled in the Rulesheet, then the **Scope** window already contains those Vocabulary terms used in the rules so far. If rules have not yet been modeled, then the Scope window is empty.

To define an alias, double-click to the term, and then type a unique name in the entry box, as shown:

Figure 50: Defining an Alias in the Scope window



Once an alias is defined, any subsequent rule modeling in the Rulesheet automatically substitutes the alias for the Vocabulary term it represents.

In the next illustration, notice that the terms in the Condition rows of the Rulesheet do not show the `FlightPlan` term. That's because the alias `plan` substitutes for `FlightPlan`.

Figure 51: Rulesheet with `FlightPlan` Alias Declared in the Scope Section

The screenshot shows the Corticon Studio interface for a rulesheet named 'FlightPlanScopeAliases.ers'. The interface is divided into several sections:

- Scope:** A tree view on the left showing the hierarchy of terms. The 'FlightPlan [plan]' node is expanded, showing sub-nodes for 'aircraft (aircraft)' and 'cargo (cargo)'. Under 'aircraft (aircraft)', there are 'maxCargoWeight' and 'tailNumber'. Under 'cargo (cargo)', there are 'manifestNumber' and 'weight'.
- Conditions:** A table with 5 rows (a-e) and 2 columns (1, 2). Row 'a' contains the condition `plan.cargo.weight > plan.aircraft.maxCargoWeight`. Row 'a' has 'T' in column 1 and 'F' in column 2. Rows 'b' through 'e' are empty.
- Actions:** A table with 5 rows (A-E) and 2 columns (1, 2). Row 'A' contains the action 'Post Message(s)'. Row 'A' has a yellow envelope icon in column 1 and a yellow envelope icon in column 2. Rows 'B' through 'E' are empty.
- Filters:** A table with 2 rows (1, 2) and 1 column. Row 1 is empty, and row 2 is empty.
- Rule Statements:** A table at the bottom with 5 columns: Ref, ID, Post, Alias, Text. It contains two rows:

Ref	ID	Post	Alias	Text
1		Violation	plan	Cargo {{plan.cargo.manifestNumber}} is too heavy for Aircraft {{plan.aircraft.tailNumber}}
2		Info	plan	Cargo {{plan.cargo.manifestNumber}} may be carried by Aircraft {{plan.aircraft.tailNumber}}

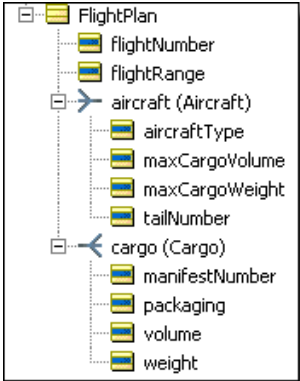
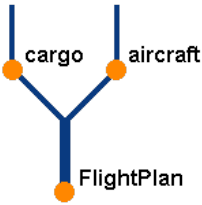
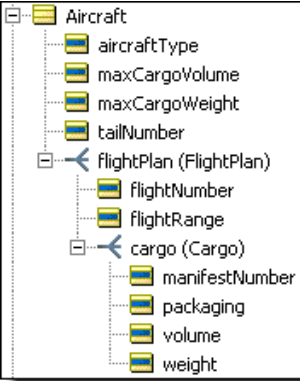

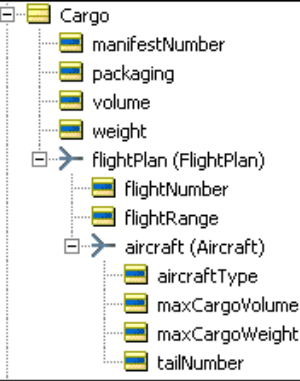

Once an alias is defined, any new Vocabulary term dropped onto the Rulesheet is adjusted accordingly. For example, dragging and dropping `FlightPlan.cargo.weight` onto the Rulesheet displays as `plan.cargo.weight`.

Note: Rules modeled without aliases do not update automatically if aliases are defined later. So if you intend to use aliases, define them as you start your rule modeling - that way they apply automatically when you drag and drop from the Vocabulary or Scope windows.

Scope and perspectives in the vocabulary tree

Because our Vocabulary is organized as a tree view in Corticon Studio, it may be helpful to extend the tree analogy to better understand what aliases do. The tree view permits us to use the business terms from a number of different *perspectives*, each perspective corresponding to one of the root-level terms and an optional set of one or more branches.

Table 1: Vocabulary Tree Views and Corresponding Branch Diagrams

Vocabulary Tree	Description	Branch Diagram
	<p>This portion of the Vocabulary tree can be visualized as the branch diagram shown to the right. Because this piece of the Vocabulary begins with the FlightPlan root, the branches also originate with the FlightPlan root or trunk. The FlightPlan's associated cargo and aircraft terms are branches from the trunk.</p> <p>Any rule expression that uses FlightPlan, FlightPlan.cargo, or FlightPlan.aircraft is using scope from this perspective of the Vocabulary tree.</p>	
	<p>This portion of the Vocabulary tree begins with Aircraft as the root, with its associated flightPlan branching from the root. A cargo, in turn, branches from its associated flightPlan.</p> <p>Any rule expression that uses Aircraft, Aircraft.flightPlan, or Aircraft.flightPlan.cargo is using scope from this perspective of the Vocabulary tree.</p>	
	<p>This portion of the Vocabulary tree begins with Cargo as the root, with its associated flightPlan branching from the root. An aircraft, in turn, branches from its associated flightPlan.</p> <p>Any rule expression that uses Cargo, Cargo.flightPlan, or Cargo.flightPlan.aircraft is using scope from this perspective of the Vocabulary tree.</p>	

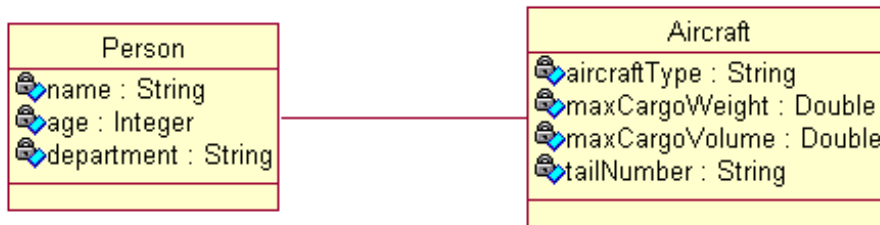
Scope can also be thought of as hierarchical, meaning that a rule written with scope of Aircraft applies to all root-level Aircraft data. And other rules using some piece (or branch) of the tree beginning with root term Aircraft, including Aircraft.flightPlan and Aircraft.flightPlan.cargo, also apply to this data and its associated collections. Likewise, a rule written with scope of Cargo.flightPlan does not apply to root-level FlightPlan data.

This provides an alternative explanation for the different behaviors between the Rulesheets in [Expressing the Rule Using Root-Level Vocabulary Terms](#) and [Rule Expressed Using FlightPlan as the Rule Scope](#). The rules in the former are written using different root terms and therefore different scopes, whereas the rules in the latter use the same `FlightPlan` root and therefore share common scope.

Roles

Using roles in the Vocabulary can often help to clarify rule context. To illustrate this point, we will use a slightly different example. The UML class diagram for a new (but related) sample Vocabulary is as shown:

Figure 52: UML Class Diagram without Roles



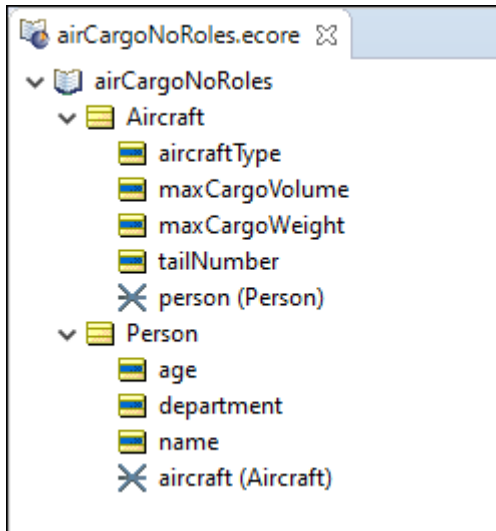
As shown in this class diagram, the entities `Person` and `Aircraft` are joined by an association. However, can this single association sufficiently represent multiple relationships between these entities? For example, a prior Fact Model might state that “a pilot flies an aircraft” and “a passenger rides in an aircraft” – both pilot and passenger are descendants of the entity `Person`. Furthermore, we can see that, in practice, some instances of `Person` may be pilots and some may be passengers. This is important because it suggests that some business rules may use `Person` in its pilot context, and others may use it in its passenger context. How do we represent this in the Vocabulary and rules we build in Corticon Studio?

Let's examine this problem in more detail. Assume we want to implement two new rules:

1. By FAA regulations, 747 aircraft must be flown by at least 2 pilots
2. A DC-10 may not carry more than 200 passengers

We call these rules “cross-entity” because they include more than one entity (both `Aircraft` and `Person`) in their expression. Unfortunately, with our Vocabulary as it is, we have no way to distinguish between pilots and passengers, so there is no way to unambiguously implement these 2 rules. This class diagram, when imported into Corticon Studio, looks like this:

Figure 53: Vocabulary without Roles



However, there are several ways to modify this Vocabulary to allow us to implement these rules. We will discuss these methods and examine the advantages and disadvantages of each.

Use Inheritance

Use two separate entities for `Pilot` and `Passenger` instead of a single `Person` entity. This may often be the best way to distinguish between pilots and passengers, especially if the two types of `Person` reside in different databases or different database tables (an aspect of deployment that rule modelers may not be aware of). Also, if the two types of `Person` have some shared and some different attributes (`Pilot` may have attributes like `licenseRenewalDate` and `typeRating` while `Passenger` may have attributes like `farePaid` and `seatSelection`) then it may make sense to set up entities as descendants of a common ancestor entity (such as `Employee`).

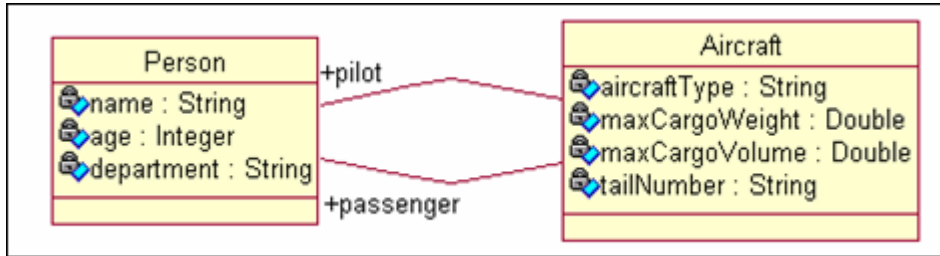
Add an Attribute to Person

If the two types of person differ only in their type, then we may decide to simply add a `personType` (or similar) attribute to the entity. In some cases, `personType` will have the value of `pilot`, and sometimes it will have the value of `passenger`. The advantage of this method is that it is flexible: in the future, persons of type `manager` or `bag handler` or `air marshal` can easily be added. Also, this construction may be most consistent with the actual structure of the employee database or database table and maintains a normalized model. The disadvantage comes when the rule modeler needs to refer to a specific type of `Person` in a rule. While this can be accomplished using any of the filtering methods discussed in [Rule Writing Techniques](#), they are sometimes less convenient and clear than the final method, discussed next.

Use Roles

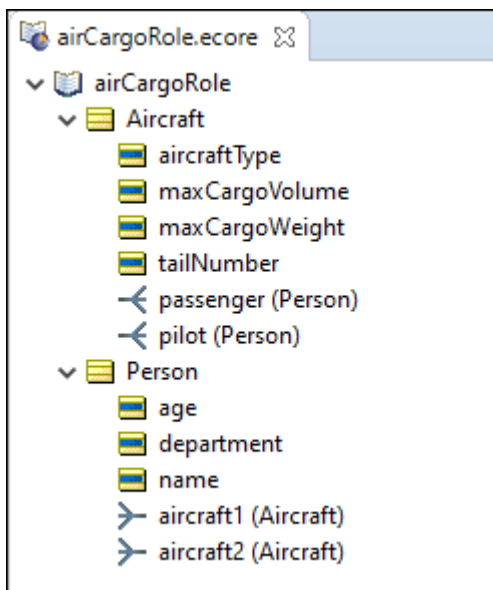
A role is a noun that labels one end of an association between two entities. For example, in our `Person-Aircraft` Vocabulary, the `Person` may have more than one role, or more than one kind of relationship, with `Aircraft`. An instance of `Person` may be a `pilot` or a `passenger`; each is a different role. To illustrate this in our UML class diagram, we add labels to the associations as follows:

Figure 54: UML Class Diagram with Roles



When the class diagram is imported into Corticon Studio, it appears as the Vocabulary below:

Figure 55: Vocabulary with Roles



Notice the differences between **Vocabulary with Roles** and **Vocabulary without Roles** – in **Vocabulary with Roles**, `Aircraft` contains 2 associations, one labeled `passenger` and the other `pilot`, even though both associations relate to the same `Person` entity. Also notice that we have updated the cardinalities of both `Aircraft`–`Person` associations to “one-to-many”.

Written using roles, the first rule appears below. There are a few aspects of the implementation to note:

- Use of aliases for `Aircraft` and `Aircraft.pilot` (`plane` and `pilotOfPlane`, respectively). Aliases are just as useful for clarifying rule expressions as they are for shortening them.
- The rule Conditions evaluate data within the context of the `plane` and `pilotOfPlane` aliases, while the Action posts a message to the `plane` alias. This enables us to act on the `aircraft` entity based upon the attributes of its associated pilots. Note that Condition row b uses a special operator (`->size`) that “counts” the number of pilots associated with a plane. This is called a collection operator and is explained in more detail in the following chapters.

Figure 56: Rule #1 Implemented using Roles

The screenshot shows the 'airCargoRole.ers' editor interface. On the left, a 'Scope' tree shows a hierarchy: Aircraft [plane] containing aircraftType, which contains pilot (Person) [pilotOfPlane]. Below this is a 'Filters' section with two rows. The main area is a table with columns for conditions and actions across three rule instances (1, 2, 3).

		Conditions	1	2	3
a	plane.aircraftType		'747'	'747'	'747'
b	pilotOfPlane -> size		{0, 1}	2	> 2
		Actions	<		
		Post Message(s)	✉	✉	✉
A					
B					
		Overrides			

Ref	ID	Post	Alias	Text
1		Violation	plane	Exactly 2 pilots are required to fly a 747 - fewer than 2 violates FAA regulations
2		Info	plane	Exactly 2 pilots are required to fly a 747 - 2 are assigned to this flight
3		Warning	plane	Exactly 2 pilots are required to fly a 747 - more than 2 is unnecessary but not unsafe

To demonstrate how Corticon Studio differentiates between entities based on rule scope, we will construct a new Ruletest that includes a single instance of `Aircraft` and 2 `Person` entities, neither of which has the role of pilot.

Figure 57: Ruletest with no `Person` entities in `Pilot` role

The screenshot shows the Corticon Studio interface for a ruletest named `airCargoRole.ert`. The main area is divided into two columns: **Input** and **Output**. Both columns show a tree view of entities and their attributes:

- Input:**
 - `Aircraft [1]`
 - `aircraftType [747]`
 - `maxCargoVolume`
 - `maxCargoWeight`
 - `tailNumber`
 - `Person [1]`
 - `age [25]`
 - `department [Flight Crew]`
 - `name [Joe Smith]`
 - `Person [2]`
 - `age [32]`
 - `department [Flight Crew]`
 - `name [Bob Roberts]`
- Output:**
 - `Aircraft [1]`
 - `aircraftType [747]`
 - `maxCargoVolume`
 - `maxCargoWeight`
 - `tailNumber`
 - `Person [1]`
 - `age [25]`
 - `department [Flight Crew]`
 - `name [Joe Smith]`
 - `Person [2]`
 - `age [32]`
 - `department [Flight Crew]`
 - `name [Bob Roberts]`

At the bottom of the interface, there is a **Rule Messages** section with a table showing a violation:

Severity	Message
Violation	Exactly 2 pilots are required to fly a 747 - fewer than 2 violates FAA regulations

Despite the fact that there are two `Person` entities, both of whom are members of the `Flight Crew` department, the system recognizes that neither of them have the role of pilot (in relation to the `Aircraft` entity), and therefore generates the violation message shown.

If we create a new Input Ruletest, this time with both persons in the role of pilot, we see a different result, as shown:

Figure 58: Ruletest with both Person entities in role of Pilot

The screenshot displays the 'airCargoRole.ert' application window. The main area is divided into two columns: 'Input' and 'Output'. Both columns show a tree structure of entities. The 'Input' column has two 'pilot (Person)' entities. The first pilot has an age of 52, department of 'Flight Crew', and name 'Joe Smith'. The second pilot has an age of 22, department of 'Flight Crew', and name 'Sam Roberts'. The 'Output' column shows the same two pilot entities, but the second pilot's name is 'Sam Roberts'. Below the main area, there are tabs for 'Rule Statements' and 'Rule Messages'. The 'Rule Messages' tab is active, showing a table with two columns: 'Severity' and 'Message'. The first row has 'Info' in the 'Severity' column and 'Exactly 2 pilots are required to fly a 747 - 2 are assigned to this flight' in the 'Message' column.

Severity	Message
Info	Exactly 2 pilots are required to fly a 747 - 2 are assigned to this flight

Finally, the rules are tested with one pilot and one passenger:

Figure 59: Ruletest with one Person entity in each of Pilot and Passenger roles

The screenshot shows the RuleTest interface for the file `*airCargoRole.ert`. The main window displays the test results for the rule `/RulesTutorial/airCargoRole.ers`. It is divided into two columns: **Input** and **Output**.

Input Data:

- Aircraft [1]
 - aircraftType [747]
 - maxCargoVolume
 - maxCargoWeight
 - tailNumber
- passenger (Person) [2]
 - age [32]
 - department [Maintenance]
 - name [Jake Jones]
- pilot (Person) [1]
 - age [52]
 - department [Flight Crew]
 - name [Carla Diaz]

Output Data:

- Aircraft [1]
 - aircraftType [747]
 - maxCargoVolume
 - maxCargoWeight
 - tailNumber
- passenger (Person) [2]
 - age [32]
 - department [Maintenance]
 - name [Jake Jones]
- pilot (Person) [1]
 - age [52]
 - department [Flight Crew]
 - name [Carla Diaz]

At the bottom, the **Rule Messages** tab is active, showing a violation:

Severity	Message
Violation	Exactly 2 pilots are required to fly a 747 - fewer than 2 violates FAA regulations

We see that despite the presence of two `Person` elements in the collection of test data, only one satisfies the rules' scope – `pilot` associated with `aircraft`. As a result, the rules determine that one pilot is insufficient to fly a 747, and the violation message is displayed.

These same concepts apply to the DC-10/Passenger business rule, which will not be implemented here.

Technical aside

Understanding Rule Associations and Scope as Relationships Between Tables in a Relational Database

Although it is not necessary for the rule modeler or developer to understand database theory, a business or systems analyst who is familiar with it may have already recognized that the preceding discussion of rule scope and context is an abstraction of basic relational concepts. Actual relational tables that contain the data for our Cargo example might look like the following:

Figure 60: Tables in a Relational Database

Aircraft		
tailNumber*	aircraftType	maxCargoWeight
N1001	747	200,000
N1002	747	200,000
N1003	DC-10	150,000

Cargo		
manifestNumber*	volume	weight
625A	300	100,000
625B	300	175,000
625C	300	150,000

FlightPlan		
flightNumber*	tailNumber	manifestNumber
101	N1001	625A
102	N1002	625B
103	N1003	625C

Each one of these tables has a column that serves as a unique identifier for each row (or *record*). In the case of the `Aircraft` table, the `tailNumber` is the unique identifier for each `Aircraft` record – this means that no two `Aircraft` can have the same `tailNumber`. `ManifestNumber` is the unique identifier for each `Cargo` record. These unique identifiers are known as “primary keys”. Given the primary key, a particular record can always be found and retrieved. A common notation uses an asterisk character (*) to indicate those table columns that serve as primary keys. If a Vocabulary has been connected to an external database using Enterprise Data Connector features, then you may notice asterisks next to attributes, indicating their designation as primary keys. See the *Data Integration Guide, Direct Database Access* chapter for complete details.

Notice that the `FlightPlan` table contains columns that did not appear in our Vocabulary. Specifically, `tailNumber` and `manifestNumber` exist in the `Aircraft` and `Cargo` entities, respectively, but we did not include them in the `FlightPlan` Vocabulary entity. Does this mean that our original Vocabulary was wrong or incomplete? No - the extra columns in the `FlightPlan` table are really duplicate columns from the other two tables – `tailNumber` came from the `Aircraft` table and `manifestNumber` came from the `Cargo` table. These extra columns in the `FlightPlan` table are called *foreign keys* because they are the primary keys *from other tables*. They are the mechanism for creating relations in a relational database.

For example, we can see from the `FlightPlan` table that `flightNumber` 101 (the first row or record in the table) includes `Aircraft` of `tailNumber` N1001 and `Cargo` of `manifestNumber` 625A. The foreign keys in `FlightPlan` serve to link or connect a specific `Aircraft` with a specific `Cargo`. If the database is queried (using a query language like SQL, for example), a user could determine the weight of `Cargo` planned for `Aircraft` N1001 – by “traversing” the relationships from the `Aircraft` table to the `FlightPlan` table, we discover that `Aircraft` N1001 is scheduled to carry `Cargo` 625A. By traversing the `FlightPlan` table to the `Cargo` table, we discover that `Cargo` 625A weighs 100,000 kilograms. Matching the foreign key in the `FlightPlan` table with the primary key in the `Cargo` table makes this traversal possible.

The Corticon Vocabulary captures this essential feature of relational databases, but abstracts it in a way that is friendlier to non-programmers. Rather than deal with concepts like foreign keys in our Vocabulary, we talk about “associations” between entities. Traversing an association in the Vocabulary is exactly equivalent to traversing a relationship between database tables. When we use a term like `Aircraft.tailNumber` in a rule, Studio creates a collection of `tailNumbers` from all records in the `Aircraft` table. This collection of data is then “fed” to the rule for evaluation. If however, the rule uses `FlightPlan.aircraft.tailNumber`, then Studio will create a collection of only those `tailNumbers` from the `Aircraft` table that have `FlightPlans` related to them – it identifies these aircraft instances by matching the `tailNumber` in the `Aircraft` table with the `tailNumber` (foreign key) in the `FlightPlan` table. If the `Aircraft` table contains 7 instances of aircraft (i.e., 7 unique rows in the table), but the `FlightPlan` table contains only 3 unique instances of flight plans, the term `FlightPlan.aircraft.tailNumber` will create a collection of only 3 tail numbers – those instances from the `Aircraft` table which have flight plans listed in the `FlightPlan` table. In database terminology, the scope of the rule determines how the tables are “joined”.

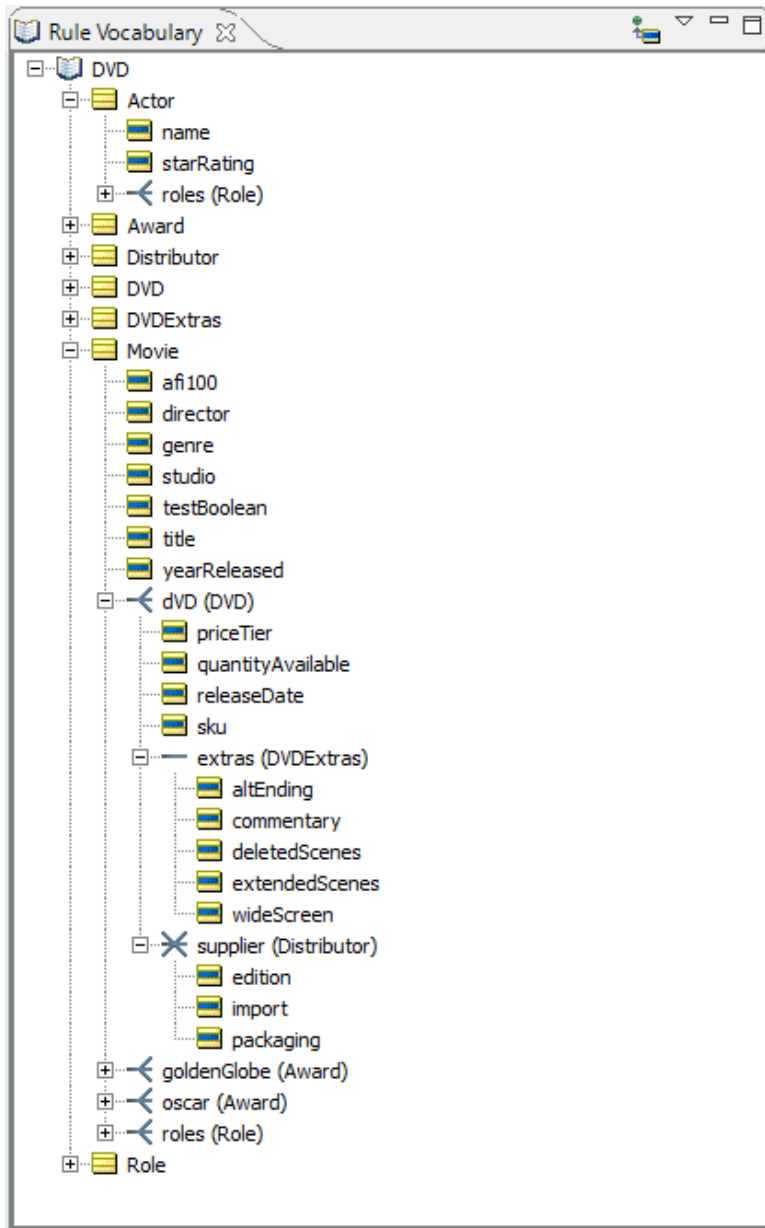
When `FlightPlan` is used as the scope for our rule, Corticon Studio automatically ensures that the collection of data contains matching foreign keys. That’s why, when we rewrote the rule using proper scope, the rule only fired 3 times – there are only 3 examples of `Aircraft-Cargo` combinations where the keys match. This also explains why, prior to using scope, the rule produced 6 spurious and irrelevant outcomes – 6 combinations of `Aircraft` and `Cargo` that were processed by the rule do not, in fact, exist in the `FlightPlan` table.

While the differences in processing requirements are not extreme in our simple example, for a large company like Federal Express, with a fleet of hundreds of aircraft and several thousand unique cargo shipments every day, the system performance differences could be enormous.

TestYourself questions for Rule scope and context

Note: Try this test, and then go to [TestYourself answers for Rule scope and context](#) on page 335 to correct yourself.

Use the following Vocabulary to answer the next questions.



1. How many root-level entities are present in the Vocabulary?
2. Which of the following terms are allowed by the Vocabulary?

Movie.roles	Actor.roles	DVD.actor	Award.movie
-------------	-------------	-----------	-------------

3. Which of the following terms are **not** allowed by the Vocabulary?

Movie.oscar	Movie.supplier	Movie.roles.actor	Movie.dVD.extras
-------------	----------------	-------------------	------------------

4. Which Vocabulary term represents the following phrases?

- A movie's Oscars _____
- A movie's roles _____
- An actor's roles _____
- A DVD's distributor _____
- A movie's DVD extras _____
- An actor's Oscars _____

5. Which of the following terms represents the phrase “an actor in a role of a movie”

Movie.roles.dVD	Actor.roles.movie	DVD.actor.movie	Actor.movie.roles
-----------------	-------------------	-----------------	-------------------

6. Since the association between Actor and Role is bidirectional, we can use both Actor.roles and _____ in our rules.
7. Which two entities are associated with each other by more than one role?
8. What are the role names?
9. Besides roles, how else could these two relationships be represented in the Vocabulary to convey the same business meaning?
10. What is the advantage of using roles in this way?
11. When more than role is used to associate two entities, each role name must be:

friendly	unique	colorful	melifluous
----------	--------	----------	------------

12. True or False. Rules evaluate only data that shares the same scope
13. Write a conditional expression in a Rulesheet for each of the following phrases:
 - If a movie's DVD has deleted scenes...
 - If an actor played a role in a movie winning an Oscar...
 - If the DVD is an import...
 - If the Movie was released more than 50 years before the DVD...
 - If the actor ever played a leading role...
 - If the movie was nominated for a Golden Globe...

- If the Distributor offers any drama DVDs...

Given the rule “Disney animated classics are priced in the high tier”, answer the following questions:

14. Which term should be used to represent Movie?
15. Which term should be used to represent DVD?
16. True or False. The following Rulesheet correctly relates the Movie and DVD entities?

The screenshot shows a Rulesheet editor with two tabs: 'DVD.ecore' and 'scope1Untitled_1.ers'. The main area is divided into 'Conditions' and 'Actions' sections. Below these is an 'Overrides' section and a 'Rule Statements' table.

Conditions		0	1
a	Movie.studio	-	'Disney'
b	Movie.genre	-	'Classic Animation'
c			
d			
e			
f			
g			
h			

Actions		0	1
Post Message(s)			✉
A	DVD.priceTier		'High'
B			
C			
D			
E			

Ref	ID	Post	Alias	Text
1		Info	Movie	Disney animated classics are priced in the high tier

17. Given our business intent, how many times do we want the rule to fire given the Input Testsheet below?

The screenshot shows an 'Input Testsheet' for a rule named 'scope1'. The tree structure is as follows:

- /scope1.erf
 - Input
 - Movie [1]
 - genre [Classic Animation]
 - studio [Disney]
 - title [Cinderella]
 - DVD [1]
 - priceTier
 - Movie [2]
 - genre [Animation]
 - studio [Pixar]
 - title [Toy Story]
 - DVD [2]
 - priceTier

18. Given the Ruletest Input above, how many times does the rule actually fire?

19. Assume we update the Rulesheet to include another rule, as shown below. Answer the following questions:

The screenshot shows a Rulesheet editor window titled 'scope1Untitled_1.ers'. It is divided into several sections:

- Conditions:** A table with columns 0, 1, and 2.

	0	1	2
a	Movie.studio	-	'Disney'
b	Movie.genre	-	'Classic Animation'
c			not {'Disney', 'MGM', 'BBC', 'PBS', 'Pixar'}
d			'Animation'
e			
f			
g			
h			
- Actions:** A table with columns 0, 1, and 2.

	0	1	2
A	DVD.priceTier	High	Low
B			
C			
D			
E			
- Overrides:** A section below the actions table.
- Rule Statements:** A table with columns Ref, ID, Post, Alias, and Text.

Ref	ID	Post	Alias	Text
1		Info	Movie	Disney animated classics are priced in the high tier
2		Warning	Movie	Other animated movies are priced in the low tier

- Assuming the same Ruletest Input as question 57, what result do we *want* for Cinderella?
- What result do we *want* for Toy Story?
- What results do we *get* when the Test is executed?
- How many times does *each* rule fire?
- How many *total* rule firings occurred?
- This set of combinations is called a _____
- Does our result make business sense?
- What changes should be made to the Rulesheet so that it functions as we intend?

20. True or False. Whenever our rules contain scope, we must define aliases in the Scope section of the Rulesheet.

21. Scope is another way of defining a specific _____ in the Vocabulary

22. If you change the spelling of an alias in the Scope section, then everywhere that alias is used in the Rulesheet will:

turn red	be deleted	be updated	be ignored
----------	------------	------------	------------

23. True or False. The spelling of an alias may be the same as the Vocabulary entity it represents?

Rule writing techniques

The Corticon Studio Rulesheet is a very flexible device for writing and organizing rules. It is often possible to express the same business rule multiple ways in a Rulesheet, with all forms producing the same logical results. Some common examples, as well as their advantages and disadvantages, are discussed in this set of topics.

For details, see the following topics:

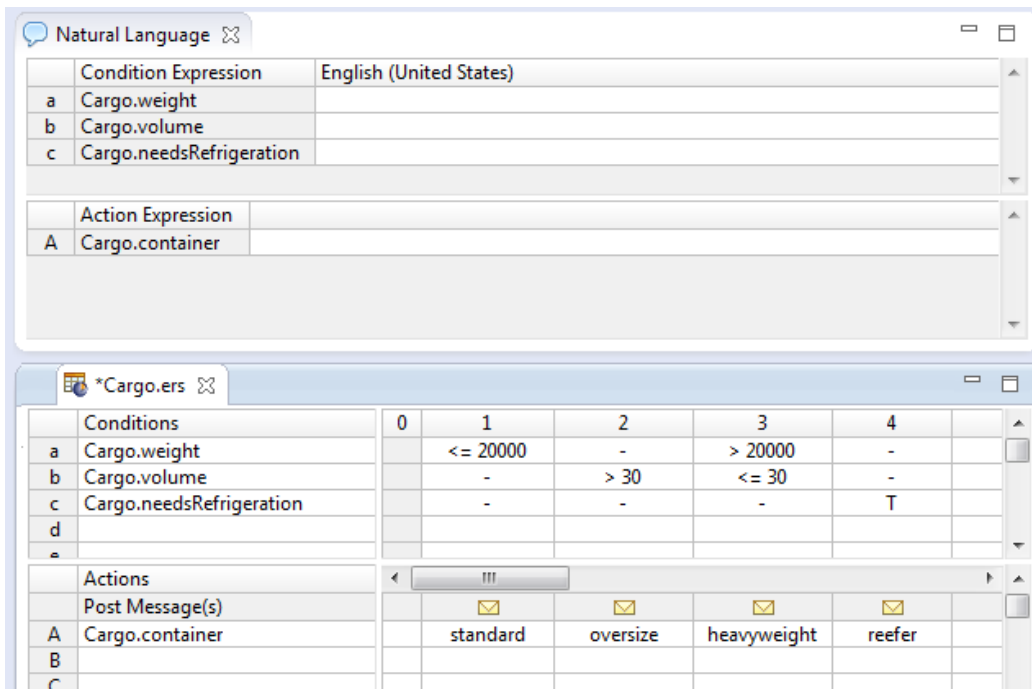
- [How to work with rules and filters in natural language](#)
- [Filters vs conditions](#)
- [Qualify rules with ranges and lists](#)
- [How to use standard boolean constructions](#)
- [How to embed attributes in posted rule statements](#)
- [How to include apostrophes in strings](#)
- [TestYourself questions for Rule writing techniques and logical equivalents](#)

How to work with rules and filters in natural language

Progress Corticon lets you use Natural Language (NL) words, phrases, and sentences as substitute terms in Rulesheet conditions and actions, making it easier to discuss the rules with stakeholders and analysts.

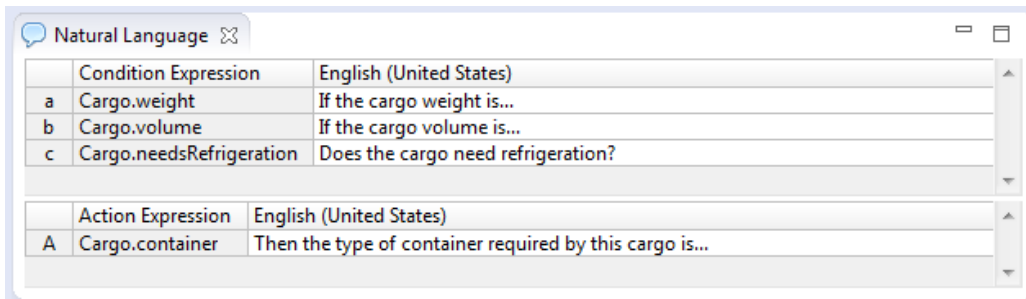
To use natural language on a Rulesheet:

1. Right-click within a Rulesheet, and then choose the dropdown menu command **Natural Language**.
2. The Natural Language view opens, and typically places itself above the Rulesheet, as shown:




Note: If the **Natural Language** window does not open, choose the menu command **Window>Show View>Natural Language**.

3. Enter plain language descriptive text for each condition and action, as shown:



While your use of natural language might vary, it is good practice to use a consistent, clear style. Here are some tips:


- Use **If** in the text for Conditions and **Then** in the text for Actions.
- Conditions that are **True/False** often read better as questions.
- Adding ... helps a reader continue the expression with the values in its column cells.
- If you enter no natural language text, the existing expression is shown.

4. Expose your natural language expressions in the Rulesheet by either clicking the **Show Natural Language** toolbar button , or the menu command **Rulesheet > Show Natural Language**. The natural language is displayed as shown:

Conditions		0	1	2	3
a	If the Cargo's weight is...	-	<= 20000	-	> 20000
b	If the Cargo's volume is...	-	-	> 30	<= 30
c	If the Cargo needs refrigeration...	-	-	-	-
d					

Actions		Post Message(s)			
A	Then the type of container required by this Cargo is...	standard	oversize	heavyweight	
B					
C					
D					
Overrides			{1, 4}		

In Natural Language mode, the values in rule columns can be edited but the Condition and Action expressions are locked and cannot be edited.

5. Save the Rulesheet to store its expressions as well as its natural language data.
6. You can revert to the actual, editable expressions by clicking the **Hide Natural Language** toolbar button , or the menu command **Rulesheet > Hide Natural Language**.
7. Close the **Natural Language** view by clicking its close button.

Using natural language as an aid to Rulesheet design

You can create Natural Language phrases for the conditions, actions, and filters *before* defining those expressions.

Natural Language View:

Filter Expression	English (United States)
1 Cargo.weight < Aircraft.maxCargoWeight	Reject any package that exceeds the assigned aircraft weight capacity
2	Reject any package that exceeds the assigned aircraft volume capacity
3	

Condition Expression	English (United States)
a Cargo.weight	What is the weight (in kilograms) of the package?
b Cargo.volume	What is the volume (LxWxH in cubic meters) of the package?
c	

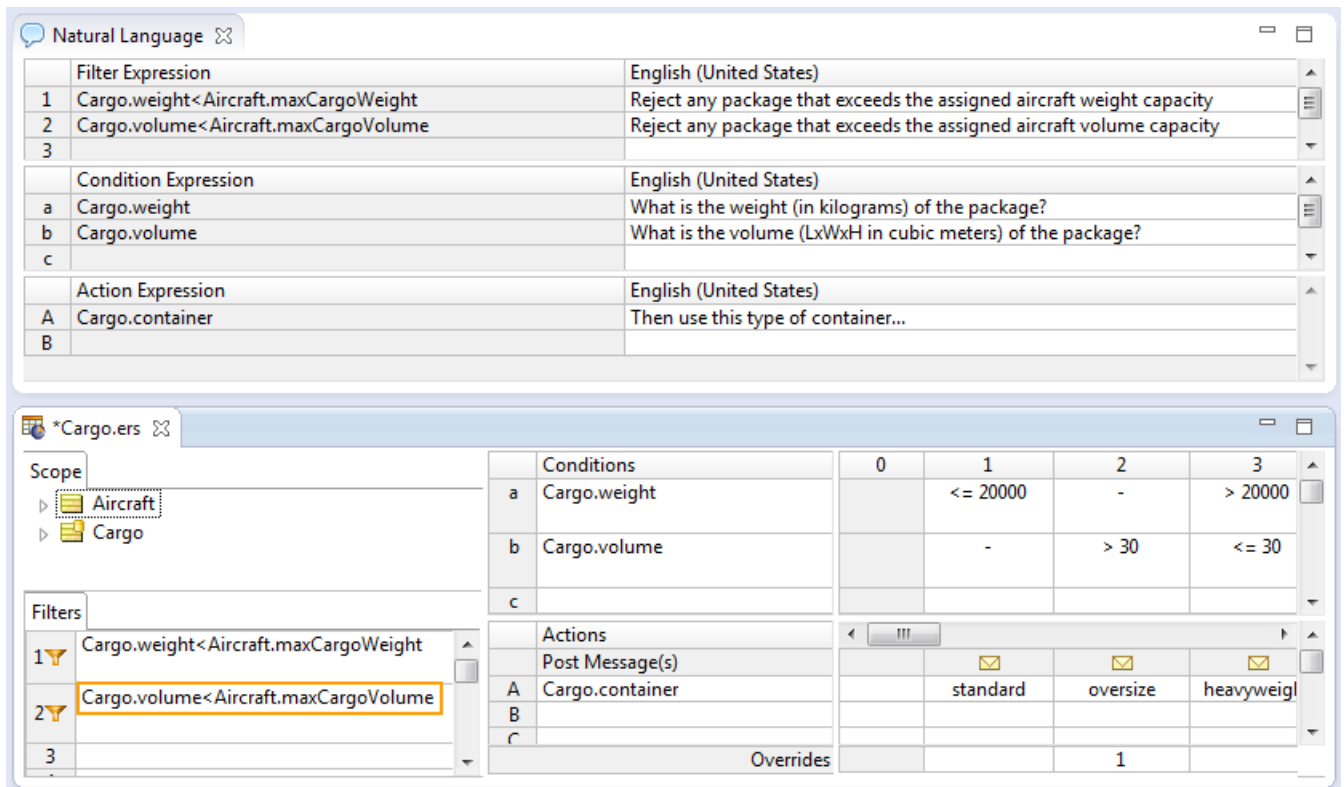
Action Expression	English (United States)
A Cargo.container	Then use this type of container...
B	

***Cargo.ers Rulesheet View:**

Conditions		0	1	2	3
a	What is the weight (in kilograms) of the package?		<= 20000	-	> 20000
b	What is the volume (LxWxH in cubic meters) of the package?		-	> 30	<= 30
c					

Actions		Post Message(s)			
A	Then use this type of container...	standard	oversize	heavyweight	
B					
C					
Overrides				1	

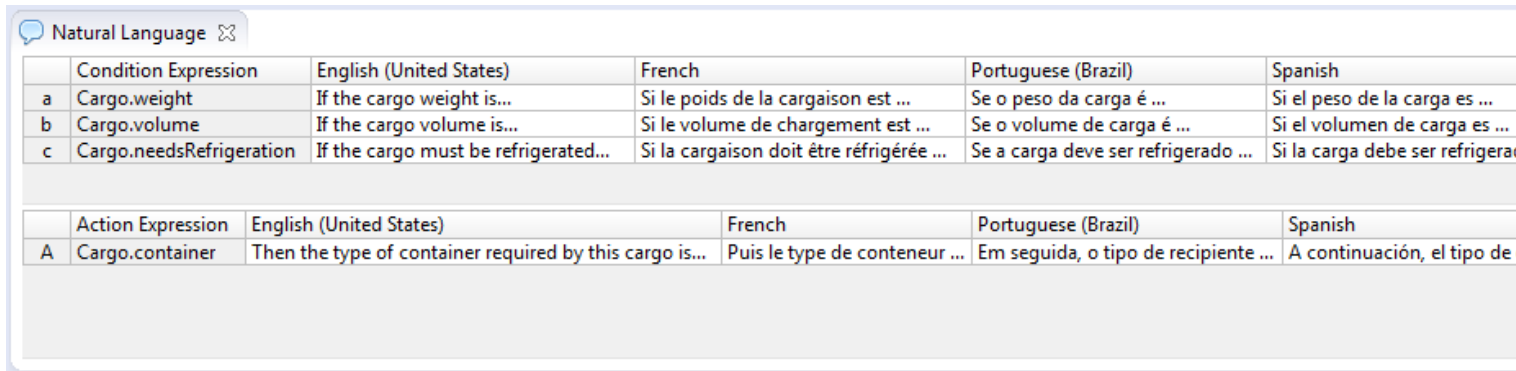
Adding the natural language phrase makes the next line available for additional entries. Then, in the Rulesheet, define the expression that satisfies the natural language phrase, as shown:



Localization with natural language

When your stakeholders are comfortable in different natural languages, you can accommodate them easily with the natural language feature.

When you enable locales, the Natural Language window adds columns for the other locales. You can then define Natural Language text for each of those locales, as illustrated:



Filters vs conditions

The Filters section of a Rulesheet can contain one or more “master” conditional expressions for that Rulesheet. In other words, other business rules will fire if and only if data a) survives the Filter, and b) shares the same scope as the rules. Using our air cargo example from the previous chapter, we model the following rule:

1. A 747 has a maximum cargo weight of 200,000 kilograms.

Figure 61: Rulesheet Using a Filter and Nonconditional Rule

The screenshot shows a Rulesheet editor window titled 'logical_equiv_pcr.ers'. The left pane shows a tree view with 'aircraft' expanded to 'Filters', containing a filter 'aircraft.aircraftType = '747''. Below this are 'aircraftType' and 'maxCargoWeight'. The right pane is split into 'Conditions' and 'Actions'. The 'Conditions' pane has a column '0' with a value of '0'. The 'Actions' pane has a column 'A' with the action 'aircraft.maxCargoWeight = 200000' and a checked checkbox. The 'Overrides' section is empty. At the bottom, there are tabs for 'Rule Statements' and 'Rule Messages'.

Here, the value of an Aircraft's `maxCargoWeight` attribute is assigned by column 0 in the Conditions/Actions pane (what we sometimes call a *Nonconditional* or *action-only* rule because it has no Conditions). The Filter acts as a master conditional expression because only Aircraft that satisfy the Filter - in other words, only those aircraft of `aircraftType = '747'`, successfully “pass through” to be evaluated by rule column 0, and are assigned a `maxCargoWeight` of 200000. This effectively “filters out” all non-747 aircraft from evaluation by rule column 0.

If this Filter were not present, *all* Aircraft, regardless of `aircraftType`, would be assigned a `maxCargoWeight` of 200000 kilograms. Using this method, additional Rulesheets may be used to assign different `maxCargoWeight` values for each `aircraftType`. The Filter section may be thought of as a convenient way to quickly add the same conditional expression or constraint to all other rules in the same Rulesheet.

We can also achieve the same results without using Filters. The following figure shows how we use a Condition/Action rule to duplicate the results of the previous Rulesheet. The rule is restated as an “if-then” type of statement: “if the `aircraftType` is 747, then its `maxCargoWeight` equals 200000 kilograms”.

Figure 62: Rulesheet Using a Conditional Rule

The screenshot shows a Rulesheet editor window with a conditional rule. The 'Conditions' pane has a column '1' with a value of '1'. The 'Actions' pane has a column 'A' with the action 'aircraft.maxCargoWeight = 200000' and a checked checkbox. The 'Overrides' section is empty. At the bottom, there are tabs for 'Rule Statements' and 'Rule Messages'. The 'Rule Statements' tab is active, showing a table with columns 'Ref', 'ID', 'Post', 'Alias', and 'Text'. The table has one row with 'Ref' 1 and 'Text' 'Aircraft max cargo weight must equal 200000 kg if aircraft type is a 747'.

Regardless of how you choose to express logically equivalent rules in a Rulesheet, the results will also be equivalent. While the logical result may be identical, the time required to produce those results may not be. See [How to optimize Rulesheets](#) on page 276 for information about compression techniques that remove redundancies.

There may be times when it is advantageous to choose one way of expressing a rule over another, at least in terms of the visual layout, organization and maintenance of the business rules and Rulesheets. The example discussed in the preceding paragraphs was very simple because only one Action was taken as a result of the Filter or Condition. In cases where there are multiple Actions that depend on the evaluation of one or more Conditions, it may make the most sense to use the Filters section. Conversely, there may be times when using a Condition makes the most sense, such as the case where there are numerous values for the Condition that each require a different Action or set of Actions as a result. In our example above, there are different types of Aircraft in the company's fleet, and each has a different `maxCargoWeight` value assigned to it by rules. This could easily be expressed on one Rulesheet by using a single row in the Conditions section. It would require many Rulesheet s to express these same rules using the Filters section. This leads us to the next topic of discussion.

Qualify rules with ranges and lists

You can use values for any data type except Boolean in Conditions, Condition cells, and Filters.

These values can be imprecise – they can be in the form of a *range* expressed in the format: `x..y`, where `x` and `y` are the starting and ending values for the range.

The values can also be very specific -- they can be in the form of a *list* expressed in the format `{x,z,y}`, where the values are in any order but must adhere to the data type or the defined labels when the data type is bound to an enumerated list with labels.

Ranges and lists in conditions and filters

Conditions and filters can qualify data by testing for inclusion in a *from-to* range of values or in a comma-delimited list. The result returned is `true` or `false`. All attribute data types except Boolean can use ranges and lists in conditions and filters.

Value ranges in condition and filter expressions

You can use value range expressions in conditions or filters.

Syntax of value ranges in conditions and filter rows

When you use the `in` operator to specify a range of values, you can specify the range in a several ways. The following illustration shows how you can encapsulate a range:

Figure 63: Rulesheet Filters showing ways to encapsulate a range

Filters	
7	
8	Entity_1.integer1 in 100..300
9	Entity_1.integer1 in {100,300}
10	Entity_1.integer1 in (100..300)
11	Entity_1.integer1 in [100..300]
12	Entity_1.integer1 in (100..300]
13	Entity_1.integer1 in [100..300)

where:

- Filter 8 does no encapsulation.
- Filter 9 uses braces for encapsulation. Its delimiter in the expression is a comma rather than two dots like the others. As this syntax defines a set and overloads the syntax for a list, it is a good practice to not use it to encapsulate a range.
- Filters 10 through 13 use (and mix) parentheses and square brackets where a bracket on either side expresses that the value on that side also passes the test.

Examples of value ranges in filter rows

The following value ranges show how the Corticon data types can be used as Filter expressions.

Figure 64: Rulesheet filters showing the syntax of ranges for each data type

Filters	
1	Entity_1.dateOnly1 in ['1/1/15'..'12/31/17']
2	Entity_1.dateTime1 in ('12/25/15 00:00:00'..'12/25/15 9:59:59')
3	Entity_1.decimal1 in [-.01..99.99]
4	Entity_1.integer1 in (-128.6..136.4)
5	Entity_1.string1 in ['a'..'z'] or Entity_1.string1 in ['A'..'Z']
6	Entity_1.timeOnly1 in ('9:00 AM'..'5:00 PM')
7	

Notice that ranges are always *from..to*. The examples show that negative decimal and integer values can be used, and that uppercase and lowercase characters are filtered separately.

Value lists in condition and filter expressions

You can use value list expressions in conditions or filters.

Syntax of value list in conditions and filter rows

When you use the `in` operator to specify a list of values, you can encapsulate the range in only one way:

Figure 65: Rulesheet Filters showing encapsulation of a list

Filters	
1	E1.a1 in {RED,BLUE,YELLOW}
2	
3	

The value list is always enclosed in braces. The order of the items in the comma-delimited list is arbitrary.

Ranges and value sets in condition cells

When using values in Condition Cells for attributes of any data type except Boolean, the values do not need to be discreet – they may be in the form of a range. A value range is typically expressed in the following format: $x..y$, where x and y are the starting and ending values for the range *inclusive* of the endpoints if there is no other notation to indicate otherwise. This is illustrated in the following figure:

Figure 66: Rulesheet Using Value Ranges in the Column Cells of a Condition Row

ValueRanges.ers					
Conditions		1	2	3	4
a	FlightPlan.flightNumber	<= 100	101..200	201..300	> 300
b					
Actions		<			
Post Message(s)					
A	FlightPlan.aircraft.maxCargoWeight	50000	100000	150000	200000
B					
Overrides					
Rule Statements					
Ref	Post	Alias	Text		
1			Aircraft max cargo weight must be 50000 when flight number is less than or equal to 100		
2			Aircraft max cargo weight must be 100000 when flight number is between 101 and 200, inclusive		
3			Aircraft max cargo weight must be 150000 when flight number is between 201 and 300, inclusive		
4			Aircraft max cargo weight must be 200000 when flight number is greater than 300		

In this example, we are assigning a `maxCargoWeight` value to each `Aircraft` depending on the `flightNumber` value from the `FlightPlan` that the `Aircraft` is associated with. The value range `101..200` represents all values (Integers in this case) between 101 and 200, including the range “endpoints” 101 and 200. This is an inclusive range in that the starting and ending values are included in the range.

Corticon Studio also gives you the option of defining value ranges where one or both of the endpoints are “exclusive”, meaning that they are **not** included in the range of values – this is the same idea as the difference between “greater than” and “greater than or equal to”. The following figure shows the same Rulesheet as in the previous figure, but with one difference: we have changed the value range 201..300 to (200..300]. The starting parenthesis (indicates that the starting value for the range, 200, is exclusive – it is **not** included in the range. The ending bracket] indicates that the ending value is inclusive. Since flightNumber is an Integer value and there are therefore no fractional values allowed, 201..300 and (200..300] are equivalent.

Figure 67: Rulesheet Using Open-Ended Value Ranges in Condition Cells

Conditions		1	2	3	4
a	FlightPlan.flightNumber	<= 100	101..200	(200..300]	> 300
b					
Actions		<			
Post Message(s)					
A	FlightPlan.aircraft.maxCargoWeight	50000	100000	150000	200000
B					
Overrides					

Ref	Post	Alias	Text
1			Aircraft max cargo weight must be 50000 when flight number is less than or equal to 100
2			Aircraft max cargo weight must be 100000 when flight number is between 101 and 200, inclusive
3			Aircraft max cargo weight must be 150000 when flight number is between 201 and 300, inclusive
4			Aircraft max cargo weight must be 200000 when flight number is greater than 300

Listed below are all of the possible combinations of parenthesis and bracket notation for value ranges and their meanings:

Figure 68: Rulesheet Using Open-Ended Value Ranges in Condition Cells

(x..y)	- is the range between x & y, excluding both x & y
(x..y]	- is the range between x & y, excluding x and including y
[x..y)	- is the range between x & y, including x and excluding y
[x..y]	- is the range between x & y, including both x & y

If a value range has no enclosing parentheses or brackets, it is assumed to be inclusive. It is therefore not necessary to use the [..] notation for a closed range in Corticon Studio. However, should either end of a value range have a parenthesis or a bracket, then the other end must also have a parenthesis or a bracket. For example, x..y) is not allowed, and is properly expressed as [x..y).

Value ranges can also be used in the Filters section of the Rulesheet. See the [Ranges and lists in conditions and filters](#) on page 94 for details on usage.

Boolean condition vs values set

Rulesheet Using a Conditional Rule illustrates a simple Boolean Condition that evaluates to either `True` or `False`. The Action related to this Condition is either selected or not, on or off, meaning the value of `maxCargoWeight` is either assigned the value of `200,000` or it is not (Action statements are “activated” by selecting the check box that automatically appears when the cell is clicked). However, there is another way to express both Conditions and Actions using Values sets.

Figure 69: Rulesheet Illustrating use of Multiple values in the same Condition Row

The screenshot shows a software interface for editing rules. At the top, there is a tab labeled 'ValueSetsInConditionalRules.ers'. Below this is a table with three columns labeled '1', '2', and '3'. The table is divided into 'Conditions' and 'Actions' sections. In the 'Conditions' section, row 'a' has 'aircraft.aircraftType' in the first column, and 'DC-10', 'A340', and '747' in columns 1, 2, and 3 respectively. Row 'b' is empty. In the 'Actions' section, row 'A' has 'aircraft.maxCargoWeight' in the first column, and '100000', '150000', and '200000' in columns 1, 2, and 3 respectively. Row 'B' is empty. Below the table is an 'Overrides' section. At the bottom, there is a 'Rule Statements' section with a table containing three rows: A1, A2, and A3. Each row has a 'Text' column with a description of the rule.

ValueSetsInConditionalRules.ers				
Conditions		1	2	3
a	aircraft.aircraftType	'DC-10'	'A340'	'747'
b				
Actions				
Post Message(s)				
A	aircraft.maxCargoWeight	100000	150000	200000
B				
Overrides				
Rule Statements				
Ref	Post	Alias	Text	
A1			Aircraft max cargo weight must be 100000 when aircraft type is a DC-10	
A2			Aircraft max cargo weight must be 150000 when aircraft type is an A340	
A3			Aircraft max cargo weight must be 200000 when aircraft type is a 747	

By using different values in the column cells of Condition and Action rows in this Rulesheet, we can write multiple rules (represented as different columns in the table) for different Condition-Action combinations. Expressing these same rules using Boolean expressions would require many more Condition and Action rows, and would fail to take advantage of the semantic pattern these three rules share.

Exclusionary syntax

The following examples are logically equivalent:

Figure 70: Exclusionary Logic Using Boolean Condition, Pt. 1

ExclusionarySyntax.ers		0	1	
Conditions				
a	aircraft.aircraftType <> '747'		T	
b				
Actions				
Post Message(s)			✉	
A	aircraft.maxCargoWeight = 100000	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
B				
Overrides				
Rule Statements ✖ Rule Messages				
Ref	ID	Post	Alias	Text
1		Info	aircraft	Aircraft max cargo weight must be 100000 when aircraft type is NOT a 747

Figure 71: Exclusionary Logic Using Boolean Condition, Pt. 2

ExclusionarySyntax.ers		0	1	
Conditions				
a	aircraft.aircraftType = '747'		F	
b				
Actions				
Post Message(s)			✉	
A	aircraft.maxCargoWeight = 100000	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
B				
Overrides				
Rule Statements ✖ Rule Messages				
Ref	ID	Post	Alias	Text
1		Info	aircraft	Aircraft max cargo weight must be 100000 when aircraft type is NOT a 747

Figure 72: Exclusionary Logic Using Negated Value

ExclusionarySyntax.ers		0	1	
Conditions				
a	aircraft.aircraftType		not '747'	
b				
Actions				
Post Message(s)			✉	
A	aircraft.maxCargoWeight = 100000	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
B				
Overrides				
Rule Statements ✖ Rule Messages				
Ref	ID	Post	Alias	Text
1		Info	aircraft	Aircraft max cargo weight must be 100000 when aircraft type is NOT a 747

Notice that the last example uses the unary function `not`, described in more detail in the *Rule Language Guide*, to negate the value `747` selected from the Values set.

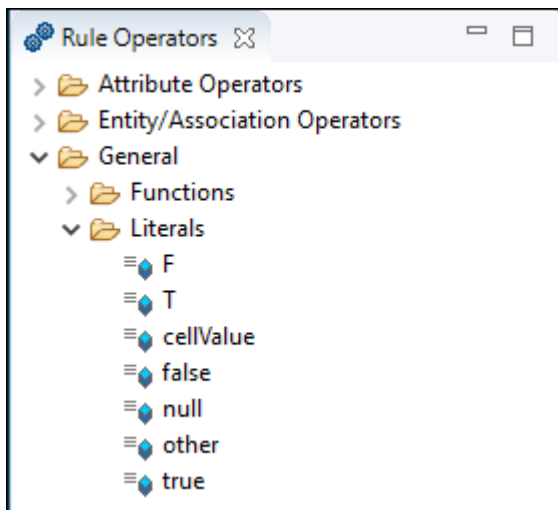
Once again we see that the same rule can be expressed in different ways on the Rulesheet, with identical results. It is left to the rule modeler to decide which way of expressing the rule is preferable in a given situation. We recommend, however, avoiding double negatives. Most people find it easier to understand `attribute=T` instead of `attribute<>F`, even though logically the two expressions are equivalent

Note: This assumes bi-value logic. If tri-value logic is assumed (such as, for a non-mandatory attribute), meaning the null value is available in addition to true and false, then these two expressions are not equivalent. If `attribute = null`, then the truth value of `attribute<>F` is true while that of `attribute=T` is false.

How to use 'other' in condition cells

Sometimes it is easier to define values we don't want matched than it is to define those we do. In the example shown above in [Exclusionary Logic Using Negated Value](#), we specify a `maxCargoWeight` to assign when `aircraftType` is *not* a `747`. But what would we write in the Conditions Cell if we wanted to specify any `aircraftType` *other than* those specified in *any of the other* Conditions Cells? For this, we use a special term in the Operator Vocabulary named `other`, shown in the following figure:

Figure 73: Literal Term `other` in the Operator Vocabulary



The term `other` provides a simple way of specifying any value *other than* any of those specified in other Cells of the same Conditions row. The following figure illustrates how we can use `other` in our example.

Here, we added a new rule (column 4) that assigns a `maxCargoWeight` of 50000 to any `aircraftType` *other than* the specific values identified in the cells in Condition row a (for example, a `727`). Our Rulesheet is now complete because all possible Condition-Action combinations are explicitly defined by columns in the decision table.

Numeric value ranges in conditions

Figure 74: Rulesheet using Numeric Value Ranges in Condition Values Set

NumericValuesInConditions.ers					
Conditions		1	2	3	4
a	Entity1.integer1	< 100	101..200	201..300	> 300
b					
Actions		<			
Post Message(s)					
A	Entity1.integer2	50000	100000	150000	200000
B					
Overrides					
Rule Statements					
Ref	Post	Alias	Text		
1			If integer1 is less than 100, then assign a value of 50000 to integer2		
2			If integer1 is between 101 and 200, inclusive, then assign a value of 100000 to integer2		
3			If integer1 is between 201 and 300, inclusive, then assign a value of 150000 to integer2		
4			If integer1 is greater than 300, then assign a value of 200000 to integer2		

In this example, we are assigning an integer2 value to Entity1 depending on its integer1 value. The value range 101..200 represents all values (integers in this case) between 101 and 200, including 101 and 200. This is an inclusive range because both the starting and ending values are included in the range.

String value ranges in condition cells

When using value range syntax with String types, be sure to enclose literal values inside single quotes, as shown in the following figure. Corticon Studio will usually perform this for you, but always check to make sure it has interpreted your entries correctly.

Figure 75: Rulesheet using String Value Ranges in Condition Values Set

String Values in Conditions.ers				
Conditions		1	2	3
a	Entity1.string1	'a'..'z'	'A'..'Z'	other
b				
Actions		<		
Post Message(s)				
A	Entity1.string2	'lowercase'	'uppercase'	'other char'
B				
Overrides				
Rule Statements				
Ref	ID	Post	Alias	Text
1				If Entity1.string1 is lowercase, set Entity1.string2 to 'lowercase'
2				If Entity1.string1 is uppercase, set Entity1.string2 to 'uppercase'
3				If Entity1.string1 is another character, set Entity1.string2 to 'other char'

Value sets in condition cells

Most Conditions implemented in the Rules section of the Rulesheet use a single value in a Cell, as shown in the following figure:

Figure 76: Rulesheet with One Value Selected in Condition Cell

Conditions		1	2
a	FlightPlan.cargo.weight	{ < 200, > 400 }	-
b		-	
Actions			
Post Message(s)			
A	FlightPlan.aircraft.aircraftType		
B			
Overrides			

Sometimes, however, it is useful to combine more than one value in the same Cell. You do this by holding **CTRL** while clicking multiple values from the Condition Cell drop-down box. Then, pressing **ENTER** will enclose the resulting set in curly brackets { . . } in the Cell as shown in the sequence of [Rulesheet with Two Values Selected in Condition Cell](#) and [Rulesheet with Value Set in Condition Cell](#). Additional values may also be typed into Cells.

Figure 77: Rulesheet with Two Values Selected in Condition Cell

Conditions		1	2
a	FlightPlan.cargo.weight		-
b			
Actions			
Post Message(s)			
A	FlightPlan.aircraft.aircraftType		
B			
Overrides			

Figure 78: Rulesheet with Value Set in Condition Cell

Conditions		1
a	FlightPlan.cargo.weight	{ < 200, > 400 }
b		
Actions		<
Post Message(s)		
A	FlightPlan.aircraft.aircraftType	'DC-10'
B		
Overrides		


Ref	ID	Post	Alias	Text
1				If the cargo weight is between 200 and 400, exclusive, the aircraftType must be DC-10

The rule implemented in Column 1 of [Rulesheet with Value Set in Condition Cell](#) is logically equivalent to the Rulesheet shown in [Rulesheet with Two Rules in Lieu of Value Set](#). Both are implementations of the following rule statement:

1. If a flightplan's cargo weight is less than 200 **OR** greater than 400, then the flightplan's aircraft type must be a DC-10

Figure 79: Rulesheet with Two Rules in Lieu of Value Set

Conditions		1	2
a	FlightPlan.cargo.weight	< 200	> 400
b			
Actions		<	
Post Message(s)			
A	FlightPlan.aircraft.aircraftType	'DC-10'	'DC-10'
B			
Overrides			

If you write rules that are logically **OR**'ed in separate Columns, performing a Compression  will reduce the Rulesheet to the fewest number of Columns possible by creating value sets in Cells wherever possible. Fewer Columns results in faster Rulesheet execution, even when those Columns contain value sets. Compressing the Rulesheet in [Rulesheet with Two Rules in Lieu of Value Set](#) will result in the Rulesheet in [Rulesheet with Value Set in Condition Cell](#).

Condition Cell value sets can also be negated using the **not** operator. To negate a value, simply type `not` in front of the leading curly bracket `{` as shown in [Negating a Value Set in a Condition Cell](#). This is an implementation of the following rule statement:

1. If a flightplan's cargo weight is **NOT** less than 200 **OR NOT** greater than 400, then the flightplan's aircraft type must be a DC-10

which, given the Condition Cell's value set, is equivalent to:

1. If a flightplan's cargo weight is between 200 and 400 (inclusive), then the flightplan's aircraft type must be a DC-10

Figure 80: Negating a Value Set in a Condition Cell

Conditions		1	
a	FlightPlan.cargo.weight	not { < 200, > 400 }	
b			
Actions		<	
Post Message(s)			
A	FlightPlan.aircraft.aircraftType	'DC-10'	
B			
Overrides			

Value sets can also be created in the Overrides Cells at the foot of each Column. This allows one rule to override multiple rules in the same Rulesheet.

Variables as condition cell values

You can use a variable as a condition's cell value. However, there are constraints:

- Either **all** of the rule cell values for a condition row contain references to the *same* variable (with the exception of dashes), or **none** of the rule cell values for a condition row reference *any* variable.
- Only one variable can be referenced by various rules for the same condition row.
- Logical expressions in the various rules for the same condition row should be logically non-overlapping.
- A condition value that uses a colon, such as A : B, is not valid.

Derived value sets are created by accounting for all logical ranges possible around the variable.

Note: The issue with using multiple attributes in a condition row (or attributes mixed with literals) is a warning not an error; as such analysis functions are not available.

The following Rulesheet uses the `Cargo` Vocabulary to illustrate the valid and invalid use of variables. Note that the Vocabulary editor marks invalid values in red.

	Conditions	0	1	2	3
a	Aircraft.maxCargoVolume		< Cargo.volume	> Cargo.volume	Cargo.volume
b	Aircraft.maxCargoVolume		<= Cargo.volume	> Cargo.volume	-
c	Aircraft.maxCargoVolume		< Cargo.volume	> Cargo.volume	-
d	Aircraft.maxCargoVolume		< Cargo.volume	-	-
e					
f	Aircraft.maxCargoVolume		< Cargo.volume	FlightPlan.cargo.volume	Cargo.volume
g	Aircraft.maxCargoVolume		< Cargo.volume	5	10..15
h	Aircraft.maxCargoVolume		< Cargo.volume	<= Cargo.volume	Cargo.volume
i	Aircraft.maxCargoVolume		A1:B2		

Derived values when using variables

The following tables abbreviate the attribute references shown in the illustration.

Table 2: Rulesheet columns

Conditions	1	2	3	Derived Value Set
A.maxCV	< C.v	> C.v	C.v	{ < C.v, > C.v, C.v }
A.maxCV	<= C.v	> C.v		{ <= C.v, > C.v }
A.maxCV	< C.v	> C.v		{ < C.v, > C.v, C.v }
A.maxCV	< C.v			{ < C.v, >= C.v }

Improper use of variables

Table 3: Rulesheet condition f: Attempt to use multiple variables

Conditions	1	2	3
A.maxCV	< C.v	> FP.c.v	C.v

Table 4: Rulesheet condition g: Attempt to mix variables and literals

Conditions	1	2	3
A.maxCV	< C.v	5	10..15

Table 5: Rulesheet condition h: Attempt to use logically overlapping expressions

Conditions	1	2	3
A.maxCV	< C.v	<= C.v	C.v

DateTime, date, and time value ranges in condition cells

When using value range syntax with date types, be sure to enclose literal date values inside single quotes, as shown:

Figure 81: Rulesheet using a Date Value Range in Condition Cells

The screenshot shows a rulesheet editor window titled "DateandSubtypeinConditions.ers". It contains a table with conditions and actions, and a "Rule Statements" section below.

Conditions	1	2	3
a Entity1.dateTime1	< '1/1/2016'	'1/1/2016'..'12/31/2016'	> '1/1/2017'
b			

Actions	1	2	3
A Entity1.string1	'earlier'	'current'	'later'
B			

Ref	ID	Post	Alias	Text
1				If dateTime1 is before Jan. 1 2016, then string1 is assigned a value of 'earlier'
2				If dateTime1 is between Jan. 1 2016 and Dec. 31 2016, then string1 is assigned a value of 'current'
3				If dateTime1 is on or after Jan. 1 2017, then string1 is assigned a value of 'later'

Inclusive and exclusive ranges

Corticon Studio also gives you the option of defining value ranges where one or both of the starting and ending values are “exclusive”, meaning that the starting/ending value is **not** included in the range of values. [Rulesheet using an Integer Value Range in Condition Values Set](#) shows the same Rulesheet as in [Rulesheet using Numeric Value Ranges in Condition Values Set](#), but with one difference: we have changed the value range 201..300 to (200..300]. The starting parenthesis (indicates that the starting value for the range, 200, is excluded – it is **not** included in the range of possible values. The ending bracket] indicates that the ending value is inclusive. Since integer1 is an Integer value, and therefore no fractional values are allowed, 201..300 and (200..300] are equivalent and our Values set in [Rulesheet using an Integer Value Range in Condition Values Set](#) is still complete as it was in [Rulesheet using Numeric Value Ranges in Condition Values Set](#).

Figure 82: Rulesheet using an Integer Value Range in Condition Values Set

The screenshot shows a Rulesheet titled 'RulesheetUsingAnIntegerValueRange.ers'. It is divided into two main sections: 'Conditions' and 'Actions'.

Conditions Table:

	1	2	3	4
a Entity1.integer1	< 100	101..200	(200..300]	> 300
b				

Actions Table:

	<			
A Entity1.integer2	50000	100000	150000	200000
B				

Rule Statements Table:

Ref	ID	Post	Alias	Text
1				If integer1 is less than 100, then assign a value of 50000 to integer2
2				If integer1 is between 101 and 200, inclusive, then assign a value of 100000 to integer2
3				If integer1 is between 201 and 300, inclusive, then assign a value of 150000 to integer2
4				If integer1 is greater than 300, then assign a value of 200000 to integer2

Listed below are all of the possible combinations of parenthesis and bracket notation for value ranges and their meanings:

- (x..y) - is the range between x & y, excluding both x & y
- (x..y] - is the range between x & y, excluding x and including y
- [x..y) - is the range between x & y, including x and excluding y
- [x..y] - is the range between x & y, including both x & y

As illustrated in [Rulesheet using Numeric Value Ranges in Condition Values Set](#) and [Rulesheet using an Integer Value Range in Condition Values Set](#), if a value range has no enclosing parentheses or brackets, it is assumed to be closed. It is therefore not necessary to use the [..] notation for a closed range in Corticon Studio; in fact, if you try to create a closed value range by entering [..], the square brackets will be automatically removed. However, should either end of a value range have a parenthesis or a bracket, then the other end must also have a parenthesis or a bracket. For example, x..y) is not allowed, and is properly expressed as [x..y).

When using range notation, always ensure x is less than y, i.e., an ascending range. A range where x is greater than y (a descending range) may result in errors during rule execution.

Value ranges that overlap

One final note about value ranges: they **might overlap**. In other words, Condition Cells may contain the two ranges 0 . . 10 and 5 . . 15. It is important to understand that when overlapping ranges exists in rules, the rules containing the overlap are frequently ambiguous and more than one rule may fire for a given set of input Ruletest data. [Rulesheet with Value Range Overlap](#) shows an example of value range overlap.

Figure 83: Rulesheet with Value Range Overlap

The screenshot shows a rulesheet editor window titled 'overlap.ers'. It contains a grid for conditions and actions, and a table for rule statements.

Conditions	0	1	2	3	4	!
a Entity_1.integer_1		< 100	100..200	150..300		
b						
c						

Actions	0	1	2	3	4	!
Post Message(s)		✉	✉	✉		
A Entity_1.intetger_2		50000	100000	150000		
B						
C						

Ref	ID	Post	Alias	Text
1		Info	Entity_1	integer is less than 100
2		Warning	Entity_1	integer is between 100 and 200
3		Violation	Entity_1	integer is between 150 and 300

Figure 84: Rulesheet expanded with Conflict Check applied

The screenshot shows the same rulesheet editor window as Figure 83, but with a conflict check applied. The overlapping cells in the conditions and actions grid are highlighted in red.

Conditions	0	1	2	3	4	!
a Entity_1.integer_1		< 100	100..200	150..300		
b						
c						

Actions	0	1	2	3	4	!
Post Message(s)		✉	✉	✉		
A Entity_1.intetger_2		50000	100000	150000		
B						
C						

Ref	ID	Post	Alias	Text
1		Info	Entity_1	integer is less than 100
2		Warning	Entity_1	integer is between 100 and 200
3		Violation	Entity_1	integer is between 150 and 300

Figure 85: Ruletest showing multiple rules firing for given test data

The screenshot shows a Ruletest interface. On the left, the 'Input' section contains a tree view with 'Entity_1 [1]' and a sub-element 'integer_1 [175]'. On the right, the 'Output' section contains a tree view with 'Entity_1 [1]' and two sub-elements: 'integer_1 [175]' and 'intetger_2 [150000]'. Below this, there are tabs for 'Rule Statements', 'Comments', and 'Rule Messages'. The 'Rule Messages' tab is active, showing a table with the following data:

Severity	Message	Entity
Warning	integer is between 100 and 200	Entity_1[1]
Violation	integer is between 150 and 300	Entity_1[1]

Alternatives to value ranges

As you might expect, there is another way to express a rule which contains a range of values. One alternative is to use a series of Boolean Conditions that cover the ranges of concern. This is illustrated in the following figure:

Figure 86: Rulesheet Using Boolean Conditions to Express Value Ranges

The screenshot shows a Rulesheet titled 'BooleansAsValueRanges.ers'. It features a decision table with four columns (1, 2, 3, 4) and three rows of conditions (a, b, c). Below the decision table is an 'Actions' section with a table for 'Post Message(s)' and 'Overrides'. The 'Post Message(s)' table has four columns corresponding to the decision table columns, with values 50000, 100000, 150000, and 200000. Below the decision table, there are tabs for 'Rule Statements' and 'Rule Messages'. The 'Rule Messages' tab is active, showing a table with the following data:

Ref	ID	Post	Alias	Text
A1				Aircraft max cargo weight must be 50000 kg when flight number is less than or equal to 100
A2				Aircraft max cargo weight must be 100000 kg when flight number is between 101 and 200, inclusive
A3				Aircraft max cargo weight must be 150000 kg when flight number is between 201 and 300, inclusive
A4				Aircraft max cargo weight must be 200000 kg when flight number is greater than 300

The rules here are identical to the rules in [Rulesheet Using Value Ranges in the Column Cells of a Condition Row](#) and [Rulesheet Using Open-Ended Value Ranges in Condition Cells](#), but are expressed using a series of three Boolean Conditions. Recall that in a decision table, values aligned vertically in the same column represent **AND**'ed Conditions in the rule. So rule 1, as expressed in column 1, reads:

```
if flightNumber is not greater than 100 and flightNumber is not greater than 200 and
flightNumber is not greater than 300, then its maxCargoWeight must equal 50000 kgs.
```

Expressing this rule in friendlier, more natural English, we might say:

```
An Aircraft's max cargo weight must be 50000 kgs when flight number is less than or equal to 100.
```

This is how the rule is expressed in the **Rule Statements** section in **Rulesheet Using Boolean Conditions to Express Value Ranges**. The same rules may also be expressed using a series of Rulesheets with the applicable range of `flightNumber` values constrained by Filters. Corticon Studio gives you the flexibility to express and organize your rules any number of possible ways – as long as the rules are logically equivalent, they will produce identical results when executed.

In the case of rules involving numeric value ranges as opposed to discrete numeric values, the value range option allows you to express your rules in a very simple and elegant way. It is especially useful when dealing with Decimal type values.

How to use standard boolean constructions

A decision table is a graphical method of organizing and formalizing logic. If you have a background in computer science or formal logic, you may have seen alternative methods. One such method is called a *truth table*.

The section "*Standard Boolean Constructions*" in the *Rule Language guide* presents several standard truth tables (AND, NAND, OR, XOR, NOR, and XNOR) with examples of usage in a Rulesheet.

How to embed attributes in posted rule statements

It is frequently useful to “embed” attribute values within a Rule Statement, so that posted messages contain actual data. Special syntax must be used to differentiate the static text of the rule statement from the dynamic value of the attribute. As shown in [Sample Rulesheet with Rule Statements Containing Embedded Attributes](#), an embedded attribute must be enclosed by curly brackets { . . } to distinguish it from the static Rule Statement text.

It may also be helpful to indicate which parts of the posted message are dynamic, so a user seeing a message knows which part is based on live data and which part is the standard rule statement. As shown in [Sample Rulesheet with Rule Statements Containing Embedded Attributes](#), square brackets are used immediately outside the curly brackets so that the dynamic values inserted into the message at rule execution will be “bracketed”. The use of these square brackets is optional – other characters may be used to achieve the intended visual distinction.

Remember, Action Rows execute in numbered order (from top to bottom in the Actions pane), so a Rule Statement that contains an embedded attribute value must not be posted before the attribute has a value. Doing so will result in a null value inserted in the posted message.

Figure 87: Sample Rulesheet with Rule Statements Containing Embedded Attributes

The screenshot shows a rulesheet editor for a file named 'EmbeddedAttributes.ers'. It is divided into several sections:

- Conditions:** A table with columns 1, 2, and 3. Row 'a' contains 'Entity1.integer1', '< 18', '18..25', and '> 25'. Row 'b' is empty.
- Actions:** A table with a 'Post Message(s)' row containing three envelope icons, and rows 'A' and 'B' which are empty.
- Overrides:** An empty table.
- Rule Statements:** A table with columns Ref, ID, Post, Alias, and Text.

Ref	ID	Post	Alias	Text
1		Info	Entity1	This person is {{Entity1.integer1}} which is less than 18, so they cannot drink or vote
2		Info	Entity1	This person is {{Entity1.integer1}} which is between 18 and 25, so they can drink, vote, and be drafted, but not rent a car
3		Info	Entity1	This person is {{Entity1.integer1}} which is greater than 25, so they can drink, vote, be drafted, and rent a car

Figure 88: Rule Messages Window Showing Bracketed Embedded Attributes (Orange Box)

The screenshot shows the 'Rule Messages' window. It has two main panes: 'Input' and 'Output', each showing a tree view of data elements. Below these panes is a table of rule messages.

Input Tree:

- Entity1 [1]
 - integer1 [15]
- Entity1 [2]
 - integer1 [23]
- Entity1 [3]
 - integer1 [33]

Output Tree:

- Entity1 [1]
 - integer1 [15]
- Entity1 [2]
 - integer1 [23]
- Entity1 [3]
 - integer1 [33]

Rule Messages Table:

Severity	Message
Info	This person is [15] which is less than 18, so they cannot drink or vote
Info	This person is [23] which is between 18 and 25, so they can drink, vote, and be drafted, but not rent a car
Info	This person is [33] which is greater than 25, so they can drink, vote, be drafted, and rent a car

When an attribute uses an Enumerated Custom Data Type, the dynamic value embedded in the posted Rule Message will be the Value, not the Label. See the *Rule Modeling Guide*, “Building the Vocabulary” chapter for more information about Custom Data Types.

No expressions in Rule Statements

A reminder about the tables "Usage restrictions" in the *Rule Language Guide*, which specifies that the only parts of the Vocabulary that may be embedded in Rule Statements are attributes. No operators or expressions are permitted inside Rule Statements. Often, operators will cause error messages when you try to save a Rulesheet. Sometimes the Rule Statement itself will turn red. Sometimes an embedded equation will even execute as you intended. But sometimes no obvious error will occur, but the rule does not executed as intended. Just remember that operators and expressions are not supported in Rule Statements.

How to include apostrophes in strings

String values in Corticon Studio are always enclosed in single quotes. But occasionally, you may want the String value to include single quote or apostrophe characters. If you enter the following text in Corticon Studio:

```
entity1.string1='Jane's dog Spot'
```

The text will turn red, because Corticon Studio thinks that the `string1` value is `'Jane'` and the remaining text `s dog Spot'` is invalid. To properly express a String value that includes single quotes or apostrophes, you must use the special character backslash (`\`) that tells Corticon Studio to ignore the apostrophe(s) as follows:

```
entity1.string1='Jane\'s dog Spot'
```

When preceded by the backslash, the second apostrophe will be ignored and assumed to be just another character within the String. This notation works in all sections of the Rulesheet, including Values sets. It also works in the Possible Values section of the Vocabulary Editor.

TestYourself questions for Rule writing techniques and logical equivalents

Note: Try this test, and then go to [TestYourself answers for Rule writing techniques and logical equivalents](#) on page 337 to correct yourself.

- Filters act as master rules for all other rules in the same Rulesheet that share the same _____.
- An expression that evaluates to a True or False value is called a _____ expression.
- True or False. Condition row values sets must be complete.
- True or False. Action row values sets must be complete.
- The special term _____ can be used to complete any Condition row values set.
- What operator is used to negate a Boolean expression?
- If a Boolean expression is written in a Condition row, what values are automatically entered in the Values set when **Enter** is pressed?
- A Filter expression written as `Entity.boolean1=T` is equivalent to (circle all that apply)

<code>Entity.boolean1</code>	<code>Entity.boolean1<>F</code>	<code>Entity.boolean1=F</code>	not (<code>Entity.boolean1=F</code>)
------------------------------	---------------------------------------	--------------------------------	---

9. Of all alternatives listed in Question 71, which is the best choice? Why?
10. Describe the error (if any) in each of the following value ranges. Assume all are used in Conditions values sets.
- a. {1...10, other}
 - b. {1..a, other}
 - c. {'a'..other}
 - d. {1..10, 5..20, other}
 - e. {1..10, [10..20), other}
 - f. {'red', 'green', 'blue'}
 - g. {<0, 0..15, >3}
11. True or False. The special term `other` may be used in Action row values sets.
12. Using best practices discussed in this section, model the following rules on a single Rulesheet:
- If the part is in stock and it has a blue tag, then the part's discount is 10%
 - If the part is in stock and it has a red tag, then the part's discount is 15%
 - If the part is in stock and it has a yellow tag, then the part's discount is 20%
 - If the part is in stock and it has a green tag, then the part's discount is 25%
 - If the part is in stock and it has any other color tag, then the part's discount is 5%
13. True or False. A Nonconditional rule is equivalent to an Action expression with no Condition.
14. True or False. A Nonconditional rule is governed by any Preconditions on the same Rulesheet.

Collections

Collections enable operations to be performed on a set of instances specified by an alias.

For details, see the following topics:

- [How Corticon Studio handles collections](#)
- [How to visualize collections](#)
- [A basic collection operator](#)
- [How to filter collections](#)
- [How to use aliases to represent collections](#)
- [Sorted aliases](#)
- [Advanced collection sorting syntax](#)
- [Statement blocks](#)
- [Using sorts to find the first or last in grandchild collections](#)
- [Singletons](#)
- [Special collection operators](#)
- [Aggregations that optimize EDC database access](#)
- [TestYourself questions for Collections](#)

How Corticon Studio handles collections

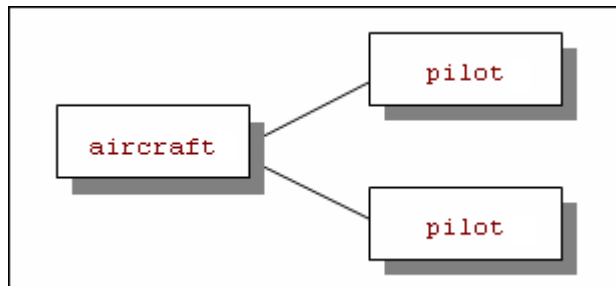
Support for using collections is extensive in Corticon Studio – in fact, the integration of collection support in the Rule Language is so seamless and complete, the rule modeler will often discover that rules are performing multiple evaluations on collections of data beyond what they anticipated! This is partly the point of a declarative environment – the rule modeler need only be concerned with *what* the rules do, rather than *how* they do it. How the system actually iterates or cycles through all the available data during rule execution should not be of concern.

As we saw in previous examples, a rule with term `FlightPlan.aircraft` was evaluated for every instance of `FlightPlan.aircraft` data delivered to the rule, either by a message or by a Ruletest (which are really the same thing, as the Ruletest simply serves as a quick and convenient way to create message payloads and send them to the rules). A rule is expressed in Corticon Studio the same way regardless of how many instances of data are to be evaluated by it – contrast this to more traditional *procedural* programming techniques, where “for-do” or “while-next” type looping syntax is often required to ensure all relevant data is evaluated by the logic.

How to visualize collections

Collections of data may be visualized as discrete portions, subsets, or branches of the Vocabulary tree – a parent entity associated with a set of child entities, which we call *elements* of the collection. The collection of pilots can be illustrated as:

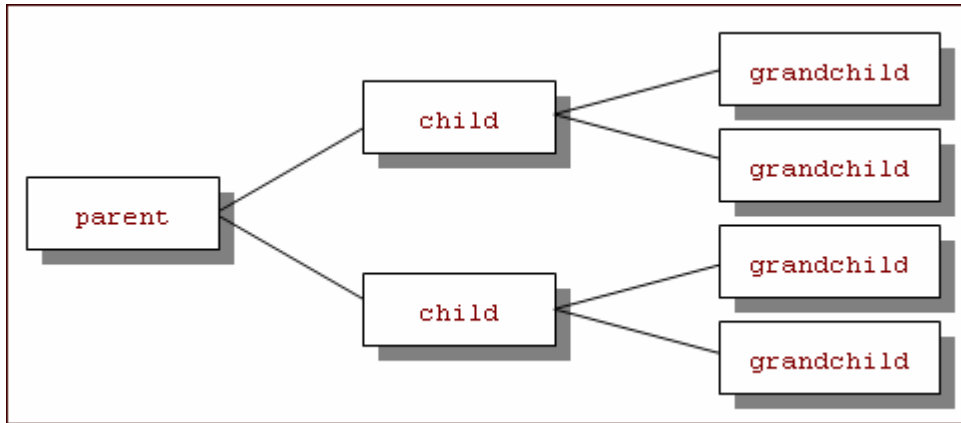
Figure 89: Visualization of a Collection of Pilots



In this figure, the `aircraft` entity is the parent of the collection, while each `pilot` is a child element of the collection. As we saw in the role example, this collection is expressed as `aircraft.pilot` in the Corticon Rule Language. It is important to reiterate that this collection contains scope – we are seeing the collection of pilots as they relate to this aircraft. Or, put more simply, we are seeing a plane and its 2 pilots, arranged in a way that is consistent with our Vocabulary. Whenever a rule exists that contains or uses this same scope, it will also *automatically* evaluate this collection of data. And if there are multiple collections with the same scope (for example, several aircraft, each with its own collection of pilots), then the rule will automatically evaluate all those collections, as well. In our lexicon, “evaluate” has a different meaning than “fire”. *Evaluate* means that a rule’s scope and Conditions will be compared to the data to see if they are satisfied. If they are satisfied, then the rule *fires* and its Actions are executed.

Collections can be much more complex than this simple pilot example. For instance, a collection can include more than one type or “level” of association:

Figure 90: 3-Level Collection



This collection is expressed as `parent.child.grandchild` in the Corticon Rule Language. Now let's look at a simple collection operator and understand how it works given the collection in **Visualization of a Collection of Pilots**.

Note: The parent and child nomenclature is a bit arbitrary. Assuming bidirectional associations, a child from one perspective could also be a parent in another.

A basic collection operator

As an example, let's use the `->size` operator (see the *Rule Language Guide* for more about this operator). This operator returns the number of elements in the collection that it follows in a rule expression. Using the collection from [Visualizing a Collection of Pilots](#):

```
aircraft.pilot -> size
```

returns the value of 2. In the expression:

```
aircraft.crewSize = aircraft.pilot -> size
```

`crewSize` (assumed to be an attribute of `Aircraft`) is assigned the value of 2.

Corticon Studio requires that all rules containing collection operators use unique aliases to represent the collections. [Using aliases to represent collections](#) is described in greater detail in this chapter. A more accurate expression of the rule above becomes:

```
plane.pilot -> size
```

or

```
plane.crewsize = plane.pilot -> size
```

where `plane` is an alias for the collection of `pilots` on `aircraft`.

How to filter collections

The process of screening specific elements from a collection is known as “filtering”, and the Corticon Studio supports filtering by a special use of Filter expressions. See the [Filters and preconditions](#) on page 195 topic for more details.

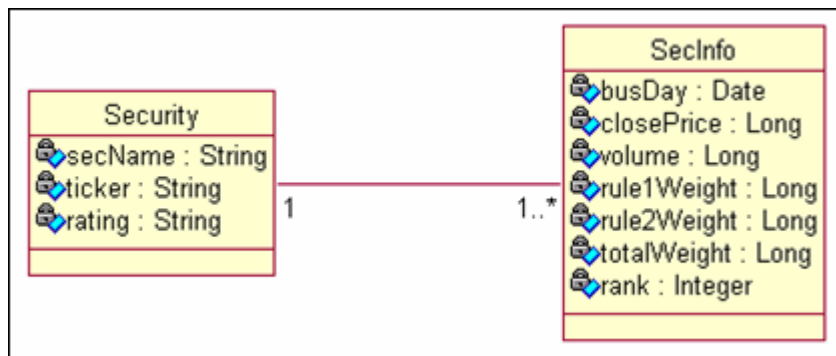
How to use aliases to represent collections

Aliases provide a means of using scope to specify elements of a collection; more specifically, we are using aliases (expressed or declared in the Scope section of the Rulesheet) to represent *copies* of collections. This concept is important because aliases give you the ability to operate on and compare multiple collections, or even copies of the same collection. There are situations where such operations and comparisons are required by business rules. Such rules are not easy (and sometimes not possible) to implement without using aliases.

Note: To ensure that the system knows precisely which collection (or copy) you are referring to in your rules, it is necessary to use a **unique alias** to refer to each collection.

For the purposes of illustration, we will introduce a new scenario and business Vocabulary. This new scenario involves a financial services company that compares and ranks stocks based on the values of attributes such as closing price and volume. A model for doing this kind of ranking can get very complex in real life; however, we will keep our example simple. Our new Vocabulary is illustrated in a UML class diagram in the following figure:

Figure 91: Security Vocabulary UML Class Diagram



This Vocabulary consists of only two entities:

Security – represents a security (stock) with attributes like security name (`secName`), ticker symbol, and rating.

SecInfo – is designed to record information for each stock for each business day (`busDay`); attributes include values recorded for each stock (`closePrice` and `volume`) and values determined by rules (`totalWeight` and `rank`) each business day.

The association between **Security** and **SecInfo** is `1..*` (one-to-many) since there are multiple instances of **SecInfo** data (multiple days of historical data) for each **Security**.

In our scenario, we will use three rules to determine a security's rank:

1. A security whose closing price today is higher than its closing price on the previous business day must have a value of 0.5 assigned to its rule 1 weight; otherwise, a value of 0 must be assigned to its rule 1 weight.
2. A security whose trading volume today is greater than its trading volume on the previous business day must have a value of 0.25 assigned to its rule 2 weight; otherwise, a value of 0 must be assigned to its rule 2 weight.
3. A security's total weight is equal to the sum of its rule 1 weight and its rule 2 weight.

Finally, rules will be used to assign a rank based on the total weight. It is interesting to note that although the rules refer to a security's closing price, volume, and rule weights, these attributes are actually properties of the `SecInfo` entity. Rulesheets that accomplish these tasks are shown in the next two figures.

Figure 92: Rulesheet with Ranking Model Rules 1 and 2

The screenshot shows a rulesheet for 'secInfo1.ers'. The 'Scope' section is expanded to show 'Security [sec]' with two 'secInfo' aliases: 'secInfo [secInfo1]' and 'secInfo [secInfo2]'. The 'Filters' section contains two rules: '1 secInfo1.busDay = today' and '2 secInfo2.busDay = today.addDays(-1)'. The 'Conditions' table has three rows: 'a' (secInfo1.closePrice > secInfo2.closePrice), 'b' (secInfo1.volume > secInfo2.volume), and 'c'. The 'Actions' section includes 'Post Message(s)' with two entries: 'A secInfo1.rule1Weight' and 'B secInfo1.rule2Weight'. A truth table on the right shows the results for conditions 'a' and 'b' across five ranks (0-4). The 'Rule Statements' table at the bottom lists four rules with their IDs, post types, aliases, and text.

Conditions	0	1	2	3	4
a		T	F	-	-
b		-	-	T	F
c					

Post Message(s)	0	1	2	3	4
A		0.5	0		
B				0.25	0

Ref	ID	Post	Alias	Text
1		Info	sec	If today's closing price > last business day's closing price, then rule 1 weight = 0.5
2		Info	sec	If today's closing price <= last business day's closing price, then rule 1 weight = 0
3		Info	sec	If today's closing volume > last business day's closing volume then rule 2 weight = 0.25
4		Info	sec	If today's closing volume <= last business day's closing volume then rule 2 weight = 0

In the figure above, we see two business rules expressed in a total of four rule models (one for each possible outcome of the two business rules). The rules themselves are straightforward, but the shortcuts (alias values) used in these rules are different than any we have seen before. In the Scope section, we see the following:

Figure 93: Close-up of the Scope Section from Rulesheet with Ranking Model Rules 1 and 2

The close-up shows the 'Scope' section with a tree view. The root is 'Security <sec>'. Under it are 'Filters', 'secInfo <secinfo1>', and 'secInfo <secinfo2>'. Each item has a plus sign icon to its left, indicating it is expandable.

`Security` is the scope for our Rulesheet, which is not a new concept. But then we see that there are two aliases for the `SecInfo` entities associated with `Security`: `secinfo1` and `secinfo2`. Each of these aliases represents a separate but identical collection of the `SecInfo` entities associated with `Security`. In this Rulesheet, we constrain each alias by using Filters; in a later example, we will see how more loosely constrained aliases can represent many different elements in a collection when the Corticon Server evaluates rules. In this specific example, though, one instance of `SecInfo` represents the current business day (`today`) and the other instance represents the previous business day (`today.addDays(-1)`).

Note: For details on the `.addDays` operator, refer to that topic in the *Rule Language Guide*.

Once the aliases are created and constrained, we can use them in our rules where needed. In the figure **Rulesheet with Ranking Model Rules 1 and 2**, we see that the use of aliases in the Conditions section allows comparison of `closePrice` and `volume` values from one specific `SecInfo` element (the one with today's date) of the collection with another (the one with yesterday's date).

The following figure shows a second Rulesheet which uses a Nonconditional rule to calculate the sum of the partial weights from our model rules as determined in the first Rulesheet, and Conditional rules to assign a rank value between 1 and 4 to each security based on the sum of the partial weights. Since we are only dealing with data from the current day in this Rulesheet (as specified in the Filters), only one instance of `SecInfo` per `Security` applies and we do not need to use aliases.

Figure 94: Rulesheet with Total Weight Calculation and Rank Determination

The screenshot shows the Corticon Rulesheet Editor for 'secInfo2.ers'. The interface is divided into several sections:

- Scope:** A tree view showing 'Security [sec]' with sub-items 'Filters' and 'secInfo [secInfo]'.
- Filters:** Two filters are listed: '1 secInfo.busDay = today' and '2'.
- Conditions:** Two conditions are defined: 'a secInfo.totalWeight' and 'b'.
- Actions:** Two actions are defined: 'A secInfo.totalWeight = secInfo.rule1Weight + secInfo.rule2Weight' and 'B secInfo.rank'.
- Rule Messages Table:** A table with columns 'Ref', 'ID', 'Post', 'Alias', and 'Text'. It shows the execution of rules 0 through 4.

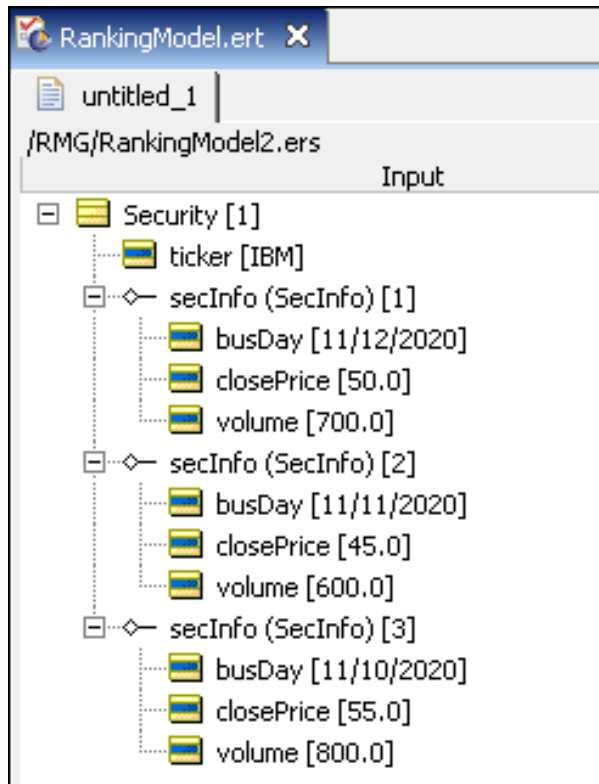
Ref	ID	Post	Alias	Text
0		Info	sec	Total weight = sum of rule 1 weight and rule 2 weight
1		Info	sec	If total weight = 0, then rank = 1
2		Info	sec	If total weight = 0.25, then rank = 2
3		Info	sec	If total weight = 0.5, then rank = 3
4		Info	sec	If total weight = 0.75, then rank = 4

We can test our new rules using a Ruleflow to combine the two Rulesheets. In a Ruletest which executes the Ruleflow, we would expect to see the following results:

1. The `Security.secInfo` collection that contains data for the current business day (we expect that this collection will reduce to just a single `secinfo` element, since only one `secinfo` element exists for each day) should be assigned to alias `secinfo1` for evaluating the model rules.
2. The `SecInfo` instance that contains data for the previous business day (again, the collection filters to a single `secinfo` element for each `Security`) should be assigned to alias `secinfo2` for evaluating the model rules.
3. The partial weights for each rule, sum of partial weights, and resulting rank value should be assigned to the appropriate attributes in the current business day's `SecInfo` element.

A Ruleflow constructed for testing the ranking model rules is as shown:

Figure 95: Ruletest for Testing Security Ranking Model Rules



In this figure, we have added one `Security` object and three associated `SecInfo` objects from the Vocabulary. The current day at the time of the Ruletest is 11/12/2020, so the three `SecInfo` objects represent the current business day and two previous business days. The third business day is included in this Ruletest to verify that the rules are using only the current and previous business days – none of the data from the third business day should be used if the rules are executing correctly. Based on the values of `closePrice` and `volume` in our two `SecInfo` objects being tested, we expect to see the highest rank of 4 assigned to our security in the current business day's `SecInfo` object.

Figure 96: Ruletest for Security Ranking Model Rules

The screenshot displays a rule testing interface with two main panels: 'Input' and 'Output'. Below these panels is a 'Rule Messages' section with a table.

Input Panel:

- Security [1]
 - ticker [IBM]
 - secInfo (SecInfo) [1]
 - busDay [11/12/2020]
 - closePrice [50.0]
 - volume [700.0]
 - secInfo (SecInfo) [2]
 - busDay [11/11/2020]
 - closePrice [45.0]
 - volume [600.0]
 - secInfo (SecInfo) [3]
 - busDay [11/10/2020]
 - closePrice [55.0]
 - volume [800.0]

Output Panel:

- Security [1]
 - ticker [IBM]
 - secInfo (SecInfo) [1]
 - busDay [11/12/2020]
 - closePrice [50.000000]
 - rank [4]
 - rule1Weight [0.500000]
 - rule2Weight [0.250000]
 - totalWeight [0.750000]
 - volume [700.000000]
 - secInfo (SecInfo) [2]
 - busDay [11/11/2020]
 - closePrice [45.000000]
 - volume [600.000000]
 - secInfo (SecInfo) [3]
 - busDay [11/10/2020]
 - closePrice [55.000000]
 - volume [800.000000]

Rule Messages Table:

Sev...	Message	Entity
Info	If today's closing price > last business day's closing price, then rule 1 weight = 0.5	Security[1]
Info	If today's closing volume > last business day's closing volume then rule 2 weight = 0.25	Security[1]
Info	Total weight = sum of rule 1 weight and rule 2 weight	Security[1]
Info	If total weight = 0.75, then rank = 4	Security[1]

We see the expected results produced above. Both `closePrice` and `volume` for 11/12/2020 were higher than the values for those same attributes on 11/11/2020; therefore, both `rule1Weight` and `rule2Weight` attributes were assigned their “high” values by the rules. Accordingly, the `totalWeight` value calculated from the sum of the partial weights was the highest possible value and a `rank` of 4 was assigned to this security for the current day.

As previously mentioned, the example above was tightly constrained in that the aliases were assigned to two very specific elements of the referenced collections. What about the case where there are multiple instances of an entity that you would like to evaluate with your rules? We will discuss just such an example next.

Our second example is also based on our security ranking scenario but, in this example, the rank assignment that was accomplished will be done in a different way. Instead, we would like to rank a number of securities based on their relative performance to one another, rather than against a preset ranking scheme like the one in [Figure 92: Rulesheet with Ranking Model Rules 1 and 2](#) on page 117. In the rules for our new example, we will compare the `totalWeight` value that is determined for each security for the current business day against the `totalWeight` of every other security, and determine a rank based on this comparison of `totalWeight` values. A Rulesheet for this alternate method of ranking securities is shown in the next figure.

Figure 97: Rulesheet with Alternate Rank Determination Rules

The screenshot shows the Progress Corticon Rulesheet Editor for a rulesheet named "AlternateRank.ers". The interface is divided into several sections:

- Scope:** A tree view showing two Security objects (sec1 and sec2). Each Security object has a Filters collection and a SecInfo collection (secInfo1 and secInfo2).
- Filters:** A list of five filters:
 - 1 sec1 <> sec2
 - 2 secInfo1.busDay = today
 - 3 secInfo2.busDay = today
 - 4
 - 5
- Conditions:** A table with columns for conditions (a-q) and three columns for truth values (0, 1, 2).

Conditions	0	1	2
a	-	T	F
b			
c			
d			
e			
f			
g			
h			
i			
j			
k			
l			
m			
n			
o			
p			
q			
- Actions:** A table with columns for actions (A-E) and three columns for truth values (0, 1, 2).

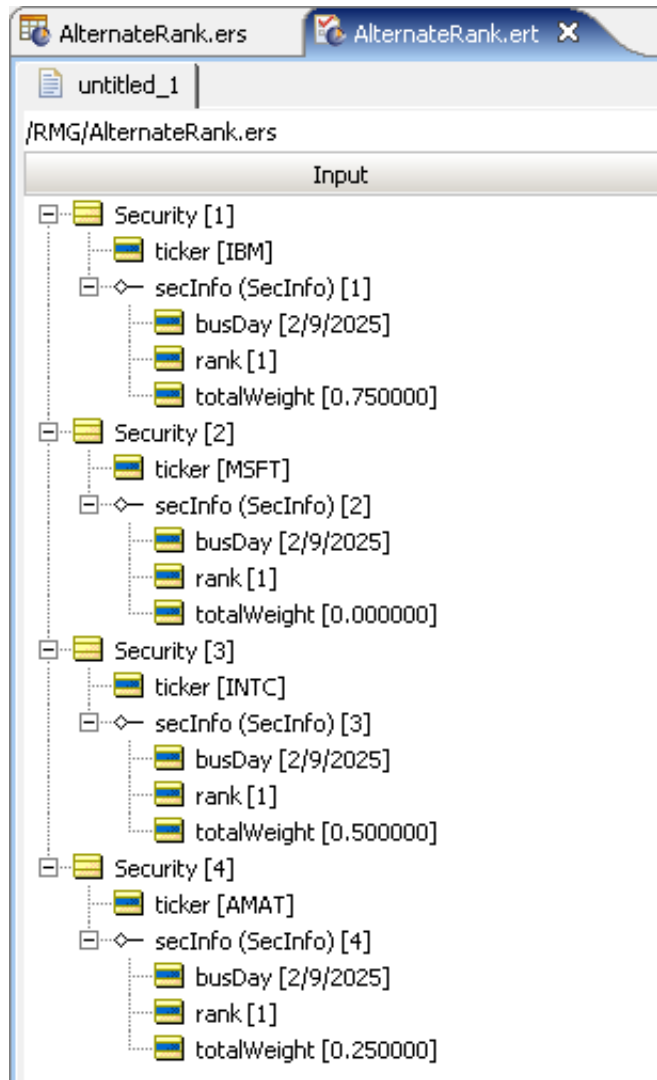
Actions	0	1	2
A		✉	✉
B		<input checked="" type="checkbox"/>	
C			
D			
E			
- Rule Statements:** A table with columns for Ref, ID, Post, Alias, and Text.

Ref	ID	Post	Alias	Text
1		Info		If Security 1 [{sec1.ticker}] total weight > Security 2 [{sec2.ticker}] total weight, then increment [{sec1.ticker}] rank by 1
2		Info		If Security 1 [{sec1.ticker}] total weight <= Security 2 [{sec2.ticker}] total weight, then take no action

In these new ranking rules, we have created aliases to represent specific instances of Security and their associated collections of SecInfo. As in the previous example, Filters constrain the aliases, most notably in the case of the SecInfo instances, where we filter secInfo1 and secInfo2 for a specific value of busDay (today's date). However, we have only loosely constrained our Security instances – we merely have a Filter that prevents the same element of Security from being compared to itself (when sec1 = sec2). No other constraints are placed on the Security aliases.

Note that we are not assigning specific, single elements of *Security* to our aliases. Instead, we are instructing the Corticon Server to evaluate all *allowable* combinations (i.e., all those combinations that satisfy the 1st Filter) of *Security* elements in our collection in each of the aliases (*sec1* and *sec2*). For each allowable combination of *Security* elements, we will compare the *totalWeight* values from the associated *SecInfo* element for *busDay = today*, and increment the *rank* value for the first *SecInfo* element (*secinfo1*) by 1 if its *totalWeight* is greater than that of the second *SecInfo* object (*secinfo2*). The end result should be the relative performance ranking of each security that we want.

Figure 98: Rulesheet for Testing Alternate Security Ranking Model Rules



This figure shows a Ruletest constructed to test these ranking rules. In our data, we have added four *Security* elements and an associated *secInfo* element for each (note that each alias will represent ALL 4 elements AND their associated *secInfo* elements). The current day at the time of the Ruletest is 2/9/2025, so each *Security.secInfo.busDay* attribute is given the value of 2/9/2025 (if we had included additional *secinfo* elements in each collection, they'd have earlier dates, and therefore would be filtered out by the Preconditions on each alias). We have initially set (or "initialized") each *Security.secInfo.rank* "loses" all comparisons with the other securities - in other words, its weight is less than the weights of all other securities. If a security's weight is less than all the other security weights, its rank will never be incremented by the rule, so its rank will remain 1. The values of equal to 1, so that the lowest ranked security will still have a value of 1. The lowest ranked security will be the one that *totalWeight* for the *SecInfo* objects are all different; therefore, we expect to see each security ranked between 1 and 4 with no identical *rank* values.

Note: If there were multiple `Security.secInfo` elements (multiple securities) with the same value for the same day, then we would expect the final `rank` assigned to these objects to be the same as well. Further, if there were multiple `Security.secInfo` entities sharing the highest relative `totalWeight` value in a given Ruletest, then the highest `rank` value possible for that Ruletest would be lower than the number of securities being ranked, assuming we initialize all `rank` values at 1.

Figure 99: Rulesheet for Alternate Security Ranking Model Rules

The screenshot displays a software interface for a rulesheet titled "AlternateRank.ers". The interface is divided into two main panes: "Input" and "Output".

Input Pane: Shows a tree structure of four "Security" objects (Security [1] to [4]). Each object contains a "secInfo (SecInfo)" element with sub-elements for "busDay", "rank", and "totalWeight".

- Security [1]: ticker [IBM], secInfo (SecInfo) [1], busDay [2/9/2025], rank [1], totalWeight [0.750000]
- Security [2]: ticker [MSFT], secInfo (SecInfo) [2], busDay [2/9/2025], rank [1], totalWeight [0.000000]
- Security [3]: ticker [INTC], secInfo (SecInfo) [3], busDay [2/9/2025], rank [1], totalWeight [0.500000]
- Security [4]: ticker [AMAT], secInfo (SecInfo) [4], busDay [2/9/2025], rank [1], totalWeight [0.250000]

Output Pane: Shows the same tree structure but with updated "rank" values:

- Security [1]: rank [4]
- Security [2]: rank [1]
- Security [3]: rank [3]
- Security [4]: rank [2]

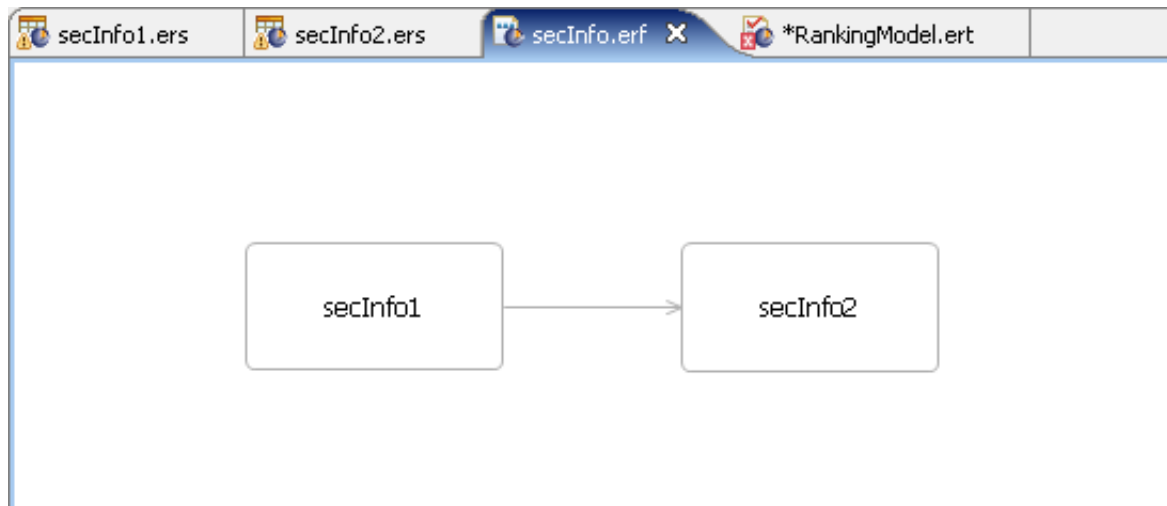
Rule Statements: A table below the panes lists 12 rules with their severity, message, and entity.

Severity	Message	Entity
Info	If Security 1 [IBM] total weight > Security 2 [AMAT] total weight, then increment [IBM] rank by 1	Security[1]
Info	If Security 1 [AMAT] total weight > Security 2 [MSFT] total weight, then increment [AMAT] rank by 1	Security[4]
Info	If Security 1 [INTC] total weight > Security 2 [MSFT] total weight, then increment [INTC] rank by 1	Security[3]
Info	If Security 1 [IBM] total weight > Security 2 [INTC] total weight, then increment [IBM] rank by 1	Security[1]
Info	If Security 1 [INTC] total weight > Security 2 [AMAT] total weight, then increment [INTC] rank by 1	Security[3]
Info	If Security 1 [IBM] total weight > Security 2 [MSFT] total weight, then increment [IBM] rank by 1	Security[1]
Info	If Security 1 [AMAT] total weight <= Security 2 [INTC] total weight, then take no action	Security[4]
Info	If Security 1 [MSFT] total weight <= Security 2 [AMAT] total weight, then take no action	Security[2]
Info	If Security 1 [AMAT] total weight <= Security 2 [IBM] total weight, then take no action	Security[4]
Info	If Security 1 [INTC] total weight <= Security 2 [IBM] total weight, then take no action	Security[3]
Info	If Security 1 [MSFT] total weight <= Security 2 [IBM] total weight, then take no action	Security[2]
Info	If Security 1 [MSFT] total weight <= Security 2 [INTC] total weight, then take no action	Security[2]

equal to 1, so that the lowest ranked security willIn this figure, our Ruletest results are as expected. The security with the highest relative `totalWeight` value ends the Ruletest with the highest `rank` value after all rule evaluation is complete. The other securities are also assigned `rank` values based on the relative ranking of their `totalWeight` values. The individual rule firings that resulted in these outcomes are highlighted in the message section at the bottom of the results sheet.

It is interesting to note that nowhere in the rules is it stated how many security entities will be evaluated. This is another example of the ability of the declarative approach to produce the intended outcome without requiring explicit, procedural instructions.

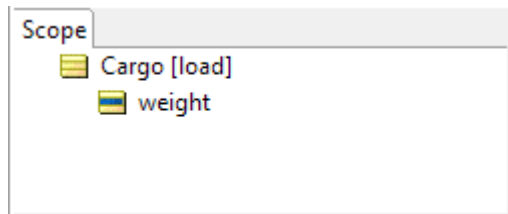
Figure 100: Ruleflow to test two Rulesheets in succession



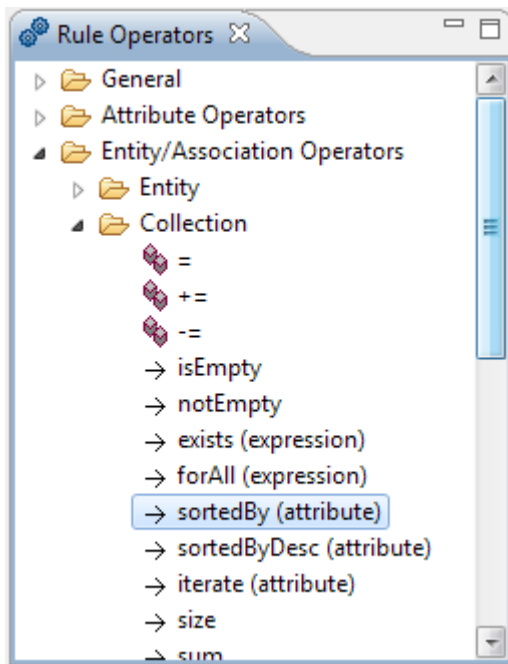
Sorted aliases

You can create a special kind of alias in the Scope section of a Rulesheet. The technique uses the specialized Sequence operator `->next` against a Sorted Alias (a special cached Sequence) inside a filter expression. The Rulesheet is set into a Ruleflow that iterates to bind the alias in each successive invocation to the next element in the sequence.

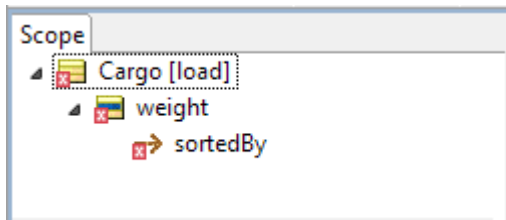
The following example shows a Rulesheet based on the `Cargo` Vocabulary. We brought the `Cargo` entity and its `weight` attribute into the scope:



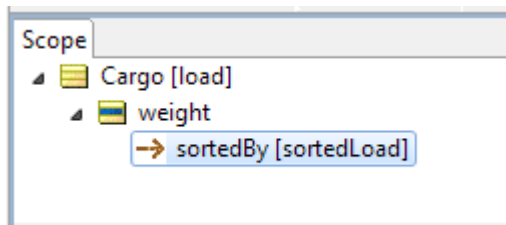
The operators `sortedBy` and `sortedByDesc` enable sorting ascending or descending order of the numeric or alphabetic values of the attribute in the set of data. Note that an attribute with a Boolean data type is not valid for this operation.



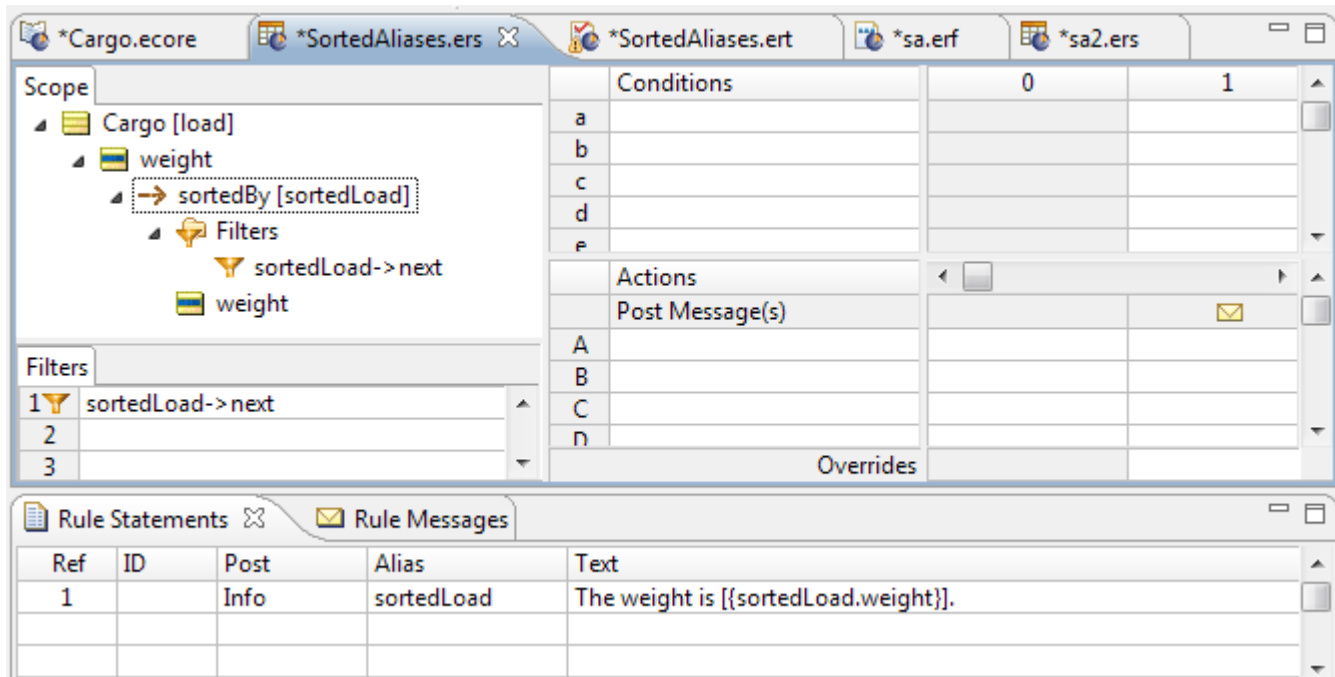
Dragging the `sortedBy` operator and dropping it (you cannot type it in) on the attribute `weight` places it in the scope yet shows an error:



The error message notes that a sorted alias node requires an alias name. When we enter an alias name, the scope is complete.



We add a filter expression to establish that, when we iterate through the list, each pass will present the next sequential item in the sorted set. We defined this by dragged `sortedBy` from the scope to filter line 1, and then appended the `->next` operator. We added a rule statement based on sorted load that echoes the weight so we can see the results in our tests.



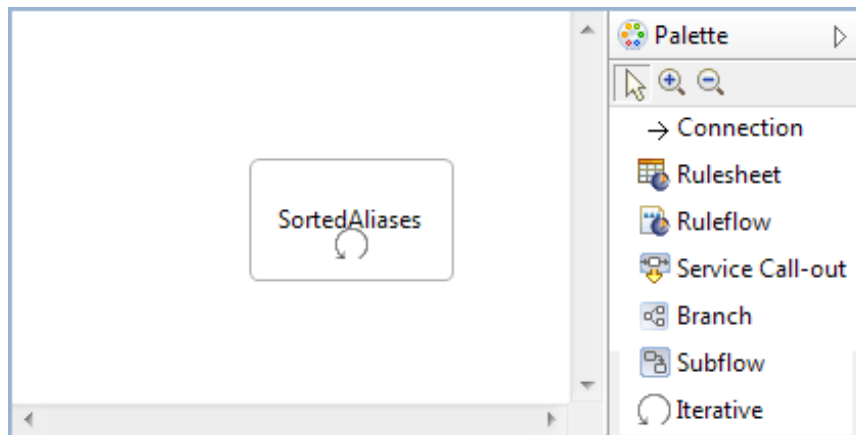
Conditions	0	1
a		
b		
c		
d		
e		

Actions	
Post Message(s)	✉
A	
B	
C	
D	

Filters
1 ✉ sortedLoad->next
2
3

Ref	ID	Post	Alias	Text
1		Info	sortedLoad	The weight is [{sortedLoad.weight}].

We saved the Rulesheet and created a Ruleflow, adding in our Rulesheet. Then we dragged an **Iterative** operation to the Rulesheet in the Ruleflow and saved it.



We created a Ruletest with a few Cargo items, each with a weight that we expect to sequence numerically when we run the test. Each iteration posts a message, and that message (the corresponding Rule Statement) contains the embedded attribute load weight. Since each member of the load collection will “trigger” the nonconditional rule, and even though the elements will be processed in no particular order, we expect to see a set of resulting messages with load weight in order. Running the tests repeatedly outputs the weights in ascending order every time.

Severity	Message
Info	The weight is [2].
Info	The weight is [333].
Info	The weight is [1111].

If we change the operator to `sortByDesc`, the results are shown in *descending* order by weight, as expected.

Advanced collection sorting syntax

Collection syntax contains some subtleties worth learning. It is helpful when writing collection expressions to step through them, left to right, as though you were reading a sentence. This helps you better understand how the pieces combine to create the full expression. It also helps you to know what else you can safely add to the expression to increase its utility. Let's try this approach in order to dissect the following expression:

```
Collection1 -> sortBy(attribute1) -> last.attribute2
```

1. `Collection1`

This expression returns the collection $\{e_1, e_2, e_3, e_4, e_5, \dots, e_n\}$ where e_x is an element (an entity) in `Collection1`. We already know that alias `Collection1` represents the entire collection.

2. `Collection1 -> sortBy(attribute1)`

This expression returns the collection $\{e_1, e_2, e_3, e_4, e_5, \dots, e_n\}$ arranged in ascending order based on the values of `attribute1` (which we call the "index").

3. `Collection1 -> sortBy(attribute1) -> last`

returns $\{e_n\}$ where e_n is the last element in `Collection1` when sorted by `attribute1`

This expression returns a **specific entity** (element) from `Collection1`. It does not return a specific value, but once we have identified a specific entity, we can easily reference the value of any attribute it contains, as in the following:

```
4. Collection1 -> sortBy(attribute1) -> last.attribute2
```

which returns `{en.attribute2}`

Entity Context

The complete expression not only returns a specific value, but just as importantly, it also returns the entity to which the value belongs. This “entity context” is important because it allows us to do things to the entity itself, like assign a value to one of its attributes. For example:

```
Collection1 -> sortBy(attribute1) -> last.attribute2='xyz'
```

The above expression will assign the value of `xyz` to `attribute2` of the entity whose `attribute1` is highest in `Collection1`. Contrast this with the following:

```
Collection1.attribute1 -> sortBy(attribute1) -> last
```

which returns a single integer value, like 14.

Notice that all we have now is a number, a *value*. We have lost the entity context, so we can't do anything to the entity that owns the attribute with value of 14. In many cases, this is just fine. Take for example:

```
Collection1.attribute1 -> sortBy(attribute1) -> last > 10
```

In this expression, it is not important that we know which element has the highest value of `attribute1`, all we want to know is if the highest value (whomever it “belongs” to) is greater than 10.

Understanding the subtleties of collection syntax and the concept of entity context is important because it helps us to use the returned entities or values correctly. For example:

Return the lower of the following two values:

- 12
- The age of the oldest child in the family

What is really being compared here? Do we care *which* child is oldest? Do we need to know his or her name? No. We simply need to compare the age of that child (whichever one is oldest) with the value of 12. So this is the expression that models this logic:

```
family.age -> sortByDesc(age) -> first.min(12)
```

The `.min` operator is an operator that *acts upon* numeric data types (Integer or Decimal). And since we are aware that `family.age -> sortByDesc(age) -> first` returns a number, then it is legal and valid to use `.min` at the end of this expression.

What about this scenario: Name the youngest child Junior.

```
family -> sortByDesc(age) -> last.name='Junior'
```

Now we want to return a *specific entity* – that of the youngest child – and assign to its name a value of `Junior`. We need to keep the entity context in order to make this assignment, and the expression above accomplishes this.

Statement blocks

Sequence operators can easily extract an attribute value from the first, last or other specific element in a sorted collection (see `->first`, `->last`, or `->at(n)` for examples). This is especially useful when the attribute's value is involved in a comparison in a Conditional or Preconditional rule. Sometimes, however, you want to identify a particular element in a sequence and flag or tag it for use in subsequent rules. This can be accomplished using special syntax called Statement Blocks.

Statement Blocks, permitted only in the Action rows of the Rulesheet, use special variables, prefixed by a `?` character, to "hold" or "pin" an element so that further action may be taken on it, including tagging it by assigning a value to one of its attributes. These special holder variables may be declared on the fly, meaning they do not need to be defined anywhere prior to use.

Here's an example. In a sales management system, the performance of sales reps is analyzed every quarter, and the highest grossing sales rep is awarded *Salesperson of the Quarter*. This special status is then used to automatically increase the rep's commission percentage on sales made in the following quarter. We will use the same generic Vocabulary as in all previous examples, but make these assumptions:

Vocabulary Term	Meaning
Entity2	a salesperson
Entity1.entity2	collection of salespeople
Entity2.string1	a salesperson's name
Entity2.decimal1	a salesperson's quarterly sales
Entity2.string2	a salesperson's award
Entity2.decimal2	a salesperson's commission percentage

Using this Vocabulary, we construct the Rulesheet shown in

Figure 101: Rulesheet using Statement Block to Identify and Reward Winner

The screenshot shows the Corticon Rulesheet editor for a rule named 'StatementBlocks.ers'. The interface includes a Scope tree on the left, a Conditions table, an Actions table, and a Rule Statements table at the bottom.

Conditions		0	1
a	Entity2.string2 = 'Salesperson of the Quarter'		T
b			

Actions		0	1
Post Message(s)			
A	?tag = e2 -> sortBy(decimal1) -> last; ?tag.string2 = 'Salesperson of the Quarter'	<input checked="" type="checkbox"/>	<input type="checkbox"/>
B	Entity2.decimal2 += 0.05	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Overrides			

Ref	ID	Post	Alias	Text
A0				The highest grossing salesperson for the quarter is awarded 'Salesperson of the Quarter'
1				The 'Salesperson of the Quarter' receives an additional 5% commission on sales

Important Notes about Statement Blocks

As expressed in Action row A in the figure above, a statement block consists of two separate expressions:

1. The first part assigns an element of a sequence to a special holder variable, prefixed by the ? character. This variable is unusual because it represents an *element*, not a *value*. Here, the highest grossing salesperson is expressed as the last element of the collection of salespeople (`e2`), sorted in ascending order according to quarterly sales (`decimal1`). Once identified by the sequencing operator `->last`, this salesperson is momentarily “held” by the `?tag` variable, which we declared “on-the-fly”.
2. The second part of the statement – the part following the semicolon – assigns a value to an attribute of the element held by the `?tag`. In our example, we are assigning a value of 'Salesperson of the Quarter' to the `string2` attribute of the salesperson held by `?tag`. In effect, we have “tagged” the highest grossing salesperson with this award.

These two parts must be included on the same Action Row, separated by a semicolon. If the two parts are separated in different sections or in different Rows of the same section, the element represented by the ? variable is “lost”, in other words, `?tag` loses its “grip” on the element identified by the sequencing operator.

Note: Using semicolons - The semicolon is an action statement end character that creates a compound action statement -- each action statement is executed sequentially. Its use, however, can make it harder to read action statements in Rulesheets and reports. It is recommended that you use semicolons only when there is no alternative, as in this example.

Now that we have tagged our winner, we can use the tagged element (*awardee*) to take additional actions. In the Conditional rule, we increase the commission percentage of the winner by 5% using the `increment` operator.

The next figure shows a Ruletest Input and Output pane. As expected, our highest grossing salesperson has been awarded “Salesperson of the Year” honors, and has had her commission raised by an additional 5%.

Figure 102: Output Panel with Winner and Adjusted Commission in Bold Black Text

Input	Output
<ul style="list-style-type: none"> Entity1 [1] <ul style="list-style-type: none"> entity2 (Entity2) [1] <ul style="list-style-type: none"> decimal1 [100000.000000] decimal2 [0.100000] string1 [Joe Smith] entity2 (Entity2) [2] <ul style="list-style-type: none"> decimal1 [120000.000000] decimal2 [0.100000] string1 [Sanjana Patel] entity2 (Entity2) [3] <ul style="list-style-type: none"> decimal1 [85000.000000] decimal2 [0.100000] string1 [Park Tae-min] entity2 (Entity2) [4] <ul style="list-style-type: none"> decimal1 [115000.000000] decimal2 [0.100000] string1 [Janet Jones] entity2 (Entity2) [5] <ul style="list-style-type: none"> decimal1 [9800.000000] decimal2 [0.100000] string1 [Jean-Marc Dubois] 	<ul style="list-style-type: none"> Entity1 [1] <ul style="list-style-type: none"> entity2 (Entity2) [1] <ul style="list-style-type: none"> decimal1 [100000.000000] decimal2 [0.100000] string1 [Joe Smith] entity2 (Entity2) [2] <ul style="list-style-type: none"> decimal1 [120000.000000] decimal2 [0.150000] string1 [Sanjana Patel] string2 [Salesperson of the Quarter] entity2 (Entity2) [3] <ul style="list-style-type: none"> decimal1 [85000.000000] decimal2 [0.100000] string1 [Park Tae-min] entity2 (Entity2) [4] <ul style="list-style-type: none"> decimal1 [115000.000000] decimal2 [0.100000] string1 [Janet Jones] entity2 (Entity2) [5] <ul style="list-style-type: none"> decimal1 [9800.000000] decimal2 [0.100000] string1 [Jean-Marc Dubois]

Using sorts to find the first or last in grandchild collections

The `SortedBy->first` and `SortedBy->last` constructs work as expected for any first-level collection regardless of datatype, determining the value of the first or last element in a sequence that was derived from a collection.

When associations are involved, you have to take care that the collection operator is not working at a grandchild level. You could construct a single collection of multiple children (rather than multiple collections of a single child) by “bubbling up” the relevant value into the child level, and then sort at that level. Another technique is to change the scope to treat the root level entity as the collection, and then apply filters so that only the ones matching the common attribute values across the associations are considered, and when you apply `SortedBy->first` or `SortedBy->last`, the intended value is the result.

Singletons

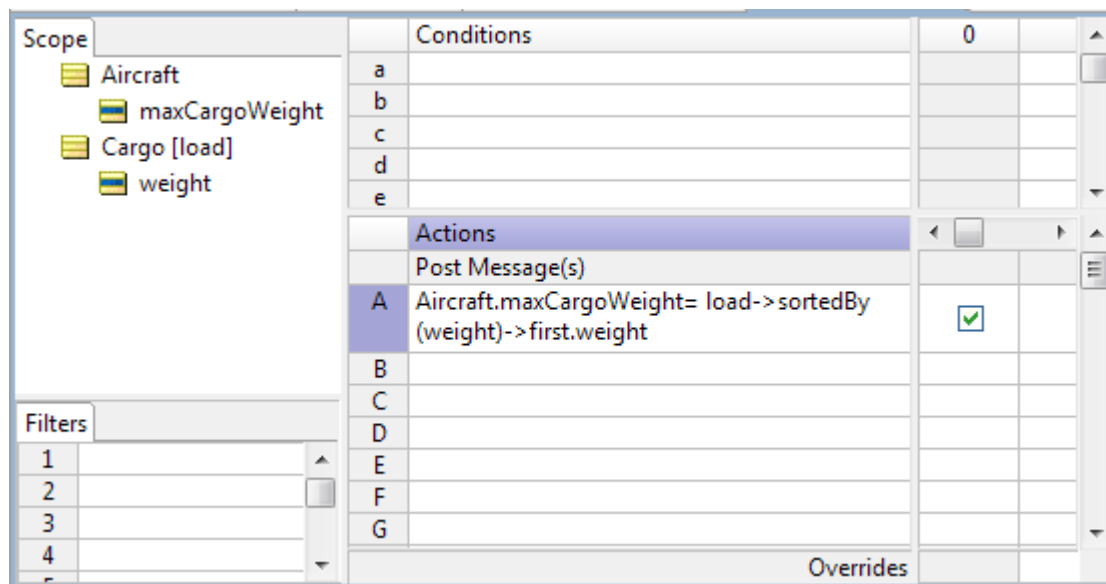
Singletons are collection operations that iterate over a set to extract one arithmetic value - the first, the last, the trend, the average, or the element at a specified position. We saw this behavior when the `sortedAlias` found the first and last element in an iterative list (as well as the elements in between) in the given order.

To examine this feature, we bring the `Aircraft` entity and its `maxCargoWeight` into the scope as well as `Cargo` (with the alias `load`) and its attribute `weight`. The unconditional action we enter is, literally:

"Show me the maximum cargo weight by examining all the cargo in the load, sorting them by weight from small to large, and returning the smallest one first."

That is entered as:

```
Aircraft.maxCargoWeight=load->sortedBy(weight)->first.weight
```



When we extend the test we used for sorted aliases, we need to add an `Aircraft` with `maxCargoWeight` to show the result of the test. The result is as expected - the lightest item passed the test.

Figure 103:

Input	Output
<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> weight [1111] Cargo [2] <ul style="list-style-type: none"> weight [2] Cargo [3] <ul style="list-style-type: none"> weight [333] Aircraft [1] <ul style="list-style-type: none"> aircraftType maxCargoVolume maxCargoWeight tailNumber 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> weight [1111] Cargo [2] <ul style="list-style-type: none"> weight [2] Cargo [3] <ul style="list-style-type: none"> weight [333] Aircraft [1] <ul style="list-style-type: none"> aircraftType maxCargoVolume maxCargoWeight [2.000000] tailNumber

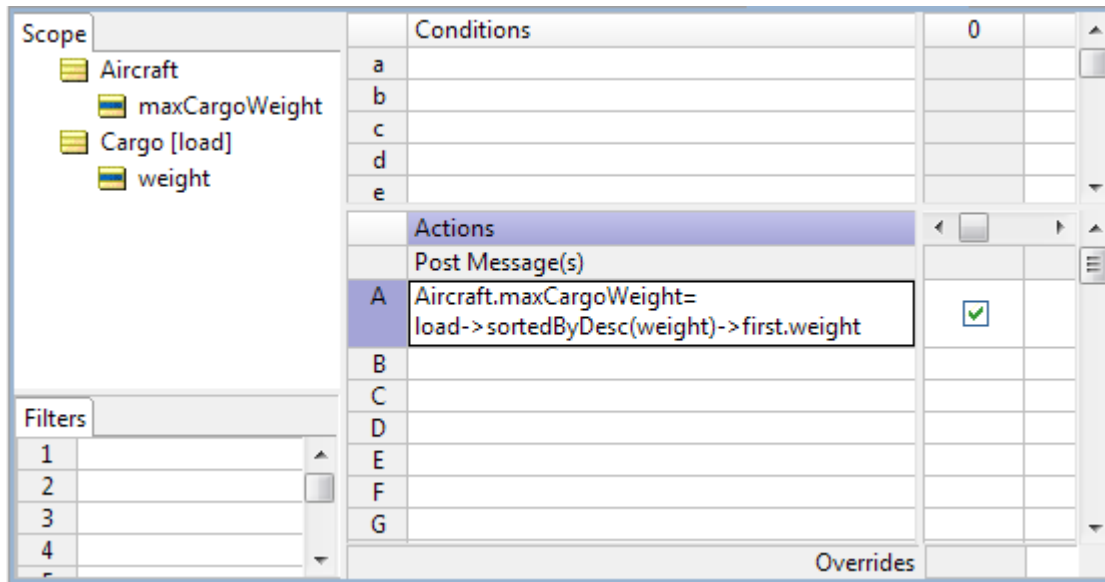
The same result is output when we modify the rule to select last item when we sort the items by descending weight.

Figure 104:

Scope	Conditions	0
<ul style="list-style-type: none"> Aircraft <ul style="list-style-type: none"> maxCargoWeight Cargo [load] <ul style="list-style-type: none"> weight 	a b c	
Filters 1 2 3	Actions Post Message(s) A Aircraft.maxCargoWeight = load -> sortedByDesc(weight) -> last.weight B C D	<input checked="" type="checkbox"/>
	Overrides	

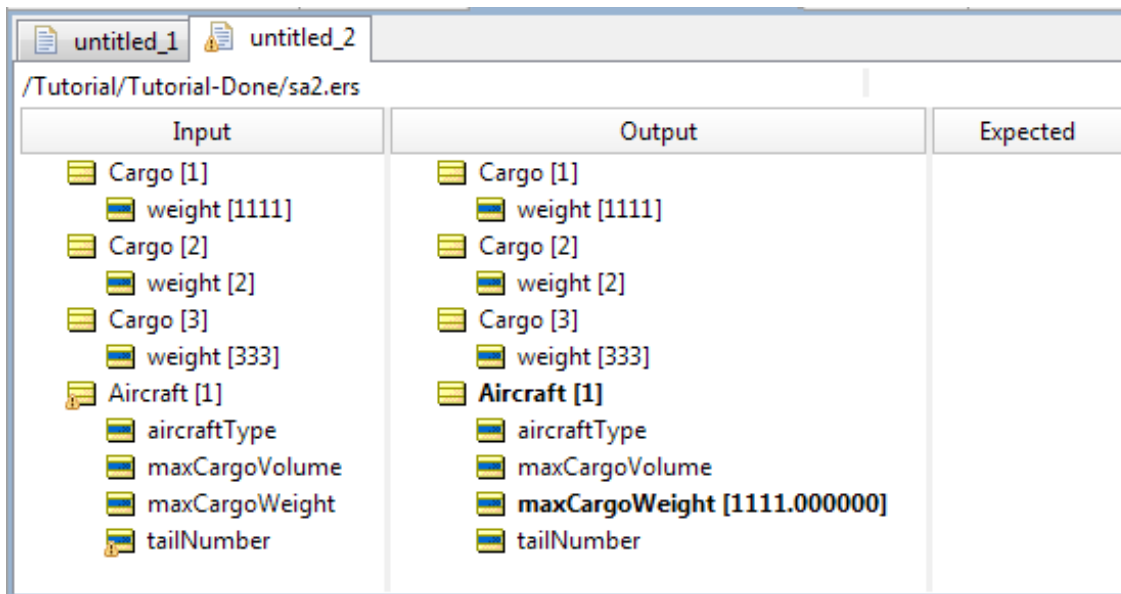
Now we reverse the test to select the first item when we sort the items by descending weight...

Figure 105:



...and the heaviest item is output.

Figure 106:



Note: Singletons do not operate against an iterative Ruleflow as was required by Sorted Aliases. The tests apply directly to the Rulesheet.

Special collection operators

There are two special collection operators available in Corticon Studio's Operator Vocabulary that allow us to evaluate collections for specific Conditions. These operators are based on two concepts from the predicate calculus: the *universal quantifier* and the *existential quantifier*. These operators return a result about the collection, rather than about any particular element within it. Although this is a simple idea, it is actually a very powerful capability – some decision logic cannot be expressed without these operators.

Universal quantifier

The meaning of the universal quantifier is that a condition enclosed by parentheses is evaluated (i.e., its “truth value” is determined) *for all* instances of an entity or collection. This is implemented as the `->forAll` operator in the Operator Vocabulary. We will demonstrate this operator with an example created using the Vocabulary from our security ranking model. Note that these operators act on collections, so all the examples shown will declare aliases in the **Scope** section.

Figure 107: Rulesheet with Universal Quantifier (“for all”) Condition

The screenshot shows the Corticon Studio Rulesheet interface. On the left is a tree view of the Operator Vocabulary, with 'Collection' > 'forAll (expression)' selected. The main area is titled 'UniversalQuantifier.ers' and contains a configuration table for a rule.

Scope	Conditions	0	1	2
Security [secty]	a secinfo -> forAll(secinfo.rank >=3)	-	T	F
rating	b			
secInfo (SecInfo) [secinfo]	c			
	d			
	e			

Filters	Actions		
1	Post Message(s)		
2	A secty.rating	High	Low
3	B		
4	C		
5			

Ref	ID	Post	Alias	Text	Rule Name
1		Info	secty	A security for which all rank values are greater than or equal to 3 should be assigned a rating of high	
2		Info	secty	A security for which not all rank values are greater than or equal to 3 should be assigned a rating of low	

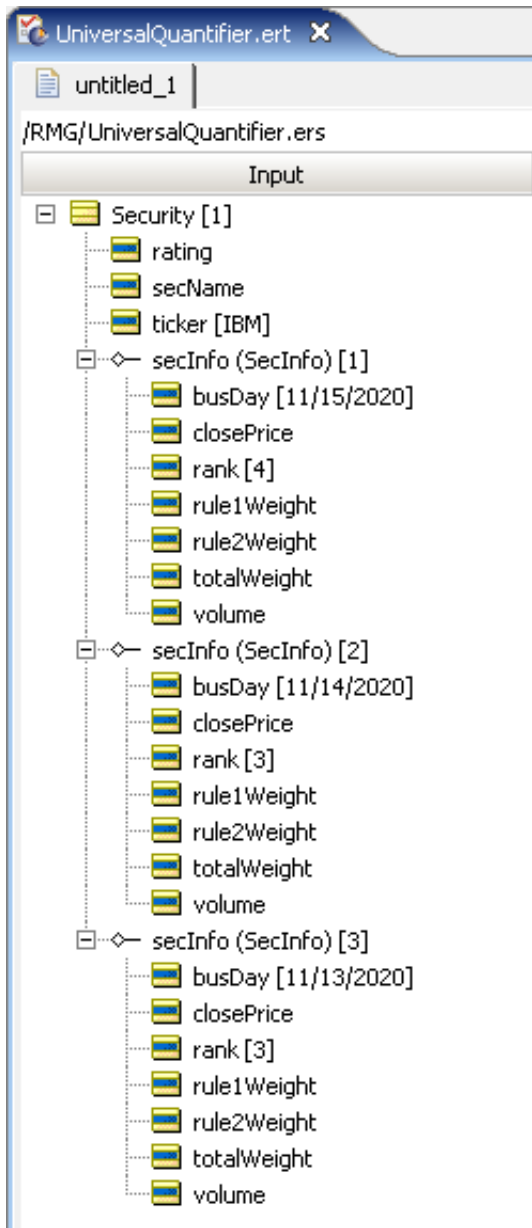
In this figure, we see the Condition

```
secinfo ->forAll(secinfo.rank >= 3)
```

The exact meaning of this Condition is that for the collection of `SecInfo` elements associated with a `Security` (represented and abbreviated by the alias `secInfo`), evaluate if the expression in parentheses (`secinfo.rank >= 3`) is true **for all** elements. The result of this Condition is Boolean because it can only return a value of true or false. Depending on the outcome of the evaluation, a value of either `High` or `Low` will be assigned to the `rating` attribute of our `Security` entity and the corresponding Rule Statement will be posted as a message to the user.

The following figure shows a Ruletest constructed to test our “for all” Condition rules.

Figure 108: Ruletest for Testing “for all” Condition Rules



In this Ruletest, we are evaluating a collection of three `SecInfo` elements associated with a `Security` entity. Since the `rank` value assigned in each `SecInfo` object is at least 3, we should expect that our “for all” Condition will evaluate to `true` and a rating value of `High` will be assigned to our `Security` object when the Ruletest is run through Corticon Server. This outcome is confirmed in the Ruletest results, as shown:

Figure 109: Ruletest for “for all” Condition Rules

The screenshot displays the UniversalQuantifier.ert application interface. The main window is titled 'untitled_1' and shows a ruletest execution. The left pane, labeled 'Input', shows a tree structure for a `Security` entity with three `SecInfo` elements. The first `SecInfo` has a `rank` of 4, the second has a `rank` of 3, and the third has a `rank` of 3. The right pane shows the output tree where the `Security` entity's `rating` is `High`. At the bottom, a message pane shows a message with severity 'Info' and the text: 'A security for which all rank values are greater than or equal to 3 should be assigned a rating of high'. The message is associated with the `Security[1]` entity.

Severity	Message	Entity
Info	A security for which all rank values are greater than or equal to 3 should be assigned a rating of high	Security[1]

Existential quantifier

The other special operator available is the existential quantifier. The meaning of the existential quantifier is that *there exists at least one* element of a collection for which a given condition evaluates to true. This logic is implemented in the Rulesheet > using the `->exists` operator from our Operator Vocabulary.

As in our last example, we can construct a Rulesheet to determine the `rating` value for a `Security` entity by evaluating a collection of associated `SecInfo` elements with the existential quantifier. In this new example, we will use `volume` rather than `rank` to determine the `rating` value for the security. The Rulesheet for this example is shown in the following figure:

Figure 110: Rulesheet with Existential Quantifier (“exists”) Condition

The screenshot shows the Corticon Rulesheet Editor interface. On the left is a tree view of operators, including 'exists (expression)'. The main workspace shows a tree view of the rule structure: 'Security [secty]' with a 'rating' attribute and a 'secInfo (SecInfo) [secinfo]' collection. The 'Conditions' table is as follows:

Scope	Conditions	0	1	2
a	secinfo ->exists(volume > 1000)	-	T	F
b				
c				
d				
e				

The 'Actions' table is as follows:

Filters	Actions	0	1	2
1	Post Message(s)		✉	✉
2	A secy.rating		'High Volume'	'Normal Volume'
3	B			
4	C			
5	Overrides			

At the bottom, the 'Rule Statements' table is shown:

Ref	ID	Post	Alias	Text
1		Info	secty	A security for which there exists a volume greater than 1000 must be classified 'High Volume'
2		Info	secty	A security for which there does not exist a volume greater than 1000 must be classified 'Normal Volume'

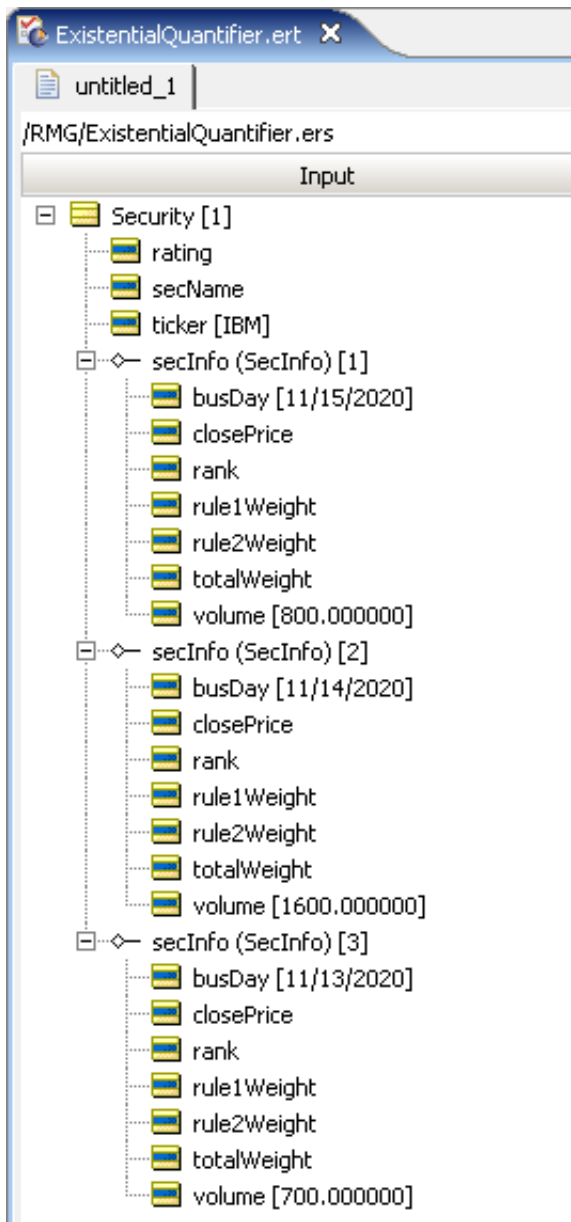
In this Rulesheet, we see the Condition

```
secinfo ->exists(secinfo.volume >1000)
```

Notice again the *required* use of an alias to represent the collection being examined. The exact meaning of the Condition in this example is that for the collection of `SecInfo` elements associated with a `Security` (again represented by the `secinfo` alias), determine if the expression in parentheses (`secinfo.volume > 1000`) holds **true** for *at least one* `Secinfo` element. Depending on the outcome of the `exists` evaluation, a value of either `High Volume` or `Normal Volume` will be assigned to the `rating` attribute of our `Security` object and the corresponding Rule Statement will be posted as a message to the user.

The following figure shows a Ruletest constructed to test our `exists` Condition rules.

Figure 111: Ruletest for Testing `exists` Condition Rules



Once again, we evaluate a collection of 3 `SecInfo` elements associated with a single `Security` entity. Since the `volume` attribute value assigned in at least one of the `SecInfo` objects (`secInfo[2]`) is greater than 1000, we should expect that our `exists` Condition will evaluate to **true** and a `rating` value of `High Volume` will be assigned to our `Security` object when the Ruletest is run through Corticon Server. This outcome is confirmed in the Ruletest shown in the following figure:

Figure 112: Ruletest for `exists` Condition Rules

The screenshot displays the ExistentialQuantifier.ert ruletest interface. It is divided into two main panels: 'Input' and 'Output'. Both panels show a tree structure representing a `Security` entity with three associated `SecInfo` objects.

Input Panel:

- `Security [1]`
 - `rating`
 - `secName`
 - `ticker [IBM]`
 - `secInfo (SecInfo) [1]`
 - `busDay [11/15/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [800.000000]`
 - `secInfo (SecInfo) [2]`
 - `busDay [11/14/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [1600.000000]`
 - `secInfo (SecInfo) [3]`
 - `busDay [11/13/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [700.000000]`

Output Panel:

- `Security [1]`
 - `rating [High Volume]`
 - `secName`
 - `ticker [IBM]`
 - `secInfo (SecInfo) [1]`
 - `busDay [11/15/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [800.000000]`
 - `secInfo (SecInfo) [2]`
 - `busDay [11/14/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [1600.000000]`
 - `secInfo (SecInfo) [3]`
 - `busDay [11/13/2020]`
 - `closePrice`
 - `rank`
 - `rule1Weight`
 - `rule2Weight`
 - `totalWeight`
 - `volume [700.000000]`

At the bottom of the interface, there is a 'Rule Messages' tab. It contains a table with the following data:

Severity	Message	Entity
Info	A security for which there exists a volume greater than 1000 must be classified 'High Volume'	Security[1]

Another example using the existential quantifier

Collection operators are powerful parts of the Corticon Rule Language – in some cases they may be the only way to implement a particular business rule. For this reason, we provide another example.

Business problem: An auto insurance company has a business process for handling auto claims. Part of this process involves determining a claim's validity based on the information submitted on the claim form. For a claim to be classified as valid, both the driver and vehicle listed on the claim must be covered by the policy referenced by the claim. Claims that are classified as invalid will be rejected, and will not be processed for payment.

From this short description, we extract our primary business rule statement:

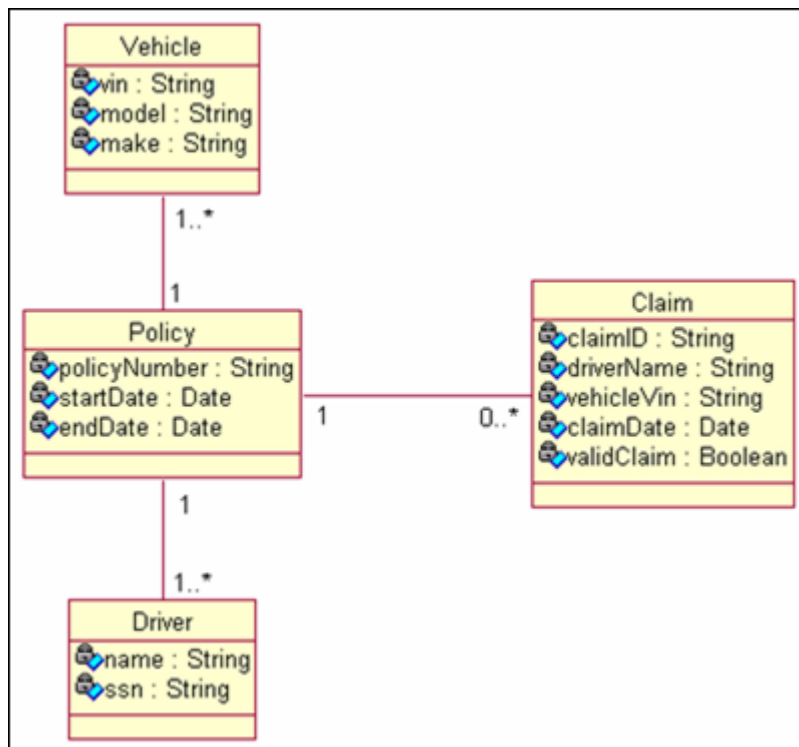
1. A claim is valid if the driver and vehicle involved in a claim are both listed on the policy against which the claim is submitted.

In order to implement our business rule, we propose the **UML Class Diagram** shown below. Note the following aspects of the diagram:

- A Policy may cover one or more Drivers
- A Policy may cover one or more Vehicles
- A Policy may have zero or more Claims submitted against it.
- The Claim entity has been denormalized to include `driverName` and `vehicleVin`.

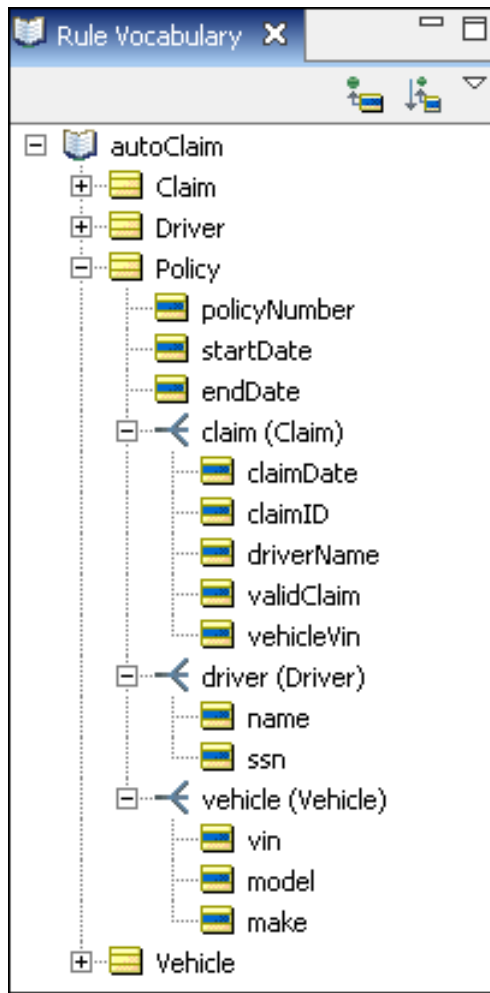
Note: Alternatively, the Claim entity could have referenced `Driver.name` and `Vehicle.vin` (by adding associations between Claim and both Driver and Vehicle), respectively, but the denormalized structure is probably more representative of a real-world scenario.

Figure 113: UML Class Diagram



This model is realized in Corticon Studio as:

Figure 114: Vocabulary



Model the following rules in Corticon Studio, as shown:

1. For a claim to be valid, the driver's name and vehicle ID listed on the claim must also be listed on the claim's policy.
2. If either the driver's name or vehicle ID on the claim is not listed on the policy, then the claim is not valid.

Figure 115: Rules Modeled in Corticon Studio

The screenshot shows the Corticon Studio interface for a rule named 'autoClaim.ers'. The interface is divided into several sections:

- Scope:** A tree view showing the rule's structure: Claim [aClaim] (containing driverName, validClaim, vehicleVin) and policy.
- Conditions:** A table defining the rule's conditions.

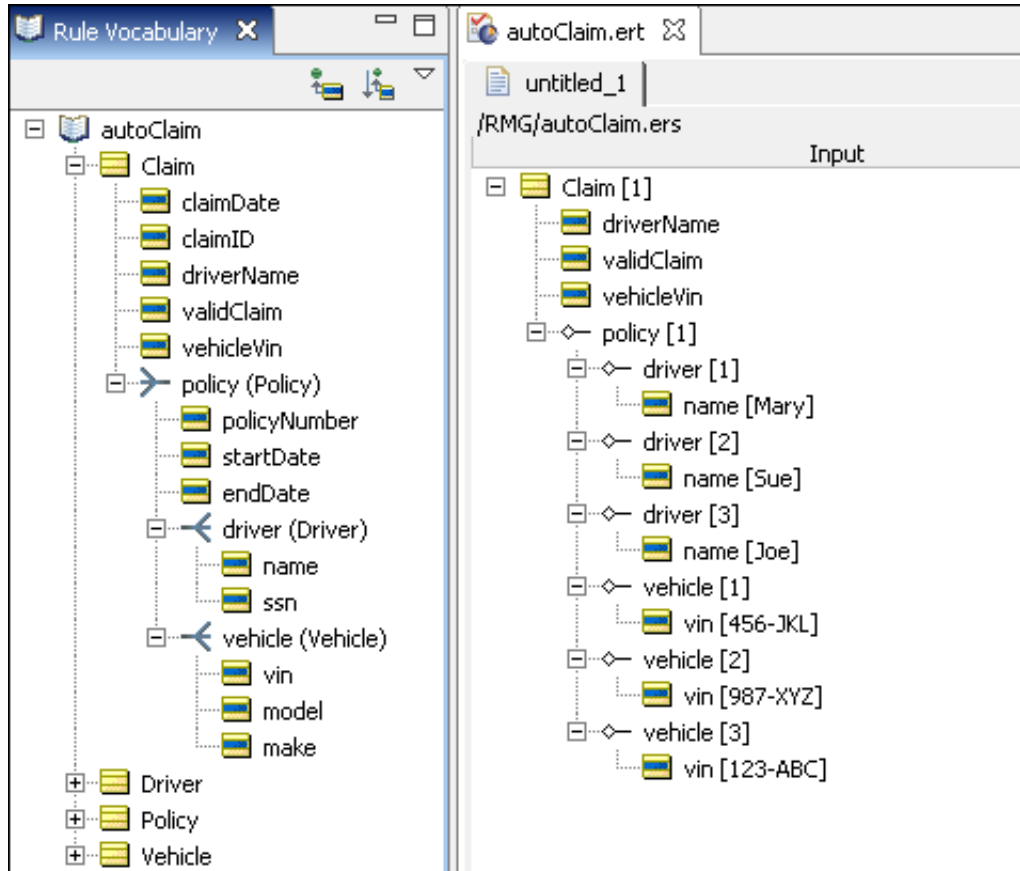
	0	1	2	3
a	-	T	F	-
b	-	T	-	F
c				
d				
- Actions:** A table defining the rule's actions.

	0	1	2	3
A		✉	✉	✉
B		T	F	F
- Rule Statements:** A table showing the generated rule statements.

Ref	ID	Post	Alias	Text
1		Info	aClaim	A claim is valid if its driver [{aClaim.driverName}] AND Vehicle match the policy against it was submitted [{aClaim.policy.driver.name}] and [{aClaim.policy.vehicle.vin}]
2		Warning	aClaim	A claim is not valid if its driver [{aClaim.driverName}] is not on the policy against which it was submitted [{aClaim.policy.driver.name}]
3		Warning	aClaim	A claim is not valid if its vehicle [{aClaim.vehicleVin}] is not on the policy against which it was submitted [{aClaim.policy.vehicle.vin}]

This appears very straightforward. But a problem arises when there are multiple drivers and/or vehicles listed on the policy—in other words, when the policy contains a collection of drivers and/or vehicles. Our Vocabulary permits this scenario because of the cardinalities we assigned to the various associations. We demonstrate this problem with the Ruletest in the following Ruletest:

Figure 116: Ruletest



Notice in the Rulestest that there are three drivers and three vehicles listed on (associated with) a single policy. When we run this Rulestest, we see the results:

Figure 117: Rulestest

Severity	Message	Entity
Info	A claim is valid if its driver [Joe] AND Vehicle match the policy against it was submitted [Joe] and [123-ABC]	Claim[1]
Warning	A claim is not valid if its driver [Joe] is not on the policy against which it was submitted [Sue]	Claim[1]
Warning	A claim is not valid if its driver [Joe] is not on the policy against which it was submitted [Mary]	Claim[1]
Warning	A claim is not valid if its vehicle [123-ABC] is not on the policy against which it was submitted [987-XYZ]	Claim[1]
Warning	A claim is not valid if its vehicle [123-ABC] is not on the policy against which it was submitted [456-JKL]	Claim[1]

As we see from the Rulestest results, the way Corticon Studio evaluates rules involving comparisons of multiple collections means that the `validClaim` attribute may have inconsistent assignments – sometimes `true`, sometimes `false` (as in this Rulestest). It can be seen from the table below that, given the Rulestest data, 4 of 5 possible combinations evaluate to `false`, while only one evaluates to `true`. This conflict arises because of the nature of the data evaluated, not the rule logic, so Studio's Conflict Check feature does not detect it.

Claim.driverName	Claim.policy.driver.name	Claim.vehicleVin	Claim.policy.vehicle.vin	Rule 1 fires	Rule 2 fires	Rule 3 fires	validClaim
Joe	Joe	123-ABC	123-ABC	X			True
Joe	Sue				X		False
Joe	Mary				X		False

		123-ABC	987-XYZ			X	False
		123-ABC	456-JKL			X	False

Let's use the existential quantifier to rewrite these rules:

Figure 118: Rules Rewritten Using Existential Quantifier.

ExistentialAutoClaim.ers

Scope

- Claim [c]
 - driverName
 - validClaim
 - vehicleVin
- policy
 - driver [cpd]
 - vehicle [cpv]

Filters

1	
2	
3	
4	
5	
6	
7	
8	

Conditions

a	cpd -> exists(name = c.driverName)	0	1	2
b	cpv -> exists(vin = c.vehicleVin)		F	-
c			-	F
d				
e				
f				
g				
h				

Actions

A	c.validClaim		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
B				
C				
D				
E				
F				

Overrides

Rule Statements

Ref	ID	Post	Alias	Text
A1		Warning	c	A claim is not valid if its driver [{c.driverName}] is not on the policy against which it is submitted
A2		Warning	c	A claim is not valid if its vehicle [{c.vehicleVin}] is not on the policy against which it is submitted
A3		Info	c	A claim is valid if its driver [{c.driverName}] AND vehicle [{c.vehicleVin}] match those on the policy

This logic tests for the existence of matching drivers and vehicles within the two collections. If matches exist within both, then the `validClaim` attribute evaluates to true, otherwise `validClaim` is false.

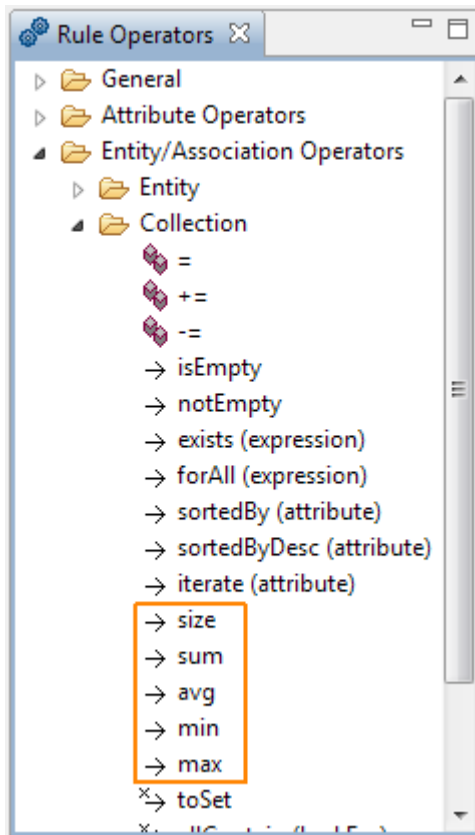
Let's use the same Ruletest data as before to test these new rules. The results are shown below:

Severity	Message	Entity
Info	A claim is valid if its driver [Joe] AND vehicle [123-ABC] match those on the policy against which it is submitted	Claim[1]

Notice that only one rule has fired, and that `validClaim` has been assigned the value of `true`. This implementation achieves the intended result.

Aggregations that optimize EDC database access

A subset of collection operators are known as *aggregation operators* because they evaluate a collection to compute one value. These aggregation operators are as highlighted:



When these aggregations are applied through the Enterprise Data Connector in a Rulesheet set to **Extend to Database**, the performance impact against large tables can be minimized by performing non-conditional actions that force the calculations onto the database. For an example of this, see [Optimize aggregations that extend to database](#) on page 239

TestYourself questions for Collections

Note: Try this test, and then go to [TestYourself answers for Collections](#) on page 338 to correct yourself.

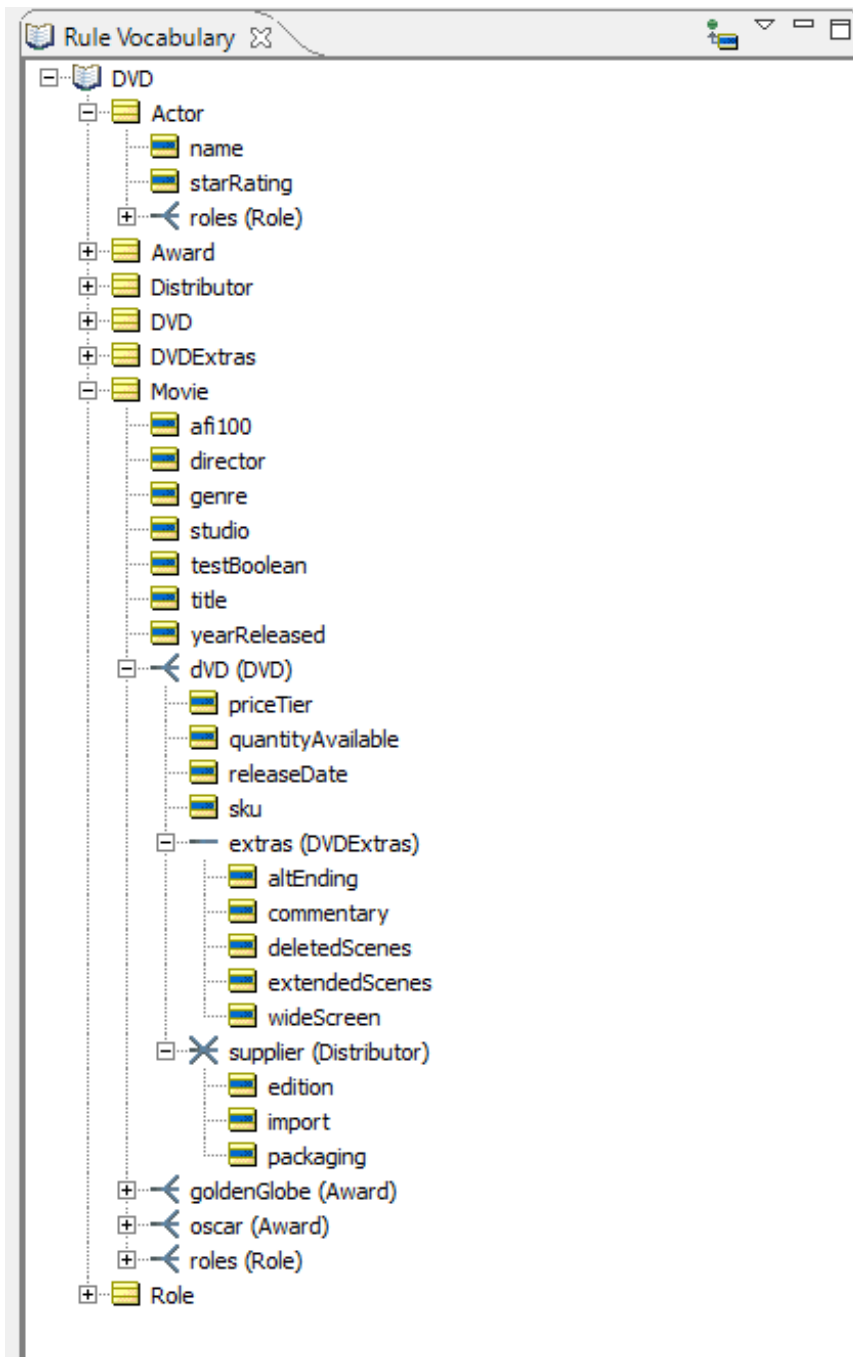
1. Children of a Parent entity are also known as _____ of a collection.
2. True or False. All collections must have a parent entity
3. True or False. Root-level entities may form a collection
4. True or False. A collection operator must operate on a collection alias.
5. List three Collection operators and describe what they do.
6. Which reference contains usage details and examples for every collection operator?
7. Write a Rule Statement that is equivalent to the syntax `Order.total = items.price->sum`
8. In the syntax in question 7, which term is the collection alias?
9. If `items` is an alias representing the `LineItem` entities associated with an `Order` entity, then what would you expect the cardinality of this association to be?

-
10. Is `Order.lineItem.price->sum` an acceptable replacement for the syntax in Question 7? Why or why not?
11. If you are a Vocabulary designer and want to prevent rule authors from building rules with `LineItem.order` terms, what can you do to prevent it?
12. When collection operators are NOT used in a Rulesheet, aliases are (circle all that apply)

Optional	Mandatory	Colorful	Convenient
----------	-----------	----------	------------

13. If a Nonconditional rule states `LineItem.price = 100`, and my Input Testsheet contains 7 `LineItem` entities, then a collection of data is processed by this rule. Is a collection alias required? Why or why not?
14. Which collection operator is known as the Universal Quantifier?
15. Which collection operator is known as the Existential Quantifier?

For questions 16-18, refer to the following Vocabulary



16. Write expressions for each of the following phrases:
- If an actor has had more than 3 roles...
 - If a movie has not been released on DVD...
 - If a movie has at least one DVD with deleted scenes...
 - If a movie won at least one Golden Globe
 - If the movie had more than 15 actors...
 - If there's at least 100 copies available of a movie...

- g.** If there's less than 2 copies available of a movie...
 - h.** If the DVD can be obtained from more than 1 supplier...
- 17.** Which entities could be grandchildren of Movie?
 - 18.** Which entites could be children of Role?
 - 19.** Describe the difference between `->forAll` and `->exists` operators.
 - 20.** Describe the difference between `->notEmpty` and `->isEmpty` operators.
 - 21.** Why are aliases required to represent collections?

6

Rules containing calculations and equations

Rules that contain equations and calculations are really no different than any other type of rule. Calculation-containing rules may be expressed in any of the sections of the Rulesheet.

For details, see the following topics:

- [Terminology](#)
- [Operator precedence and order of evaluation](#)
- [Datatype compatibility and casting](#)
- [Supported uses of calculation expressions](#)
- [Unsupported uses of calculation expressions](#)
- [TestYourself questions for Rules containing calculations and equations](#)

Terminology

First we will introduce some terminology that will be used throughout this section. In the simple expression $A = B$, we define A to be the *Left-hand Side* (LHS) of the expression, and B to be the *Right-hand Side* (RHS). The equals sign is an *Operator*, and is included in the Operator Vocabulary in Corticon Studio. But even such a simple expression has its complications. For example, does this expression compare the value of A to B in order to take some action, or does it instead assign the value of B to A ? In other words, is the equals operator performing a *comparison* or an *assignment*? This is a common problem in programming languages, where a common solution is to use two different operators to distinguish between the two meanings -- the symbol `==` might signify a comparison operation, whereas `:=` might signify an assignment.

In Corticon Studio, special syntax is unnecessary because the Rulesheet itself helps to clarify the logical intent of the rules. For example, typing $A=B$ into a Rulesheet's Condition row (and pressing **Enter**) automatically causes the Values set $\{T, F\}$ to appear in the rule column cell drop-down lists. This indicates that the rule modeler has written a comparison expression, and Studio expects a value of `true` or `false` to result from the comparison. $A=B$, in other words, is treated as a test – is A equal to B or isn't it?

On the other hand, when $A=B$ is entered into an Action or Nonconditional row (Actions rows in Column 0), it becomes an assignment. In an assignment, the RHS of the equation is evaluated and its value is assigned to the LHS of the equation. In this case, the value of B is simply assigned to A . As with other Actions, we have the ability to activate or deactivate this Action for any column in the decision table (numbered columns in the Rulesheet) simply by “checking the box” that automatically appears when the Action's cell is clicked.

In the *Rule Language Guide*, the equals operator ($=$) is described separately in both its assignment and comparison contexts.

Note: A Boolean attribute does not reset when non-boolean input is provided for a non-conditional rule

While this is the expected behavior in the Corticon language, it can cause unexpected results. On input of a Boolean attribute, if the value of the element is `true` or `1`, Corticon interprets that as a `true` Boolean value, otherwise it defaults to a `false` Boolean value. Attributes in the input document are not modified unless the value is actually changed in the rule; that is, setting a `true` Boolean attribute to the value of `true` does not modify the element.

You can have reliable behavior when you use following workaround. To guarantee a modification in the data, you need to guarantee that the rules actually change the value of the attribute. For example, instead of action...

```
Entity_1.booleanAttr1 = T
```

...first set the value of the attribute to null, and then set it to true:

```
Entity_1.booleanAttr1 = null
Entity_1.booleanAttr1 = T
```

Operator precedence and order of evaluation

Operator precedence -- the order in which Corticon Studio evaluates multiple operators in an equation -- is described in the following table (also in the *Rule Language Guide*. This table specifies for example, that $2 * 3 + 4$ evaluates to 10 and not 14 because the multiplication operator $*$ has a higher precedence than the addition operator $+$. It is a good practice, however, to include clarifying parentheses even when Corticon Studio does not require it. This equation would be better expressed as $(2 * 3) + 4$. Note the addition of parentheses here does not change the result. When expressed as $2 * (3 + 4)$, however, the result becomes 14.

The precedence of operators affects the grouping and evaluation of expressions. Expressions with higher-precedence operators are evaluated first. Where several operators have equal precedence, they are evaluated from left to right. The following table summarizes Corticon's Rule Operator precedence and their order of evaluation .

Operator precedence	Operator	Operator Name	Example
1	()	Parenthetic expression	(5.5 / 10)
2	-	Unary negative	-10
	not	Boolean test	not 10
3	*	Arithmetic: Multiplication	5.5 * 10
	/	Arithmetic: Division	5.5 / 10
	**	Arithmetic: Exponentiation (Powers and Roots)	5 ** 2 25 ** 0.5 125 ** (1.0/3.0)
4	+	Arithmetic: Addition	5.5 + 10
	-	Arithmetic: Subtraction	10.0 – 5.5
5	<	Relational: Less Than	5.5 < 10
	<=	Relational: Less Than Or Equal To	5.5 <= 5.5
	>	Relational: Greater Than	10 > 5.5
	>=	Relational: Greater Than Or Equal To	10 >= 10
	=	Relational: Equal	5.5=5.5
	<>	Relational: Not Equal	5.5 <> 10
6	(<i>expression</i> , <i>expression</i>)	Logical: AND	(>5.5,<10)
	(<i>expression</i> or <i>expression</i>)	Logical: OR	(<5.5 or >10)

Note: While expressions within parentheses that are separated by logical AND / OR operators are valid, the component expressions are not evaluated individually when testing for completeness, and might cause unintended side effects during rule execution. Best practice within a Corticon Rulesheet is to represent AND conditions as separate condition rows and OR conditions as separate rules -- doing so allows you to get the full benefit of Corticon's logical analysis.

Note: It is recommended that you place arithmetic exponentiation expressions in parentheses.

Datatype compatibility and casting

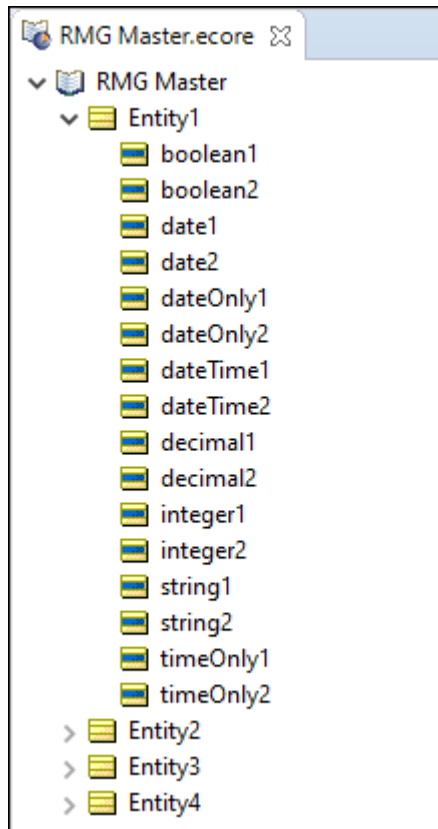
An important prerequisite of any comparison or assignment operation is data type compatibility. In other words, the data type of the equation's LHS (the data type of A) must be compatible with whatever data type results from the evaluation of the equation's RHS (the data type of B). For example, if both attributes A and B are Decimal types, then there will be no problem assigning the Decimal value of attribute B to attribute A .

Similarly, a comparison between the LHS and RHS makes no real sense unless both refer to the same kinds of data. How does one compare `orange` (a String) to `July 4, 2014 12:00:00` (a DateTime)? Or `false` (a Boolean) to `247.82` (a Decimal)?

In general, the data type of the LHS must match the data type of the RHS before a comparison or assignment can be made. (The exception to this rule is the comparison or assignment of an Integer to a Decimal. A Decimal can safely contain the value of an Integer without using any special casting operations.) Expressions that result in inappropriate data type comparison or assignment should turn red in Studio.

In the examples that follow, we will use the generic Vocabulary from the *Rule Language Guide*, since the generic attribute names indicate their data types:

Figure 119: Generic Vocabulary used in the Rule Language Guide



The following figure shows a set of Action rows that illustrate the importance of data type compatibility in assignment expressions:

Figure 120: Datatype Mismatches in Assignment Expressions

Conditions		0	1
a			
b			
Actions		<	
Post Message(s)			
A	Entity1.boolean1 = Entity1.boolean2	<input type="checkbox"/>	
B	Entity1.dateTime1 = Entity1.string1		
C	Entity1.string1 = Entity1.dateTime1		
D	Entity1.decimal1 = Entity1.integer1	<input type="checkbox"/>	
E	Entity1.boolean1 = Entity1.decimal1		
Overrides			

Description	Resource
<ul style="list-style-type: none"> Errors (7 items) <ul style="list-style-type: none"> Data type mismatch: Expecting type [Boolean], Actual type [Decimal]. Data type mismatch: Expecting type [DateTime], Actual type [String]. Data type mismatch: Expecting type [String], Actual type [DateTime]. 	<ul style="list-style-type: none"> ActionsNotMatching.ers ActionsNotMatching.ers ActionsNotMatching.ers

Let's examine each of the Action rows to understand why each is valid or invalid.

A – this expression is valid because the data types of the LHS and RHS sides of the equation are compatible (they're both Boolean).

B – this expression is invalid and turns red because the data types of the LHS and RHS sides of the equation are incompatible (the LHS resolves to a DateTime and the RHS resolves to a String).

C – this expression is invalid and turns red because the data types of the LHS and RHS sides of the equation are incompatible (the LHS resolves to a String and the RHS resolves to a DateTime).

D – this expression is valid because the data types of the LHS and RHS sides of the equation are compatible *even though they are different!* This is an example of the one exception to our general rule regarding data type compatibility: Decimals can safely hold Integer values.

E – this expression is invalid and turns red because the data types of the LHS and RHS sides of the equation are incompatible (the LHS resolves to a Boolean and the RHS resolves to a Decimal). Here, the tool tip provides essentially the same information.

Note that the **Problems** window contains explanations for the red text shown in the Rulesheet.

The following figure shows a set of Conditional expressions that illustrate the importance of data type compatibility in comparisons:

Figure 121: Datatype Mismatches in Comparison Expressions

Conditions	0	1
b Entity1.string1 = Entity1.dateTime1		
c Entity1.boolean1 = Entity1.decimal1		
d Entity1.decimal1 = Entity1.integer1		
e Entity1.integer2 <= Entity1.decimal1		

Description	Resource
Errors (6 items)	
Data type mismatch: Expecting type [Boolean], Actual type [Decimal].	ConditionsNotMatching.ers
Data type mismatch: Expecting type [String], Actual type [DateTime].	ConditionsNotMatching.ers

Let's examine each of these Conditional expressions to understand why each is valid or invalid:

a – This comparison expression is valid because the data types of the LHS and RHS sides of the equation are compatible (they're both Strings). Note that Corticon Studio confirms the validity of the expression by recognizing it as a comparison and automatically entering the Values set $\{T, F\}$ in the Values column.

b – This comparison expression is invalid because the data types of the LHS and RHS sides of the equation are incompatible (the LHS resolves to a String and the RHS resolves to a DateTime). Note that, in addition to the red text, Corticon Studio emphasizes the problem by not entering the Values set $\{T, F\}$ in the Values column.

c – This comparison expression is invalid because the data types of the LHS and RHS sides of the equation are incompatible (the LHS resolves to a Boolean and the RHS resolves to a Decimal).

d – This comparison expression is valid because the data types of the LHS and RHS sides of the equation are compatible. This is another example of the one exception to our general rule regarding data type compatibility: Decimals may be safely compared to Integer values.

e – This comparison expression is valid because the data types of the LHS and RHS sides of the equation are compatible. Like example 4, this illustrates the one exception to our general rule regarding data type compatibility: Decimals may be safely compared to Integer values. Unlike an assignment, however, whether the Integer and Decimal types occupy the LHS or RHS of a comparison is unimportant.

Datatype of an expression

It is important to emphasize that the idea of a data type applies not only to specific attributes in the Vocabulary, but to entire expressions. Our examples above have been simple, and the data types of the LHS or the RHS of an equation simply correspond to the data types of those single attributes. But the data type to which an expression resolves may be a good deal more complicated.

Figure 122: Examples of Expression Datatypes

Data Type Of Expression.ers	
Conditions	
a	0
b	
Actions	
Post Message(s)	
A	e1.integer1 = e1.dateTime1.dayOfWeek <input checked="" type="checkbox"/>
B	e1.integer2 = e1.string1.size <input checked="" type="checkbox"/>
C	e1.boolean1 = e2 -> isEmpty <input checked="" type="checkbox"/>
D	e1.boolean2 = e2 -> exists(dateTime1 = today) <input checked="" type="checkbox"/>
E	e1.decimal1 = e2.integer1 -> sum <input checked="" type="checkbox"/>
Overrides	

Again, we will examine each assignment to understand what is happening:

- A** – The RHS of this equation resolves to an Integer data type because the `.dayOfWeek` operator “extracts” the day of the week from a `DateTime` value (in this case, the value held by attribute `dateTime1`) and returns it as an Integer between 1 and 7. Since the LHS also has an Integer data type, the assignment operation is valid.
- B** – The RHS of this equation resolves to an Integer because the `.size` operator counts the number of characters in a `String` (in this case the `String` held by attribute `string1`) and returns this value as an Integer. Since the LHS also has an Integer data type, the assignment operation is valid.
- C** – The RHS of this equation resolves to a Boolean because the `->isEmpty` collection operator examines a collection (in this case the collection of `Entity2` children associated with parent `Entity1`, represented by collection alias `e2`) and returns `true` if the collection is empty (has no elements) or `false` if it isn't. Since the LHS also has a Boolean data type, the assignment operation is valid.
- D** – The RHS of this equation resolves to a Boolean because the `->exists` collection operator examines a collection (in this case, `e2` again) and returns `true` if the expression in parentheses is satisfied at least once, and `false` if it isn't. Since the LHS also has a Boolean data type, the assignment operation is valid.
- E** – the RHS of this equation resolves to an Integer because the `->sum` collection operator adds up the values of all occurrences of an attribute (in this case, `integer2`) in a collection (in this case, `e2` again). Since the LHS has a Decimal data type, the assignment operation is valid. This is the lone case where type casting occurs automatically.

Note: The `.dayOfWeek` operator and others used in these examples are described fully in the *Rule Language Guide*

Defeating the parser

The part of Corticon Studio that checks for data type mismatches (along with all other syntactical problems) is the Parser. The Parser exists to ensure that whatever is expressed in a Rulesheet can be correctly translated and compiled into code executable by Corticon Studio's Ruletest as well as by the Corticon Server. Because this is a critical function, much effort has been put into the Parser's accuracy and efficiency. But rule modelers should understand that the Parser is not perfect, and can't anticipate all possible combinations of the rule language. It is still possible to “slip one past” the Parser. Here is an example:

Figure 123: LHS and RHS Resolve to Integers

Conditions		0
a		
b		
Actions		<
Post Message(s)		
A	Entity1.integer1 = (Entity1.integer2 * 2) + 1	<input checked="" type="checkbox"/>
B		
Overrides		

In the figure above, we see an assignment expression where both LHS and RHS return Integers under all circumstances. But making a minor change to the RHS throws this result into confusion:

Figure 124: Will the RHS Still Resolve to an Integer?

Conditions		0
a		
b		
Actions		<
Post Message(s)		
A	Entity1.integer1 = ((Entity1.integer2 * 2) + 1) / 2	<input checked="" type="checkbox"/>
B		
Overrides		

The minor change of adding a division step to the RHS expression has a major effect on the data type of the RHS. Prior to modification, the RHS always returns an Integer, but an *odd* Integer! When we divide an odd Integer by 2, a Decimal always results. The Parser is smart, but not smart enough to catch this problem.

When the rule is executed, what happens? How does the Corticon Server react when the rule instructs it to force a Decimal value into an attribute of type Integer? The server responds by truncating the Decimal value. For example if `integer2` has the value of 2, then the RHS returns the Decimal value of 2.5. This value is truncated to 2 and then assigned to `integer1` in the LHS.

When we focus on this rule here, alone and isolated, it's relatively easy to see the problem. But in a complex Rulesheet, it may be difficult to uncover this sort of problem. Your only clue to its existence may be numerical test results that do not match the expected values. To be safe, it's usually a good idea to ensure the LHS of numeric calculations has a Decimal data type so no data is inadvertently lost through truncation.

Manipulating datatypes with casting operators

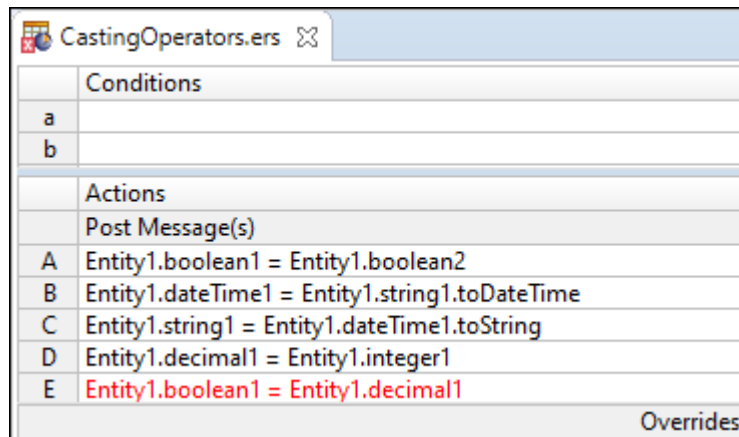
A special set of operators is provided in the Corticon Studio's Operator Vocabulary that allows the rule modeler to control the data types of attributes and expressions. These casting operators are described below:

Table 6: Table: Special Casting Operators

Casting Operator	Applies to data of type...	Produces data of type...
.toInteger	Decimal, String	Integer
.toDecimal	Integer, String	Decimal
.toString	Integer, Decimal, DateTime, Date, Time	String
.toDateTime	String, Date, Time	DateTime
.toDate	DateTime	Date
.toTime	DateTime	Time

Returning to [Datatype Mismatches in Comparison Expressions](#), we use these casting operators to correct some of the previous problems:

Figure 125: Using Casting Operators



Casting operators have been used in Nonconditional rules N.2 and N.3 to make the data types of the LHS and RHS match. Notice however, that no casting operator exists to cast a Decimal into a Boolean data type.

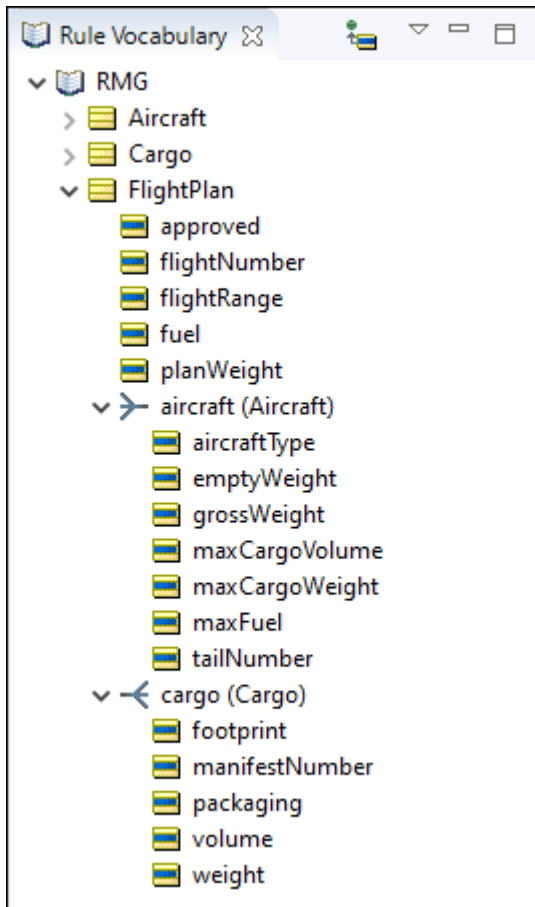
Supported uses of calculation expressions

You can do comparisons and assignments in a few different ways:

- [Calculation as a comparison in a precondition](#) on page 163
- [Calculation as an assignment in a noncondition](#) on page 164
- [Calculation as a comparison in a condition](#) on page 164
- [Calculation as an assignment in an action](#) on page 166

To make our examples more interesting and allow for a bit more complexity in our rules, we have extended the basic Tutorial Vocabulary (`Cargo.ecore`) to include a few more attributes. The extended Vocabulary is shown below:

Figure 126: Basic Tutorial Vocabulary Extended



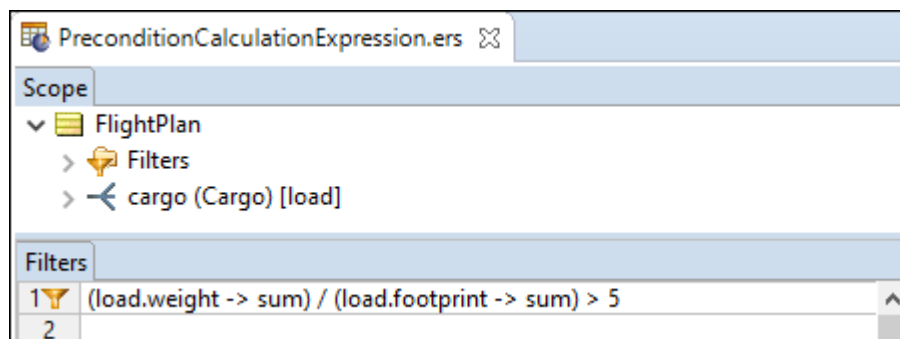
The new attributes are described in the table below:

Table 7: Table: Table of New Attributes Added to the Basic Tutorial Vocabulary

Attribute	Data type	Description
Aircraft.emptyWeight	Decimal	The weight of an Aircraft with no fuel or cargo onboard.(kilograms)
Aircraft.grossWeight	Decimal	The maximum amount of weight an Aircraft can safely lift, equal to the sum of cargo and fuel weights. (kilograms)
Aircraft.maxfuel	Decimal	The maximum amount of fuel an Aircraft can carry. (liters)
Cargo.footprint	Decimal	The floor space required for this Cargo. (square meters)
FlightPlan.approved	Boolean	Indicates whether the FlightPlan has been approved or “cleared” for operation.
FlightPlan.planWeight	Decimal	The total amount of all Aircraft and Cargo weights for this FlightPlan. (kilograms)
FlightPlan.flightRange	Decimal	The distance the Aircraft is expected to fly. (kilometers)
FlightPlan.fuel	Decimal	The amount of fuel actually loaded on the Aircraft assigned to this FlightPlan. (liters)

Calculation as a comparison in a precondition

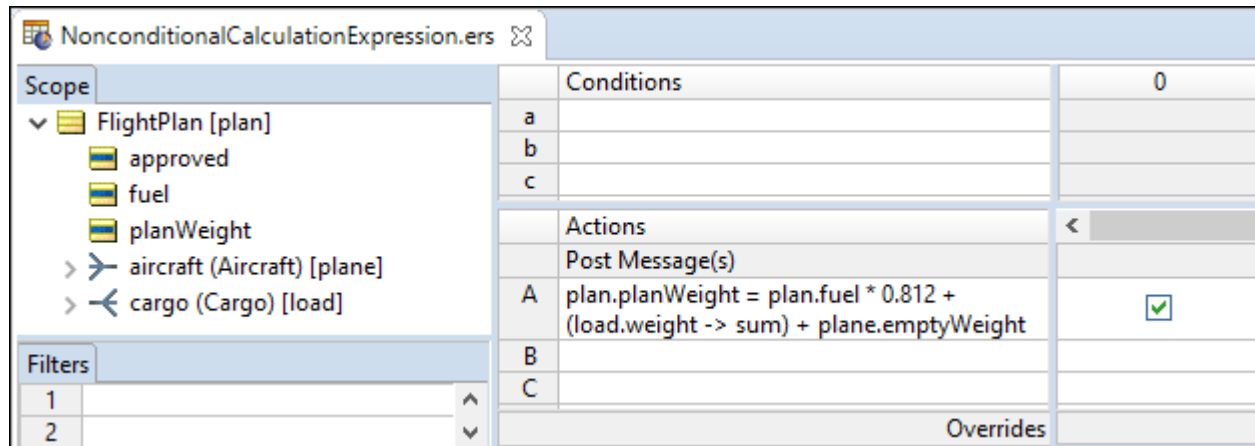
Figure 127: A Calculation in a Preconditional Expression



In this figure, a numeric calculation is used as a comparison in the Filters section of the Rulesheet. The LHS of the expression essentially calculates the average pressure exerted by the total cargo load on the floor of the aircraft (sum of the cargo weights divided by the sum of the cargo containers' footprints). This result is compared to the RHS, which is simply the literal value 5. We might expect to see this type of calculation in a set of rules that deals with special cargos where a lot of weight is concentrated in a small area. This might, for example, require the use of special aircraft with sturdy, reinforced cargo bay floors. Such a Filter expression might be the first step in handling cargos that satisfy this special criterion.

Calculation as an assignment in a noncondition

Figure 128: A Calculation in a Nonconditional Expression



The example shown in this figure uses a calculation in the RHS of the assignment to derive the total weight carried by an Aircraft on the FlightPlan, where the total weight equals the weight of the fuel plus the weight of all Cargos onboard plus the empty weight of the Aircraft itself. The portion

```
plan.fuel * 0.812
```

converts a fuel load measured in liters -- the unit of measure that airlines purchase and load fuel -- into a weight measured in kilograms -- unit of measure used for the weight of the cargo as well as the aircraft and crew. Note that this conversion is a bit conservative as Jet A1 fuel expands as it warms up so this figure considers it to be at the cool end of its range. This portion is then added to:

```
load.weight -> sum
```

which is equal to the sum of all Cargo weights loaded onto the Aircraft associated with this FlightPlan. The final sum of the fuel, cargo, and Aircraft weights is assigned to the FlightPlan's `planWeight`. Note the parentheses used here are not required -- the calculation will produce the same result without them -- they have been added for improved clarity.

Calculation as a comparison in a condition

Once `planWeight` has been derived by the Nonconditional calculation in the figure below, it may be used immediately elsewhere in this or subsequent Rulesheets.

Note: "Subsequent Rulesheets" means Rulesheets executed later in a Ruleflow. The concept of a Ruleflow is discussed in the *Quick Reference Guide*.

An example of such usage appears in the following figure:

Figure 129: planWeight Derived and Used in Same Rulesheet

Scope		Conditions	1
<ul style="list-style-type: none"> ▼ FlightPlan [plan] <ul style="list-style-type: none"> approved fuel planWeight > aircraft (Aircraft) [plane] > cargo (Cargo) [load] 	a	plan.planWeight > plane.grossWeight	T
	b		
	c		
Filters		Actions	
1			
2			
		Post Message(s)	
	A	plan.planWeight = plan.fuel * 0.13368 * 50.4 + (load.weight -> sum) + plane.emptyWeight	<input checked="" type="checkbox"/>
	B	plan.approved	F
	C		
		Overrides	

In Condition row a, `planWeight` is compared to the aircraft's `grossWeight` to make sure the aircraft is not overloaded. An overloaded aircraft must not be allowed to fly, so the `approved` attribute is assigned a value of `false`.

This has the advantage of being both clear and easy to reuse – the term `planWeight`, once derived, may be used anywhere to represent the data produced by the calculation. It is also much simpler and cleaner to use a single attribute in a rule expression than it is a long, complicated equation.

But this does not mean that the equation cannot be modeled in a Conditional expression, if preferred. The example shown in the figure below places the calculation in the LHS of the Conditional comparison to derive `planWeight` and compare it to `grossWeight` all in the same expression.

Figure 130: A Calculation in a Conditional Expression

Scope		Conditions	1
<ul style="list-style-type: none"> ▼ FlightPlan [plan] <ul style="list-style-type: none"> approved fuel planWeight > aircraft (Aircraft) [plane] < cargo (Cargo) [load] 	a	plan.planWeight = plan.fuel * 0.13368 * 50.4 + (load.weight -> sum) + plane.emptyWeight	T
	b		
	c		
Filters		Actions	
1			
2			
		Post Message(s)	
	A	plan.approved	F
	B		
	C		
	D		
		Overrides	

This approach might be preferable if the results of the calculation were not expected to be reused, or if adding an attribute like `planWeight` to the Vocabulary were not possible. Often, attributes like `planWeight` are very convenient “intermediaries” or “holders” to carry calculated values that will be used in other rules in a Rulesheet. In cases where such attributes are conveniences only, and are not used by external applications consuming a Rulesheet, they may be designated as “transient” attributes in the Vocabulary, which causes their icons to change from blue/yellow to orange/yellow. More details on transient attributes are included in [Step 6 Model the Vocabulary in Corticon Studio](#) on page 19 of this guide.

Calculation as an assignment in an action

Figure 131: A Calculation in an Action Expression

Scope		Conditions		1	2
FlightPlan [plan]	a	plane.aircraftType		'747'	'DC-10'
aircraft (Aircraft) [plane]	b				
cargo (Cargo) [load]					
Filters		Actions			
1		A	plane.maxFuel = plane.grossWeight - plane.maxCargoWeight - plane.emptyWeight	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2		B	plane.maxFuel = 1000	<input type="checkbox"/>	<input checked="" type="checkbox"/>
			Overrides		

This figure shows two rules that each make an assignment to `maxFuel`, depending on the type of aircraft. In rule 1, the `maxFuel` load for 747s is derived by subtracting `maxCargoWeight` and `emptyWeight` from `grossWeight`. In rule 2, `maxFuel` for DC-10s is simply assigned the literal value 100,000.

Unsupported uses of calculation expressions

Some calculation expressions you might want to try simply do not provide expected or reliable results.

Calculations in value sets and column cells

The Conditional expression shown below is not supported by Studio, even though it does not turn red. Some simpler equations may actually work correctly when inserted in the Values cell or a rule column cell, but it's a dangerous habit to get into because more complex equations generally do not work. It's best to express equations as shown in the previous sections.

Figure 132: Calculation in a Values Cell and Column

Scope		Conditions		0	1
FlightPlan [plan]	a	plan.planWeight			plane.emptyWeight + plan.fuel + load.weight
fuel	b				
aircraft [plane]	c				
cargo [load]	d				
	e				

Calculations in rule statements

While it is possible to embed *attributes* from the Vocabulary inside Rule Statements, it is not possible to embed equations or calculations in them. Operators and equation syntax not enclosed in curly brackets { . . } are treated like all other characters in the Rule Statement – nothing will be calculated. If the Rule Statement shown in the following figure is posted by an Action in rule 1, the message will be displayed exactly as shown; it will not calculate a result of any kind.

Figure 133: Calculation in a Rule Statement

Ref	ID	Post	Alias	Text
1				2 * 3 + 4

Likewise, including equation syntax *within* curly brackets along with other Vocabulary terms is also not permitted. Doing so may cause your text to turn red, as shown:

Figure 134: Embedding a Calculation in a Rule Statement

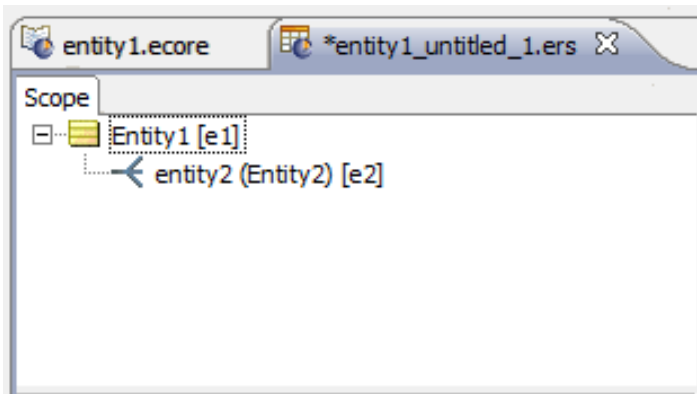
Ref	ID	Post	Alias	Text
1				The value of maxFuel squared is {plane.maxFuel ** 2}
				Invalid token: [**].

However, even if the syntax does not turn red, you should still not attempt to perform calculations in Rule Statements – it may cause unexpected behavior. When red, the tool tip should give you some guidance as to why the text is invalid. In this case, the exponent operator (**) is not allowed in an embedded expression.

TestYourself questions for Rules containing calculations and equations

Note: Try this test, and then go to [TestYourself answers for Rules containing calculations and equations](#) on page 339 to correct yourself.

1. What are the two possible meanings of the equals operator =? In which sections of the Rulesheet is each of these meanings applicable?
2. What is the result of each of the following equations?
 - a. $10 + 20 / 5 - 4$ ___
 - b. $2 * 4 + 5$ ___
 - c. $10 / 2 * 6 - 8$ ___
 - d. $2 ** 3 * (1 + 2)$ ___
 - e. $-5 * 2 + 5 * 2$ ___
3. Is the following assignments expression valid? Why or why not? `Entity1.integer1 = Entity1.decimal1`
4. What is the data type of each of the following expressions based on the scope shown below?



- e1.dateTime1.year ____
- e1.string1.toUpperCase ____
- e2 -> forAll (integer1 = 10) ____
- e2.decimal1 -> avg ____
- e1.boolean1 ____
- e1.decimal1 > e1.decimal2 ____
- e2.string2.contains('abc') ____

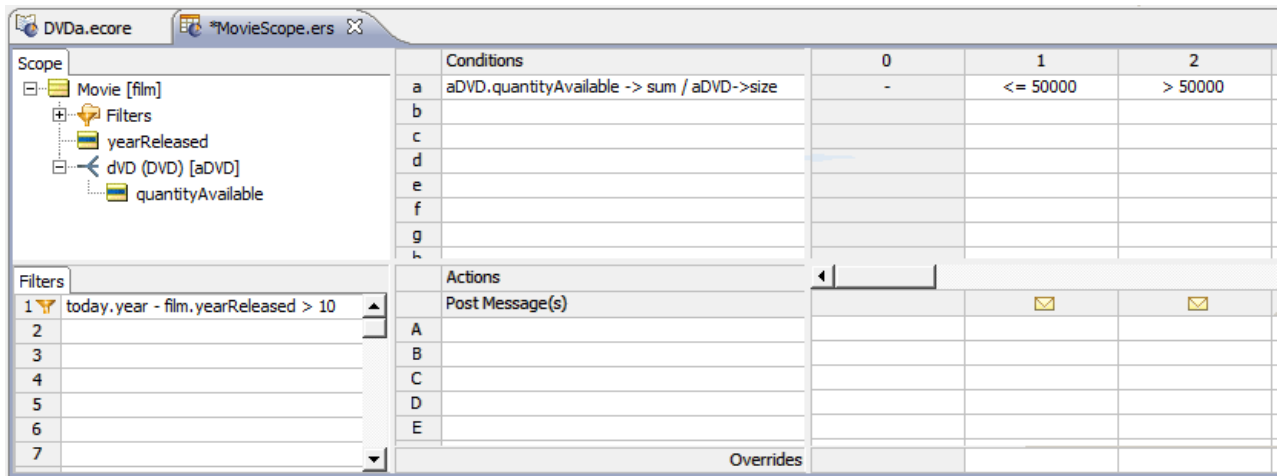
5. Write "valid" or "invalid" for each of the following assignments

- e1.decimal1 = e2.integer1 ____
- e2.decimal2 = e2.string2 ____
- e1.integer1 = e2.dateTime1.day _____
- e2.integer1 = e2 -> size ____
- e1.boolean2 = e2 -> exists (string1 = 'abc') _____
- e2.boolean2 = e1.string1.toBoolean _____
- e1.boolean2 = e2 -> isEmpty _____

6. The part of Corticon Studio that checks for syntactical problems is called the _____.

7. True or False. If an expression typed in Corticon Studio does not turn red, then the expression is guaranteed to work as expected.

Referring to the following illustration, answer questions 8 through 10:



8. What does Filters row 1 test?
9. What does Conditions row "a" test? Is there a simpler way to accomplish this same thing using a different operator available in the Corticon Rule Language?
10. Write a Rule Statement for rule column 1. (Assume that the only action required for this rule is to post a Warning message as shown.)
11. True or False. The following sections of the Rulesheet accept equations and calculations:
 - Scope ____
 - Rule Statements ____
 - Condition rows ____
 - Action rows ____
 - Column 0 ____
 - Condition cells ____
 - Action cells ____
 - Filters ____

Rule dependency in chaining and looping

This section explores how Corticon determines the sequencing of rules, and looping, which involves controls you can set over the revisiting, re-evaluating, and possible re-firing of rules.

What is rule dependency?

Dependencies between rules exist when a Conditional expression of one rule evaluates data produced by the Action of another rule. The second rule is said to be "dependent" on the first.

For details, see the following topics:

- [Forward chaining](#)
- [Rulesheet processing modes of looping](#)
- [Looping controls in Corticon Studio](#)
- [Looping examples](#)
- [How to use conditions as a processing threshold](#)
- [TestYourself questions for Rule dependency chaining and looping](#)

Forward chaining

The first step in learning to use looping is to understand how it differs from normal inferencing behavior of executing rules, whether executed by Corticon Studio or Corticon Server. When a Ruleflow is compiled into a Decision Service, a *dependency network* for the rules is automatically generated. Corticon uses this network to determine the order in which rules fire at runtime. For example, in the simple rules below, the proper dependency network is 1 > 2 > 3 > 4.

1. If value = A, then set value = B
2. If value = B, then set value = C
3. If value = C, then set value = D
4. If value = D, then set value = B

This is not to say that all three rules will always *fire* for a given test – clearly a test with B as the initial value will only cause rules 2, 3, and 4 to fire. But the dependency network ensures that rule 1 is always *evaluated* before rule 2, and rule 2 is always *evaluated* before rule 3, and so on. This mode of Rulesheet execution is called **Optimized Inferencing**, meaning the rules execute in the optimal sequence determined by the dependency network generated by the compiler. **Optimized Inferencing** is the default mode of rule processing for all Rulesheets.

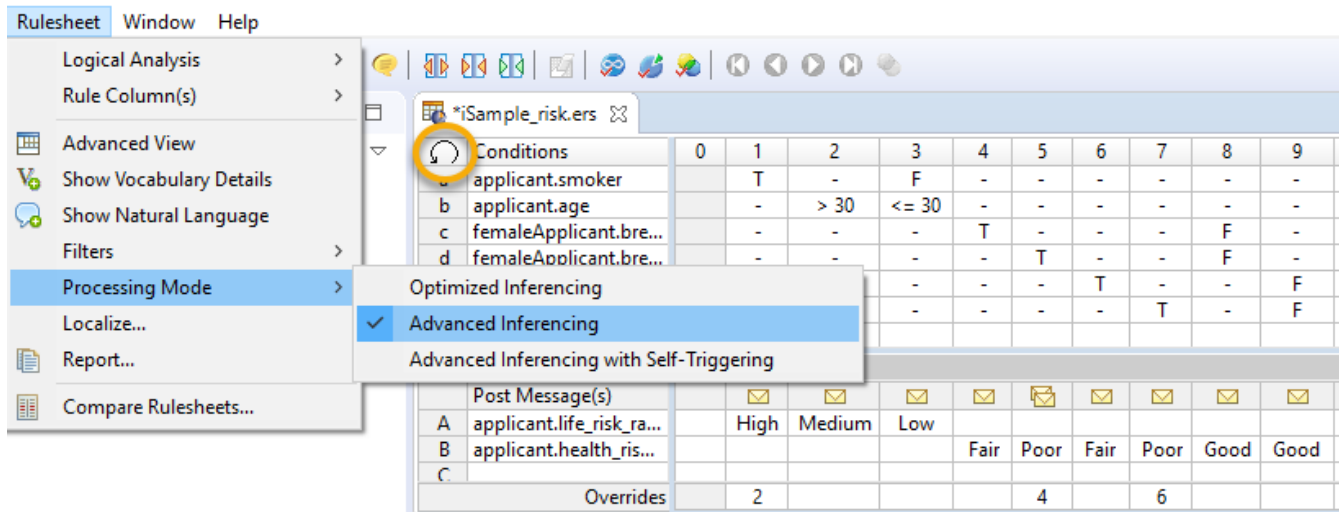
Optimized Inferencing processing is a powerful capability that enables the rule modeler to “break up” complex logic into a series of smaller, less complex rules. Once broken up into smaller or simpler rules, the logic will be executed in the proper sequence automatically, based on the dependencies determined by the compiler.

An important characteristic of Optimized Inferencing processing: the flow of rule execution is single-pass, meaning a rule in the sequence is evaluated once and never revisited, even if the data values (or data “state”) evaluated by its Conditions change over the course of rule execution. In our example above, this effectively means that rule execution ceases after rule 4. Even if rule 4 fires (with resulting value = B), the second rule **will not** be revisited, re-evaluated, or re-fired even though its Condition (If value = B) would be satisfied by the current value (state). We can *force* rule 2 to be re-evaluated only if a one of Corticon Studio's looping processing modes is enabled for the Rulesheet. Remember, just because sequential processing occurs automatically does not mean looping will occur too. Looping and its enablement are discussed next.

Rulesheet processing modes of looping

Occasionally, we *want* rules to be re-evaluated and re-fired (if satisfied). This scenario requires the Corticon rule engine to make multiple passes through the same Rulesheet. We call this behavior *advanced inferencing*, and to enable it in Rulesheet execution, we must set Rulesheet processing mode to **Advanced Inferencing** by selecting **Rulesheet > Processing Mode > Advanced Inferencing** from the Studio menubar, as shown:

Figure 135: Selecting Advanced Inferencing Processing Mode for a Rulesheet



We emphasize it here with an orange highlight to the immediate left of the Conditions header.

If the rule engine is permitted to loop through the rules above, the following events occur:

Given a value of **A** as the initial data, the Condition in rule 1 will be satisfied and the rule will fire, setting the value to **B**. The 2nd rule's Condition is then satisfied, so the value will advance (or be reset) to **C**, and so on, until the value is once again **B** after the 4th rule fires. Up to this point, the rule engine is exhibiting standard, Optimized Inferencing behavior.

Now here's the new part: the value (state) has changed since the 2nd rule last fired, so the rule engine will re-evaluate the Condition, and, finding it satisfied, will fire the 2nd rule again, advancing the value to C. The 3rd rule will also be re-evaluated and re-fired, advancing the value to D, and so on. This sequence is illustrated in the following figure.

Figure 136: Loop Iterations

step #	Input value	Rule fired	Output value	Loop Iteration
1	A	1	B	
2	B	2	C	
3	C	3	D	
4	D	4	B	
5	B	2	C	1
6	C	3	D	
7	D	4	B	
8	B	2	C	2
9	C	3	D	
10	D	4	B	
...

Here's the key to understanding looping: when a looping processing mode is enabled, rules will be continually re-evaluated and re-fired in a sequence determined by their dependency network as long as data state has changed since their last firing. Once data state no longer changes, looping will cease.

Notice that the last column of the table indicates the number of loop iterations – the first loop does not begin until rule 2 fires for the *second* time. The first time through the rules (steps 1-4) does not count as the first loop iteration because the loop does not actually start until step 5.

Types of loops

Infinite Loops

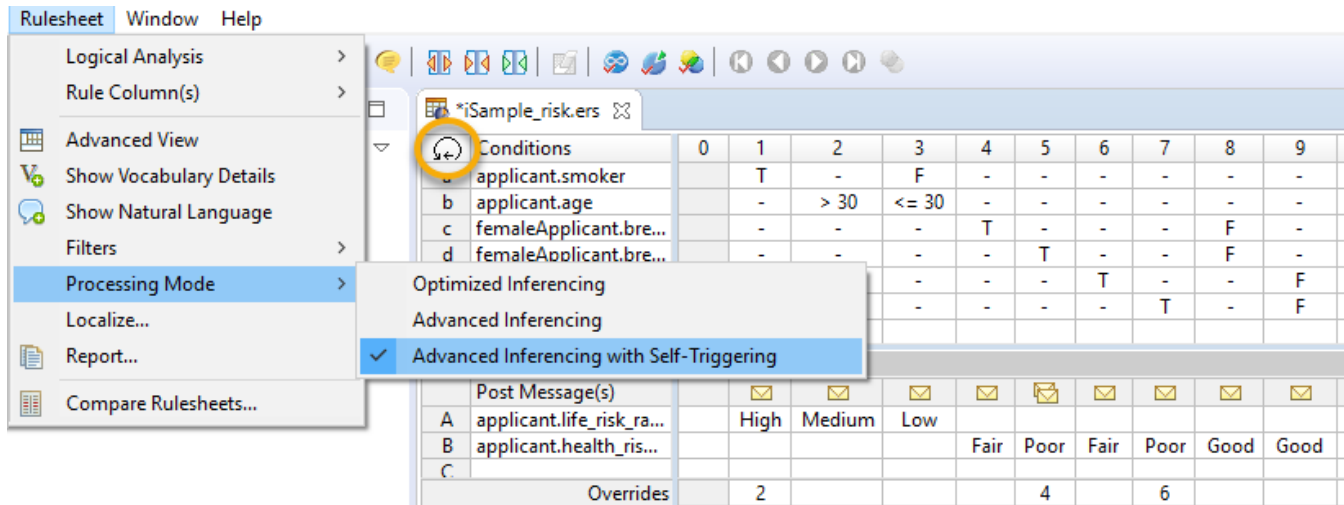
In the example above, looping between rules 2, 3 and 4 continues indefinitely because there is nothing to stop the cycle. Some loops, especially those inadvertently introduced, are not self-terminating. Because these loops will not end by themselves, they are called infinite loops. Infinite loops can be especially vexing to a rule modeler because it isn't always apparent when a Rulesheet has entered one. A good indication, however, is that rule execution takes longer than expected to complete! A special control is provided to prevent infinite loops. This control is described in the [Terminating Infinite Loops](#) section, below.

Trivial Loops

Single-rule loops, or loops caused by rules that depend logically on themselves, are also known as “trivial loops”. We consider single-rule loops to be a special kind of loop because they consist of just a single rule that successively revisits, or “triggers”, itself.

To enable the self-triggering mode of looping, we must select **Rulesheet > Processing Modes > Advanced Inferencing with Self-Triggering** from the Corticon Studio menubar, as shown in

Figure 137: Selecting Advanced Inferencing with Self-Triggering Processing Mode for a Rulesheet



Notice the icon to the left of the Conditions header - it contains the additional tiny arrow, which indicates self-triggering is active.

Here's an example of a loop created by a self-triggering rule:

Figure 138: Example of an Infinite Single-Rule Loop

The screenshot shows the Corticon Studio interface for a rulesheet named 'InfiniteSingleLoop.ers'. The rule has a self-triggering condition and an action that increments the weight.

Conditions	1
a Cargo.weight >= 0	T
b	
Actions	<
Post Message(s)	
A Cargo.weight += 1	<input checked="" type="checkbox"/>
B	
Overrides	

Let's trace this rule to make sure we understand how it works.

When `Cargo.weight` has a value equal to or greater than 0, then rule 1 fires and the value of `Cargo.weight` is incremented by 1. Data state has now *changed*, in other words, the value of at least one of the attributes has changed. In this case, it's the value of `Cargo.weight` which has changed.

Because it was rule 1 execution that *caused* the data state change, and since self-triggering is enabled, the same rule 1 will be re-evaluated. Now, if the value of `Cargo.weight` satisfied the rule initially, it certainly will do so again, so the rule fires again, and self-triggers again. And so on, and so on. This is also an example of an infinite loop, because no logic exists in this rule to prevent it from continuing to loop and fire.

An Exception to Self-Triggering

Self-triggering logic can also be modeled in Column 0 of the Rulesheet, as shown:

Figure 139: Example of an Infinite Loop created by a Self-Triggering Rule

SingleLoopAsNonconditional.ers		
Conditions		0
a		
b		
Actions		<
Post Message(s)		
A	Cargo.weight += 1	<input checked="" type="checkbox"/>
B		
Overrides		

But this figure is also a good example of why it might be appropriate to disable self-triggering processing: we only want the `weight` to increment once, not enter into an infinite loop, which it would otherwise do, unconditionally! This is a special case where we have intentionally prevented this rule from iterating, even though self-triggering is enabled. This rule will execute only once, regardless of looping processing mode.

Another example of a loop caused by self-triggering rule, but one which is not infinite, is shown below. The behavior described only occurs when Rulesheet processing mode is set to **Advanced Inferencing with Self-Triggers** :

Figure 140: Example of a Finite Single-Rule Loop

FiniteSingleRuleLoop.ers		
Conditions		1
a	Cargo.weight	0..20
b		
Actions		<
Post Message(s)		
A	Cargo.weight += 1	<input checked="" type="checkbox"/>
B		
Overrides		

In the figure above, the rule continues to fire until `Cargo.weight` reaches a value of 21, whereupon it fails to satisfy the Condition, and firing ceases. The loop terminates with `Cargo.weight` containing a final value of 21.

It's important to note that in all three examples, an initial `Cargo.weight` value of 0 or higher was necessary to “activate” the loop. A negative (or null) value, for example, would not have satisfied the rule's Condition and the loop would not have begun at all.

Multi-rule Loops

As the name suggests, multi-rule loops exist when 2 or more rules are mutually dependent. As with single-rule loops, the Rulesheet containing the looping rules must be configured to process them. This is accomplished as before. Choose **Rulesheet > Processing Mode > Advanced Inferencing** from the Studio menubar, as shown previously in [Selecting Advanced Inferencing Processing Mode for a Rulesheet](#).

Here's an example of a multi-rule logical loop:

Figure 141: Example of a Finite Multi-Rule Loop

MultiLoopRule.ers		1	2	3
Conditions				
a	Cargo.weight	1..10	-	> 10
b	Cargo.volume > 0	-	T	-
Actions				
Post Message(s)		✉	✉	✉
A	Cargo.volume = Cargo.weight * 2	✓		
B	Cargo.weight += 1		✓	
Overrides				
Rule Statements				
Ref	ID	Post	Alias	Text
1		Info	Cargo	If weight is between 0 and 10 [{Cargo.weight}] then volume is twice weight [= {Cargo.volume}]
2		Warning	Cargo	As long as volume is greater than 0, increment weight by 1 [now {Cargo.weight}]
3		Violation	Cargo	weight has exceeded the threshold, so the loop terminates

In the figure above, rule 2 is dependent upon rule 1, and rule 1 is dependent upon rule 2. We've also added a rule 3, which does not participate in the 1—2 loop, but will generate a nice `Violation` message when the 1—2 loop finally terminates. Note, rule 3 does not *cause* the 1—2 loop to terminate, it just *announces* that the loop has terminated. Let's test these rules and see how they behave. In **Ruletest for the Multi-rule Rulesheet**, we see a simple Ruletest.

Figure 142: Ruletest for the Multi-rule Rulesheet

MultiLoop.ert	
untitled_1	
/RulesTutorial/MultiLoopRule.ers	
Input	
▼	Cargo [1]
	weight [1]

We're providing a starting value of `Cargo.weight` just to get the loop going. According to the Condition in rule 1, this value needs to be between 1 and 10 (inclusive).

Figure 143: Ruletest for the Multi-rule Rulesheet

The screenshot shows the Corticon Studio interface for a rule test. The top part displays the rule sheet structure with input and output variables. The input variables are `Cargo [1]` and `weight [1]`. The output variables are `Cargo [1]`, `volume [20.000000]`, and `weight [11.000000]`. Below this, the 'Rule Statements' section shows a table of messages and their severity levels.

Severity	Message	Entity
Info	If weight is between 0 and 10 [1] then volume is twice weight [=2.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=2.000000]	Cargo[1]
Info	If weight is between 0 and 10 [2.000000] then volume is twice weight [=4.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=3.000000]	Cargo[1]
Info	If weight is between 0 and 10 [3.000000] then volume is twice weight [=6.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=4.000000]	Cargo[1]
Info	If weight is between 0 and 10 [4.000000] then volume is twice weight [=8.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=5.000000]	Cargo[1]
Info	If weight is between 0 and 10 [5.000000] then volume is twice weight [=10.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=6.000000]	Cargo[1]
Info	If weight is between 0 and 10 [6.000000] then volume is twice weight [=12.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=7.000000]	Cargo[1]
Info	If weight is between 0 and 10 [7.000000] then volume is twice weight [=14.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=8.000000]	Cargo[1]
Info	If weight is between 0 and 10 [8.000000] then volume is twice weight [=16.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=9.000000]	Cargo[1]
Info	If weight is between 0 and 10 [9.000000] then volume is twice weight [=18.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=10.000000]	Cargo[1]
Info	If weight is between 0 and 10 [10.000000] then volume is twice weight [=20.000000]	Cargo[1]
Warning	As long is volume is greater than 0, increment weight by 1 [now=11.000000]	Cargo[1]
Violation	weight has exceeded the threshold, so the loop terminates	Cargo[1]

When intentionally building looping rules, it is often helpful to post messages with embedded attribute values (as shown in the Rule Statements section of [Figure 141: Example of a Finite Multi-Rule Loop](#) on page 177) so we can trace the loop's operation and verify it is behaving as expected. It should be clear to the reader that the Ruletest shown in **Ruletest for the Multi-rule Rulesheet** contains the expected results.

Looping controls in Corticon Studio

To handle the various aspects of rule looping, Corticon Studio provides several mechanisms for identifying and controlling looping behavior.

Although we've only shown simple examples so far, looping rules can get much more complicated. Sometimes, rules have mutual dependencies by accident – we didn't intend to include loops when we built the Rulesheet. It is for this reason that all loop processing is disabled by default (in other words, the default Rulesheet processing mode is Optimized Inferencing, which does not permit revisiting rules that have already been evaluated once). We must manually enable the loop processing mode of our choice to cause the loops to execute. This is the strongest, most fool-proof mechanism for preventing unexpected looping behavior – simply keep loop processing disabled.

How to identify loops

Assuming we haven't intentionally incorporated looping logic in our Rulesheet, then we need a way to discover if unintentional loops occur in our rules.

The loop detection tool

To help identify inadvertent loops, Corticon Studio provides a **Check for Logical Loops** tool in the Corticon Studio toolbar. The tool contains a powerful algorithm that analyzes dependencies between rules on the same Rulesheet, and reports discovered loops to the rule modeler. For the Loop Detector to notice mutual dependencies, a Rulesheet must have looping enabled using one of the choices described earlier.

Clicking the **Check for Logical Loops** icon displays a window that describes the mutual dependencies found on the Rulesheet. To illustrate loop detection, we will use a few of the same examples from before.

Figure 144: Example of an Infinite Single-Rule Loop

Conditions		1
a	Cargo.weight >= 0	T
b		
Actions		<
Post Message(s)		
A	Cargo.weight += 1	<input checked="" type="checkbox"/>
B		
Overrides		

When applied to a Rulesheet containing just the single-rule loop shown in this figure, the **Check for Logical Loops** tool displays the following window:

Figure 145: Checking for Logical Loops in a Rulesheet

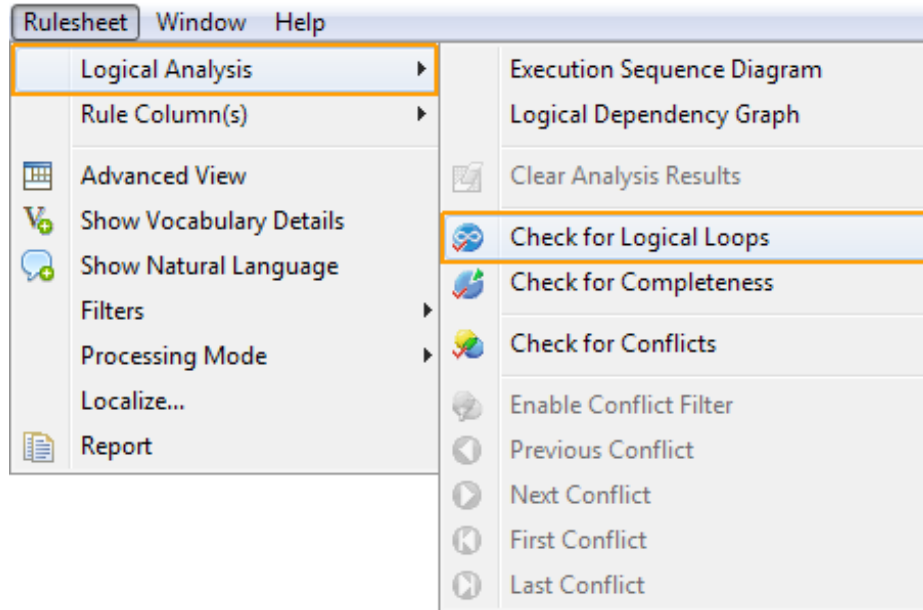
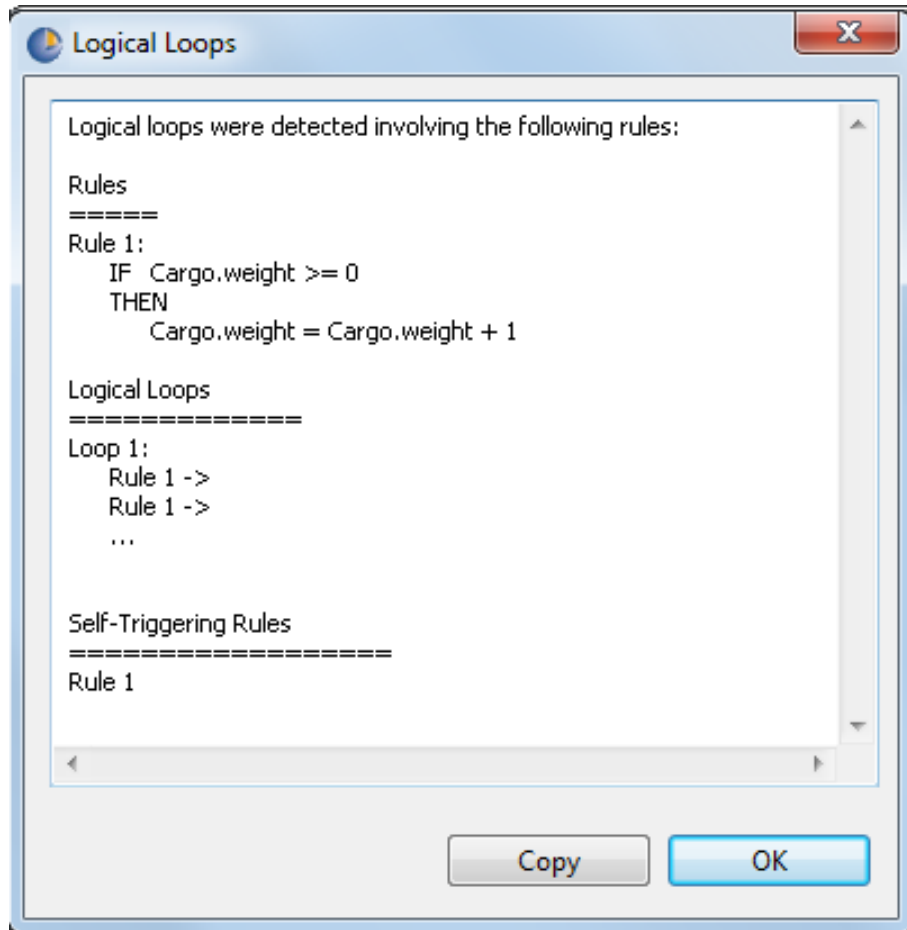


Figure 146: A Single-Rule Loop Detected by the Check for Logical Loops Tool



The Check for Logical Loops tool first lists rules where mutual dependencies exist. Then, it lists the distinct, independent loops in which those rules participate, and finally it lists where self-triggering rules exist (if any). In this simple single-rule loop example, only one rule contains a mutual dependency, and only one loop exists in the Rulesheet.

Note: The **Check for Logical Loops** tool does not automatically fix *anything*, it just points out that our rules *have* loops, and gives us an opportunity to remove or modify the offending logic.

How to remove loops

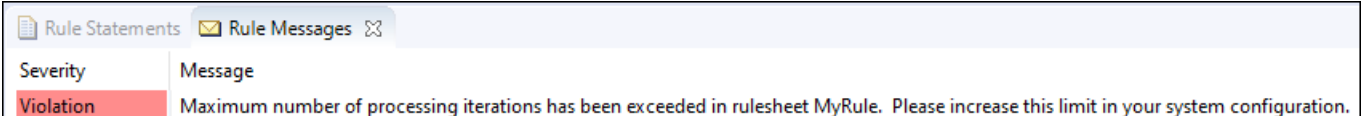
If the Check for Logical Loops tool detects loops, we can take one of several corrective actions:

- If no loops are what you want, then click **Rulesheet > Processing Mode** and de-select whichever of the two looping options is currently selected. Once done, the **Check for Logical Loops** tool will no longer detect loops and the software will no longer process them.
- If loops are what you want, then take measures to ensure that none of the loops can be infinite. Normally, this means adding conditional logic to one of the looping rules to make sure that the rule can't be satisfied indefinitely. This is similar to the bounding of Condition 1 in [Example of a Finite Multi-Rule Loop](#) using a Values set of 0..20. Once `Cargo.weight` reaches 21, the rule's Condition will no longer be satisfied and the loop will terminate.
- If some loops are good and some are not, then remove the inter-dependencies in the unwanted loops and ensure the selected loops are not infinite.

How to terminate infinite loops

By definition, infinite loops won't terminate by themselves. Therefore, Corticon provides a safety valve that caps the number of iterations allowed before the system automatically terminates a loop. The default setting is 100, meaning that a loop is allowed to iterate up to 100 times normally. Once the number of loops exceeds the `maxloops` setting, then the system automatically terminates the loop and generates a `Violation` error message. This means that the final number of loop iterations will be 101: 100 normal iterations plus the final iteration that causes the `Violation` message to appear and the loop to terminate. The `Violation` message is shown below:

Figure 147: Maxloop Exceeded Violation Message



Severity	Message
Violation	Maximum number of processing iterations has been exceeded in rulesheet MyRule. Please increase this limit in your system configuration.

If you are comfortable writing looping rules, and want the software to be able to loop more than 100 times, be sure to reset this property to a higher value. Keep in mind that the more iterations the system performs, the longer rule execution may take. If the Rulesheets you intend to deploy require high iteration counts, set the value that determines what constitutes an endless loop. For Decision Services that have Rulesheets with a **Processing mode** that allows looping, it is important to limit the loop count and prevent endless loops.

In the `brms.properties` file, add the following property with your preferred maximum number of iterations allowed for any loop:

```
com.corticon.reactor.rulebuilder.maxloops=100
```

Looping examples

The following examples show how looping can be useful in your models.

Determine the next working day when given a date

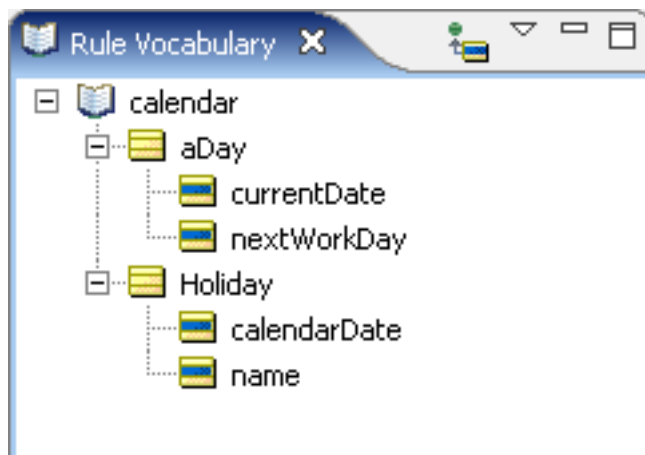
Problem

For any given date, determine the next working day. Take into consideration weekends and holidays.

Solution

Implemented correctly in Corticon Studio, these rules should start with a given input date, and increment as necessary until the next workday is identified (workday defined here as any day *not* Saturday, Sunday, or a national holiday). A simple Vocabulary that supports these rules is shown in [Example of a Finite Single-Rule Loop](#).

Figure 148: Sample Vocabulary for Holiday Rules



Next, the rules are implemented in the Rulesheet shown in the following figure:

Figure 149: Sample Rulesheet for Determining Next Workday

	0	1	2	3	4	5
Conditions						
a	aDay.nextWorkDay = Holiday.calendarDate					
b	aDay.nextWorkDay.dayOfWeek					
c						
Actions						
Post Message(s)						
A	aDay.nextWorkDay = aDay.currentDate.addDays(1)					
B	aDay.nextWorkDay = aDay.nextWorkDay.addDays(1)					
C	aDay.nextWorkDay = aDay.nextWorkDay.addDays(2)					
D						
Overrides						

Ref	Post	Alias	Text
0	Info	aDay	Today is [{aDay.currentDate}] and the next day is [{aDay.nextWorkDay}]
1	Warning	aDay	The next day falls on a holiday, so increment to the next day [{aDay.nextWorkDay}]
2	Info	aDay	The next day does not fall on a holiday, so do not increment
3	Warning	aDay	The next day falls on a Sunday, so increment to the next day to [{aDay.nextWorkDay}]
4	Warning	aDay	The next day falls on a Saturday, so increment two days to [{aDay.nextWorkDay}]
5	Info	aDay	The next day does not fall on a Saturday or Sunday, so do not increment

Let's step through this Rulesheet.

1. First, notice that the Scope section is not used. We are using a very simple Vocabulary with short entity names and no associations, so aliases are not necessary. Furthermore, none of our rules use collection operations, so aliases representing collections are not required either.
2. The first rule executed is the Nonconditional equation (in Condition/Action column 0) setting `nextWorkDay` equal to `currentDate` plus one day.
3. Rule 1 (in column 1) checks to see if the `DateTime` of the `nextWorkDay` matches any of the holidays defined in one or more `Holiday` entities. If it does, then the Action row B increments `nextWorkDay` by one day and posts a warning message.
4. Rule 3 checks to see if the `nextWorkDay` falls on a Sunday. Notice that this rule uses the `.dayOfWeek` operator, which is described in full detail in the *Rule Language Guide*. If the day of the week is Sunday (in other words, `.dayOfWeek` returns a value of 1), then the Action increments `nextWorkDay` by one day and posts a Warning message.
5. Rule 4 checks to see if the `nextWorkDay` falls on a Saturday. If the day of the week is Saturday (in other words, `.dayOfWeek` returns a value of 7), then the Action row C increments `nextWorkDay` by two days and posts a Warning message. By incrementing 2 days, we skip an extra iteration because we know Sunday is also a non-workday!

Do not forget to check for conflicts – they do exist in this Rulesheet. However, we will make the assumption that a holiday never falls on a weekend.

Note: Resolution of the conflicts is straightforward, so we won't address that in detail here. One conflict – that between rules 1 and 4 - is left unresolved because we have assumed that a holiday never falls on a weekend. See [Logical Analysis](#) chapter more a complete discussion of conflict and other logical problems.

A modified Rulesheet displays the overrides added to resolve the conflicts in the following figure:

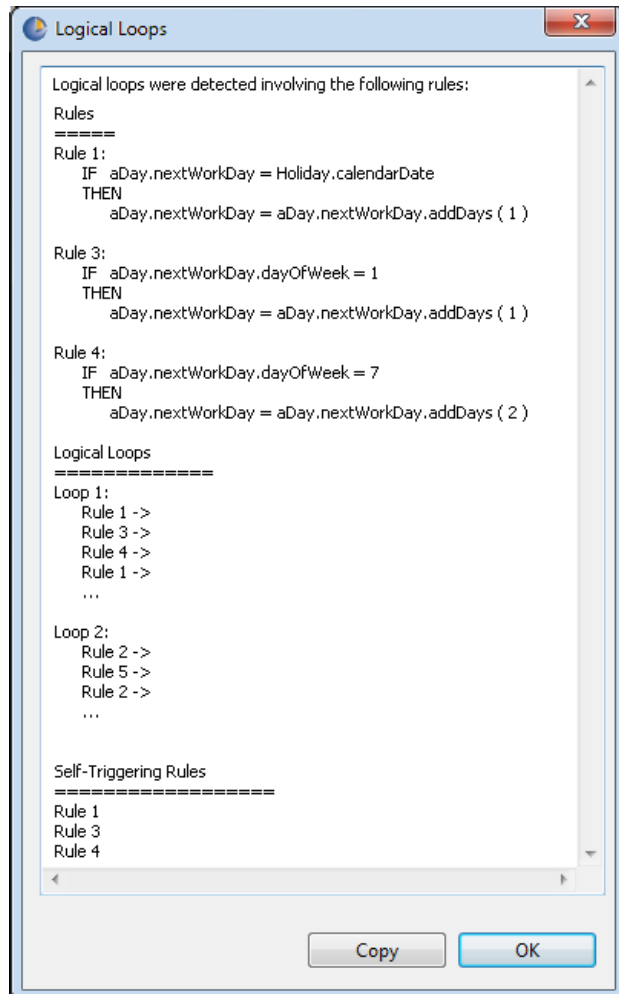
Figure 150: Holiday Rules with Ambiguities Resolved by Overrides

The screenshot shows a software interface for rule modeling. The top window, titled 'nextDay2.ers', contains a 'Conditions' section with two rules: 'a' (aDay.nextWorkDay = Holiday.calendarDate) and 'b' (aDay.nextWorkDay.dayOfWeek). Below this is an 'Actions' section with four rules: 'A' (aDay.nextWorkDay = aDay.currentDate.addDays(1)), 'B' (aDay.nextWorkDay = aDay.nextWorkDay.addDays(1)), 'C' (aDay.nextWorkDay = aDay.nextWorkDay.addDays(2)), and 'D'. To the right of these sections is a calendar grid with columns for days 0 through 5. The grid shows the day of the week (T, F, -, -, -, other) and checkboxes for each day. Below the grid is an 'Overrides' section with values 5, 2, and 2 for days 1, 3, and 4 respectively. The bottom window, titled 'Rule Statements', has two tabs: 'Rule Statements' and 'Rule Messages'. The 'Rule Messages' tab is active, showing a table with columns 'Ref', 'Post', 'Alias', and 'Text'. The table contains five entries with references 0 through 5, each with a specific post type and alias, and a text description of the rule's behavior.

Ref	Post	Alias	Text
0	Info	aDay	Today is [{aDay.currentDate}] and the next day is [{aDay.nextWorkDay}]
1	Warning	aDay	The next day falls on a holiday, so increment to the next day [{aDay.nextWorkDay}]
2	Info	aDay	The next day does not fall on a holiday, so do not increment
3	Warning	aDay	The next day falls on a Sunday, so increment to the next day to [{aDay.nextWorkDay}]
4	Warning	aDay	The next day falls on a Saturday, so increment two days to [{aDay.nextWorkDay}]
5	Info	aDay	The next day does not fall on a Saturday or Sunday, so do not increment

Using the same rules as before, let's click the **Logical Loop Checker**  icon in the Corticon Studio toolbar. The following window opens:

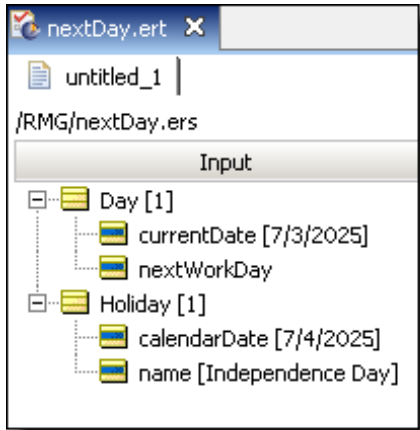
Figure 151: Results of Logical Loop Check



This window first identifies exactly which rules are involved in loops. Secondly, the window outlines the specific attribute interactions that create the loops.

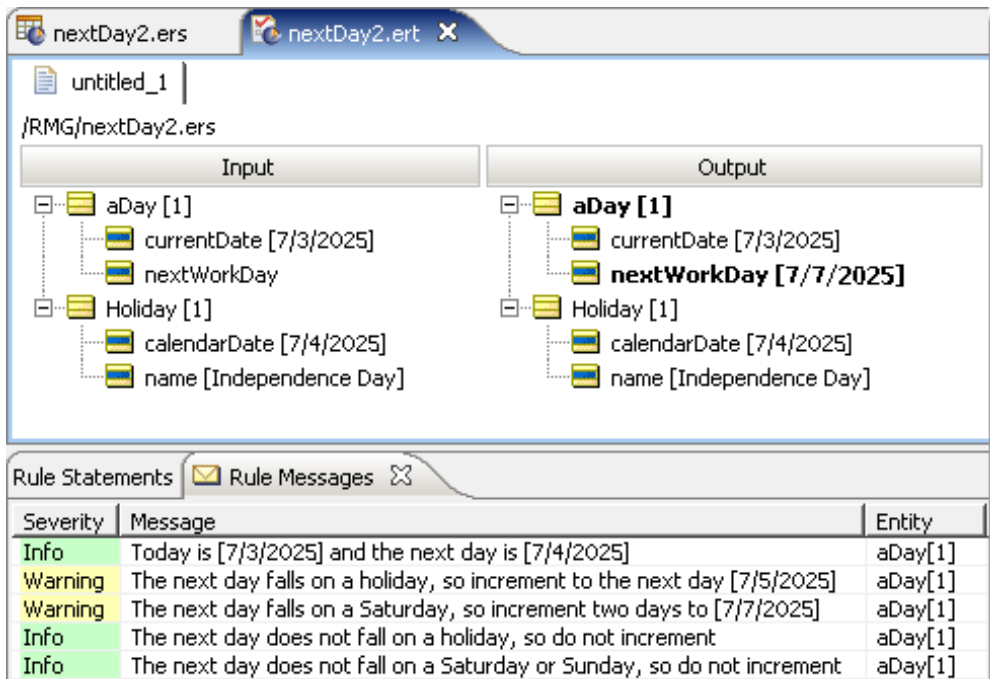
Now that we fully understand the looping logic present in our Rulesheet, let's create a Ruletest to verify that the loops operate as intended and produce the correct business results.

Figure 152: Ruletest for Holiday Rules



Given that July 4th, 2025 falls on a Friday, we expect `nextWorkDay` to contain a final value of July 7th, 2025 – a Monday – when the loops terminate. When we run the Ruletest, we see the following:

Figure 153: Ruletest for Holiday Rules



As you can see, we got the result we wanted...a three-day weekend!

Remove duplicated children in an association

Problem

For a `Customer`→`Address` association (one-to-many), each address must be unique.

Solution

Compare every address associated with a customer with every other address associated with that customer, and -- when a match is found -- remove (or mark) one of the addresses.

The following example compares ALL pairs of addresses that meet a filter condition. That process occurs in no specific order so you might notice that one run starts with address 4 and address 2 ($id=1 < id=4$), yet the next time it runs, it might start with address 3 and address 1 ($id=2 < id=3$). So the results might seem different. However, all that is required is that only **one** of each unique address survive.

To assure that we can control the filtering process, we need unique identifier attribute values to distinguish the instances. If the address already has an attribute that is a unique identifier, then you could use that in the filter; otherwise we need to create a transient, integer attribute, `id`, in the `Address` entity in the Vocabulary:

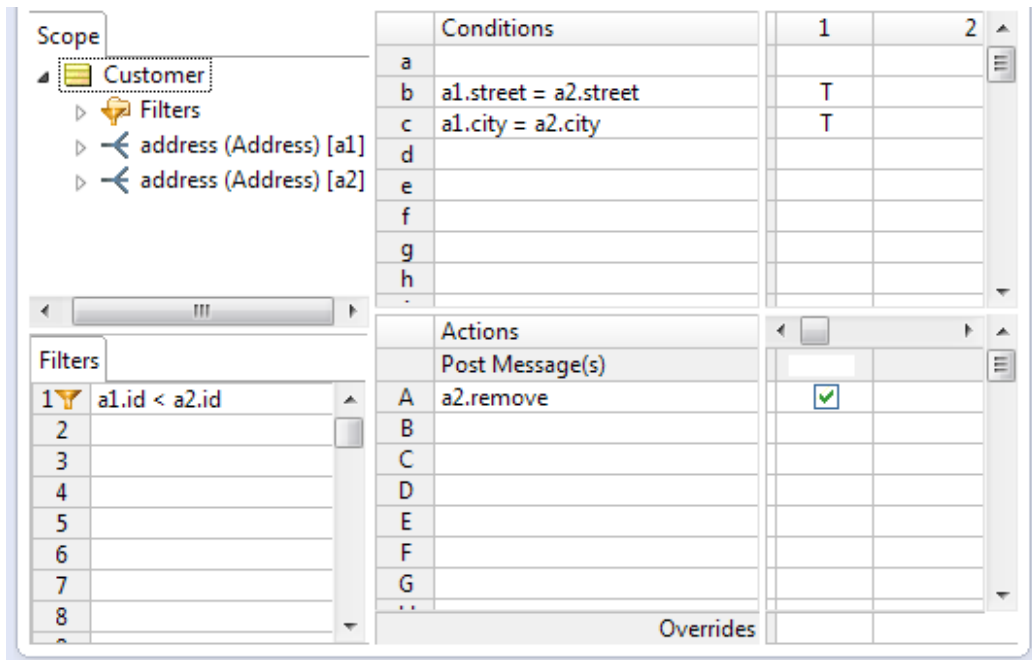
Property Name	Property Value
Attribute Name	id
Data Type	Integer
Mandatory	No
Mode	Transient

Using our created identifier attribute, we create a Rulesheet to identify each unique address. It uses two aliases to run through the addresses associated with a given customer. The actions initialize the `id`, and then add an incremented `id` value to each associated `Address` in memory:

Conditions	0
a	
b	
c	
d	
e	

Actions	0
Post Message(s)	
A any.id	0
B any.id = all.id -> max+1	<input checked="" type="checkbox"/>
C	
D	

Once each address has a unique identity, the second Rulesheet will do the removal action. It iterates through the associations to identify whether an association has a match, and -- if it does -- to remove the matching association from memory, as shown:



A Ruleflow puts the two Rulesheets into sequence, as shown:



A Ruletest that uses this Ruleflow as the test subject shows the "survivors" in its output:

Input	Output
<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> address (Address) [1] <ul style="list-style-type: none"> city [city1] street [street1] address (Address) [2] <ul style="list-style-type: none"> city [city1] street [street1] address (Address) [3] <ul style="list-style-type: none"> city [city2] street [street2] address (Address) [4] <ul style="list-style-type: none"> city [city1] street [street1] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> address (Address) [3] <ul style="list-style-type: none"> city [city2] id [4] street [street2] address (Address) [4] <ul style="list-style-type: none"> city [city1] id [1] street [street1]

After this processing is done, subsequent Rulesheets in the Ruleflow will see only unduplicated addresses for each customer.

Note: Rule Statements were not requested for this process. As we are actually removing the duplicates during the execution of the rule, each removed address has been dropped from memory, and no longer has a meaningful reference when statement message is generated.

Flagging duplicate children

You might want to identify the duplicated records rather than delete them. To do so, just uncheck (or delete) the `.remove` action, and add an appropriate `.comment` value to the address. This examples uses, 'Duplicate', as shown:

The screenshot shows the Rule Modeler interface with the following configuration:

- Scope:** Customer
 - Filters
 - address (Address) [a1]
 - address (Address) [a2]
- Filters:**
 - 1 a1.id < a2.id
 - 2
 - 3
 - 4
 - 5
 - 6
 - 7
 - 8
- Conditions:**

	Conditions	1	2
a			
b	a1.street = a2.street	T	
c	a1.city = a2.city	T	
d			
e			
f			
g			
h			
- Actions:**

	Actions	1	2
Post Message(s)			
A	a2.remove		
B	a2.comment		'Duplicate'
C			
D			
E			
F			
G			
..			

When the same Ruletest runs, this time shows all the input records, with duplicated records displaying their comment value:

The screenshot shows the Input and Output trees for the rule execution:

- Input:**
 - Customer [1]
 - address (Address) [1]
 - city [city1]
 - street [street1]
 - address (Address) [2]
 - city [city1]
 - street [street1]
 - address (Address) [3]
 - city [city2]
 - street [street2]
 - address (Address) [4]
 - city [city1]
 - street [street1]
- Output:**
 - Customer [1]
 - address (Address) [1]
 - city [city1]
 - comment [Duplicate]
 - id [3]
 - street [street1]
 - address (Address) [2]
 - city [city1]
 - comment [Duplicate]
 - id [4]
 - street [street1]
 - address (Address) [3]
 - city [city2]
 - id [2]
 - street [street2]
 - address (Address) [4]
 - city [city1]
 - id [1]
 - street [street1]

Note: Again, Rule Statements were not used. There are in fact three duplicates – address 4 and address 1, address 4 and address 2, address 1 and address 2 – so three messages (referencing 1, 4, and 4) would be generated since all of the addresses are still in memory. Two get marked as duplicates, and one survives. In a subsequent Rulesheet, you could delete all addresses that have been flagged as 'Duplicate'.

How to use conditions as a processing threshold

We want to distinguish looping, which involves revisiting, re-evaluating, and possible re-firing rules, and which requires you to enable one of the looping modes discussed above, from another behavior that may appear similar on the surface.

You have almost certainly noticed Corticon's inherent ability to process multiple test scenarios at once. For example, a rule written using the Vocabulary term `Cargo.weight` will be evaluated (and potentially fired) for every instance of `Cargo` encountered during execution. If a Ruletest contains 4 `Cargo` entities, then the rule engine will test the rule's conditions with each of them. If any of the `Cargo` entities satisfy the rule's conditions, then the rule will fire. This could mean that the rule fires once, twice, or up to four times, depending on the actual data values of each `Cargo`. We know from our prior discussion of Scope that a rule will evaluate *all* data that shares the same scope as the rule itself.

This iterative behavior is a natural part of the Corticon rule engine design – there's nothing special we need to do to enable it or “turn it on”. Note, that this behavior is different from the modes of looping discussed above because the `Cargo.weight` rule is not re-evaluated for a given piece of data. Rule execution is still single-pass. It is just that it makes a single pass through *each* of the 4 `Cargo` entities.

The advantage of this natural iteration is that we don't need to force it – the rule engine will automatically process all data that shares the same scope as the rule. If the Ruletest contains 4 `Cargos`, the rule will be evaluated 4 times. If the Ruletest contains 4000 `Cargos`, the rule will be evaluated 4000 times. We don't write the rule any differently in Corticon Studio.

But this advantage can also be a disadvantage. What if we *want* rule execution to stop part-way through its evaluation of a given set of entity data (which we call a “binding”). What if, after finding a `Cargo` that satisfies the rule among the set (binding) of `Cargo` entities, we want to *stop* evaluation mid-stream? In normal operation, this is not possible.

Here's a simple example.

Figure 154: Rulesheet and Ruletest, no threshold condition, CaPT disabled

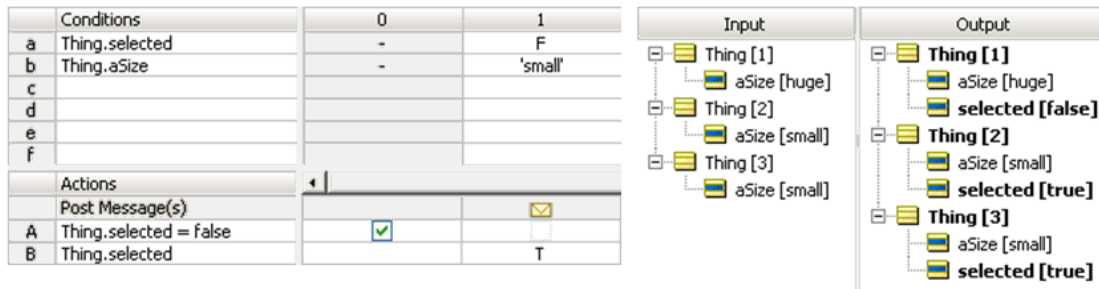
	Conditions	0	1
a	Thing.aSize	-	'small'
b			
c			
d			
e			
f			
Actions			
	Post Message(s)		
A	Thing.selected		T

Input	Output
Thing [1] aSize [huge]	Thing [1] aSize [huge]
Thing [2] aSize [small]	Thing [2] aSize [small] selected [true]
Thing [3] aSize [small]	Thing [3] aSize [small] selected [true]

In the example above, no threshold condition, CaPT disabled, we see a simple rule that sets `thing.selected = true` for all `thing.aSize = 'small'`. Notice in the adjacent Ruletest, that each small `Thing` is selected. `Thing[2]` and `Thing[3]` are both small, so they are both selected by the rule. The rule has evaluated all three `Things`, but finding only two that satisfy the rule's condition, only fires twice. This iteration happened automatically.

What if we wanted rule execution to stop after finding the first `Thing` that satisfies the rule? In other words, allow the rule engine to fire for `Thing[2]` but stop processing *before* firing for `Thing[3]`. Is that possible? You might think the following Rulesheet would accomplish this goal.

Figure 155: Rulesheet and Ruletest, threshold condition added, CaPT disabled



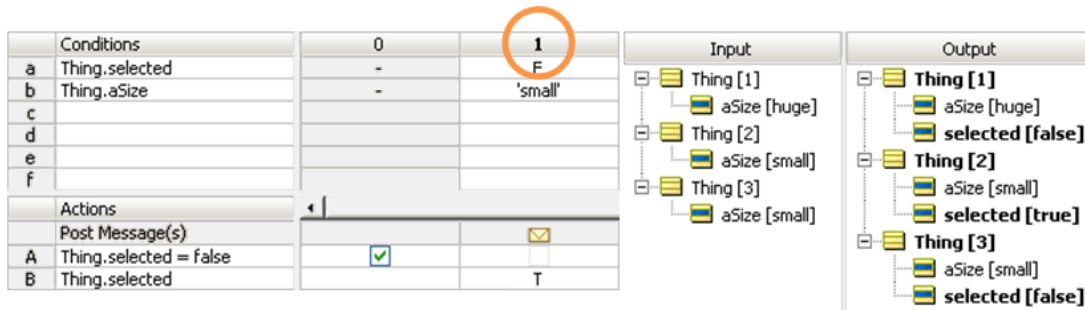
The example in this figure includes two changes: 1) `Thing.selected` is defaulted to `false` in the Nonconditional rule (Action row A0). And 2) a second Condition row checks for `Thing.selected = false` as part of rule 1. This is called a “threshold” condition.

You might be tempted to think that when `Thing[2]` fires the rule, its value of `selected` (re-set to `true`) would be sufficient to stop further evaluation and execution of `Thing[3]`. But as we see in the adjacent Ruletest, that this isn't the case. The reason is that `Thing[3]` is an entirely separate entity within the binding, and is entitled to its own evaluation of rule 1 regardless of what happened with `Thing[2]`. The addition of the threshold condition accomplished nothing.

A special feature in Corticon Studio, called **Use Condition as Processing Threshold** (abbreviated as CaPT), allows us to interrupt processing of the binding. You activate this option by selecting the rule column involved, then from the Corticon Studio menu bar, choose **Rulesheet > Rule Columns(s) > Use Condition as Processing Threshold**.

Once selected, CaPT causes the rule column header to display in bold type, as shown below, circled in orange:

Figure 156: Rulesheet and Ruletest, threshold condition added, CaPT enabled



When CaPT is activated, it breaks out of the automatic binding iteration whenever an instance in the binding fails to satisfy the threshold condition. In this case, `Thing[2]`, having just fired rule 1, no longer satisfies the threshold condition, and causes rule execution to stop before evaluating `Thing[3]`. If we re-ran this Ruletest, we might see `Thing[3]` evaluated first, in which case rule execution would stop before evaluating `Thing[2]`.

Within a binding, sequence of evaluation of elements is *random* and may change from execution to execution. There is nothing about the binding that enforces an order or sequence among the bound elements.

Test Yourself questions for Rule dependency chaining and looping

Note: Try this test, and then go to [Test Yourself answers for Rule dependency and inferencing](#) on page 340 to correct yourself.

1. What is the main difference between inferencing and looping?
2. A loop that does not end by itself is known as an _____ loop.
3. A loop that depends logically on itself is known as a single-rule or _____ loop.
4. True or False. The **Check for Logical Loops** tool in Corticon Studio will always find mutual dependencies in a Rulesheet if they are present.
5. True or False. The **Check for Logical Loops** tool in Corticon Studio can fix inadvertent loops.

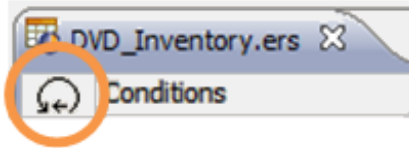
Referring to the following illustration, answer questions 6 through 8.

Conditions		0	1	2
a	DVD.priceTier		'High'	'Medium'
b	DVD.quantityAvailable		> 100000	-
c	DVD.releaseDate > today.addMonths(-6)		-	T
d				

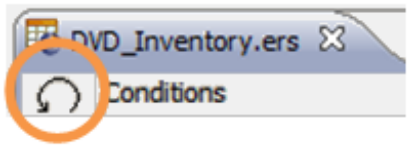
Actions				
Post Message(s)			✉	✉
A	DVD.priceTier		'Medium'	
B	DVD.quantityAvailable += 25000			☑

Ref	ID	Post	Alias	Text
1		Warning	DVD	If DVD price tier is High and > 100,000 copies are available, change price tier to medium to decrease inventory
2		Info	DVD	If DVD price tier is Medium and DVD < 6 months old, then increase inventory by 25,000 copies to meet expected demand

6. Given these two rules, is it necessary for the Rulesheet to use the Inferencing mode shown? Why or why not?
7. Is there any potential harm in having this Rulesheet configured to Advanced Inferencing with Self-Triggering? Why or why not?
8. If the Rulesheet as shown above were tested with a DVD having a price tier of `High`, quantity available of 150,000, and release date within the past 6 months, what would be the outcome of the test?
9. This icon indicates which type of inferencing is enabled for this Rulesheet?



10. This icon indicates which type of inferencing is enabled for this Rulesheet?



11. A _____ determines the sequence of rule execution and is generated when a Rulesheet is _____.

Filters and preconditions

Conditional expressions modeled in the **Filters** section of a Rulesheet can behave in two different ways: as filters alone or as filters *plus* preconditions. Both behaviors are explained and illustrated in this section.

Filters can be set to be [Database filters](#) on page 204 when its entity is defined to persist in a datastore and the entity is set to extend to database.

We refer to any conditional expression entered in the **Filters** window of a Rulesheet generically as a *filter*, regardless of its strict mode of behavior. This will help you differentiate the expression itself from its specific behaviors.

For details, see the following topics:

- [What is a filter](#)
- [What is a precondition](#)
- [How to use collection operators in a filter](#)
- [Filters that use OR](#)
- [TestYourself questions for Filters and preconditions](#)

What is a filter

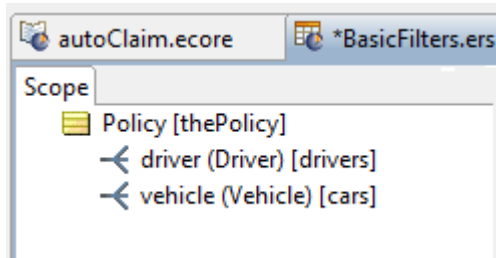
A Filter expression acts to limit or reduce the data in working memory to only that subset whose members satisfy the expression. A Filter *does not* permanently remove or delete any data; it simply *excludes* data from evaluation by other rules in the same Rulesheet.

We often say that data satisfying a Filter expression “survives” the Filter. Data that does not survive the Filter is said to be “filtered out”. Data that has been filtered out is *ignored* by other rules in the same Rulesheet.

A Filter expression, regardless of its full behavior, is unaffected by Filter expressions in other Rulesheets.

As an example, look at the Rulesheet sections shown in the following two figures:

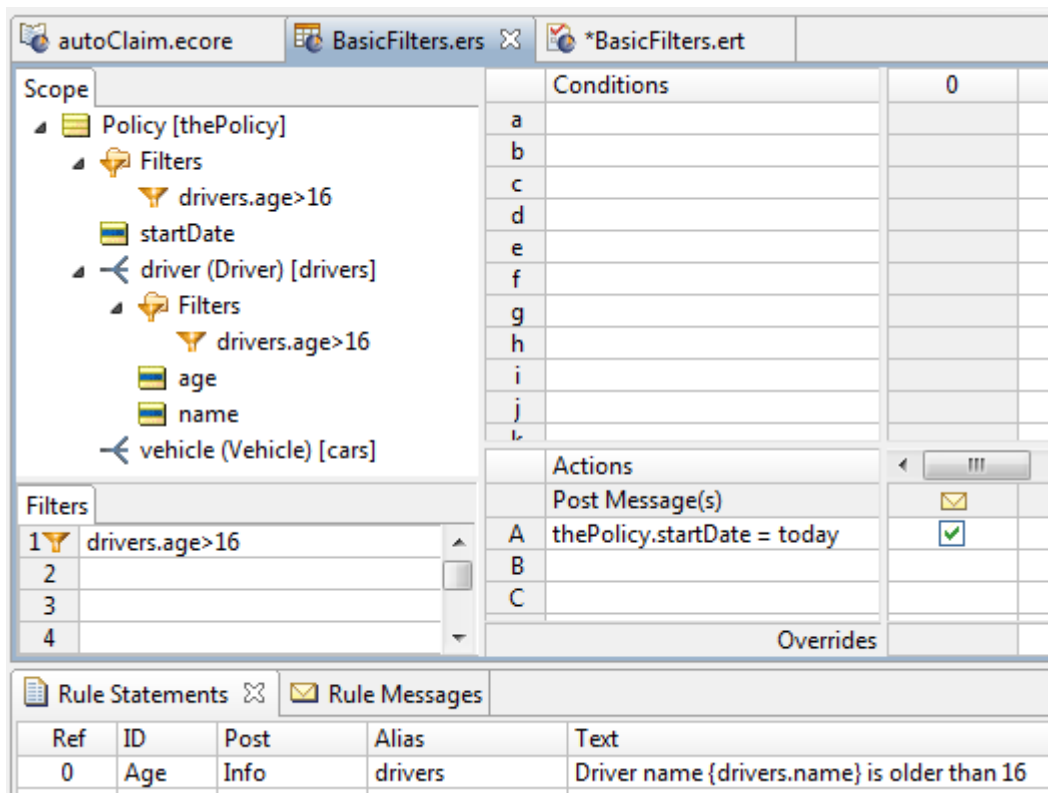
Figure 157: Aliases Declared



The **Scope** window in this figure defines aliases for a root-level `Policy` entity, a collection of `Driver` entities related to that `Policy`, and a collection of `Vehicle` entities related to that `Policy`, named `thePolicy`, `drivers`, and `cars`, in that order.

To start with, we will write a simple Filter and observe its default behavior. In the simple scenario below, the Filter expression reduces the set of data acted upon by the Nonconditional rule (column 0), which in this case merely posts the Rule Statement as a message.

Figure 158: Rulesheet to Illustrate Basic Filter Behavior



Our result is not unexpected: for every element in the collection (every `Driver`) whose `age` attribute is greater than 16, we see a posted message in the Ruletest, as shown below:

Figure 159: Ruletest to test Filter Behavior

The screenshot shows a software interface with several tabs: 'autoClaim.ecore', '*BasicFilters.ers', and '*BasicFilters.ert'. The main window is titled 'untitled_1' and shows a tree view of a policy structure. The path is '/Training/Advanced/BasicFilters.ers'. The tree is divided into 'Input' and 'Output' columns.

Input	Output
<ul style="list-style-type: none"> Policy [1] <ul style="list-style-type: none"> startDate driver (Driver) [1] <ul style="list-style-type: none"> age [18] name [Jacob] driver (Driver) [2] <ul style="list-style-type: none"> age [14] name [John] driver (Driver) [3] <ul style="list-style-type: none"> age [21] name [Lisa] 	<ul style="list-style-type: none"> Policy [1] <ul style="list-style-type: none"> startDate [03/25/13] driver (Driver) [1] <ul style="list-style-type: none"> age [18] name [Jacob] driver (Driver) [2] <ul style="list-style-type: none"> age [14] name [John] driver (Driver) [3] <ul style="list-style-type: none"> age [21] name [Lisa]

Below the tree view, there are two tabs: 'Rule Statements' and 'Rule Messages'. The 'Rule Messages' tab is active, showing a table with two rows of messages:

Severity	Message
Info	Driver name Lisa is older than 16
Info	Driver name Jacob is older than 16

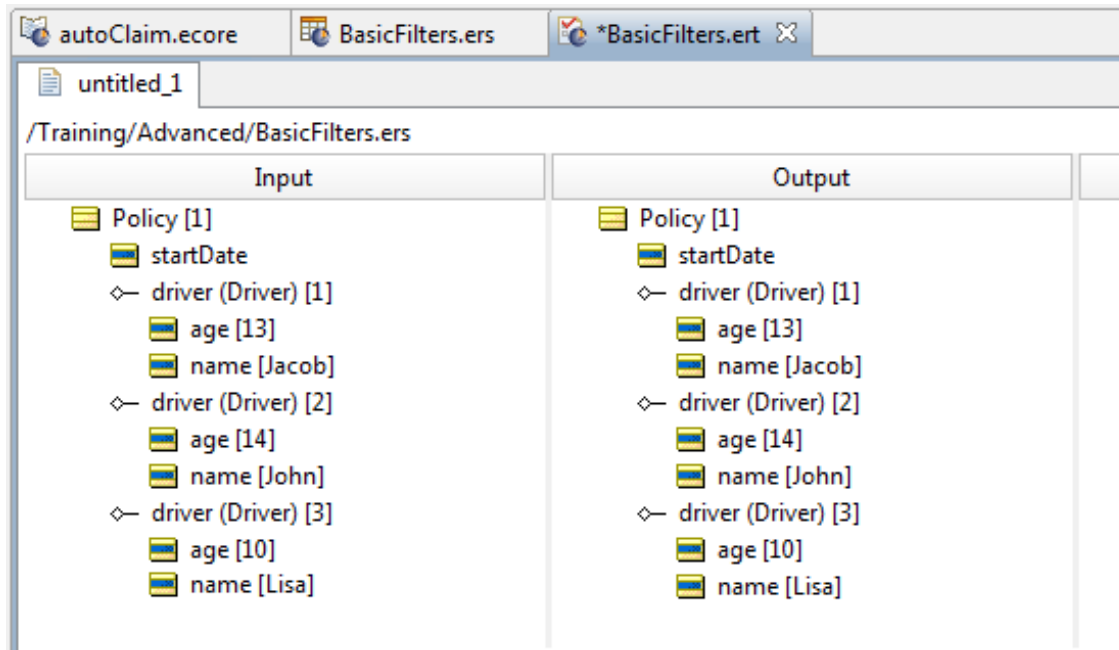
The policy is issued because there are drivers over 16. But because only `Jacob` and `Lisa` are older than 16, Rule Messages are posted only for them.

Full filters

By default, each Filter you write acts as a *full* filter. This means not only will the data not satisfying the Filter be filtered out of subsequent evaluations, but in cases where this data is a collection where no elements survive the Filter, *the parent entity will also be filtered out!*

Here is the Testsheet with three juvenile drivers:

Figure 160: Ruletest for Full Filter

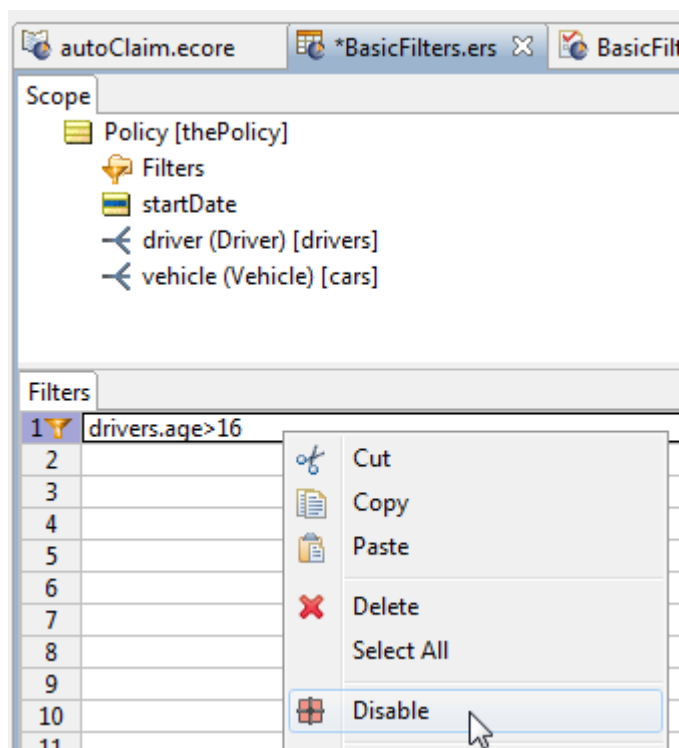


Notice two important things about this Ruletest's results: first, none of the `Driver` entities in the Input are older than 16, which means none of them survives the Filter. Second, because the parent `Policy` entity does not contain at least one `Driver` which satisfies the Filter, then the parent `Policy` itself also fails to survive the Filter. If no `Policy` entity survives the Filter, then rule Column 0 has no data upon which to act, so no `Policy` is assigned a `startDate` equal to `today`. The Testsheet's Output, shown in the figure above, confirms the behavior.

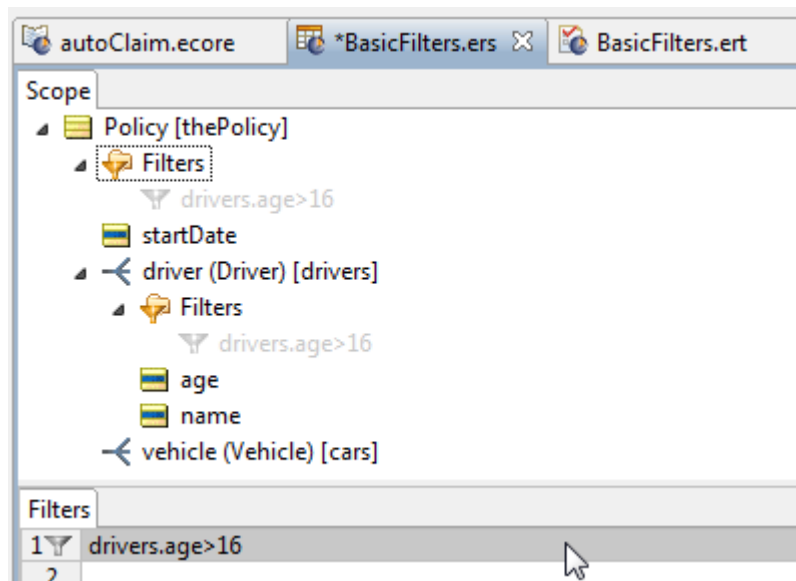
Why would we want a Filter to behave this way? Perhaps because, if these are the only drivers seeking a policy, there must be at least one driver of legal age to warrant issuing a policy. While you will probably find that the full filter behavior is generally what you want when filtering your data, it might be too strict in other situations. If other rules on the Rulesheet act or operate on `Policy`, then a maximum filter gives you a very easy way to specify and control *which* `Policy` entities are affected.

Disabling a Full Filter

In testing you will find times when you might want to remove one filter. Instead of deleting the filter, you can simply *disable* it by right-clicking the rule and then choosing **Disable**, as shown:



Once disabled all applications of the filter are rendered in gray, as shown:



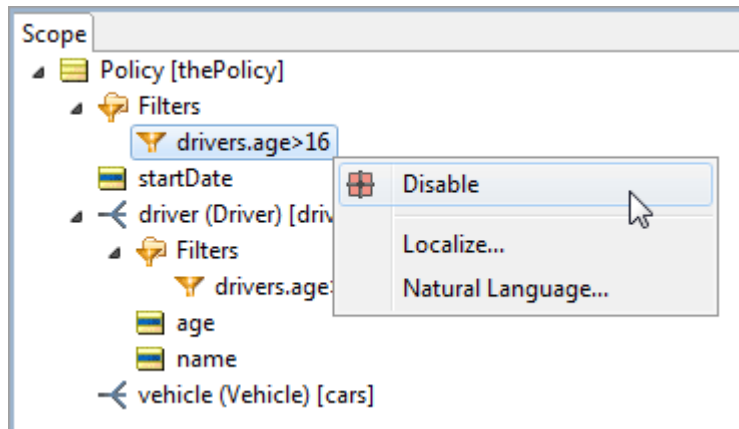
A disabled full filter is really no filter at all. You can perform the corresponding action to again **Enable** the filter.

Limiting filters

There are occasions, however, when the all-or-nothing behavior of a full Filter is unwanted because it is too strong. In these cases, we want to apply a Filter to specified elements of a collection but still keep the selected entities even if none of the children survive the Filter.

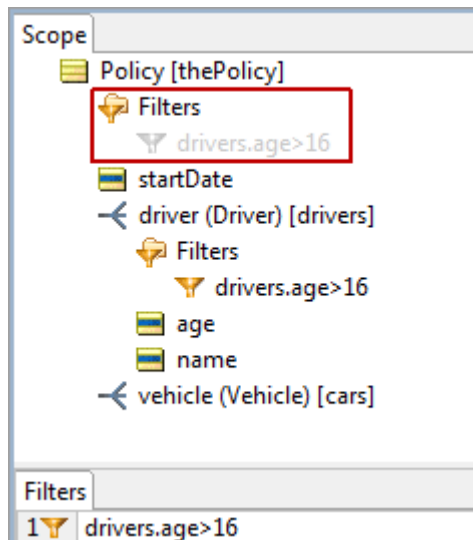
To turn a Filter expression into a limiting Filter, right-click on a Filter in the scope section and select **Disable** from the menu, as shown:

Figure 161: Selecting to limit a filter



This causes that specific filter position to no longer apply, indicated in gray:

Figure 162:



Notice that the filter is still enabled, and that it will still be applied at the `Driver` level. We have **limited** the filter.

Use case for limiting filters

The preceding example was basic. Let's explore some more complex examples of limited filters.

Consider the case where there is a rule component designed to process customers and orders.

A Customer has a 1 to many relationship with an Order.

The rule component has 2 objectives, one to process customers and the second to process orders.

If we define a filter that tests for a GOLD status on an order, we can have four logical iterations of how the filter could be applied to the ruleset.

- Case 1: filter is not applied at all.
- Case 2: filter is applied to all customers and all orders.
- Case 3: filter is only applied to customers.

Case 4: filter is only applied to orders.

A business statement for these cases could be as follows:

Case 1: Process all customers and all orders.
 Case 2: Process only GOLD status orders and only customers that have a GOLD status order.
 Case 3: Process only customers that have a GOLD status order and all orders of a processed customer.
 Case 4: Process all customers and only GOLD status orders.

For filter modeling, the filter expression could be written as `Customer.order.status = 'GOLD'` The modeling consideration for the cases are:

Case 1: Filter is not entered (or filter disabled, or filter disabled at both Customer and Customer.order levels in the scope).
 Case 2: Filter is entered with no scope modifications (enabled at both Customer and Customer.order levels in the scope).
 Case 3: Filter is entered and then disabled at the Customer.order level in the scope.
 Case 4: Filter is entered and then disabled at the Customer level in the scope.

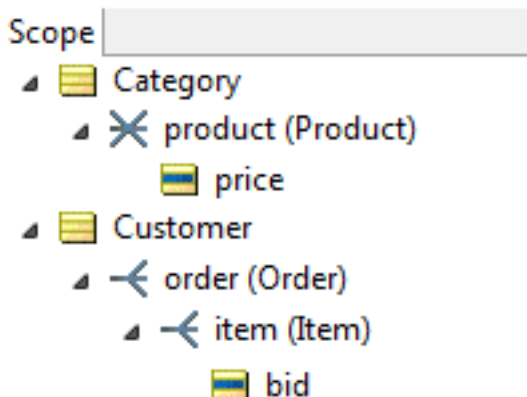
You see how one filter can apply limits to the full filter to achieve the preferred profile of what survives the filter and what gets filtered out.

Next, let's look at more complex set of limiting filters.

Example of limiting filters

Consider the following Rulesheet Scope of a Vocabulary:

Figure 163: Scope in a Rulesheet that will be filtered

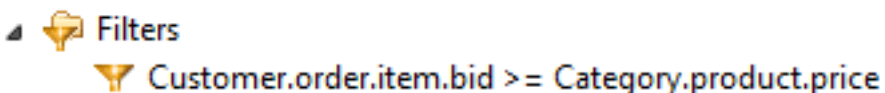


Consider the filter to be applied to data:

```
Customer.order.item.bid >= Category.product.price
```

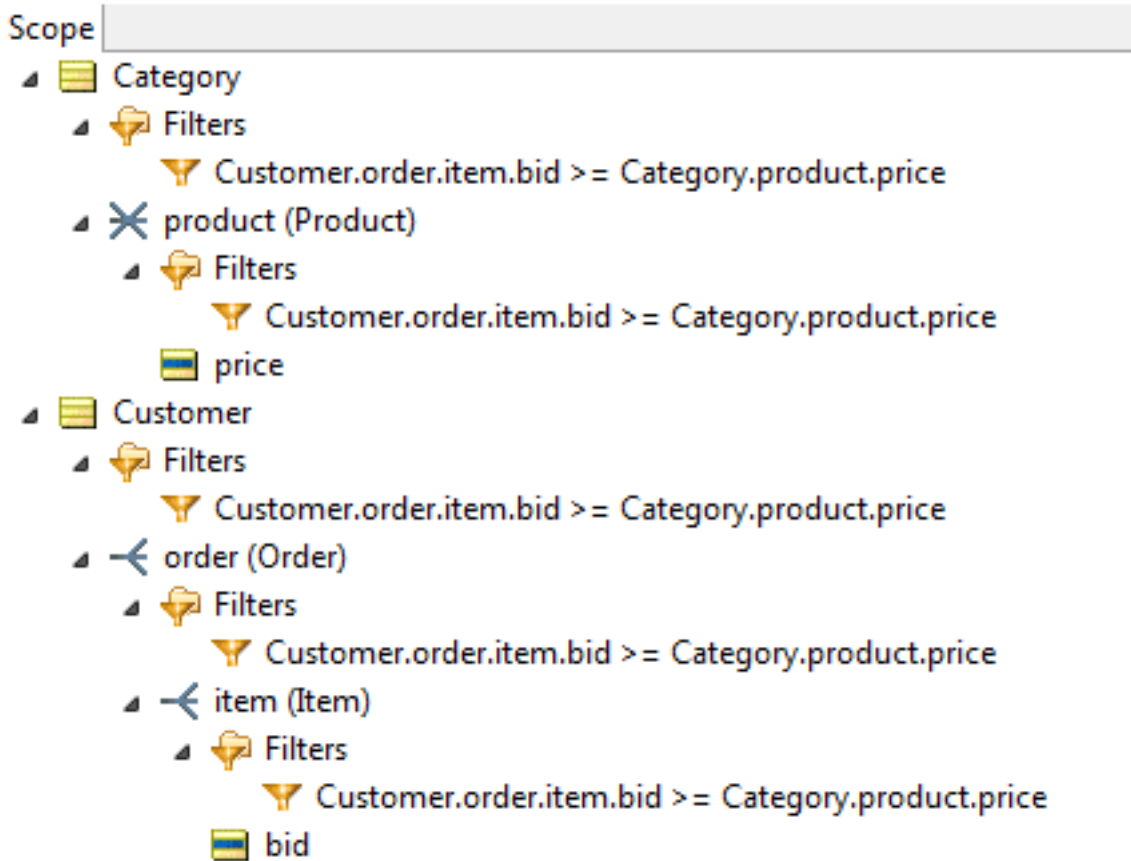
This is shown in the Rulesheet's **Filters** section as:

Figure 164: Definition of a filter



The resulting filter application applies at several levels, as shown:

Figure 165: Application of the filter to the Scope's tree structure



A Ruletest Testsheet might be created as follows:

This data tree contains five entity types (Customer, Order, Item, Category, Product).

This filter is evaluated as follows:

```
Customer[1],Order[1],Item[1],Category[1],Product[1] false
Customer[1],Order[1],Item[1],Category[1],Product[2] true
Customer[1],Order[1],Item[1],Category[2],Product[2] true
Customer[1],Order[1],Item[1],Category[2],Product[3] true
Customer[1],Order[1],Item[1],Category[3],Product[1] false
Customer[1],Order[1],Item[2],Category[1],Product[1] false
Customer[1],Order[1],Item[2],Category[1],Product[2] false
Customer[1],Order[1],Item[2],Category[2],Product[2] false
Customer[1],Order[1],Item[2],Category[2],Product[3] false
Customer[1],Order[1],Item[2],Category[3],Product[1] false
Customer[1],Order[2],Item[3],Category[1],Product[1] false
Customer[1],Order[2],Item[3],Category[1],Product[2] false
Customer[1],Order[2],Item[3],Category[2],Product[2] false
Customer[1],Order[2],Item[3],Category[2],Product[3] true
Customer[1],Order[2],Item[3],Category[3],Product[1] false
Customer[2],Order[3],Item[5],Category[1],Product[1] false
Customer[2],Order[3],Item[5],Category[1],Product[2] false
Customer[2],Order[3],Item[5],Category[2],Product[2] false
Customer[2],Order[3],Item[5],Category[2],Product[3] false
Customer[2],Order[3],Item[5],Category[3],Product[1] false
```

The tuples that evaluate to true are:

```
Customer[1],Order[1],Item[1],Category[1],Product[2]
Customer[1],Order[1],Item[1],Category[2],Product[2]
Customer[1],Order[1],Item[1],Category[2],Product[3]
Customer[1],Order[2],Item[3],Category[2],Product[3]
```

The entities that survive the filter are:

```
Customer[1]
Customer[1],Order[1]
Customer[1],Order[2]
Customer[1],Order[1],Item[1]
Customer[1],Order[2],Item[3]
Category[1]
Category[2]
Category[1],Product[2]
Category[2],Product[2]
Category[2],Product[3]
```

The Scope section of the Rulesheet expands as follows:

Notice how the filter is applied towards each discrete entity referenced in the expression:

- When the filter is applied to `Customer`, then the survivor of the filter is `Customer[1]`, if not applied then `{Customer[1], Customer[2]}` survive the filter.
- When the filter is applied to `Customer.order` then the surviving tuples are `{Customer[1], Order[1]}` and `{Customer[1], Order[2]}`. When **not** applied then it is the same (because there was no `Order` child of `Customer[1]` that did not survive the filter).
- When the filter is **not** applied at the `Customer` level as well as the `Customer.order` level, then all `Customer.order` tuples survive the filter with result `{Customer[1], Order[1]}`, `{Customer[1], Order[2]}`, `{Customer[2], Order[3]}`
- When the filter is applied to `Customer.order.item` then the surviving tuples are `{Customer[1], Order[1], Item[1]}` and `{Customer[1], Order[2], Item[3]}`. When not applied

(at this level but at higher levels) then the surviving tuples will be {Customer[1],Order[1],Item[1]}, {Customer[1],Order[1],Item[2]}, {Customer[1],Order[2],Item[3]}

- When the filter is applied to `Category` then the surviving entities are `Category[1]`, `Category[2]`. When **not** applied then `Category[1]`, `Category[2]`, `Category[3]`.
- When the filter is applied to the `Category.product` level then the surviving tuples will be {`Category[1]`, `Product[2]`}, {`Category[2]`, `Product[2]`}, {`Category[2]`, `Product[3]`}

You see how a filter applied (at each level) determines which entities are processed when a rule references a subset of the filter's entities. With the *limiting filters* feature, the filter may or may not be applied to each entity referenced by the filter.

Database filters

When a Vocabulary has elected to have an EDC Datasource, setting an entity's **Datastore Persistent** property to **Yes** declares that the entity will map to a table in the Datasource. A database cylinder decorates the icons of the entity and its attributes, as shown:

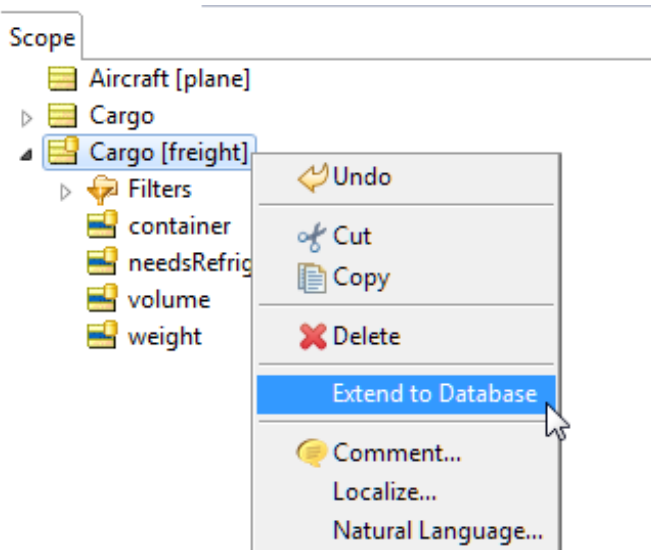
The screenshot shows a tree view on the left with the following structure:

- Cargo
 - Aircraft
 - Cargo (selected)
 - container
 - manifestNumber
 - needsRefrigeration
 - volume
 - weight
 - flightPlan (FlightPlan)
 - FlightPlan

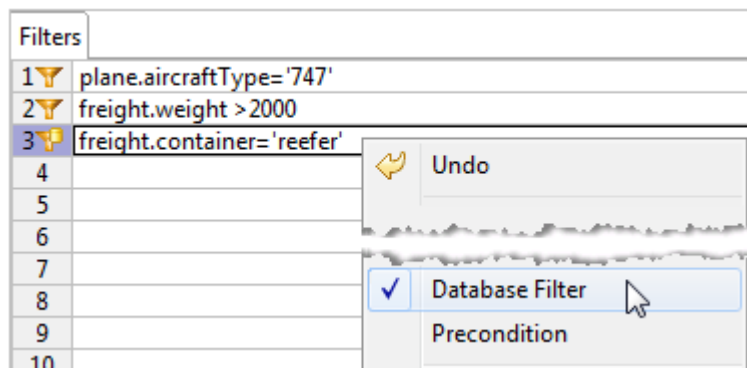
The right panel shows the 'Basic Properties' and 'EDC Datasource Properties' for the selected 'Cargo' entity. The 'Datastore Persistent' property is highlighted in orange.

Basic Properties	
Property Name	Property Value
Entity Name	Cargo
Inherits From	
EDC Datasource Properties	
Entity Identity	
Datastore Persistent	Yes
Table Name	
Datastore Caching	
Identity Strategy	
Identity Column Name	
Identity Sequence	
Identity Table Name	
Identity Table Name Column Name	
Identity Table Value Column Name	
Version Strategy	
Version Column Name	

Once that is set, right-clicking on a Entity's alias in a Rulesheet's Scope section presents the menu command to **Extend to Database**, as shown:



Then you can define filters and set them each as a **Database Filter**, as shown:



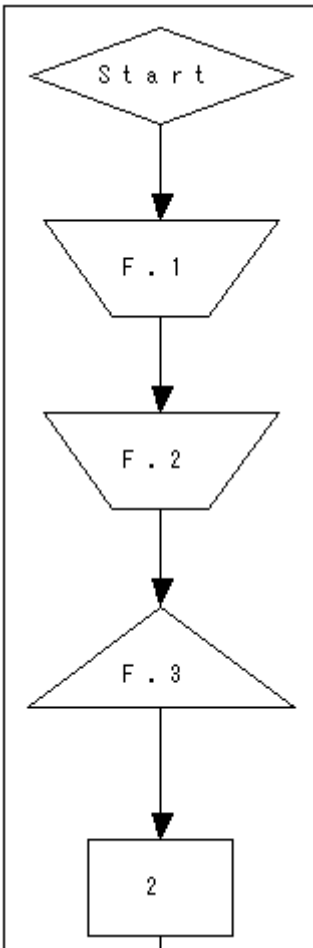
When checked, the filter becomes a *database query* that will retrieve data from the connected database, and then add the retrieved data to working memory.

When the option is cleared, the filter is applied only to data currently in working memory.

Note: See [Precondition and filters as query filters](#) on page 240 for qualifications and supported operators.

Database filters in an execution sequence diagram

When you choose **Rulesheet > Logical Analysis > Execution Sequence Diagram**, the graphic that is generated distinguishes a database filter from local filter by its shape:



In this example, **F.1**, the database query, is displayed within a triangle while **F.2**, the local filter, is displayed within an inverted trapezoid (a quadrilateral with parallel horizontal bases and legs that converge downward.)

Error Conditions

It is important to note that you could set a database filter on an entity that is not Datastore Persistent or extended to database, but if you do so, the filter is marked in red, as shown. The error notes that the filter cannot be processed by a database.

Scope

- Aircraft [plane]
 - Filters
 - plane.aircraftType='747'
 - aircraftType
 - Cargo [freight]
 - Filters
 - freight.weight > 2000
 - freight.container='reefer'
 - container

Filters

1	plane.aircraftType='747'
2	freight.weight > 2000
3	freight.container='reefer'

What is a precondition

If you're comfortable with the limiting and full behaviors of a Filter expression, then its precondition behavior is even easier to understand. While reading this section, keep in mind that *Filters always act as either limiting or full filters, but they can also act as preconditions* if you enable that behavior as described in this section. If you think of filtering as a *mandatory* behavior but a precondition as an extra, *optional* behavior, then you will be in good shape later. Also, it may be helpful to think of the precondition behavior, if enabled, taking effect *after* the filtering step is complete.

Precondition behavior of a Filter ensures that execution of a Rulesheet **stops** unless *at least one* piece of data survives the Filter. If execution of a Rulesheet stops because no data survived the Filter, then execution moves on to the next Rulesheet (in the case where the Rulesheet is part of a Ruleflow). If no more Rulesheets exist in the Ruleflow, then execution of the entire Ruleflow is complete.

In effect, a Filter with precondition behavior enabled acts as a “gatekeeper” for the entire Rulesheet - if no data survived the Filter, then the Rulesheet's “gate stays closed” and no additional rules on that Rulesheet will be evaluated or executed *no matter what*.

If however, data survived the Filter, then the “gate opens” and the surviving data can be used in the evaluation and execution of other rules on the same Rulesheet.

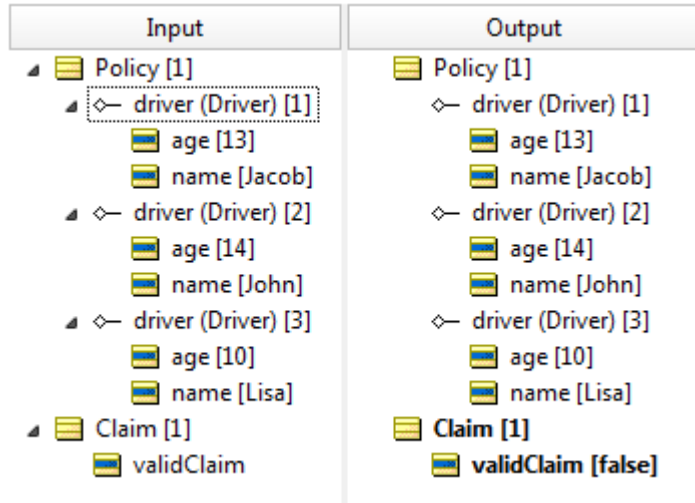
The precondition behavior of a Filter is significant because it allows us to control Rulesheet execution regardless of the scope used in the rules. Take for example the Rulesheet shown in the following figure. The Filter in row 1 is acting in its standard default mode of full filter. This means that `Driver` entities in the collection named `drivers` and the collection's parent entity `Policy` are both affected by this Filter. Only those elements of `drivers` older than 16 will survive, and at least one must survive for the parent `Policy` also to survive.

Figure 166: Input Rulesheet for Precondition

Scope	Conditions	
Claim	a	0
Policy [thePolicy]	b	
Filters	c	
drivers.age>16	d	
startDate	e	
driver (Driver) [drivers]	f	
vehicle (Vehicle) [cars]	g	
	h	
	i	
	j	
	k	
	l	
Filters	Actions	
1 drivers.age>16	Post Message(s)	
2	A Claim.validClaim	F
3	B	
4	C	
5	D	
6	Overrides	
7		
8		

But how does this affect the `Claim` in Nonconditional row A (of rule column 0)? `Claim`, as a root-level entity, is safely *outside of the scope* of our Filter, and therefore unaffected by it. Nothing the Filter does (or doesn't do) has any effect on what happens in Action row A – the two logical expressions are completely independent and unrelated. As a result, `Claim.validClaim` will always be `false`, even when none of the elements in `drivers` are older than 16. A quick Ruletest verifies this prediction:

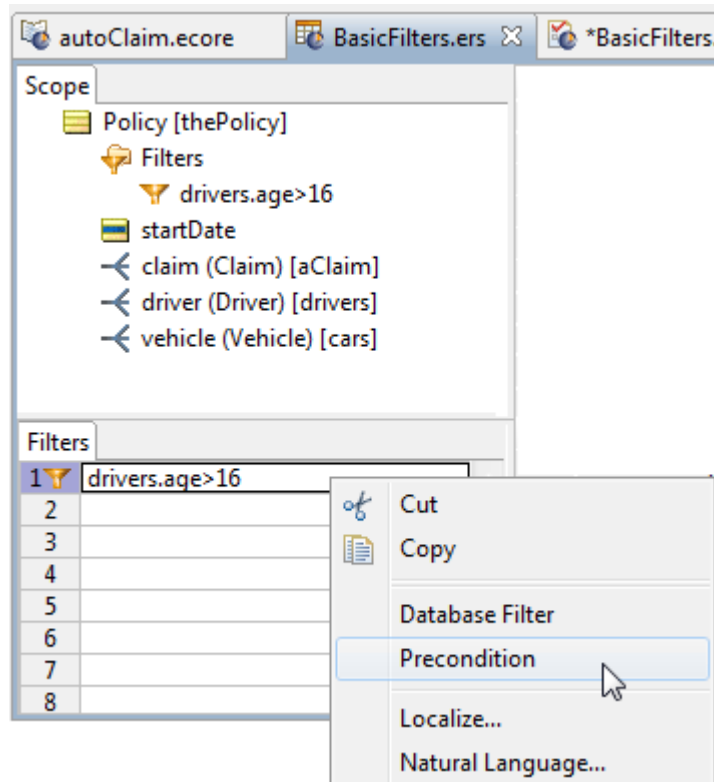
Figure 167: Rulesheet for an Action Unaffected by a Filter



But what if the business intent of our rule is to update `Claim` based on the evaluation of `Policy` and its collection of `Drivers`? What if the business intent *requires* that the `Policy` and `Claim` really be related in some way? How do we model this?

Using the same example as in above, right-click on Filter row 1 and select **Precondition**.

Figure 168: Selecting Precondition Behavior from the Filter Right-Click Popup Menu



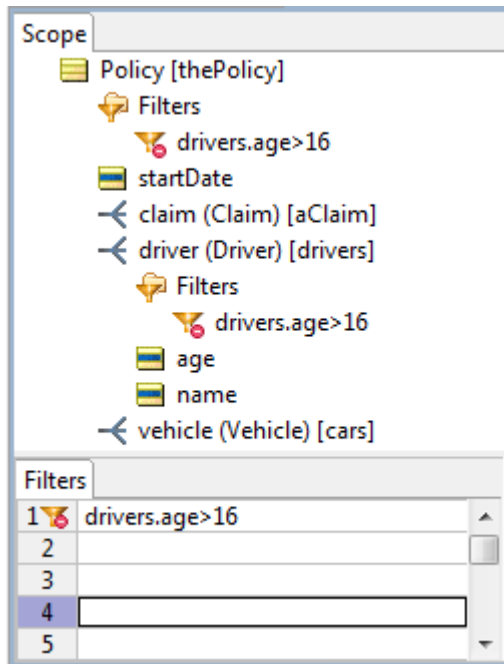
Note that the two options **Precondition** and **Limiting Filter** are mutually exclusive: turning one on turns the other off. A Filter cannot be both a Precondition AND a limiting Filter because at least one piece of data ALWAYS survives a limiting filter, so a Precondition would never stop execution.

Selecting **Precondition** causes the following:

- The yellow funnel icon in the **Filter** window receives a small red circle symbol
- The yellow funnel icons in the **Scope** window receive small red circle symbols

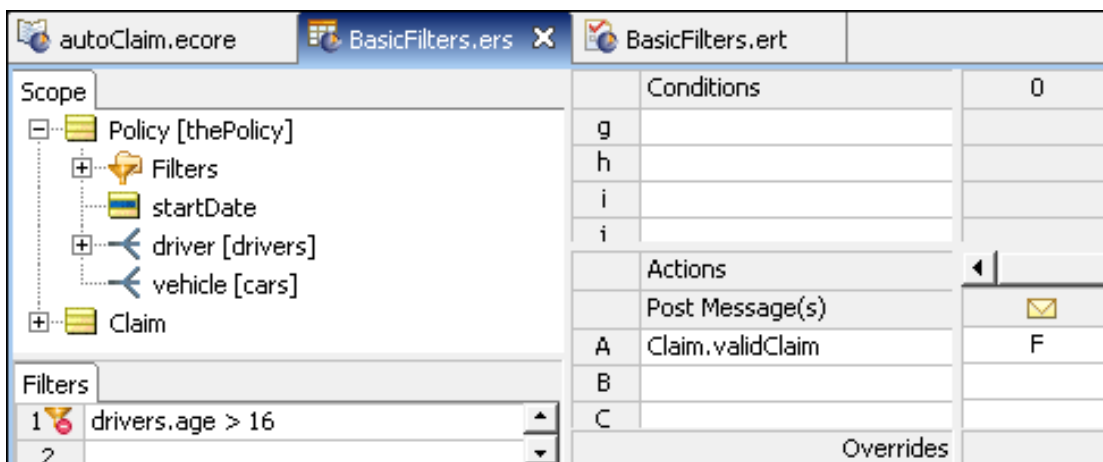
The following figure shows a Filter in **Precondition** mode.

Figure 169: A Filter in Precondition Mode



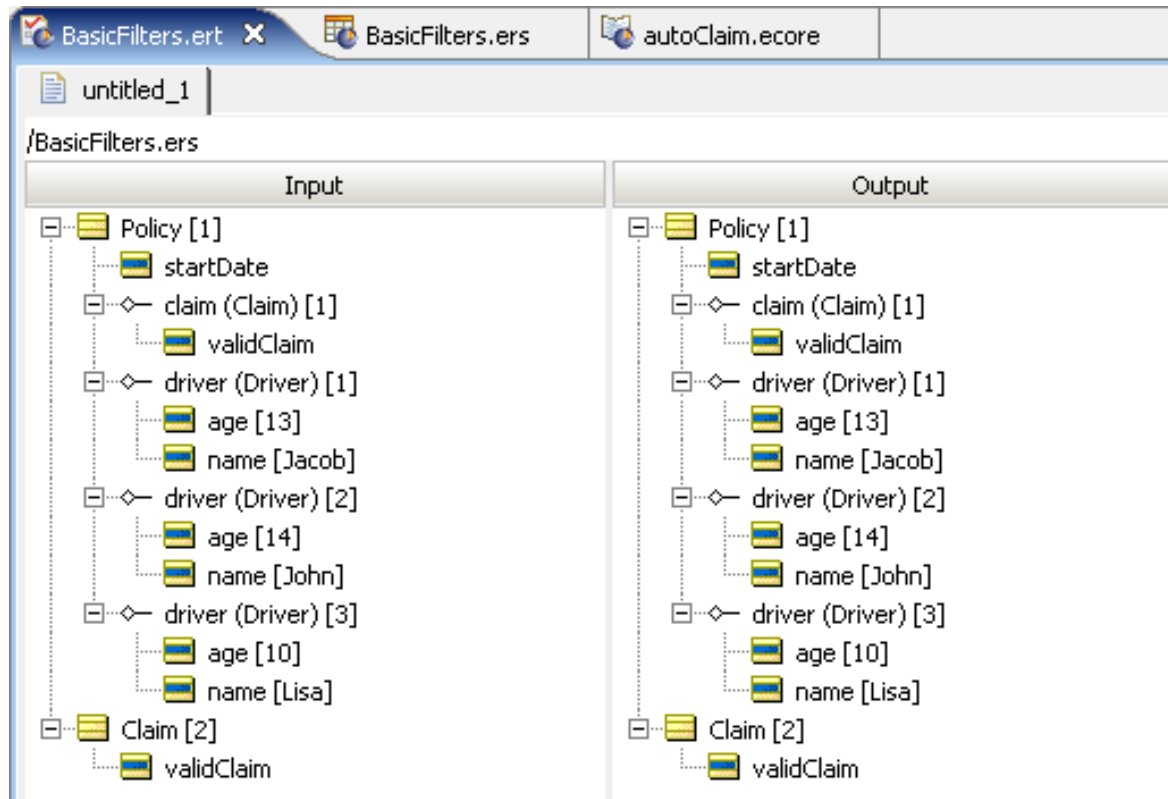
As described before, the precondition behavior of the Filter will cause Rulesheet execution to stop whenever no data survives the Filter. So in the original case where `Policy` and `Claim` were unassociated, a Filter in precondition mode, as shown:

Figure 170: Rulesheet with a Filter in Precondition Mode



accomplishes our business intent without artificially changing our Vocabulary or underlying data model. A final proof is provided in the following figure:

Figure 171: Testsheet for a Filter in Precondition Mode



Summary of filter and preconditions behaviors

- A Filter just reduces the available data for other rules in the Rulesheet to use. Filters produce shades of gray - all data, some data, or no data may result from a filter.
- A Filter in **Precondition** mode stops Rulesheet execution if no data survives the filter. Preconditions produce black and white results: either data survives the filter and the precondition allows Rulesheet execution to continue, or no data survives and the precondition forces Rulesheet execution to stop.
- Filter expressions always acts as a filter. By default, they act as filters *only*. If you also need true precondition behavior, then setting the Filter to **Precondition** mode will enable precondition behavior while keeping filter behavior.

Performance implications of the precondition behavior

A rule fires whenever data sharing the rule's scope exists that satisfies the rule's conditions. In other words, to fire any rule, the rule engine must first collect the data that shares the rule's scope, and then check if any of it satisfies the rule's conditions. So even in a Rulesheet where no rules actually fire, the rule engine may have still needed to work hard to come to that conclusion. And hard work requires time, even for a high-performance rule engine like Corticon has.

A Filter expression acting only as a filter never stops Rulesheet execution; it simply limits the amount of data used in rule evaluations and firings. In other words, it *reduces the set of data that is evaluated* by the rule engine, but it does not actually stop the rule engine's *evaluation* of remaining rules. Even if a filter successfully filters out all data from a given data set, the rule engine will still evaluate this empty set of data against the available remaining rules. Of course, no rules will fire, but the evaluation process still occurs and still takes time.

Filter expressions also acting as preconditions change this. Now, if no data survives the filter (remember, Filter expressions always act as filters even when also acting as preconditions) then Rulesheet execution stops in its tracks. No additional evaluations are performed by the rule engine. That Rulesheet is done and the rule engine begins working on the next Rulesheet. This can save time and improve engine performance when the Rulesheet contains many additional rules that would have been at least evaluated were the expression in filter-only mode (the default mode).

How to use collection operators in a filter

In the following examples, all Filter expressions use their default Filter-only behavior. As detailed in the [Rule Writing Techniques](#) topics, the logic expressed by the following three Rulesheets provides the same result:

Figure 172: A Condition/Action rule column with 2 Conditional rows

The screenshot shows a Rulesheet editor window titled "CollectionOperatorsInAFilter.ers". The interface is divided into several sections:

- Scope:** A tree view showing "Person [p]".
- Conditions:** A table with columns for condition ID (a, b, r) and their expressions (p.skydiver, p.age > 40).
- Filters:** A table with 4 rows. Row 1 is empty, row 2 is empty, row 3 is empty, and row 4 is empty.
- Actions:** A table with columns for action ID (A, B) and their expressions (p.riskRating).
- Overrides:** A table with columns for override ID and their expressions.
- Rule Statements:** A table with columns for Ref, ID, Post, Alias, and Text. Row 1 has Ref 1 and Text "A person over 40 who skydives is high risk".

Scope		Conditions		0	1
+	Person [p]	a	p.skydiver		T
		b	p.age > 40		T
		r			

Filters		Actions		0	1
1			Post Message(s)		
2		A	p.riskRating		'high'
3		B			
4		Overrides			

Ref	ID	Post	Alias	Text
1				A person over 40 who skydives is high risk

Figure 173: Rulesheet with one Condition row moved to Filters row

The screenshot shows a Rulesheet editor window titled "ConditionalMovedToPrecondition.ers". The interface is divided into several sections:

- Scope:** A tree view showing "Person [p]".
- Conditions:** A table with columns for condition ID (a, b, r) and their expressions (p.age > 40).
- Filters:** A table with 4 rows. Row 1 contains the filter expression "p.skydiver = T", row 2 is empty, row 3 is empty, and row 4 is empty.
- Actions:** A table with columns for action ID (A, B) and their expressions (p.riskRating).
- Overrides:** A table with columns for override ID and their expressions.
- Rule Statements:** A table with columns for Ref, ID, Post, Alias, and Text. Row 1 has Ref 1 and Text "A person over 40 who skydives is high risk".

Scope		Conditions		0	1
+	Person [p]	a	p.age > 40		T
		b			
		r			

Filters		Actions		0	1
1	p.skydiver = T		Post Message(s)		
2		A	p.riskRating		'high'
3		B			
4		Overrides			

Ref	ID	Post	Alias	Text
1				A person over 40 who skydives is high risk

Figure 174: Rulesheet with Filter and Condition rows swapped

Scope		Conditions		0	1
+ Person [p]		a	p.skydiver		T
		b			
		c			
Filters		Actions			
1	p.age > 40	Post Message(s)			
2		A	p.riskRating		'high'
3		B			
4		Overrides			
Rule Statements		Rule Messages			
Ref	ID	Post	Alias	Text	
1				A person over 40 who skydives is high risk	

Even though expressions in the Filters section of the Rulesheet are evaluated before Conditions, the results are the same. This holds true for all rule expressions that do not involve collection operations (and therefore do not need to use aliases – we have used aliases in this example purely for convenience and brevity of expression): conditional statements, whether they are located in the Filters or Conditions sections, are **AND**'ed together. Order does not matter.

In other words, to use the logic from the preceding example:

```
If person.age > 40 AND person.skydiver = true, then person.riskRating = 'high'
```

Because it does not matter which conditional statement is executed first, we could have written the same logic as:

```
If person.skydiver = true AND person.age > 40, then person.riskRating = 'high'
```

This independence of order is similar to the commutative property of multiplication: $4 \times 5 = 20$ and $5 \times 4 = 20$. Aliases work perfectly well in a declarative language (like Corticon's) because regardless of the order of processing, the outcome is always the same.

Location matters

Unfortunately, order independence does **not** apply to conditional expressions that include collection operations. In the following Rulesheets, notice that one of the conditional expressions uses the collection operator `->size`, and therefore must use an alias to represent the collection `Person`.

Figure 175: Collection Operator in Condition row

Scope		Conditions		0	1
+ Person [person]		a	person -> size > 3	-	T
		b			
		c			
		d			
Filters		Actions			
1	person.skydiver	Post Message(s)			
2		A	person.riskRating		'high'
3		B			

Figure 176: Collection Operator in Filter row

Scope		Conditions		0	1
+ Person [person]		a	person.skydiver	-	T
		b			
		c			
		d			
Filters		Actions			
1	person -> size > 3	Post Message(s)			
2		A	person.riskRating		'high'
3		B			

The Rulesheets appear identical with the exception of the location of the two conditional statements. But do they produce identical results? Let's test the Rulesheets to see, testing **Collection Operator in Condition row** first:

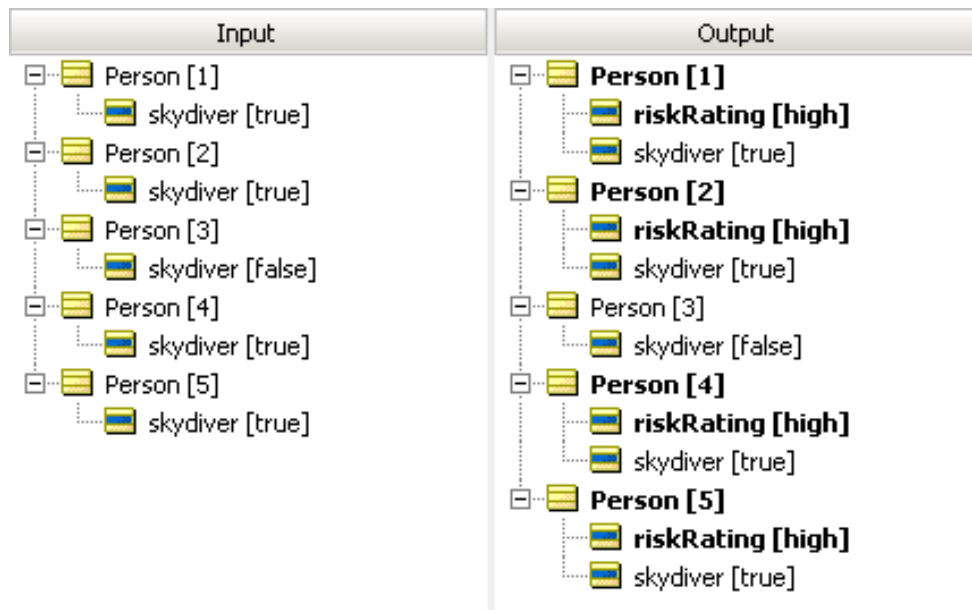
Figure 177: Ruletest with 3 Skydivers

Input	Output
Person [1]	Person [1]
skydiver [true]	skydiver [true]
Person [2]	Person [2]
skydiver [true]	skydiver [true]
Person [3]	Person [3]
skydiver [false]	skydiver [false]
Person [4]	Person [4]
skydiver [true]	skydiver [true]

What happened here? Because Filters are always applied first, our Rulesheet initially “screened” or “filtered out” the elements of collection `person` whose `skydiver` value was `false`. Think of the Filter as allowing only skydivers to “pass through” to the rest of the Rulesheet. The Conditional rule then checks to see if the number of elements in collection `person` is more than 3. If it is, then ALL `person` elements in the collection *that pass through the filter* (in other words, all skydivers) receive a `riskRating` value of `'high'`. Because our first Ruletest included only 3 skydivers, the collection fails the Conditional rule, and no value is assigned to `riskRating` for any of the elements, skydiver or not.

Let's modify the Ruletest and rerun the rules:

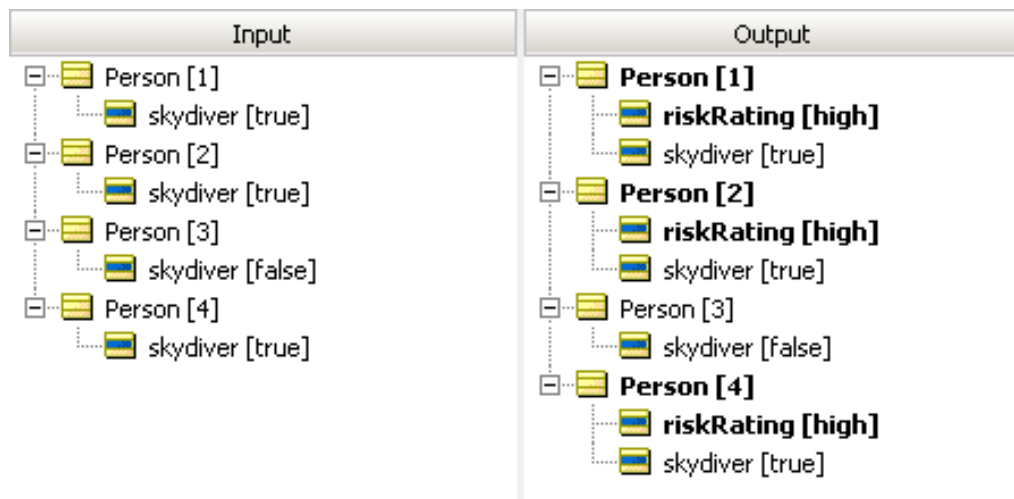
Figure 178: Ruletest with 4 Skydivers



It's clear from this run that our rules fired correctly, and assigned a `riskRating` of `'high'` to all skydivers for a collection containing more than 3 skydivers.

Now let's test the Rulesheet in **Collection Operator in Filter row**, where the rule containing the collection operation is in the Filters section.

Figure 179: Ruletest with 3 Skydivers



What happened this time? Because Filters apply first, the `->size` operator counted the number of elements in our `person` collection, regardless of who skydives and who does not. Here, the Filter allows any collection – *and the whole collection* – of more than 3 persons to “pass through” to the Conditions section of the Rulesheet. Then, the Conditional rule checks to see if any of the elements in collection `person` skydive. Each person who skydives receives a `riskRating` value of `high`. Even though our Ruletest included only 3 skydivers, the collection contains 4 persons and therefore passes the Preconditional filter. Any skydiver in the collection then has its `riskRating` assigned a value of `high`.

It's important to point out that the Rulesheets in **Collection Operator in Condition row** and **Collection Operator in Filter row** really implement two different business rules. When we built our Rulesheets, we neglected to write the plain-language business rule statements (violating our methodology!). The rule statements for these two Rulesheets would look like this:

1. All skydivers in groups of more than 3 **skydivers** must be assigned a `riskRating` of `'high'`
2. All skydivers in groups of more than 3 **persons** must be assigned a `riskRating` of `'high'`

The difference here is subtle but important. In the first rule statement, we are testing for skydivers within groups that contain more than 3 *skydivers*. In the second, we are testing for skydivers within groups of more than 3 *people*.

Multiple filters on collections

Let's construct a slightly more complicated example by adding a third conditional expression to our rule.

Figure 180: Rulesheet with 2 Conditions

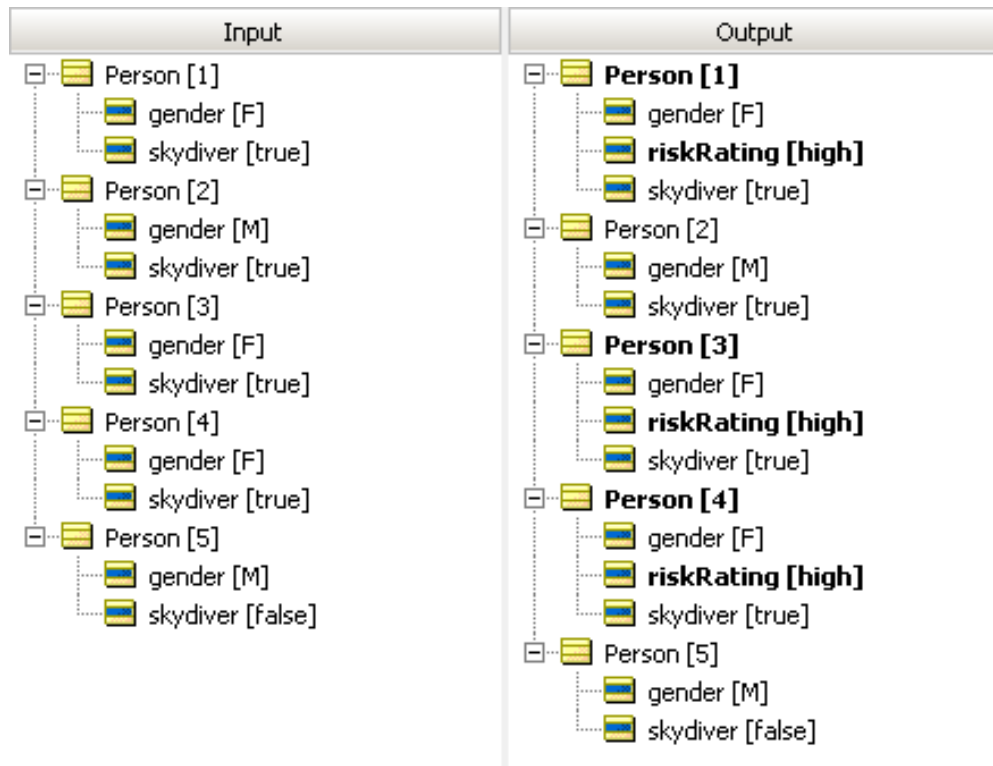
Scope		Conditions	0	1
+ Person [person]	a	person -> size > 3		T
	b	person.gender = 'F'		T
	c	.		
Filters		Actions		
1	person.skydiver = true	Post Message(s)		
2		A	person.riskRating	'high'
3		-	Overrides	

Figure 181: Rulesheet with 2 Filters

Scope		Conditions	0	1
+ Person [person]	a	person -> size > 3		T
	b			
	c	.		
Filters		Actions		
1	person.skydiver = true	Post Message(s)		
2	person.gender = 'F'	A	person.riskRating	'high'
3		-	Overrides	

Once again, our Rulesheets differ only in the location of a Conditional expression. In the first rulesheet above, the gender test is modeled in the second Conditional row, whereas in the other rulesheet (Rulesheet with 2 Filters), it's implemented in the second Filter row. Does this difference have an impact on rule execution? Let's build a Ruletest and use it to test the Rulesheet in **Rulesheet with 2 Conditions** first.

Figure 182: Ruletest for Rulesheet with 2 Conditions



As we see in this figure, the combination of a Condition that uses a collection operator (the size test) with another Condition that does not (the gender test) produces an interesting result. What appears to have happened is that, for a collection of more than 3 skydivers, all females in that group have been assigned a `riskRating` of 'high'. Step-by-step, here is what the Corticon Server did:

1. The Filter screened the collection of Persons (represented by the alias `person`) for skydivers.
2. If there are more than 3 "surviving" elements in `person` (i.e., skydivers), then all females in the filtered collection are assigned a `riskRating` value of `high`. It may be helpful to think of the Corticon Server checking to make sure there are more than three surviving elements, then "cycling through" those whose gender is female, and assigning `riskRating` one element at a time.

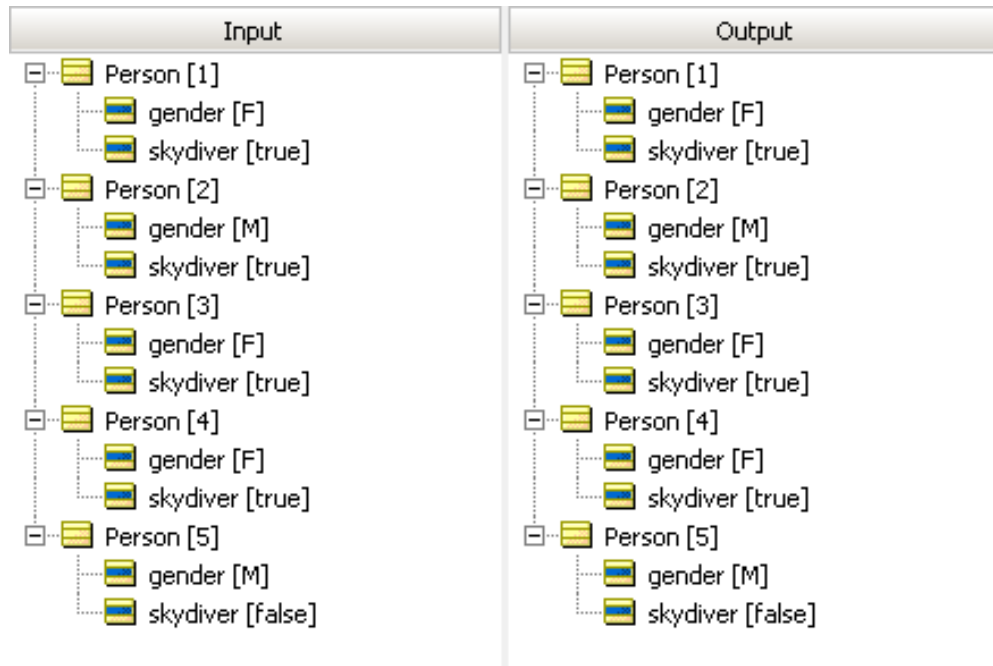
Expressed as a plain-language rule statement, our Rulesheet implements the following rule statement:

1. All female skydivers in a group of more than 3 skydivers must be assigned a `riskRating` value of `high`

It's important to note that Conditions **do not** have the same filtering effect on collections that Filter expressions do, and the order of Conditions in a rule has *no effect whatsoever* on rule execution.

Now that we understand the results in the **Ruletest for Rulesheet with 2 Conditions**, let's see what our second Rulesheet produces.

Figure 183: Ruletest for Rulesheet with 2 Filters

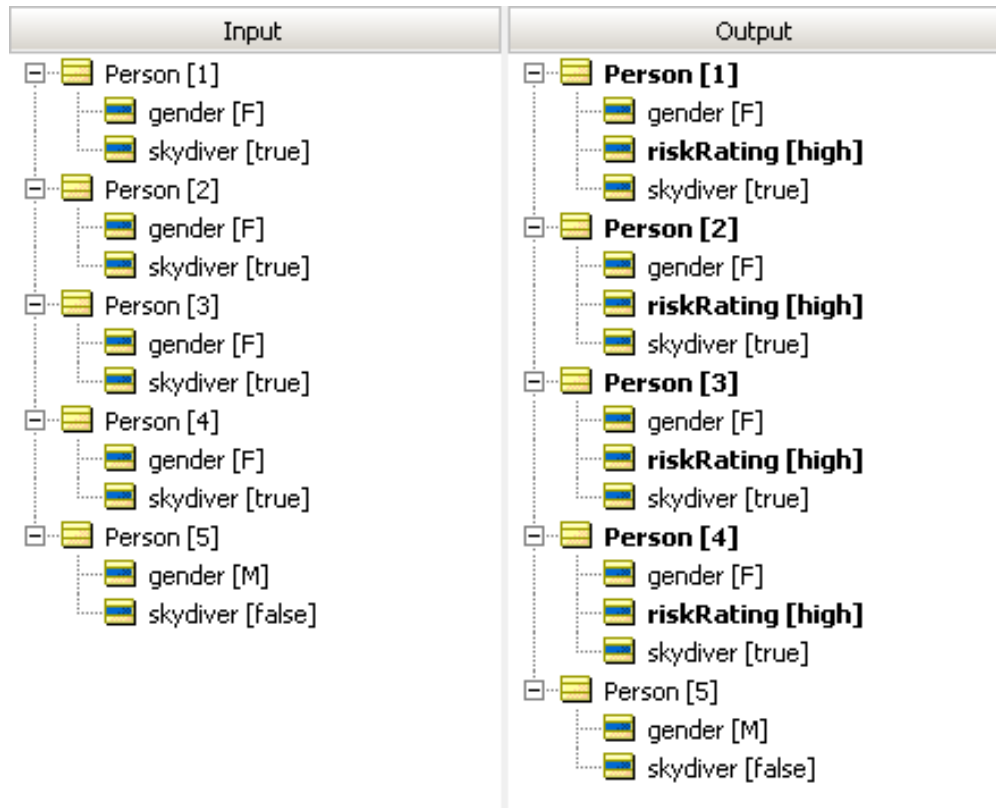


This time, no `riskRating` assignments were made to any element of collection `person`. Why? Because multiple Filters are logically **AND**'ed together, forming a compound filter. In order to survive the compound filter, elements of collection `person` must be both skydivers **AND** female. Elements that survive this compound filter pass through to the "size test" in the Condition/Action rule, where they are counted. If there are more than 3 remaining, then all surviving elements are assigned a `riskRating` value of `high`. Rephrased, our Rulesheet implements the following rule statement:

1. All female skydivers in a group of more than 3 female skydivers must be assigned a `riskRating` of `high`

Just to confirm we understand how the Corticon Server is executing this Rulesheet, let's modify our Ruletest and rerun:

Figure 184: Ruletest with Risk Ratings



That Ruletest includes 4 female skydivers, so, if we understand our rules correctly, we expect all 4 to pass through the compound filter and then satisfy the size test in the Conditions. This should result in all 4 surviving elements receiving a `riskRating` of `high`. That test confirms that our understanding is correct.

Filters that use OR

Just as compound filters can be created by writing multiple Preconditions, filters can also be constructed using the special word `or` directly in the Rulesheet. See the *Rule Language Guide* for an example.

TestYourself questions for Filters and preconditions

Note: Try this test, and then go to [TestYourself answers for Filters and preconditions](#) on page 341 to correct yourself.

1. True or False. All expressions modeled in the Filters section of the Rulesheet behave as filters.
2. True or False. All expressions modeled in the Filters section of the Rulesheet behave as preconditions.
3. True or False. Some rules may be unaffected by Filters expressions on the same Rulesheet.

4. When 2 conditional expressions are expressed as 2 Filter rows, they are logically _____ together.

or'ed	and'ed	replaced	duplicated
-------	--------	----------	------------

5. True or False. A Filter row is a stand-alone rule that can be assigned its own Rule Statement

6. A null collection is a collection that:

- a. has a parent but no children
- b. has children but no parent
- c. has no parent and no children
- d. has a parent and children

7. An empty collection is a collection that:

- a. has a parent but no children
- b. has children but no parent
- c. has no parent and no children
- d. has a parent and children

8. A Filter expression is equivalent to a Conditional expression as long as it includes _____ collection operators in the expression.

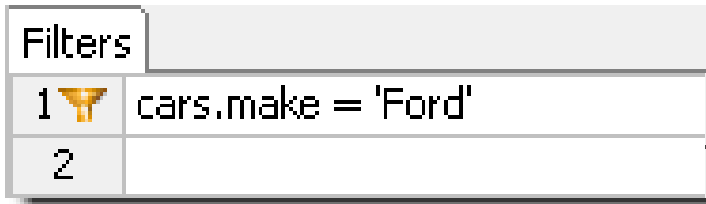
some	all	no	at least one
------	-----	----	--------------

9. True or False. To join two Filters with an or operator, you must use the word or in between expressions.

10. By default, all Filter expressions are _____ filters


limiting	coffee	full	extreme
----------	--------	------	---------

11. The Filter expression shown below has which behavior(s)?



limiting filter	full filter	precondition	noncondition
-----------------	-------------	--------------	--------------

12. The Filter expression shown below has which behavior(s)?

Filters	
1 	<code>cars.make = 'Ford'</code>
2	

limiting filter	full filter	precondition	noncondition
-----------------	-------------	--------------	--------------

13. What happens when a Filter expression, acting as a precondition, is not satisfied?
- The expression is ignored and Rulesheet execution continues
 - The Rulesheet is re-executed from the beginning
 - The last Rulesheet is executed
 - The next Rulesheet is executed
 - All Rulesheet execution stops
 - Execution of that Rulesheet stops
14. Which Filters behaviors may be active at the same time?
- Full filter and precondition
 - Limiting filter and precondition
 - Limiting and full filter
 - Precondition may only act alone
15. For the sample data shown below, determine which data survives the Filter for each question. Enter the entity number (the number in square brackets) for each survivor in the appropriate column. Assume the collection `Movie` has alias `movies`, `Movie.dvd` has alias `dvds`, and `Movie.oscar` has alias `oscars`. None behave as Preconditions.

untitled_1	Precondition/Filter Expressions	Movie	DVD	Oscar
	<p><i>example:</i> movies.studio = 'RKO'</p>	1	1	1,2,3,4,5
	a. dvd.priceTier = 'high'			
	b. oscars -> size > 4			
	c. oscars.win = T			
	d. oscars.nomination			
	e. oscars.win or oscars.category = 'Best Actor'			
	f. oscars.win and oscars.category = 'Best Actor'			
	g. dvd.quantityAvailable > 100			
	h. oscars -> exists(win = T)			
	i. movies.yearReleased.yearsBetween (today) > 50			
	j. dvd -> notEmpty			
	k. movies -> isEmpty			
	l. dvd.releaseDate > '1/1/2000'			
	m. movies.genre <> 'Drama'			
	n. oscars -> forAll(win = T)			
	o. oscars -> size > 2			

How to recognize and model parameterized rules

Patterns emerge in rules that show that there are limits and constraints that you have to handle.

For details, see the following topics:

- [Parameterized rule where a specific attribute is a variable or parameter within a general business rule](#)
- [Parameterized rule where a specific business rule is a parameter within a generic business rule](#)
- [How to populate an AccountRestriction table from a sample user interface](#)
- [TestYourself questions for Recognizing and modeling parameterized rules](#)

Parameterized rule where a specific attribute is a variable or parameter within a general business rule

During development, **patterns** may emerge in the way business rules define relationships between Vocabulary terms. For example, in our sample FlightPlan application, a recurring pattern might be that all aircraft have limits placed on their maximum takeoff weights. We might notice this pattern by examining specific business rules captured during the business analysis phase:

1. 747 aircraft must not exceed maximum cargo weight of 200,000 kgs.
2. DC-10 aircraft must not exceed maximum cargo weight of 150,000 kgs.

These rules are almost identical; only a few key parts – *parameters* – are different. Although aircraft type (747 or DC-10) and max cargo weight (200,000 or 150,000 kilograms) are different in each rule, the basic form of the rule is the same. In fact, we can generalize the rule as follows:

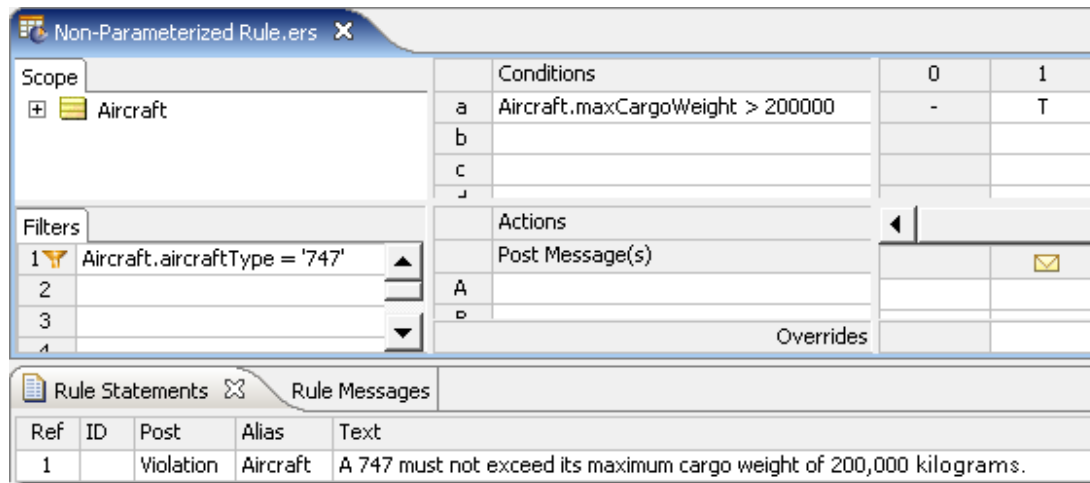
3. X aircraft must not exceed maximum cargo weight of Y kilograms.

Where the parameters X and Y can be organized in table form as shown below:

Aircraft type X	Maximum cargo weight Y
747	200,000
DC-10	150,000

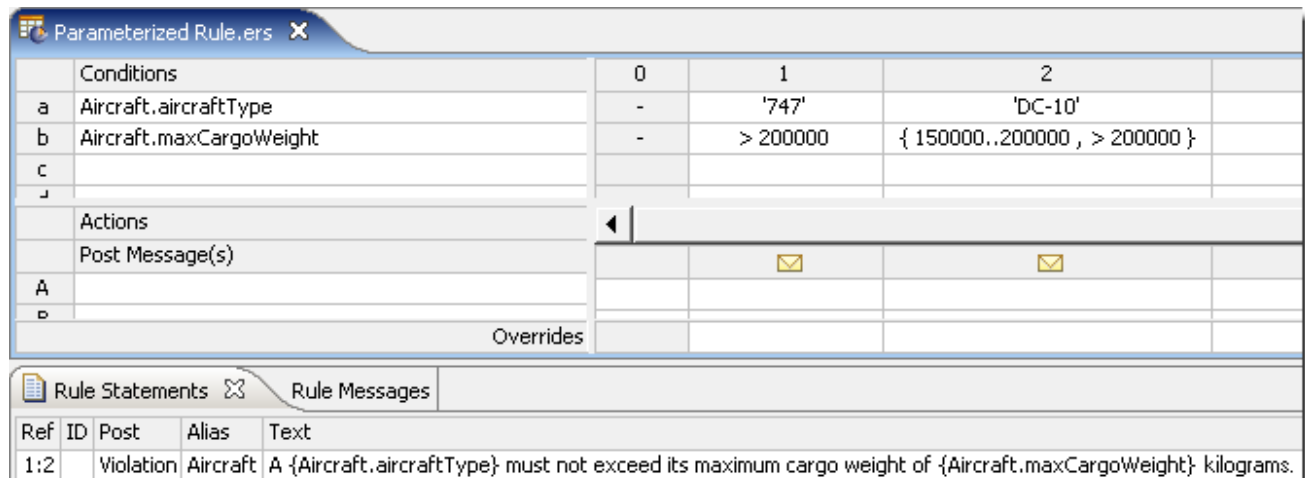
It is important to recognize these patterns because they can drastically simplify rule writing and maintenance in Corticon Studio. As shown in the following figure, we could build these two rules as a pair of Rulesheets, each with a Filter expression that filters data by `aircraftType`.

Figure 185: Non-Parameterized Rule



But there is a simpler and more efficient way of writing these two rules that leverages the concept of parameterization. The following figure illustrates how this is accomplished:

Figure 186: Parameterized Rules



Notice how both rules are modeled on the same Rulesheet. This makes it easier to organize rules that share a common pattern and maintain them over time. If the air cargo company decides to add new aircraft types to its fleet in the future, the new aircraft types can simply be added as additional columns.

Also notice the business rule statements in the Rule Statements section. By entering 1 : 2 in the **Ref** column and inserting attribute names into the rule statement, the same statement can be reused for both rule columns. The syntax for inserting Vocabulary terms into a rule statement requires the use of { . . } curly brackets enclosing the term. See the *Rule Language Guide* for more details on embedding dynamic values in Rule Statements.

In addition to collecting parameterized rules on the same Rulesheet, other things can be done to improve rule serviceability. In the **Trade Allocation** sample application that accompanies the Corticon Studio installation, two parameterized rules are accessible directly from the application's user interface – the user can update these parameters without entering the Corticon Studio because they are stored externally. When the application runs, Corticon Studio accesses the parameter table to determine which rules should fire.

Parameterized rule where a specific business rule is a parameter within a generic business rule

The previous section illustrated the simplest examples of parameterized rules. Other subtler examples occur frequently. For example, let's return to the **Trade Allocation** sample application included in the Corticon Studio installation.

A recurring pattern in **Trade Allocation** might be that specific accounts prohibit or restrict the holding of specific securities for specific reasons. We might notice this pattern by examining specific business rules captured during the business analysis phase:

1. The Airbus Account must not hold securities issued by its competitors.
2. The Puritan Pensions Account must not hold securities issued by companies in the Tobacco industry.
3. The SafeHaven Investments Account must not hold securities of less than investment grade quality (less than Bbb)

The first specific rule might be motivated by another, general rule that states:

4. A client's account must not invest in its competition

The general rule explains why Airbus places this specific restriction on its account holdings – Boeing is a competitor. The second rule is very similar in that it also defines an account restriction for a security attribute (the issuer's industry classification), even though the rule has a different motivation. (A client's investments must not conflict with its ethical guidelines?)

There may be many other business rules that share a common structure, meaning similar entity context and scope. This pattern allows us to define a generic business rule:

5. An **Account** may restrict holding a **type of Security** for a **specific reason**

Or, rewritten as a constraint:

6. An Account must not hold a type of Security for a specific reason

Absent a method for accommodating many similar rules as a single, generalized case, we need to enter each specific rule separately into a Rulesheet. This makes the task of capturing, optimizing, testing, and managing these rules more difficult and time-consuming than necessary.

How to populate an AccountRestriction table from a sample user interface

Parameterizing rules can improve reuse and simplify maintenance. In fact, maintenance of some well-defined rule patterns can be further simplified by enabling users to modify them *external* to Corticon Studio altogether. A user may define and maintain specific rules that follow the generic rule pattern (analogous to an *instance* of a generic rule *class*) using a graphical interface or database table built for this purpose.

The following is a sample user interface that could be constructed to manage parameterized rules that share similar patterns. Note, this sample interface is discussed here only as an example of a parameterized rule maintenance application. It is not provided as part of the Corticon Studio installation.

Figure 187: Sample GUI Window for Populating a Rule's Parameter Table

1. The user selects an Account for which the Account Restriction will be created. Referring back to our example, the user would select `Airbus` from the list box.
2. The user enters a specific business rule that provides the motivation for the Account Restriction. The prior example used `no competitor securities` and `no tobacco securities`.
3. The user selects the type of restriction being created. Our example used `issuer.name` and `industry.name`.
4. Once all components of the Account Restriction are entered and selected, clicking `Add Restriction` creates the restriction by populating the `AccountRestriction` table in an external database.

AccountRestriction table				
Account	Security.type	Issuer.name	Industry.name	Business Rule
Airbus	---	Boeing	---	No competitor securities
Airbus	---	---	Tobacco	No tobacco securities

- After adding a restriction, it appears in the lower scrolling text box. Selecting the Business Rule in the scrolling text box and clicking *Delete Restriction* will remove it from the box and from the table.
- The checkbox indicates an active or inactive Business Rule. This allows the user to deactivate a rule without deleting it. In practice, another attribute could be added to the `AccountRestriction` entity called `active`. A Precondition might filter out inactive rules to prevent them from firing during runtime.

WARNING!

Whenever you decide to maintain rule parameters outside of Corticon Studio, you run the risk of introducing ambiguities or conflicts into your Rulesheet. The Conflict Checker may not help you discover these problems since some of the rule data isn't shown in Corticon Studio. So always try to design your parameter maintenance forms and interfaces to prevent ambiguities from being introduced.

TestYourself questions for Recognizing and modeling parameterized rules

Note: Try this test, and then go to [TestYourself answers for Recognizing and modeling parameterized rules](#) on page 342 to correct yourself.

- When several rules use the same set of Conditions and Actions, but different values for each, we say that these rules share a common _____.
- Another name for the different values in these expressions is _____.
- True or False. When several rules share a pattern, the best way to model them is as a series of Boolean Conditions.
- What's a potential danger of maintaining rule parameters outside of a Corticon Studio Rulesheet?
- Write a generalized rule that identifies the pattern in the following rule statements:
 - Platinum customers buy \$100,000 or more of product each year
 - Gold customers buy between \$75,000 and less than \$100,000 of product each year
 - Silver customers buy more than \$50,000 and less than \$75,000 of product each year
 - Bronze customers buy between \$25,000 and \$50,000 of product each year
- In the rules listed above, what are the parameters?
- Describe the ways in which these parameters can be maintained. What are the advantages and disadvantages of each option?

How to write rules to access external data

Corticon provides three mechanisms that let you interface your rules with databases and other data sources:

- **Enterprise Data Connector (EDC)** — This technique provides access to a single database from a project Vocabulary. You map your Vocabulary to the database and rely on Corticon to retrieve data when needed. EDC makes data access very simple and is a great option when small amounts of data are needed or performance is not paramount. EDC is tightly integrated with rule models, so the functions described in this chapter are how you effectively create queries to the database.
- **Advanced Data Connectors (ADC)** — This technique provides control over the SQL queries used to retrieve or update data in a database. Using ADC requires more database knowledge but provides benefits such as optimized query performance when retrieving large amounts of data, and the ability to map a vocabulary to multiple data sources. ADC is recommended when performing batch rule processing.
- **REST Datasource (REST Service)** — This read-only technique provides secure access to REST services to retrieve data for use in your decision services. Queries—either preset or specified by data in your payload—limit the results brought into the server's memory, which are then filtered to get the data needed to enrich the rule in process.

For additional information, see the *Data Integration topics*.

Overview

Corticon lets you define mappings to a Datasource so that rules can access (query) a database directly, and then retrieve what it needs during execution, thus enriching the information available to the rules, and then writing data to the database when appropriate.

This capability is transparent to the rule modelers so that they are only concerned with getting the rules right, and do not have to get into SQL syntax to interface with an EDC Datasource.

This section focuses on the aspects of rule modeling that are affected by a defined Corticon Enterprise Data Connector.

While you could start learning how to use any of these Datasources, it is a good idea to start with *"Getting Started with EDC" in the Data Integration Guide*.

For details, see the following topics:

- [A scope refresher](#)
- [Quick steps for setting up the Cargo sample](#)
- [Enable database access for rules using root-level entities](#)
- [Precondition and filters as query filters](#)
- [Insert new records in a middle table](#)
- [Integrate EDC Datasource data into rule output](#)
- [TestYourself questions for how to write rules to access external data](#)

A scope refresher

The concept of *scope* is key to rule design and execution. Scope in a Rulesheet helps define or constrain which data is included in rule processing, and which data is excluded. If a rule uses the Vocabulary term `FlightPlan.cargo.weight`, then we know that those `FlightPlan` entities without associated `Cargo` entities will be ignored.

We also know that Vocabulary root-level entities – `FlightPlan`, for example – bring every instance of the entity into scope. This means that a rule using root-level `FlightPlan` acts on every instance of `FlightPlan`, including `Cargo.flightPlan`, `Aircraft.flightPlan`, or any other role using `FlightPlan` that may exist in our Vocabulary.

When we add the ability for the Corticon Server and Studio to dynamically retrieve data from a database, rule scope determines which data to retrieve. This is exactly the same concept as Studio determining which data in an Input Ruletest to process and which to ignore based upon a rule's scope. So if we write rules using root-level `FlightPlan`, then the Studio will process all `FlightPlans` present in the Input Ruletest during rule execution.

Quick steps for setting up the Cargo sample

For the examples that use Cargo, here is a succinct set of steps to set up the sample data in Corticon Studio and your preferred database:

1. In your database administrative tool, create a database named `Cargo`.
2. In Corticon Studio:
 - a. Import the `Cargo` sample.
 - b. Create the EDC Datasource, and then define and test its connection to the `Cargo` database.
 - c. On each of the three entities, set **Datastore Persistent** to `Yes`, and choose its appropriate **Entity Identity**:
 - **Aircraft**: `tailNumber`
 - **Cargo**: `manifestNumber`

- **FlightPlan:** `flightNumber`
- d. On the EDC Datasource tab, click **Create/Update Schema**
3. Copy the contents of the project's `Cargo_data.sql` file to your database administrative tool's editor, and then click **Execute**.

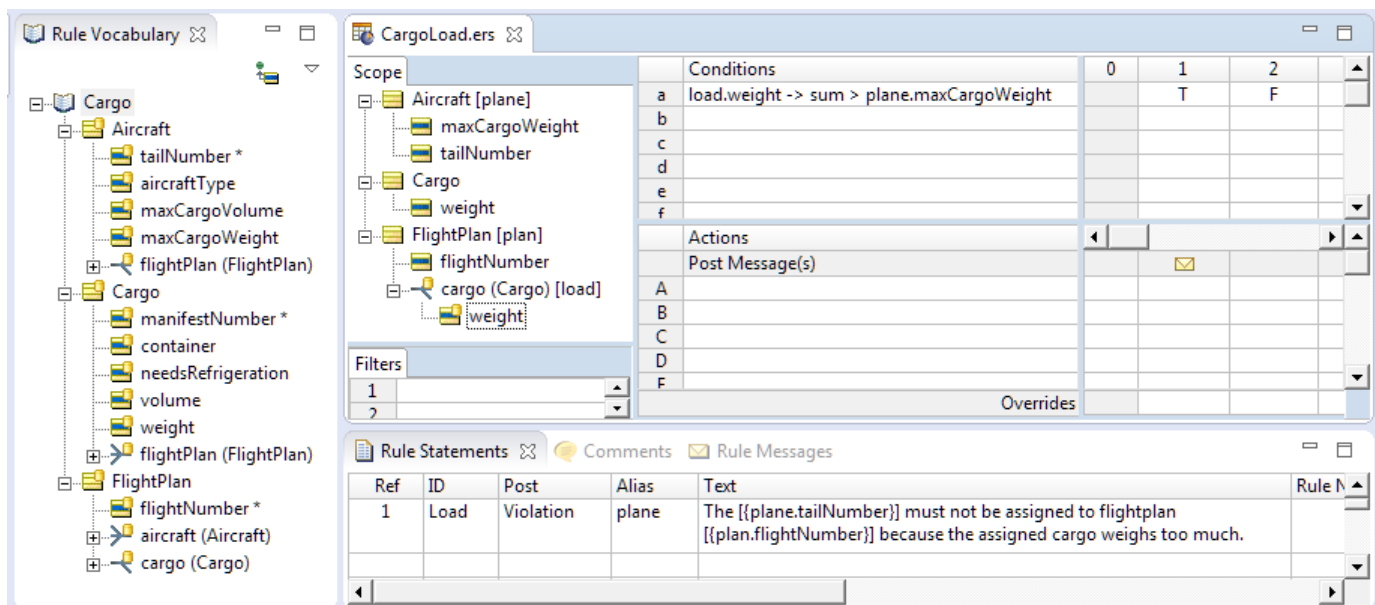
Enable database access for rules using root-level entities

Once interfaced with EDC, the amount of test data is no longer limited to that contained in a single Input Ruletest – it is limited by the sizes in the connected database. Rules using root-level `FlightPlan` (or any other root-level entity) will force the Server or Studio to retrieve ALL `FlightPlan` entities (records) from the database. If the database is very large, then that will mean a large amount of data is retrieved. For this reason, **database access for root-level rules is turned off by default**. This ensures that you do not accidentally force the Server to perform extremely large and time-consuming data retrievals from the database unless you explicitly require it.

Since database access for rules using root-level terms is disabled by default, we need to know how to enable it for those circumstances when we do want it. We call this *extending* a root-level entity to the database. To illustrate, we'll use a simple rule based on the Cargo project's Vocabulary, as follows:

1. In the Corticon Studio, create a new Rulesheet in the Cargo project, and open its advanced view.
2. Drag from the Vocabulary into the Scope as shown, including adding `Cargo.weight` to the `FlightPlan` association as shown.
3. Add the aliases in the Scope as shown.
4. Write the rule condition and its values in columns 1 and 2
5. Add the rule statement as shown
6. Save the Rulesheet as `CargoLoad.ers`

Figure 188: CargoLoad Rulesheet

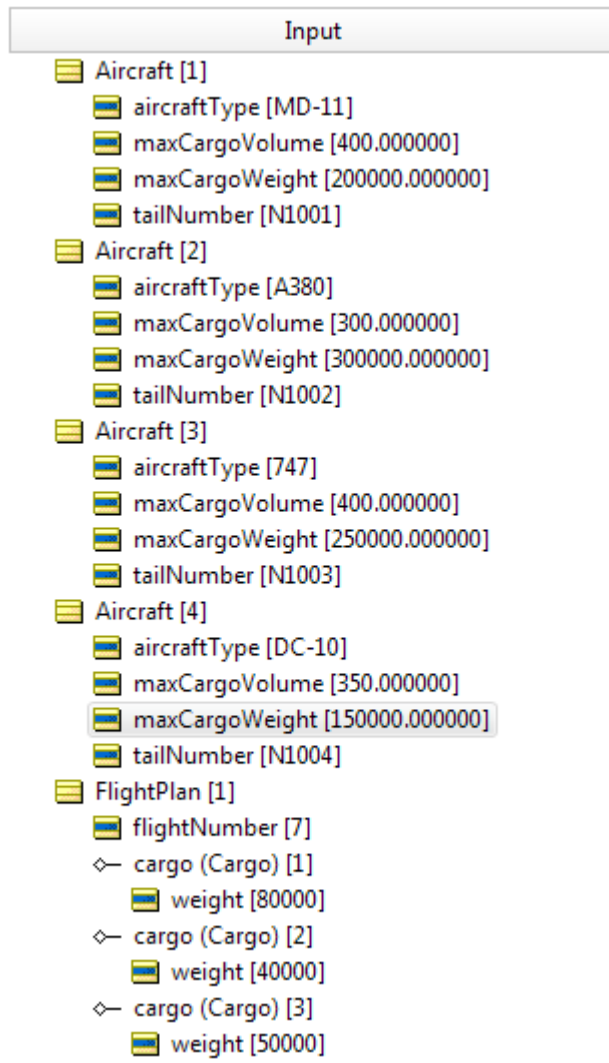


The Rulesheet shown adds up (sums) the *collection* (see [Collections](#) on page 113) of `Cargo` weights associated with a `FlightPlan` (`load.weight`) and compares this to the `maxCargoWeight` of the root-level `Aircraft`. Our intention is to perform this comparison for every available `Aircraft`, so we have used the root-level `Aircraft` in our Conditional expression. Any `Aircraft` whose `maxCargoWeight` is inadequate will be identified with a posted `Violation` message.

Test the Rulesheet with database access disabled

Testing this Rulesheet without database access is a simple matter of building an Input Ruletest with all necessary data. An example of this is a Ruletest we create against the `Cargo.ecore` named `CargoLoad.ert`. Its input data is as shown:

Figure 189: Sample Input Ruletest



Looking at this Input Ruletest, we see a single `FlightPlan` with its collection of `Cargo` this collection is what we're representing with the alias `load` in our Rulesheet's Scope section. Each `Cargo` has a `weight` value entered.

The four root-level `Aircraft` entities are also shown. Each one has a `maxCargoWeight`, which will be compared to the sum of `load.weight` during rule execution.

Given what we know about rule scope, we can confidently predict that the test data provided in this Input Ruletest will be processed by the Rulesheet because it contains the same scope!

In the following figure, we've executed the Test and see that it functioned as expected. Since `load.weight` sums to 170000 kilograms, and the `Aircraft` with `tailNumber` N1004 can only carry 150000 kilograms, we receive a `Violation` message for that `Aircraft` and that `Aircraft` alone. All other `Aircraft` have `maxCargoWeight` values of 200000 kilograms or more, so they fail to fire the rule.

Figure 190: Ruletest Violation Message

Severity	Message	Entity
Violation	The [N1004] must not be assigned to flightplan [7] because the assigned cargo weighs too much.	Aircraft[4]

So far, this behavior is exactly what we have come to expect from rules – they process data of the same scope.

Save the `CargoLoad.ert` Ruletest

Test the Rulesheet with database access enabled

First, let's update the database we have been using in the EDC tutorial to prepare for the features that we want to demonstrate. The Ruletest we just created, `CargoLoad.ert`, has the aircraft data we want including the primary key. We'll copy the Ruletest, drop those unwanted inputs, and then update the database column `tailNumber`. It actually extends the tutorial's data with one added row. But it has cargo info we want to keep aside for now.

Note: The procedure for connecting and mapping a Vocabulary to an external database, and setting an Input Ruletest to access that database in **Read Only/Read/Update** modes is discussed in the topic *"How data from an EDC Datasource integrates into rule output"* section of the *Data Integration Guide*.

To load the aircraft data:

1. In the Project Explorer, copy and paste the `CargoLoad.ert` file. Name the copy `AircraftLoader.ert`.
2. Open `AircraftLoader.ert`.
3. In the Input area, click on `FlightPlan`, and then press **Delete**.
4. Select the menu option **Ruletest > Testsheet > Database Access > Read/Update**.
5. Select the menu command **Ruletest > Testsheet > Run Test**.

Look at the `Aircraft` table in the database. You see the updated values and the new row:

	tailNumber	aircraftType	maxCargoVolume	maxCargoWeight
	N1001	747	400.00	250000.00
	N1002	DC-10	300.00	150000.00
	N1003	DC-10	400.00	200000.00
	N1004	747	350.00	250000.00
▶*	NULL	NULL	NULL	NULL

To make the test effective, we need to add some heavy cargo to one of the flight plans. Here, we created four SQL query lines to add four new Cargo manifests to one flight:

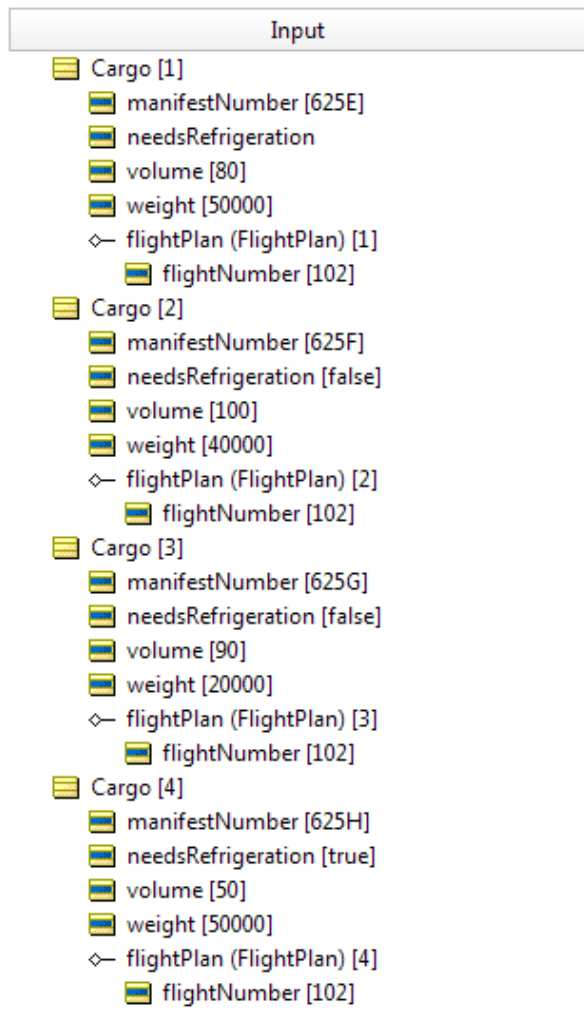
```
INSERT INTO Cargo.dbo.Cargo
    (manifestNumber,RflightPlanAssoc_flightNumber,
     needsRefrigeration,container,volume,weight)
VALUES ('625E',102,null,null,80,50000);
INSERT INTO Cargo.dbo.Cargo
    (manifestNumber,RflightPlanAssoc_flightNumber,
     needsRefrigeration,container,volume,weight)
VALUES ('625F',102,0,null,100,40000);
INSERT INTO Cargo.dbo.Cargo
    (manifestNumber,RflightPlanAssoc_flightNumber,
     needsRefrigeration,container,volume,weight)
VALUES ('625G',102,0,null,90,20000);
INSERT INTO Cargo.dbo.Cargo
    (manifestNumber,RflightPlanAssoc_flightNumber,
     needsRefrigeration,container,volume,weight)
VALUES ('625H',102,1,null,50,50000);
```

Copy the text in the codeblock and paste it into a new SQL Query in your database, and execute it.

Alternate approach: Using a Ruletest to load a database

You could instead create a Ruletest, *CargoLoader*, with these values and the associated *flightPlan*, entering the values as shown, and then running the test in **Read/Update** mode:

Figure 191: Using a Ruletest to add Cargo rows to the connected external database



Setting up the test

The `Cargo` table now shows that there are eight items, five of which are assigned to one flight:

Figure 192: Cargo Table from Database

	manifestNum...	container	needsRefrigera...	volume	weight
▶	625A	NULL	NULL	10	1000
	625B	NULL	False	40	1000
	625C	NULL	False	20	30000
	625D	NULL	True	10	1000
	625E	NULL	NULL	80	50000
	625F	NULL	False	100	40000
	625G	NULL	False	90	20000
	625H	NULL	True	50	50000
*	NULL	NULL	NULL	NULL	NULL

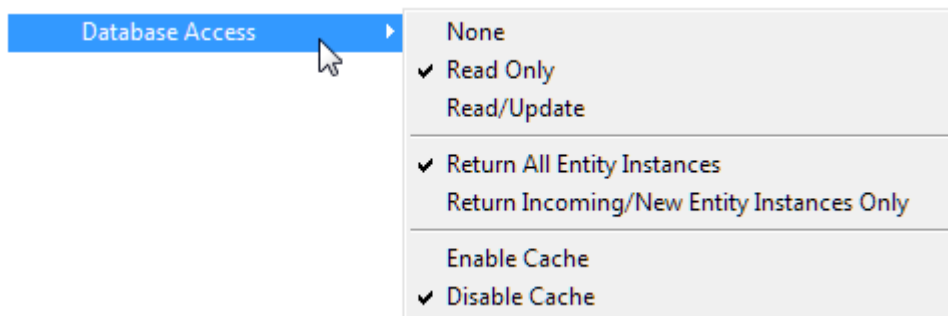
Let's create a new Ruletest that uses the test subject we created earlier, the `CargoLoad.ers` Rulesheet: [CargoLoad Rulesheet](#). We will create a new Input Ruletest that just takes the `FlightPlan` entity from the scope, and then enter the `flightNumber` value 102. When we run the test, the Output is identical to the input and there are no messages. That seemed to do nothing:

Figure 193: Ruletest of FlightPlan Seed Data

Input	Output
<ul style="list-style-type: none"> FlightPlan [1] flightNumber [102] 	<ul style="list-style-type: none"> FlightPlan [1] flightNumber [102]

Notice that the only data necessary to provide in the Input Ruletest is a `FlightPlan.flightNumber` value – since this attribute serves as the primary key for the `FlightPlan` table, Studio has all the “seed data” it needs to retrieve the associated `Cargo` records from the `Cargo` database table. In addition to retrieving the `load.weight` collection, we also needed all `Aircraft` records from the `Aircraft` table. But this didn't happen – no `Aircraft` records were retrieved, so the rule's comparison couldn't be made, so the rule couldn't fire. We should have expected this since we have already learned that database access for root-level terms is disabled by default.

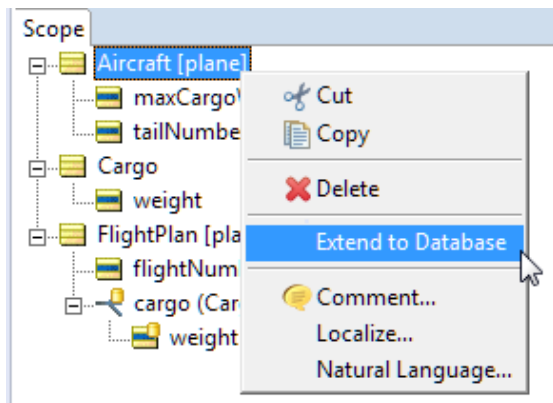
Let's set the Ruletest to read data from the database and return everything that it finds. Toggle the menu options in the **Ruletest > Testsheet** menu as shown:



When we run the test again, the output is the same as the input and there are no messages.

Extend to Database

What we want to do now is set the Rulesheet to **Extend to Database**, and then see how it impacts the test. On the `CargoLoad.ers` Rulesheet, right-click `Aircraft` in the **Scope** area, and then select **Extend to Database**, as shown:



Save your Rulesheet to ensure that the changes take effect. Now, retest the same Input Ruletest shown in [Input Ruletest with Seed Data](#). The results are as follows:

Figure 194: Results Ruletest Showing a Successful Extend-to-Database Retrieval

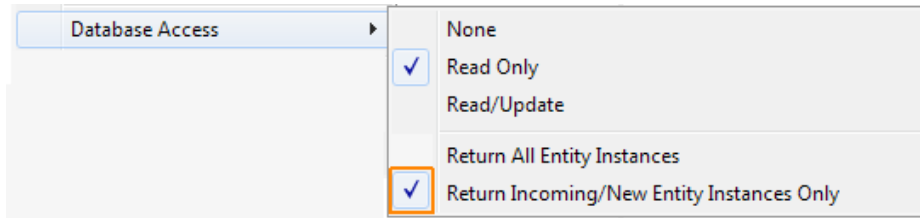
Input	Output	Expected
<ul style="list-style-type: none"> FlightPlan [1] <ul style="list-style-type: none"> flightNumber [102] 	<ul style="list-style-type: none"> FlightPlan [1] <ul style="list-style-type: none"> flightNumber [102] cargo (Cargo) [1] cargo (Cargo) [2] cargo (Cargo) [3] cargo (Cargo) [4] cargo (Cargo) [5] <ul style="list-style-type: none"> container manifestNumber [625E] needsRefrigeration volume [80] weight [50000] Aircraft [1] Aircraft [2] Aircraft [3] Aircraft [4] <ul style="list-style-type: none"> aircraftType [DC-10] maxCargoVolume [350.000000] maxCargoWeight [150000.000000] tailNumber [N1004] 	

Severity	Message	Entity
Violation	The [N1004] must not be assigned to flightplan [102] because the assigned ...	Aircraft[4]

These results are much different! Corticon has successfully retrieved all `Aircraft` records, performed the summation of all the cargo in the given flightplan, and identified an `Aircraft` record that fails the test. Given this set of sample data, it is the `Aircraft` with `tailNumber` `N1004` that receives the `Violation` message.

Returning all instances can be overwhelming

While this rich relational data retrieval is good to see, we are only have four planes and five packages in the flight plan. What if we have 1,000 planes and hundreds of thousands of packages every day? That amount of data would be overwhelming. So what we can do is constrain the return data to just relevant new information by toggling the Ruletest's return option to **Return Incoming/New Entity Instances Only**, as shown:

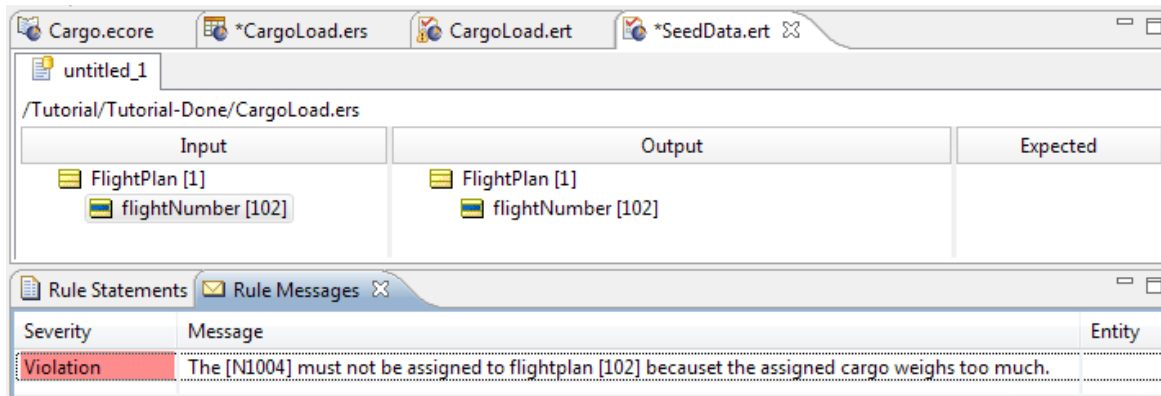


The data that returns is drawn only from those entities that were:

- Directly used in the rules.
- Present in the request message.
- Generated by the rules (if any).

Note: This option can be set in Deployment Descriptor file (.cdd), or as a parameter in the 9-parameter version of addDecisionService method in the Server API scripts.

When you run the Ruletest now, the output is unchanged yet we got the Violation message as to which plane cannot be assigned that flight plan.



That result is concise, providing what could be all we really wanted to know in this test.

Optimize aggregations that extend to database

Our Rulesheet used a condition statement that did a calculation and a difference, calling a statement when it evaluated as true, as shown:

Scope	Conditions	0	1
a	load.weight -> sum > plane.maxCargoWeight	-	T
b			
c			
d			
e			

Actions	Post Message(s)
A	<input checked="" type="checkbox"/>
B	
C	

As written, `load.weight ->sum > plane.maxCargoWeight`, the condition will copy all the relevant cargo records into Corticon's memory to perform its `sum`, and then evaluate whether total weight is greater than the plane's capacity. As we are extended to database, the number of values could be large. Corticon lets you optimize such calculations for non-conditional (column 0) actions.

You can recast the conditions by creating an attribute in the `FlightPlan` entity to store a calculation. Here, we created the `load` attribute, and then set its properties so that the Data Type, `Integer` is the same as the `weight` data it will aggregate, and setting the Mode to `Transient` as this is data that will be just used locally:

Property Name	Property Value
Attribute Name	load
Data Type	Integer
Mandatory	No
Mode	Transient

You could rewrite the conditions and actions to create a non-conditional rule followed by a conditional test of the computed result, as follows:

Scope	Conditions	0	1	2
a	plan -> notEmpty	-	-	-
b	plan.load > plane.maxCargoWeight	-	T	-
c				
d				

Actions	Post Message(s)
A	<input checked="" type="checkbox"/>
B	
C	
D	
E	
F	

Ref	ID	Post	Alias	Text	R
1	Load	Violation	plane	The plane {{plane.tailNumber}} must not be assigned flightplan {{plan.flightNumber}} because the assigned cargo weight of {{plan.load}} exceeds its limit.	

This optimizes the performance by calculating `load` on the database-side, and then evaluating the `load` against `maxCargoWeight` in memory.

Note: This feature applies to all Collection operators that are **aggregation** operators: `sum`, `avg`, `size`, `min`, and `max`. See [Aggregations that optimize EDC database access](#) on page 147 for more information about these Collection operators.

Precondition and filters as query filters

When the Enterprise Data Connector is in use, Scope rows in a Rulesheet can act as queries to an external database. When an alias definition is designated as **Extend to Database**, the scope of the alias is assumed to include all database records in the Entity's corresponding table. But we often want or need to qualify those queries to further constrain the data returned to Server or Studio. You can think of conditional clauses written in the Preconditions/Filters section of the Rulesheet as placing constraints on these queries. If you are familiar with structured query languages (SQL), then you may recognize these constraints as "WHERE clauses" in a SQL query.

If you are not familiar with SQL, that's OK. Review the [Filters& Preconditions](#) chapter of this manual to learn more about how a **Precondition/Filter** expression serves to reduce or "filter" the data in working memory so that only the data that satisfies the expression "survives" to be evaluated and processed by other rules on the same Rulesheet. EDC simply extends working memory to an external database; the function of the Precondition/Filter expression remains the same.

For performance reasons, it is often desirable to perform a complete query -- including any `WHERE` clauses -- inside the database before returning the results set (the data) to Studio or Server. An unconstrained or unfiltered results set from an external database may be very large, and takes time to transfer from the database to Studio or Server. Once the results set has entered Studio's or Server's working memory, then Preconditions/Filters expressions serve to reduce (or filter) the results set further before rules are applied. But if we believe the unfiltered results set will take too much time to transfer, then we may decide to execute the Preconditions/Filters expressions inside the database query, thereby reducing the results set prior to transmission to Studio or Server. This may make the entire database access process faster.

Filter query qualification criteria

When **any** of the following are true, the Precondition/Filter expression **does not qualify** as a Query Filter:

1. If it does not contain at least one alias which has been extended to the database.
2. If it contains any attributes of Boolean datatype. Boolean datatypes are implemented inconsistently in commercial RDBMS, and cannot be included in Query Filters.
3. If it has relational operators with Boolean operands.
4. If it uses an operator not supported by databases (see list below)
5. If it references more than one alias not extended to database.

Operators supported in query filters

Query Filters are Corticon Rule Language expressions which are performed in the database. As such, the operators used in these expressions must be compatible with the database's native query language, which is always based on some form of SQL. Not all Corticon Rule Language operators have comparable functions in SQL. Those operators supported by standard SQL and therefore also permitted in Query Filters are shown in the table below:

Table 8: Operators supported by Query Filters

Operator Name	Operator Syntax	Datatypes Supported
Add	+	Decimal, Integer
Subtract	-	Decimal, Integer
Multiply	*	Decimal, Integer
Divide	/	Decimal, Integer
Equal To (comparison)	=	DateTime, Decimal, Integer, String
Not Equal To	<>	DateTime, Decimal, Integer, String
Less Than	<	DateTime, Decimal, Integer, String
Greater Than	>	DateTime, Decimal, Integer, String
Less Than or Equal To	<=	DateTime, Decimal, Integer, String
Greater Than or Equal To	>=	DateTime, Decimal, Integer, String
Absolute Value	.absval	Decimal, Integer
Character Count	.size	String
Convert to Upper Case	.toUpper	String
Convert to Lower Case	.toLower	String
Substring	.substring	String
Equal To (comparison)	.equals	String
Collection is Empty	->isEmpty	Collection
Collection is not Empty	->notEmpty	Collection
Size of Collection	->size	Collection
Sum	->sum	Collection

Operator Name	Operator Syntax	Datatypes Supported
Average	->avg	Collection
Minimum	->min	Collection
Maximum	->max	Collection
Exists	->exists	-

Note: The Collection operators listed above must be used directly on the extended-to-database alias in order to qualify as a Query Filter. If the collection operator is used on an associated child alias of the extended-to-database alias, then the expression is processed in memory.

How to use multiple filters in filter queries

One or more filters can be set as a database filter. When multiple filters are set as database filters, Corticon logically combines them with the AND operator to form one database query.

Note: If the database filters have different entity/alias references they will not be logically combined into one query. Each filter will execute in processing order. To determine which expression gets processed first, generate an execution sequence diagram by choosing **Rulesheet > Rulesheet > Execution Sequence Diagram** from Studio's menubar.

Consider the filters:

- `Customer.age > 18`
- `Customer.status = 'GOLD'`

the result is one database query:

```
Select * from Customer where age > 18 and status = "GOLD"
```

However, when the two filters are:

- `Customer.age > 18`
- `Order.total > 1000`

the result is two database queries (because Customer and Order are not logically related):

```
Select * from Customer where age > 18
```

```
Select * form Order where total > 1000
```

When the database filter contains more than one database entity/alias -- a compound filter -- it still acts as a single query. For example:

- `Order.bid >= Item.price`

which results in the query:

```
Select * from Order o,Item i where o.bid > i.price
```

When there are multiple filters related to one or more of the entities in a compound filter, they are combined with the AND operator For example, consider the filters:

- `Order.bid >= Item.price`
- `Order.status = 'VALID'`
- `Item.qty > 0`

which results in the query:

```
Select * from Order o,Item I where o.bid > i.price and o.status = "VALID" and i.qty > 0
```

Insert new records in a middle table

In relational databases, many-to-many relationships are modeled using a “middle” table (also known as an “intersection” table). Assume we have two tables named **A** and **B**, and they have a many-to-many relationship. A third or “middle” table named **AB** has a many-to-1 relationship with both **A** and **B**.

A many-to-many Association between two Entities in the Vocabulary can be mapped to such a middle table. Therefore, table **AB** does not need to correspond to a specific Entity in the Vocabulary. However, should the middle table contain additional business fields, then it must have a corresponding Entity in the Vocabulary. In such a situation, attempting to create a new record/row in table **AB** using rules may run into limitations depending on:

- the cardinalities of the associations between **AB** and **A**, and **AB** and **B**
- the identity strategy used for **A**, **B**, and **AB**.

The table below highlights known limitations for combinations of entity identity (Application or Datastore) and association directionality (**bidirectional** or **unidirectional**):

Application Identity			Datastore Identity (using 'identity' strategy)		
Both Uni	Both Bi	One Uni/One Bi	Both Uni	Both Bi	One Uni/One Bi
OK	NO	NO	OK	OK	OK

The *one uni / one bi* configuration should be avoided when Application Identity is used.

Integrate EDC Datasource data into rule output

EDC introduces a new dimension to rule execution. When EDC is not used, data management during Decision Service execution is relatively straight-forward: incoming data contained in the request payload is modified by rules and the resulting updated state for all objects is returned in the response.

However, when EDC is used, data management becomes more complicated. Data in the database needs to synchronize with the data in the request payload and the data produced by Decision Service execution.

This functionality is discussed in detail in the section *"How data from an EDC Datasource integrates into rule output"* in the *Data Integration Guide*.

Using several scenarios, that section describes the algorithms used by Corticon Server to perform this synchronization in a variety of read-only and read-write cases. All scenarios use the familiar `Cargo.ecore`, as set up and verified in [Quick steps for setting up the Cargo sample](#) on page 230.

Test Yourself questions for how to write rules to access external data

Note: Try this test, and then go to [Test Yourself answers for Logical analysis and optimization](#) on page 343 to correct yourself.

1. Rule scope determines which _____ is processed during rule execution.
2. Why is root-level database access disabled by default?
3. When a Scope row is shown in bold text, what do we know about that entity's database access setting?
4. True or False. Only root-level entities can be extended to a database.
5. Where can I learn more about accessing external data?
6. In general, does a rule author need to care about where actual data is stored, how it is retrieved, or how it is sent to the rules when creating Rule Sets?
7. Are there any exceptions to the general rule you defined in the question above?

Logical analysis and optimization

A strength of Corticon's toolset is the ability to perform extensive tests and analysis of your rules using traditional methods as well as within Studio. You can evaluate the completeness of rule coverage, conflicts between rules, and looping in rules. You can even test the subtleties of rule executions with expected results. You are offered techniques to compress and optimize your rules.

For details, see the following topics:

- [Test, validate, and optimize your rules](#)
- [Traditional means of analyzing logic](#)
- [Validate and test Rulesheets in Corticon Studio](#)
- [Test rule scenarios in the Ruletest Expected panel](#)
- [How to optimize Rulesheets](#)
- [Precise location of problem markers in editors](#)
- [TestYourself questions for Logical analysis and optimization](#)

Test, validate, and optimize your rules

Corticon Studio provides the rule modeler with tools to test, validate, and optimize rules and Rulesheets prior to deployment. Before proceeding, let's define these terms.

Scenario testing

Scenario testing is the process of comparing *actual* decision operation to *expected* operation, using data scenarios or test cases. The Ruletest provides the capability to build test cases using real data, which may then be submitted as input to a set of rules for evaluation. The actual output produced by the rules is then compared to the output we expected those rules to produce. If the actual output matches the expected output, then we may have *some* degree of confidence that the decision is performing properly. Why only *some* confidence and not *complete* confidence will be addressed in this set of topics.

For complete details on settings and analysis for scenario testing, see [Test rule scenarios in the Ruletest Expected panel](#) on page 266

Rulesheet analysis and optimization

Analysis and optimization is the process of examining and correcting or improving the logical construction of Rulesheets, *without* using test data. As with testing, the analysis process verifies that our rules are functioning correctly. Testing, however, does nothing to inform the rule builder about the execution efficiency of the Rulesheets. Optimization of the rules ensures they execute most efficiently, and provide the best performance when deployed in production.

The following example illustrates the point:

Two rules are implemented to profile life insurance policy applicants into two categories, high risk and low risk. These categories might be used later in a business process to determine policy premiums.

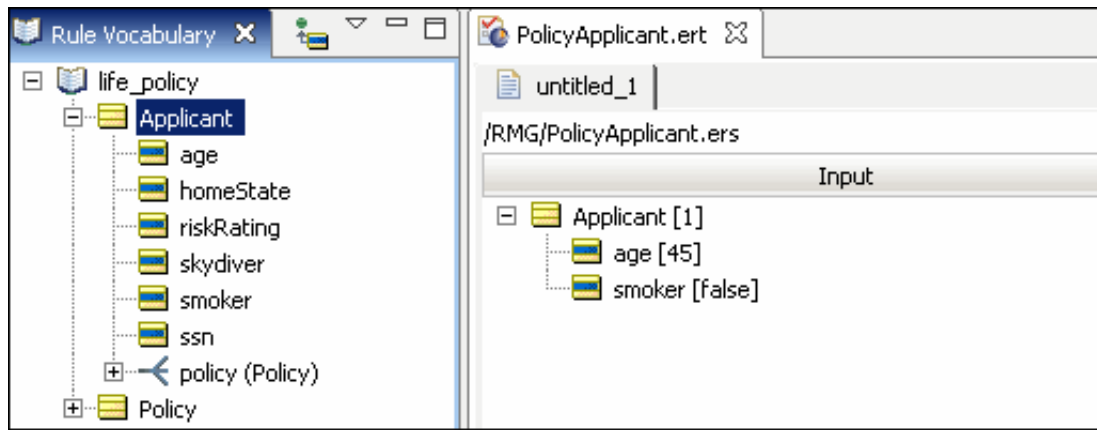
Figure 195: Simple Rules for Profiling Insurance Policy Applicants

Conditions		0	1	2
a	Applicant.age		<= 55	-
b	Applicant.smoker		-	T
c				
d				

Actions		0	1	2
Post Message(s)			✉	✉
A	Applicant.riskRating		'low risk'	'high risk'
B				

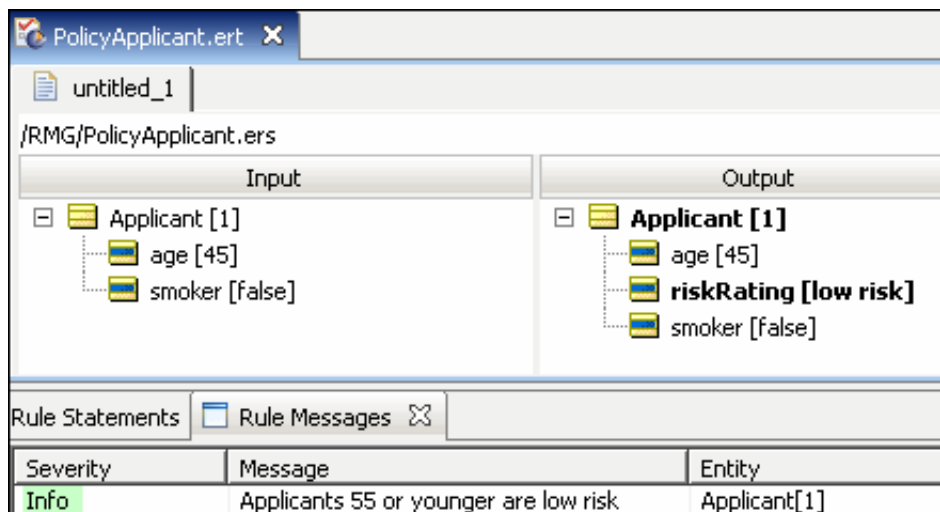
Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk

To test these rules, we create a new scenario in a Ruletest, as shown:



In this scenario, we have created a single example of `Person`, a non-smoker aged 45. Based on the rules we just created, we expect that the Condition in Rule 1 will be satisfied (*People aged 55 or younger...*) and that the person's `riskRating` will be assigned the value of `low`. To confirm our expectations, we run the Ruletest:

Figure 196: Ruletest



As we see in that figure, our expectations are confirmed: Rule 1 fires and `riskRating` is assigned the value of `low`. Furthermore, the `.post` command displays the appropriate rule statement. Based on this single scenario, can we say conclusively that these rules will operate properly for other possible scenarios; i.e., for all instances of `Person`? How do we answer this critical question?

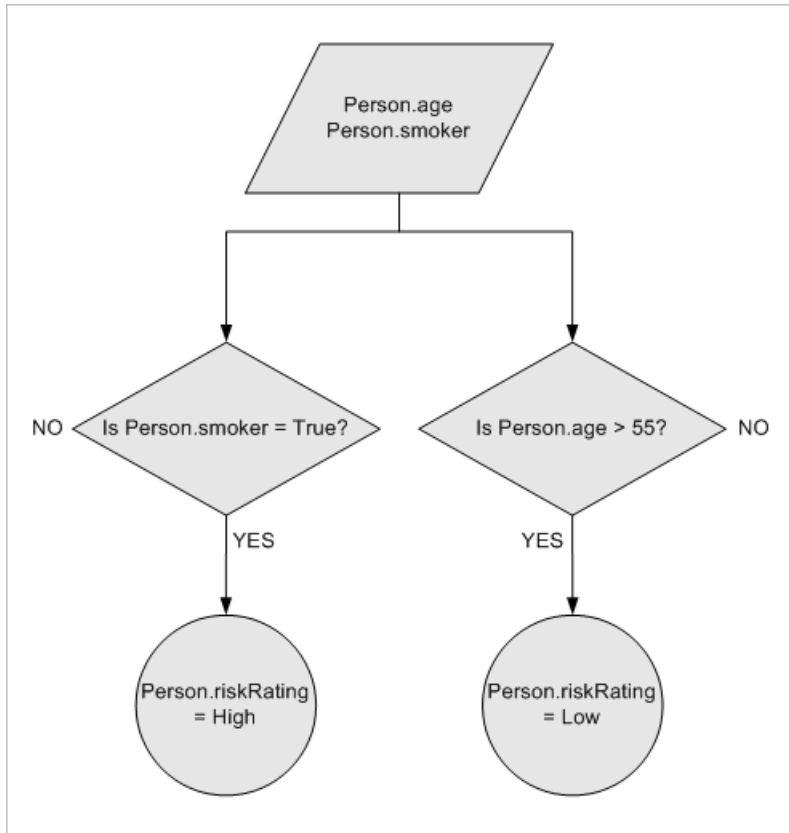
Traditional means of analyzing logic

The question of proper decision operation for all possible instances of data is fundamentally about analyzing the logic in each set of rules. Analyzing each individual rule is relatively easy, but business decisions are rarely a single rule. More commonly, a decision has dozens or even hundreds of rules, and the ways in which the rules interact can be very complex. Despite this complexity, there are several traditional methods for analyzing sets of rules to discover logical problems.

Flowcharts

A flowchart that captures these two rules might look like the following:

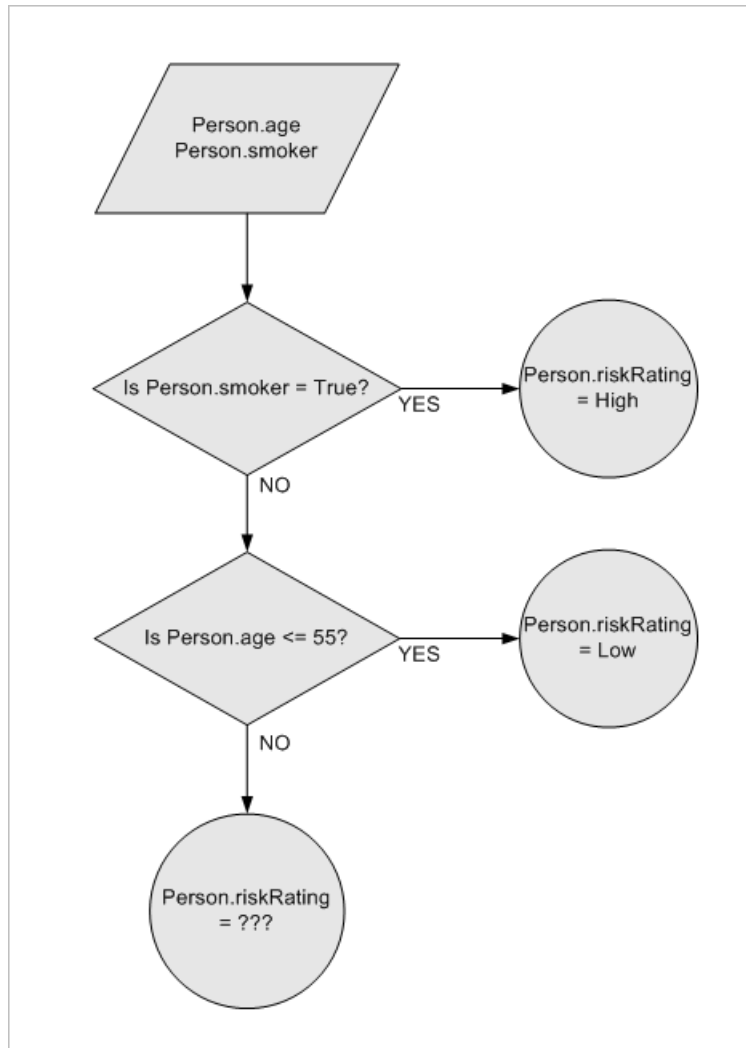
Figure 197: Flowchart with 2 Rules



Upon closer examination, the flowchart reveals two problems with our rules: what Action(s) should be taken if either test fails, in other words, if `Person.age > 55` or if `Person.smoker = false`? The rules built in [Simple Rules for Profiling Insurance Policy Applicants](#) do not handle these two cases. But there is also a third, subtler problem here: what happens if **both** Conditions are satisfied, specifically when `Person.age <= 55` **and** `Person.smoker = true`? When `Person.age <= 55`, we want `Person.riskRating` to be given the value of low. But when `Person.smoker = true`, we want `Person.riskRating` to be given the value of high.

We have discovered a dependency between our rules – they are not truly separate and independent evaluations because they both assign a value to the same attribute. So the flowchart we began with turns out to be an incorrect graphical representation of our rules, because the decision flow does not truly follow two parallel and independent paths. Let's try a different flowchart:

Figure 198: Flowchart with 2 Dependent Rules



In the flowchart in Flowchart with 2 Dependent Rules, we have acknowledged an interdependence between the two rules, and have arranged them accordingly. However, a few questions still exist. For example, why did we choose to place the smoker rule *before* the age rule? By doing so we are giving the smoker rule an implicit priority over the age rule because any smoker will immediately be given a `riskRating` value of `High` regardless of what their `age` is. Is this what the business intends, or are we as modelers making unjustified assumptions?

We call this a problem of **logical conflict**, or **ambiguity** because it's simply not clear from our two rules, as they have been written, what the correct outcome should be. Does one rule take priority over the other? *Should* one rule take priority over the other? This is, of course, a business question, but the rule writer must be aware of the dependency problem and resulting conflict in order to ask the question in the first place. Also, notice that there is still no outcome for a non-smoker older than 55. We call this a problem of **logical completeness** and it must be taken into consideration, no matter which flowchart we use.

The point we are making is that discovery of logical problems in sets of rules using the flowcharting method is very difficult and tedious, especially as the number and complexity of rules in a decision (and the resulting flowcharts) grows.

Test suites

The use of a test suite is another common method for testing rules (or any kind of business logic, for that matter). The idea is to build a large number of test cases, with carefully chosen data, and determine what the correct system response should be for each case.

Then, the test cases are processed by the logical system and output is generated. Finally, the *expected* output is compared to the *actual* output, and any differences are investigated as possible logical bugs.

Let's construct a very small test table with only a few test cases, determine our expected outcomes, then run the tests and compare the results. We want to ensure that our rules execute properly for all cases that might be encountered in a "real-life" production system. To do this, we must create a set of cases that includes **all** such possibilities.

In our simple example of two rules, this is a relatively straightforward task:

Table 9: Table: All Combinations of Conditions in Table Form

condition	Smoker (smoker = true)	Non-Smoker (smoker = false)
Age <= 55		
Age > 55		

In this table, we have assembled a matrix using the Values sets from each of the Conditions in our rules. By arranging one set of values in rows, and the other set in columns, we create the Cross Product (also known as the *direct product* or *cross product*) of the two Values sets, which means that every member of one set is paired with every member of the other set. Since each Values set has only two members, the Cross Product yields 4 distinct possible combinations of members (2 multiplied by 2). These combinations are represented by the *intersection* of each row and column in the table above. Now let's fill in the table using the expected outcomes from our rules.

Rule 1, the age rule, is represented by row 1 in the table above. Recall that rule 1 deals exclusively with the age of the applicant and is not impacted by the applicant's smoker value. To put it another way, the rule produces the same outcome *regardless* of whether the applicant's smoker value is `true` or `false`. Therefore, the action taken when rule 1 fires (`riskRating` is assigned the value of `low`) should be entered into both cells of row 1 in the table, as shown:

Figure 199: Rule 1 Expected Outcome

condition	Smoker (smoker = true)	Non-Smoker (smoker = false)
Age <= 55	low	low
Age > 55		

Likewise, rule 2, the smoker rule, is represented by column 1 in the table above, **All Combinations of Conditions in Table Form**. The action taken if rule 2 fires (`riskRating` is assigned the value of `high`) should be entered into both cells of column 1 as shown:

Figure 200: Rule 2 Expected Outcome

condition	Smoker (smoker = true)	Non-Smoker (smoker = false)
Age <= 55	low, high	low
Age > 55	high	

The table format illustrates the fact that a complete set of test data should contain four distinct cases (each cell corresponds to a case). Rearranging, our test cases and expected results can be summarized as follows:

Figure 201: Test Cases Extracted from Cross Product

Test case	age	smoker	Expected outcome
1	<= 55	true	low, high
2	<= 55	false	low
3	> 55	true	high
4	> 55	false	

The table format also highlights two problems we encountered earlier with flowcharts. In the figure **Rule 2 Expected Outcome**, row 1 and column 1 intersect in the upper left cell (this cell corresponds to test case #1 in the figure above). As a result, each rule tries to assert its own action – one rule assigns a `low` value, and the other rule assigns a `high` value. Which rule is correct?

Logically speaking, they both are. But if the rule analyst had a *business* preference, it was certainly lost in the implementation. As before, we simply can't tell by the way the two rules are expressed. Logical conflict reveals itself once more.

Also notice the lower right cell (corresponding to test case #4) – it is empty. The combination of `age>55` **AND** non-smoker (`smoker=false`) produces no outcome because neither rule deals with this case – the logical incompleteness in our business rules reveals itself once more.

Before we deal with the logical problems discovered here, let's build a Ruletest in Studio that includes all four test cases in the figure above.

Figure 202: Inputs and Outputs of the 4 Test Cases

The screenshot shows a Ruletest interface with two main panels: 'Input' and 'Output'. Each panel contains four test cases, each with its own set of input parameters. Below these panels is a 'Rule Messages' table.

Severity	Message	Entity
Info	Applicants 55 or younger are low risk	Applicant[1]
Warning	Applicants who smoke are high risk	Applicant[1]
Info	Applicants 55 or younger are low risk	Applicant[2]
Warning	Applicants who smoke are high risk	Applicant[3]

Let's look at the test case results in the figure above. Are they consistent with our expectations? With a minor exception in case #1, the answer is yes. In case #1, `riskRating` has been assigned the value of `high`. But also notice the rule statements posted: case #1 has produced two messages which indicate that both the age rule and the smoker rule fired as expected. But since `riskRating` can hold only one value, the system non-deterministically (at least from our perspective) assigned it the value of `high`.

So if using test cases works, what is wrong with using it as part of our Analysis methodology? Let's look at the assumptions and simplifications made in the previous example:

1. We are working with just two rules with two Conditions. Imagine a rule pattern comprising three Conditions – our simple 2-dimensional table expands into three dimensions. This may still not be too difficult to work with as some people are comfortable visualizing in three dimensions. But what about four or more? It is true that large, multi-dimensional tables can be “flattened” and represented in a 2-D table, but these become very large and awkward very quickly.
2. Each of our rules contains only a single Conditional parameter limited to only two values. Each also assigns, as its Action, a single parameter which is also limited to just two values.

When the number of rules and/or values becomes very large, as is typical with real-world business decisions, the size of the Cross Product rapidly becomes unmanageable. For example, a set of only six Conditions, each choosing from only ten values produces a Cross Product of 10^6 , or one *million* combinations. Manually analyzing a million combinations for conflict and incompleteness is tedious and time-consuming, and still prone to human error.

In many cases, the potential set of cases is so large, that few project teams take the time to rigorously define all possibilities for testing. Instead, they often pull test cases from an actual database populated with real data. If this occurs, conflict and incompleteness may never be discovered during testing because it is unlikely that every possible combination will be covered by the test data.

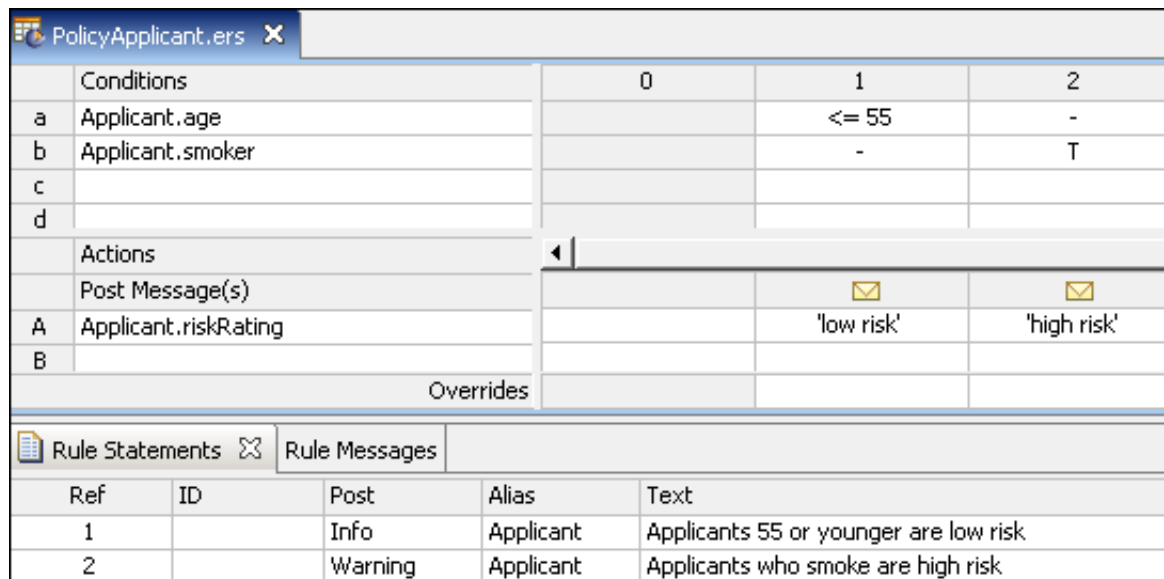
Validate and test Rulesheets in Corticon Studio

Now, having demonstrated how to test rules with real cases (as performed in [Inputs and Outputs of the 4 Test Cases](#)) as well as having discussed two manual methods for developing these test cases, it is time to demonstrate how Corticon Studio performs conflict and completeness checking automatically.

How to expand rules

Returning to our original rules (reproduced from [Simple Rules for Profiling Insurance Policy Applicants](#)):

Figure 203: Simple Rules for Profiling Insurance Policy Applicants



Conditions		0	1	2
a	Applicant.age		<= 55	-
b	Applicant.smoker		-	T
c				
d				

Actions			
Post Message(s)			
A	Applicant.riskRating	'low risk'	'high risk'
B			

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk

As illustrated by the table in [Rule 1 Expected Outcome](#), rule 1 (the age rule) is really a combination of two *sub-rules*; we specified an age value for the first Condition but did not specify a smoker value for the second Condition. Because the smoker Condition has two possible values (`true` and `false`), the two sub-rules can be stated as follows:

1. Applicants aged 55 or younger **AND** who do not smoke are assigned a risk rating of low risk
2. Applicants aged 55 or younger **AND** who do smoke are assigned a risk rating of low risk


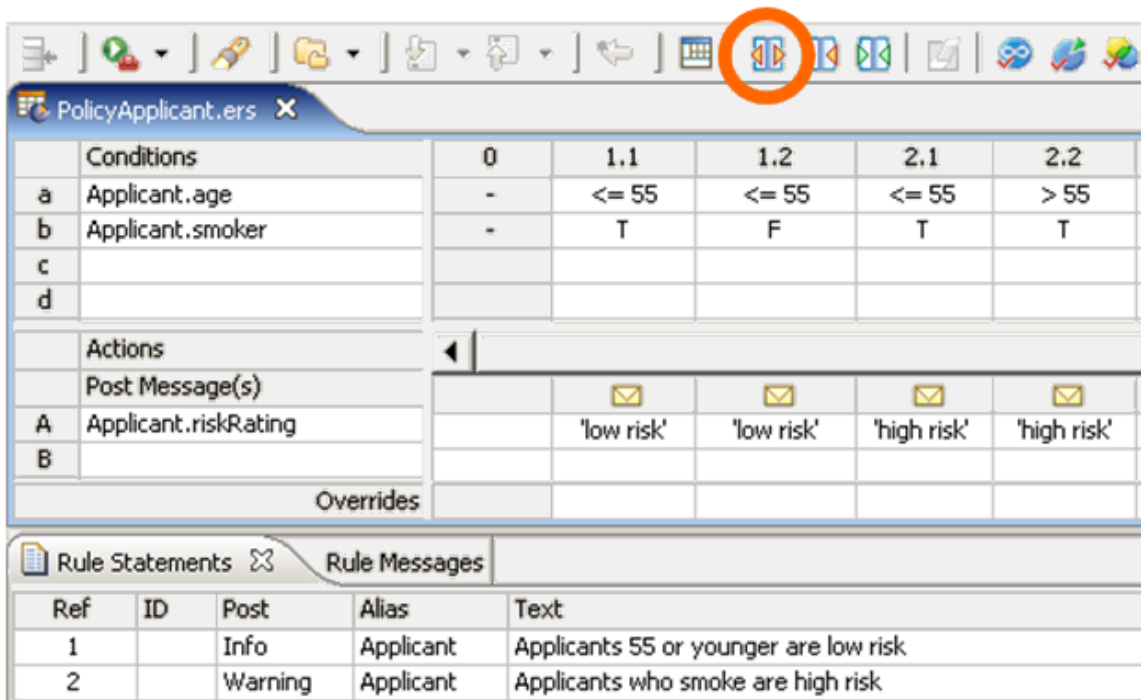
Corticon Studio makes it easy to view sub-rules for any or all columns in a Rulesheet. By clicking the **Expand Rules**  button on the toolbar, or simply double-clicking the column header, Corticon Studio will display sub-rules for any selected column. If no columns are selected, then all sub-rules for all columns will be shown. Sub-rules are labeled using Decimal numbers: rule 1 below has two sub-rules labeled 1.1 and 1.2. Sub-rules 1.1 and 1.2 are equivalent to the upper left and upper right cells in [Rule 1 Expected Outcome](#).

Figure 204: Expanding Rules to Reveal Components



Conditions		0	1.1	1.2	2.1	2.2
a	Applicant.age	-	<= 55	<= 55	<= 55	> 55
b	Applicant.smoker	-	T	F	T	T
c						
d						
Actions						
Post Message(s)			✉	✉	✉	✉
A	Applicant.riskRating		'low risk'	'low risk'	'high risk'	'high risk'
B						
Overrides						

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk

As we pointed out before, the outcome is the same for each sub-rule. Because of this, the sub-rules can be summarized as the general rules shown in column 1 of [Simple Rules for Profiling Insurance Policy Applicants](#). We also say that the two sub-rules collapse into the rules shown in column 1. The 'dash' symbol in the smoker value of column 1 indicates that the actual value of smoker does not matter to the execution of the rule – it will assign `riskRating` the value of `low` no matter what the smoker value is (as long as `age <= 55`, satisfying the first Condition). Looking at it a different way, only those rules with dashes in their columns have sub-rules, one for each value in the complete value set determined for that Condition row.

The conflict checker


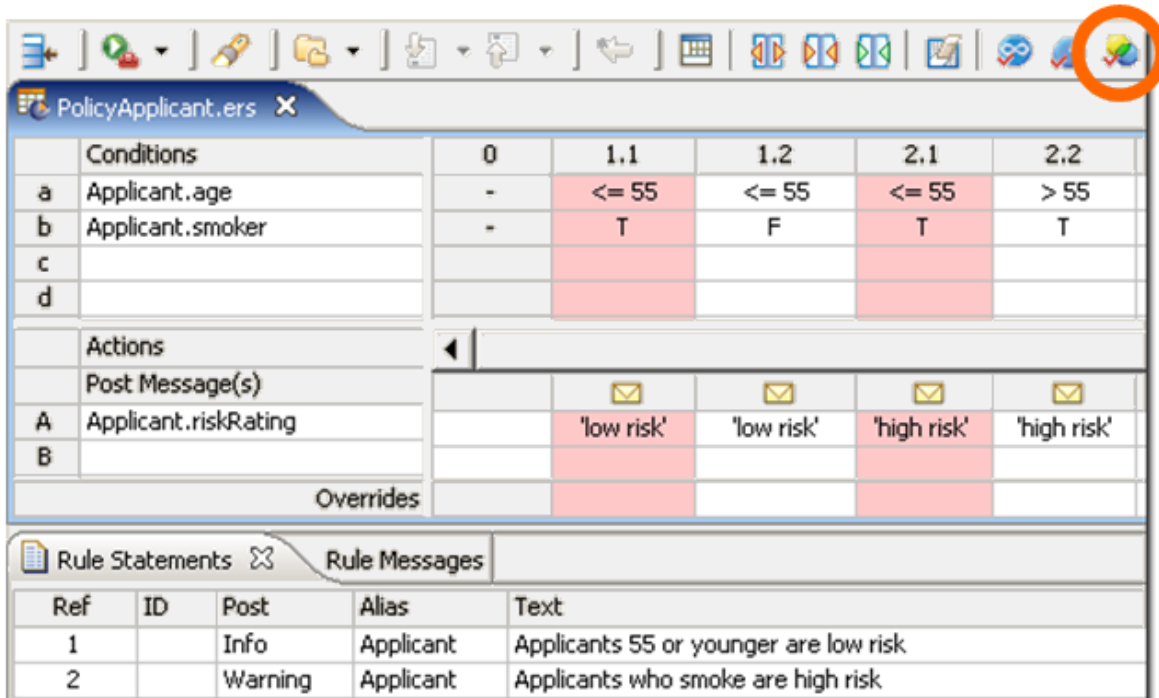
With our two rules expanded into four sub-rules as shown in [Expanding Rules to Reveal Components](#), most of the Cross Product is displayed for us. Click the **Check for Conflicts**  button in the toolbar.



Figure 205: A Conflict Revealed by the Conflict Checker



	0	1.1	1.2	2.1	2.2
Conditions					
a Applicant.age	-	<= 55	<= 55	<= 55	> 55
b Applicant.smoker	-	T	F	T	T
c					
d					
Actions					
Post Message(s)					
A Applicant.riskRating		'low risk'	'low risk'	'high risk'	'high risk'
B					
Overrides					

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk

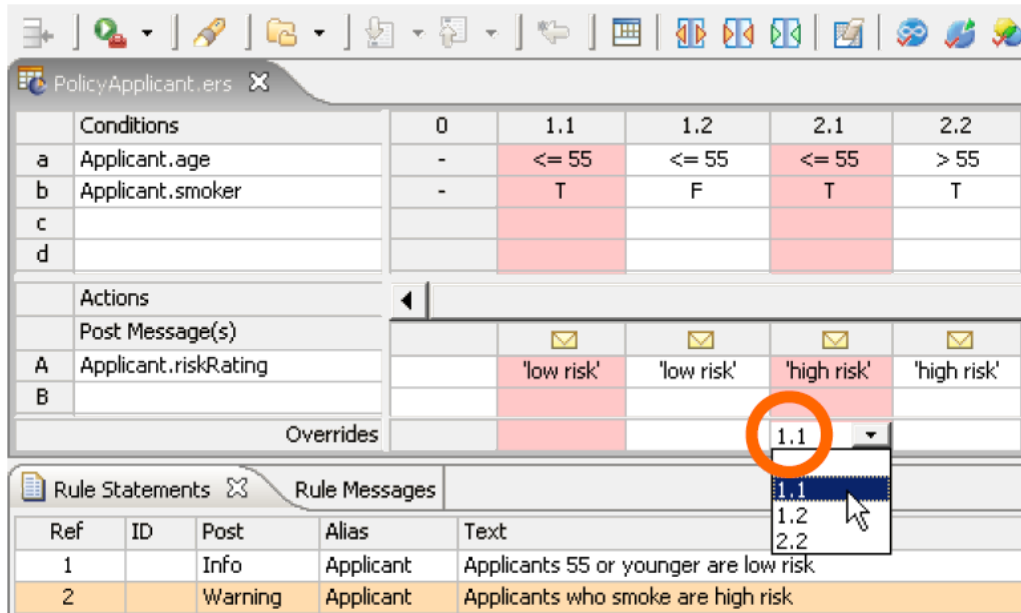
The mechanics of stepping through and resolving each conflict are described in detail in the *Corticon Studio - Basic Tutorial*.

Note: Refresher on conflict discovery and resolution -- On a Rulesheet, click **Check for Conflicts** , and then expand the rules by clicking **Expand Rules** . Expansion shows all of the logical possibilities for each rule. To resolve conflict, either change the rules, or decide that one rule should override another. To do that, in the **Overrides** row at each column intersection where an override is intended, select the one or more column numbers that will be overridden when that rule fires. Click **Check for Conflicts** again to confirm that the conflicts are resolved.

In this topic, our intent is to correlate the results of the automatic conflict check with the problems we identified first with the flowchart method, then later with test cases. Sub-rules 1.1 and 2.1, the sub-rules highlighted in pink and yellow in [Figure 205: A Conflict Revealed by the Conflict Checker](#) on page 255, correspond to the intersection of column 1 and row 1 of [Rule 2 Expected Outcome](#) or test case #1 in [Test Cases Extracted from Cross Product](#). But note that Corticon Studio does not instruct the rule writer how to resolve the conflict – it simply alerts the rule writer to its presence. The rule writer, ideally someone who knows the business, must decide how to resolve the problem. The rule writer has two basic choices:

1. Change the Action(s) for one or both rules. We could change the Action in sub-rule 1.1 to match 2.1 or vice versa. Or we could introduce a new Action, say riskRating = medium, as the Action for both 1.1 and 2.1. If either method is used, the result will be that the Conditions and Actions of sub-rule 1.1 and 2.1 are *identical*. This removes the conflict, but introduces redundancy, which, while not a logical problem, can reduce processing performance in deployment. Removing redundancies in Rulesheets is discussed in the [How to optimize Rulesheets](#) on page 276 topics.
2. Use an **Override**. Think of an override as an exception. To override one rule with another means to instruct the Corticon Server to fire *only one* rule even when the Conditions of both rules are satisfied. Another way to think about overrides is to refer back to the discussion surrounding the flowchart in [Flowchart with 2 Dependent Rules](#). At the time, we were unclear which decision should execute first – no priority had been declared in our rules. But it made a big difference how we constructed our flowchart and what results it generated. To use an override here, we simply select the number of the sub-rule *to be overridden* from the drop-down box at the bottom of the column of the *overriding* sub-rule, as shown circled in the following figure. This is expressed simply as “sub-rule 2.1 overrides 1.1”. It is incorrect to think of overrides as defining execution sequence. An override does not mean “fire rule 2.1 **then** fire rule 1.1.” It means “fire rule 2.1 and **do not** fire rule 1.1”.

Figure 206: Override Entered to Resolve Conflict



An override is essentially another business rule, which should to be expressed somewhere in the *Rule Statements* section of the Rulesheet. To express this override in plain English, the rule writer might choose to modify the rule statement for the *overridden* rule:

1. Applicants aged 55 or younger are assigned a low risk rating *unless* they smoke, in which case they are assigned a high risk rating.

This modification successfully expresses the effect of the override.

If ever in doubt as to whether you have successfully resolved a conflict, simply click the **Check for Conflicts** button again. The affected sub-rules should not highlight as you step through any remaining ambiguities. If all ambiguities have been resolved, you will see the following window:

Figure 207: Conflict Resolution Complete



Note: How does one rule override another rule? - To understand overrides, the first concept to learn is *condition context*. The condition context of a rule is the set of all entities, aliases, and associations that are needed to evaluate all the conditional expressions of a rule. The second concept is the *override context*. The override context is defined using set algebra. The override context of two rules is the intersection of the two rule's condition contexts. To evaluate the override, the set of entities that fulfill the overriding rule's conditions are trimmed to the override context and recorded. Before the conditions of the overridden rule are evaluated, the entities that are part of the override context are tested to determine if they have been recorded; if so, the rule is overridden and processing of the rule with those entities is halted. If the override context is empty, then any execution of the overriding rule will stop all executions of the overridden rule.

Use overrides to handle conflicts that are logical dependencies

Overrides can be used for more than just conflicting rules. While the basic use of overrides is in cases where rules are in conflict to allow the modeler to control execution, it is not the only use. The more advanced usage applies cases where there is a *logical dependency* -- cases where a rule might modify the data so that another rule can also execute. This type of conflict is not detected by the conflict checker.

Consider a simple Cargo Rulesheet:

Conditions		0	1	2
a	Cargo.volume		100	200
b				
c				
Actions		<input type="text" value=" "/>		
Post Message(s)				
A	Cargo.volume		200	150
R				
Overrides				

When tested, the first rule is triggered and its action sets a value that triggers rule 2:

Input	Output
<ul style="list-style-type: none"> ▲ Cargo [1] <ul style="list-style-type: none"> ▣ container ▣ volume [100] ▣ weight ▲ Cargo [2] <ul style="list-style-type: none"> ▣ container ▣ volume [200] ▣ weight 	<ul style="list-style-type: none"> ▲ Cargo [1] <ul style="list-style-type: none"> ▣ container ▣ volume [150] ▣ weight ▲ Cargo [2] <ul style="list-style-type: none"> ▣ container ▣ volume [150] ▣ weight

The Ruletest result shows that the value set in the first rule's action modified the data so that the change in the condition's value triggered the second rule. If this effect is not what is intended, an override can be used. The use of an override here ensures that the modification of data will not trigger execution of the second rule -- they are *mutually exclusive* (mutex). When an override is set on rule 1 that specifies that, if it fired, it should skip rule 2...

Conditions		0	1	2
a	Cargo.volume		100	200
b				
c				
Actions		<input type="text" value=" "/>		
Post Message(s)				
A	Cargo.volume		200	150
R				
Overrides			2	

... the rules produce the preferred output:

Input	Output
<ul style="list-style-type: none"> ▲ Cargo [1] <ul style="list-style-type: none"> ▣ container ▣ volume [100] ▣ weight ▲ Cargo [2] <ul style="list-style-type: none"> ▣ container ▣ volume [200] ▣ weight 	<ul style="list-style-type: none"> ▲ Cargo [1] <ul style="list-style-type: none"> ▣ container ▣ volume [200] ▣ weight ▲ Cargo [2] <ul style="list-style-type: none"> ▣ container ▣ volume [150] ▣ weight

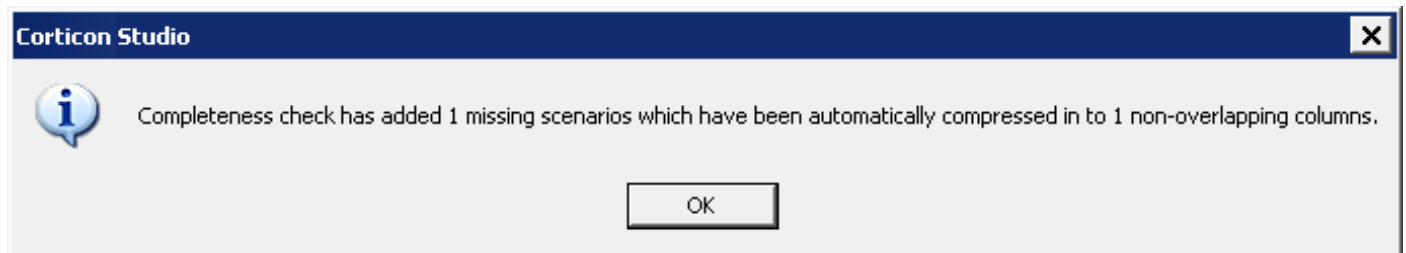
If these rules were re-ordered, the override would be unnecessary.

The completeness checker

While our rules are expanded, let's check for incompleteness. Again, the mechanics of this process are described in the *Tutorial: Basic Rule Modeling*. Our discussion here will be limited to correlating results with the previous manual methods of logical analysis.

Clicking the **Check for Completeness**  button, the message window is displayed:

Figure 208: Completeness Check Message Window



Clicking **OK** to dismiss the message window, we see that the Completeness Check has produced a new column (3), shaded in green:

Figure 209: New Rule Added by Completeness Check

Conditions	0	1.1	1.2	2.1	2.2	3
a Applicant.age	-	<= 55	<= 55	<= 55	> 55	> 55
b Applicant.smoker	-	T	F	T	T	F
c						
d						
Actions						
Post Message(s)		✉	✉	✉	✉	
A Applicant.riskRating		'low risk'	'low risk'	'high risk'	'high risk'	
B						
Overrides				1.1		

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk

2. An applicant older than 55 who does not smoke is profiled as medium risk

This new rule, the combination of `age>55 AND smoker=false` corresponds to the intersection of column 2 and row 2 in [Rule 2 Expected Outcome](#) and test case #4 in [Test Cases Extracted from Cross Product](#). The Completeness Checker has discovered our missing rule! To do this, the Completeness Checker employs an algorithm which calculates all mathematical combinations of the Conditions' values (the Cross Product), and compares them to the combinations defined by the rule writer as other columns (other rules in the Rulesheet). If the comparison determines that some combinations are missing from the Rulesheet, these combinations are automatically added to the Rulesheet. As with the Conflict Check, the Action definitions of the new rules are left to the rule writer. The rule writer should also remember to enter new plain-language **Rule Statements** for the new columns so it is clear what logic is being modeled. The corresponding rule statement might look like this:

2. An applicant older than 55 who does not smoke is profiled as medium risk

Automatically determine the complete values set

As values are manually entered into column cells in a Condition row, Corticon Studio automatically creates and updates a set of values, which for the given datatype of the Condition expression, is complete. This means that as you populate column cells, the list of values in the drop-down boxes you select from will grow and change.

In the drop-down box, you will see the list of values you have entered, plus null if the attribute or expression can have that value. But this list displayed in the drop-down is not the *complete* list – Corticon Studio maintains the complete list “under the covers” and only shows you the elements which you have manually inserted.

This automatically generated complete value list serves to feed the Completeness Checker with the information it needs to calculate the Cross Product and generate additional “green” columns. Without complete lists of possible values, the calculated Cross Product itself will be incomplete.

Automatically compress the new columns

An important aspect of the Completeness Checker's operation is the automatic compression it performs on the resulting set of missing Conditions. As we see from the message displayed in [Completeness Check Message Window](#), the algorithm not only identifies the missing rules, but it also compresses them into *non-overlapping* columns. Two important points about this statement:

1. The compression performed by the Completeness Checker is a different kind of compression from that performed by the Compression Tool introduced in the [Optimization](#) section. The optimized columns produced by the Completeness Check contain *no redundant sub-rules* (that's what non-overlapping means), whereas the Compression Tool will intentionally inject redundant sub-rules in order to create dashes wherever possible. This creates the optimal visual representation of the rules.
2. The compression performed here is designed to reduce the results set (which could be extremely large) into a manageable number while simultaneously introducing no ambiguities into the Rulesheet (which might arise due to redundant sub-rules being assigned different Actions).

Handle limitations of the completeness checker

The Completeness Checker is powerful in its ability to discover missing combinations of Conditions from your Rulesheet. However, it is not smart enough to determine if these combinations make *business sense* or not. The example in the following figure shows two rules used in a health care scenario to screen for high-risk pregnancies:

Figure 210: Example Prior to Completeness Check

Conditions		0	1	2
a	Patient.gender		'female'	'female'
b	Patient.age		<= 40	> 40
c	Patient.pregnant		T	T
d				

Actions			
Post Message(s)			
A	Patient.riskFactor	'normal'	'elevated'
B			

Ref	ID	Post	Alias	Text
1		Info	Patient	Pregnant patients age 40 and younger are assigned a risk factor of normal risk
2		Warning	Patient	Pregnant patients older than 40 are assigned a risk factor of elevated risk

Now, we will click on the Completeness Checker:

Figure 211: Example after Completeness Check

Conditions		0	1	2	3	4
a	Patient.gender	-	'female'	'female'	<> 'female'	'female'
b	Patient.age	-	<= 40	> 40	-	-
c	Patient.pregnant	-	T	T	-	F
d						

Actions					
Post Message(s)					
A	Patient.riskFactor		'normal'	'elevated'	
B					

Ref	ID	Post	Alias	Text
1		Info	Patient	Pregnant patients age 40 and younger are assigned a risk factor of normal risk
2		Warning	Patient	Pregnant patients older than 40 are assigned a risk factor of elevated risk

Progress Corticon Studio

Completeness check has added 6 missing scenarios which have been automatically compressed in to 2 non-overlapping columns.

OK

Notice that columns 3-4 have been automatically added to the Rulesheet. But also notice that column 3 contains an unusual Condition: `gender <> female`. Because the other two Conditions in column 3 have dash values, we know it contains component or sub-rules. By double-clicking on column 3's header, its sub-rules are revealed:

Figure 212: Non-Female Sub-Rules Revealed

3.1	3.2	3.3	3.4
<> 'female'	<> 'female'	<> 'female'	<> 'female'
<= 40	<= 40	> 40	> 40
T	F	T	F

Because our Rulesheet is intended to identify high-risk pregnancies, it would not seem necessary to evaluate non-female (i.e., male) patients at all. And if male patients are evaluated, then we can say with some certainty that the scenarios described by sub-rules 3.1 and 3.3 – those scenarios containing pregnant males – are truly unnecessary. While these combinations may be members of the Cross Product, they are clearly not combinations that can occur in real life. If other rules in an application prevent combinations like this from occurring, then sub-rules 3.1 and 3.3 may also be unnecessary here. On the other hand, if no other rules catch this faulty combination earlier, then we may want to use this opportunity to raise an error message or take some other action that prompts a re-examination of the input data.

Renumber rules

Assume that we agree that sub-rules 3.1 and 3.3 are impossible, and so may be safely ignored. However, we decide to keep sub-rules 3.2 and 3.4 and assign Actions T to them. For this example, we will just post violation messages to them.

However, when we try to enter Rule Statements for sub-rules 3.2 and 3.4, we discover that Rule Statements can only be entered for general rules (whole-numbered columns), not sub-rules. To convert column 3, with its four sub-rules, into four whole-numbered general rules, select **Rulesheet > Rule Column(s) > Renumber Rules** from the **Studio** menubar.

Figure 213: Sub-Rules Renumbered and Converted to General Rules

The screenshot shows the Studio interface with a Rulesheet window titled 'CompletenessCheckerLimitations.ers'. The Rulesheet has columns 0 through 7. Column 0 is 'Conditions'. Columns 1-7 contain conditions for Patient.gender, Patient.age, and Patient.pregnant. Below the Rulesheet is the 'Actions' section with 'Post Message(s)' and 'Patient.riskFactor' (with sub-rules A and B). At the bottom is the 'Rule Messages' table.

Conditions	0	1	2	3	4	5	6	7
a Patient.gender	-	'female'	'female'	<> 'female'	<> 'female'	<> 'female'	<> 'female'	'female'
b Patient.age	-	<= 40	> 40	<= 40	<= 40	> 40	> 40	-
c Patient.pregnant	-	T	T	T	F	T	F	F
d								

Ref	ID	Post	Alias	Text
1		Info	Patient	Pregnant patients age 40 and younger are assigned a risk factor of normal risk
2		Warning	Patient	Pregnant patients older than 40 are assigned a risk factor of elevated risk

Now that the columns have been renumbered, Rule Statements may be assigned to columns 4 and 6, and columns 3 and 5 can be deleted or disabled (if you want to do so).

When impossible or useless rules are created by the Completeness Checker, we recommend disabling the rule columns rather than deleting them. When disabled, the columns remain visible to all modelers, eliminating any surprise (and shock) when future modelers apply the Completeness Check and discover missing rules that you had already found and deleted. And if you disable the columns, be sure to include a Rule Statement that explains why. See the following figure for an example of a fully complete and well-documented Rulesheet

Figure 214: Final Rulesheet with impossible rules disabled

The screenshot shows the 'CompletenessCheckerLimitations.ers' window. It features a grid with columns 0-7 and rows for conditions (a-d), actions (A-B), and overrides. Below the grid is a 'Rule Statements' tab with a table of messages.

	Conditions	0	1	2	3	4	5	6	7
a	Patient.gender	-	'female'	'female'	<> 'female'	<> 'female'	<> 'female'	<> 'female'	'female'
b	Patient.age	-	<= 40	> 40	<= 40	<= 40	> 40	> 40	-
c	Patient.pregnant	-	T	T	T	F	T	F	F
d									
Actions									
Post Message(s)									
A	Patient.riskFactor		✉	✉	✉	✉	✉	✉	✉
B									
Overrides									

Ref	ID	Post	Alias	Text
1		Info	Patient	Pregnant patients age 40 and younger are assigned a risk factor of normal risk
2		Warning	Patient	Pregnant patients older than 40 are assigned a risk factor of elevated risk
{ 4 , 6 }		Warning	Patient	Non-pregnant, non-females not considered by this decision
{ 3 , 5 }		Violation	Patient	Pregnant non-females are not possible: these rules have been disabled
7		Warning	Patient	Non-pregnant females not considered by this decision

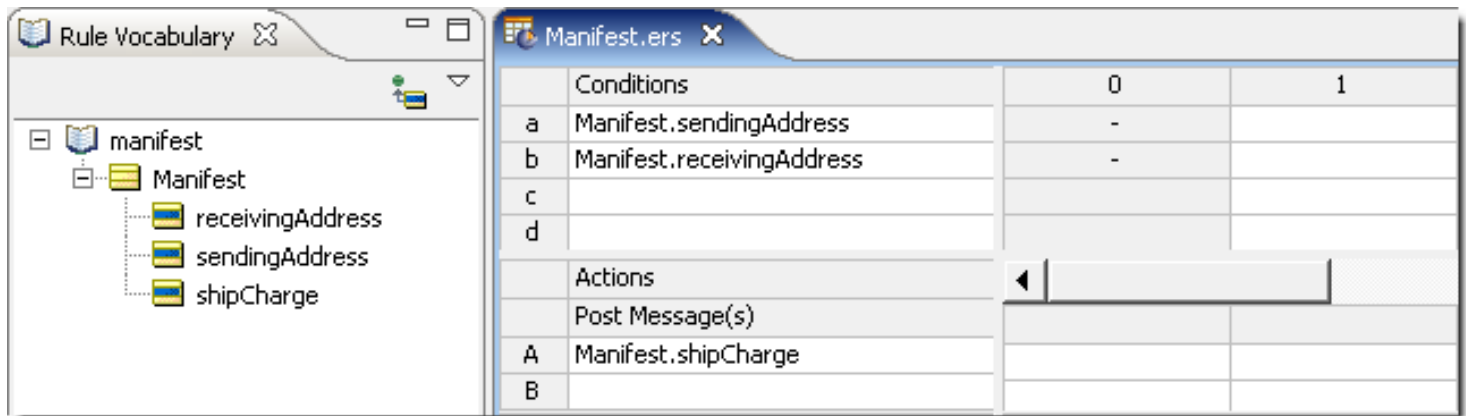
Let the expansion tool work for you with tabular rules

Business rules, especially those found in operational manuals or procedures, often take the form of tables. Take for example the following table that generates shipping charges between two geographic zones:

Matrix to Calculate Shipping Charges per Kilogram					
From/To	zone 1	zone 2	zone 3	zone 4	zone 5
zone 1	\$1 . 25	\$2 . 35	\$3 . 45	\$4 . 55	\$5 . 65
zone 2	\$2 . 35	\$1 . 25	\$2 . 35	\$3 . 45	\$4 . 55
zone 3	\$3 . 45	\$2 . 35	\$1 . 25	\$2 . 35	\$3 . 45
zone 4	\$4 . 55	\$3 . 45	\$2 . 35	\$1 . 25	\$2 . 35
zone 5	\$5 . 65	\$4 . 55	\$3 . 45	\$2 . 35	\$1 . 25

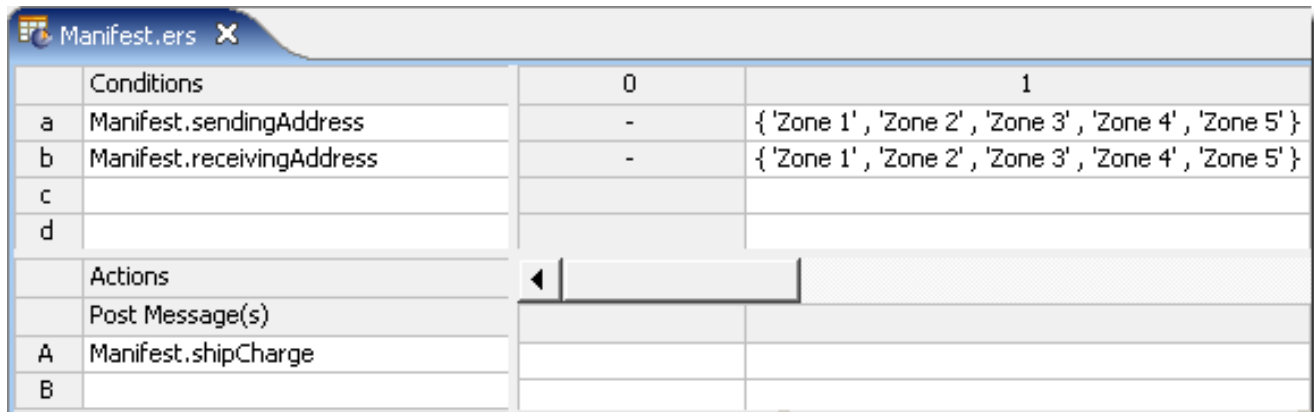
In the following figure, we have built a simple Vocabulary with which to implement these rules. Because each cell in the table represents a single rule, our Rulesheet will contain 25 columns (the Cross Product equals 5x5 or 25).

Figure 215: Vocabulary and Rulesheet to Implement Matrix



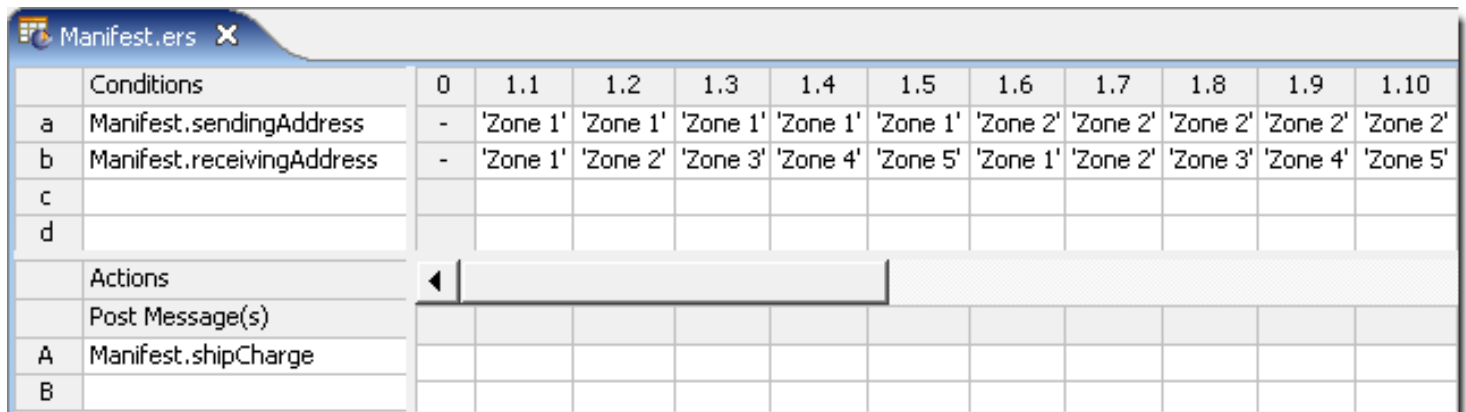
Rather than manually create all 25 combinations (and risk making a mistake), you can use the Expansion Tool to help you do it. This is a three-step process. Step 1 consists of entering the full range of values found in the table in the Conditions cells, as shown:

Figure 216: Rulesheet with Conditions Automatically Populated



Now, use the Expansion Tool to expand column 1 into 25 non-overlapping columns. We now see the 25 sub-rules of column 1 (only the first ten sub-rules are shown in the following figure due to page width limitations in this document):

Figure 217: Rule 1 Expanded to Show Sub-Rules



Each sub-rule represents a single cell in the original table. Now, select the appropriate value of `shipCharge` in the **Actions** section of each sub-rule as shown:

Figure 218: Rulesheet with Actions Populated

Conditions		0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10
a	Manifest.sendingAddress	-	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 2'	'Zone 2'	'Zone 2'	'Zone 2'	'Zone 2'
b	Manifest.receivingAddress	-	'Zone 1'	'Zone 2'	'Zone 3'	'Zone 4'	'Zone 5'	'Zone 1'	'Zone 2'	'Zone 3'	'Zone 4'	'Zone 5'
c												
d												
Actions		←										
Post Message(s)												
A	Manifest.shipCharge		0.25	0.35	0.45	0.55	0.65	0.35	0.25	0.35	0.45	0.55
B												

In step 3, shown in the following figure, we select **Rulesheet > Rule Column(s) > Renumber Rules** to *renumber* the sub-rules to arrive at the final Rulesheet with 25 general rules, each of which may now be assigned a Rule Statement.

Figure 219: Rulesheet with Renumbered Rules

Conditions		0	1	2	3	4	5	6	7	8	9	10
a	Manifest.sendingAddress	-	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 2'	'Zone 2'	'Zone 2'	'Zone 2'	'Zone 2'
b	Manifest.receivingAddress	-	'Zone 1'	'Zone 2'	'Zone 3'	'Zone 4'	'Zone 5'	'Zone 1'	'Zone 2'	'Zone 3'	'Zone 4'	'Zone 5'
c												
d												
Actions		←										
Post Message(s)												
A	Manifest.shipCharge		0.25	0.35	0.45	0.55	0.65	0.35	0.25	0.35	0.45	0.55
B												

We will revisit this example in the [Optimization](#) section.

Memory management

As you might suspect, the Completeness Checker and Expansion algorithms are memory-intensive, especially as Rulesheets become very large. If Corticon Studio runs low on memory, get details on increasing Corticon Studio's memory allotment in *"Increase Corticon Studio memory allocation"* in the *Corticon Installation Guide*.


Logical loop detection

Corticon Studio has the ability to both detect and control rule looping. This is important because loops are sometimes inadvertently created during rule implementation. Other times, looping is intentionally introduced to accomplish specific purposes. .

Test rule scenarios in the Ruletest Expected panel

Using Ruletests you can submit request data as input to Rulesheets or Ruleflows to see how the rules are evaluated and the resulting output. You can make Ruletests even more powerful by specifying the results you expected, and then seeing how it reconciles with the output. Running the test against a specified Rulesheet or Ruleflow automatically compares the actual **Output** data to your **Expected** data, and color codes the differences for easy review and analysis.


You can establish the expected data in either of two ways:

1. Create expected data from test output:
 - a. Create or import a request into a Ruletest
 - b. Run the test against an appropriate Rulesheet or Ruleflow.
 - c. Choose the menu command **Ruletest > Testsheet > Data > Output > Copy to Expected**, or click  button in the Corticon Studio toolbar.
2. Create expected data directly from the Vocabulary:
 - a. Drag and drop nodes from the **Rule Vocabulary** window to create a tree structure in the **Expected** panel that is identical to the input tree.
 - b. Enter expected values for the **Input** attributes as well as the attributes that will be added in the **Output** panel.

Note: See the topics in [Techniques that refine rule testing](#) on page 270.

How to navigate in Ruletest Expected comparison results

When reviewing the results of a test run, two navigation features help you focus your attention :

- **Synchronized scrolling** - When you slide the scroll tab in the Ruletest panels, the three columns do not move together, making alignment of data points difficult. You can set (or unset) synchronized scrolling of the columns by either right-clicking any of the Ruletest panels and then choosing **Scroll Lock**, or clicking  in the Corticon Studio toolbar. Once set to synchronize, all panels will synchronize their scrolling, even advancing across collapsed entities and associations to stay synchronized on the first displayed line.
- **Navigation to differences** - The Ruletest window provides a set of controls that report the number of discovered differences and controls to navigate across the items. In the upper right of the Ruletest window, the following image shows that the test results have identified six differences:

Differences: 6 

The four buttons, as appropriate, take you to the first, previous, next, and last discovered difference.

Review test results when using the Expected panel

The following topics present a variety of test results.

Output results match expected exactly

In the example below, both `packaging` values are shown in **bold** text, indicating that these values were changed by the rules. Because all colors are black and the differences count is **0**, the **Output** data is consistent with the **Expected** data.

The screenshot shows the Ruletest Expected panel for a file named 'untitled_1'. The path is '/Tutorial/Tutorial-Done/tutorial_example.erf' and the differences count is 0. The panel is divided into three columns: Input, Output, and Expected. The Input data consists of two cargo items, each with container, volume, and weight attributes. The Output data is identical to the Input data, but the 'container' attribute for both cargo items is bolded and labeled as '[standard]'. The Expected data is identical to the Input data. Below the comparison panel is a 'Rule Messages' panel with a table showing two Info messages: 'Cargo weighing <= 20,000 kilos must be packaged in a standard container.' for Cargo[2] and Cargo[1].

Severity	Message	Entity
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[2]
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[1]

Different values output than expected

In the example shown below, one difference has been identified. The expected value of `Cargo[2]` packaging value is `standard`, but the Ruletest produced an actual value of `oversize`. Since the **Output** does not match the **Expected** data, the text is colored red.

The screenshot shows a software interface with a window titled 'untitled_1'. The main area is divided into three columns: 'Input', 'Output', and 'Expected'. The 'Input' column shows two cargo items: 'Cargo [1]' with attributes 'container', 'volume [10]', and 'weight [1000]'; and 'Cargo [2]' with attributes 'container', 'volume [30]', and 'weight [600]'. The 'Output' column shows 'Cargo [1]' with 'container [standard]', 'volume [10]', and 'weight [1000]'; and 'Cargo [2]' with 'container [oversize]', 'volume [30]', and 'weight [600]'. The 'Expected' column shows 'Cargo [1]' with 'container [standard]', 'volume [10]', and 'weight [1000]'; and 'Cargo [2]' with 'container [standard]', 'volume [30]', and 'weight [600]'. The 'Output' and 'Expected' columns have a 'Differences: 1' indicator. Below the comparison is a 'Rule Messages' table with two entries:

Severity	Message	Entity
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[2]
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[1]

In this example, notice that it is the value determined by the rule that changed, not the input values. Research indicates that the designer changed the rule for volume from >30 to ≥ 30 thereby triggering the different container requirement.

Fewer values output than expected

In the example below, `Cargo[2]` has no input attribute values in the **Input** panel. The rule test failed because of inadequate input data, and the two missing attributes (and their expected values) are colored green.

untitled_1
/Tutorial/Tutorial-Done/tutorial_example.erf Differences: 3

Input	Output	Expected
<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [standard] volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [standard] volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container [standard] volume [30] weight [600]

Severity	Message	Entity
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[1]

More values output than expected

In the example below, Cargo [3] was added in the **Input**, and shown correctly in the **Output** panel. But because it was not anticipated by the **Expected** panel, it is colored blue as one difference at the entity level.

/Tutorial/Tutorial-Done/tutorial_example.erf Differences: 1

Input	Output	Expected
<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container volume [30] weight [600] Cargo [3] <ul style="list-style-type: none"> container volume [75] weight [22000] 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [standard] volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container [standard] volume [30] weight [600] Cargo [3] <ul style="list-style-type: none"> container [oversize] volume [75] weight [22000] 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [standard] volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container [standard] volume [30] weight [600]

Severity	Message	Entity
Info	Cargo with volume > 30 cubic meters must be packaged in an oversize container.	Cargo[3]
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[2]
Info	Cargo weighing <= 20,000 kilos must be packaged in a standard container.	Cargo[1]

All Expected panel problems

In this example, there are three differences. The designer changed the trigger point for volume so `Cargo[1]` chose a container that is different from what was previously expected. `Cargo[3]` is on the input and likewise in the output, but `Cargo[2]` was expected and is missing from the output.

The screenshot displays a comparison of data between three panels: Input, Output, and Expected. The file path is `/Tutorial/Tutorial-Done/tutorial_example.erf` and there are 3 differences.

Input	Output	Expected
<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container volume [10] weight [1000] Cargo [3] <ul style="list-style-type: none"> container volume [75] weight [22000] 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [oversize] volume [10] weight [1000] Cargo [3] <ul style="list-style-type: none"> container [oversize] volume [75] weight [22000] 	<ul style="list-style-type: none"> Cargo [1] <ul style="list-style-type: none"> container [standard] volume [10] weight [1000] Cargo [2] <ul style="list-style-type: none"> container [standard] volume [30] weight [600]

Severity	Message	Entity
Info	Cargo with volume > 30 cubic meters must be packaged in an oversize container.	Cargo[1]
Info	Cargo with volume > 30 cubic meters must be packaged in an oversize container.	Cargo[3]

Techniques that refine rule testing

The following settings help you tune the results of comparing the output data and expected data so that irrelevant errors are minimized:

Set selected attributes to ignore validation

When different values are output than what was expected, it could mean that the **Expected** panel data created from **Output** data were reflecting dynamic values such as dates and time. If your Rulesheets use `now` or `today`, the **Expected** values will evaluate as errors very soon. To handle that situation, you can choose to ignore validation for selected values in the **Expected** panel.

Consider the following example:

The selected attribute in this test has no input value and no expected value

Input	Output	Expected
<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [0] type [Standard] 		<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [2220.000000] type [Standard]

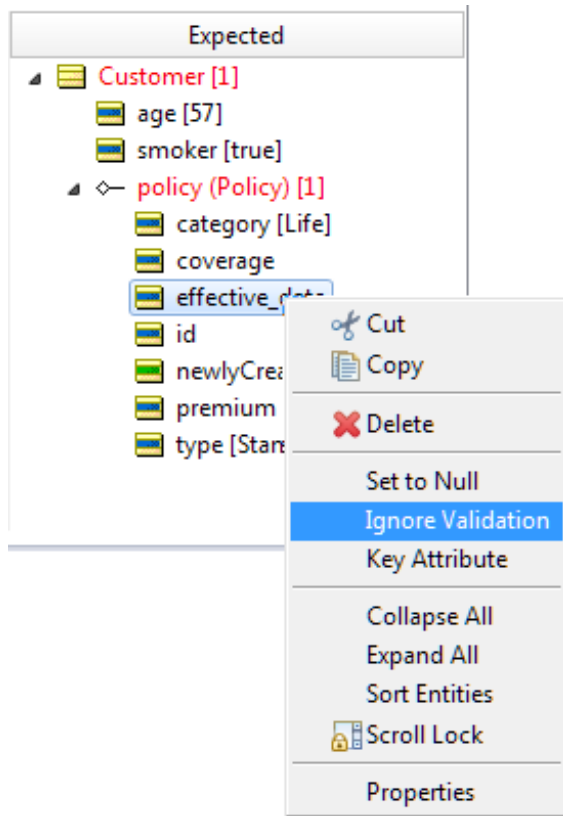
When the test runs, it is valid.

Input	Output	Expected
<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [0] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [2220.000000] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [2220.000000] type [Standard]

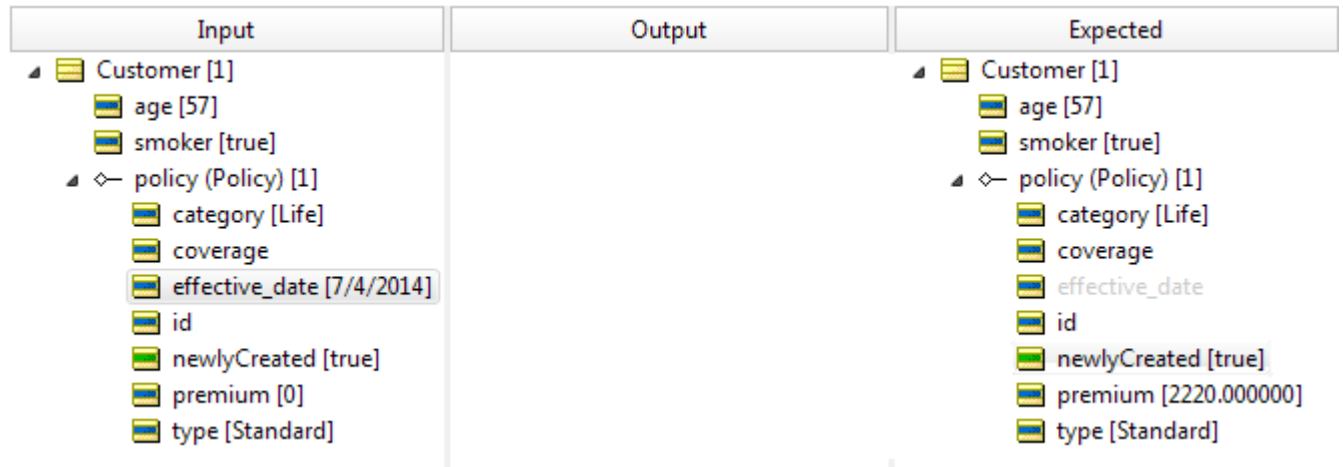
But when the input gets a value and the output still has no value (or a different value), the test fails.

Input	Output	Expected
<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date [7/4/2014] id newlyCreated [true] premium [0] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date [7/4/2014] id newlyCreated [true] premium [2220.000000] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [2220.000000] type [Standard]

Clicking on the expected attribute, you can choose **Ignore Validation**.



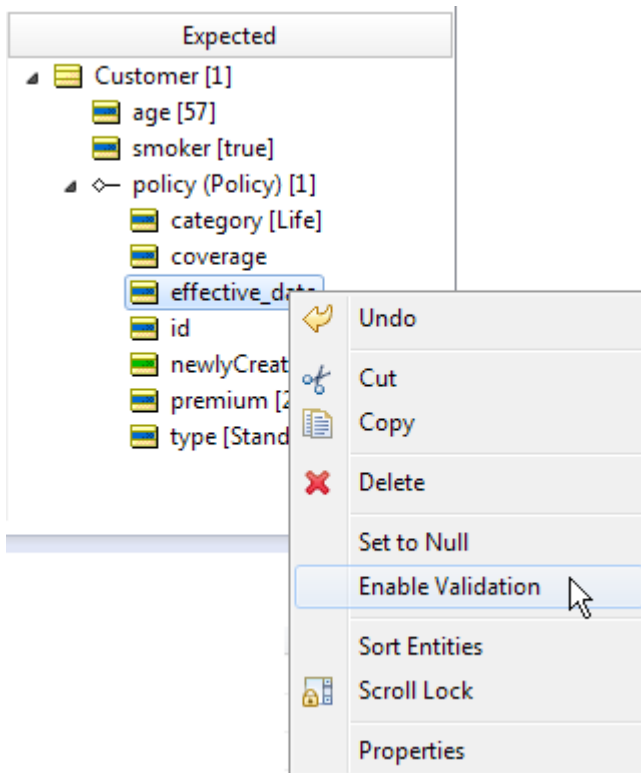
An attribute that will be ignored is greyed out.



Running the same test, the test passes.

Input	Output	Expected
<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date [7/4/2014] id newlyCreated [true] premium [0] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date [7/4/2014] id newlyCreated [true] premium [2220.000000] type [Standard] 	<ul style="list-style-type: none"> Customer [1] <ul style="list-style-type: none"> age [57] smoker [true] policy (Policy) [1] <ul style="list-style-type: none"> category [Life] coverage effective_date id newlyCreated [true] premium [2220.000000] type [Standard]

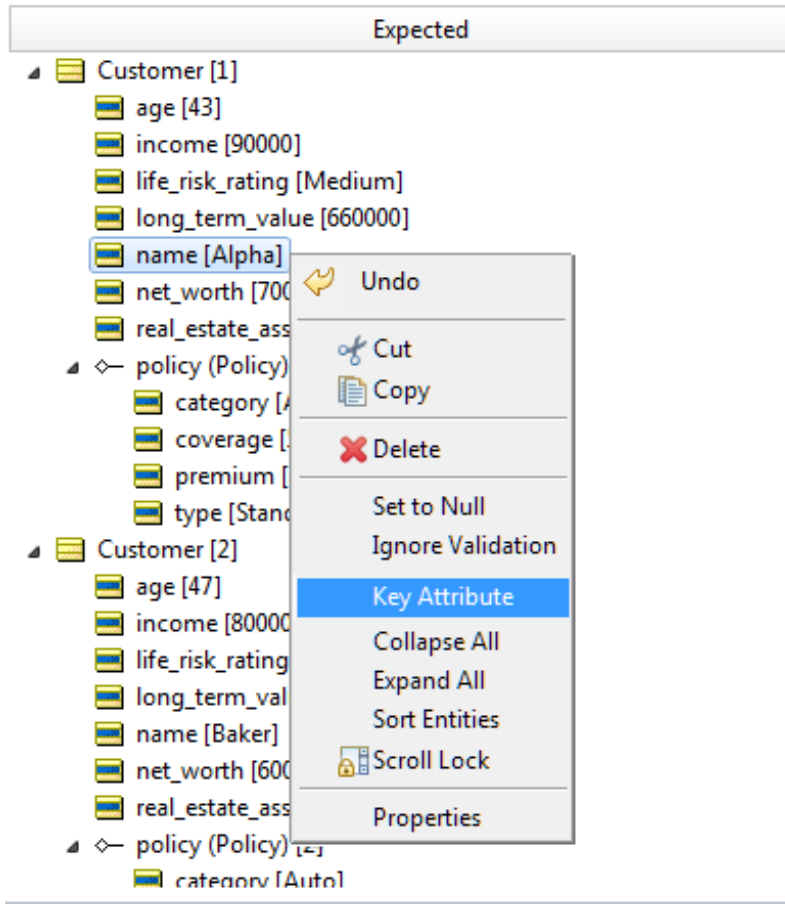
The setting can revert by selecting the attribute and then choosing **Enable Validation**.



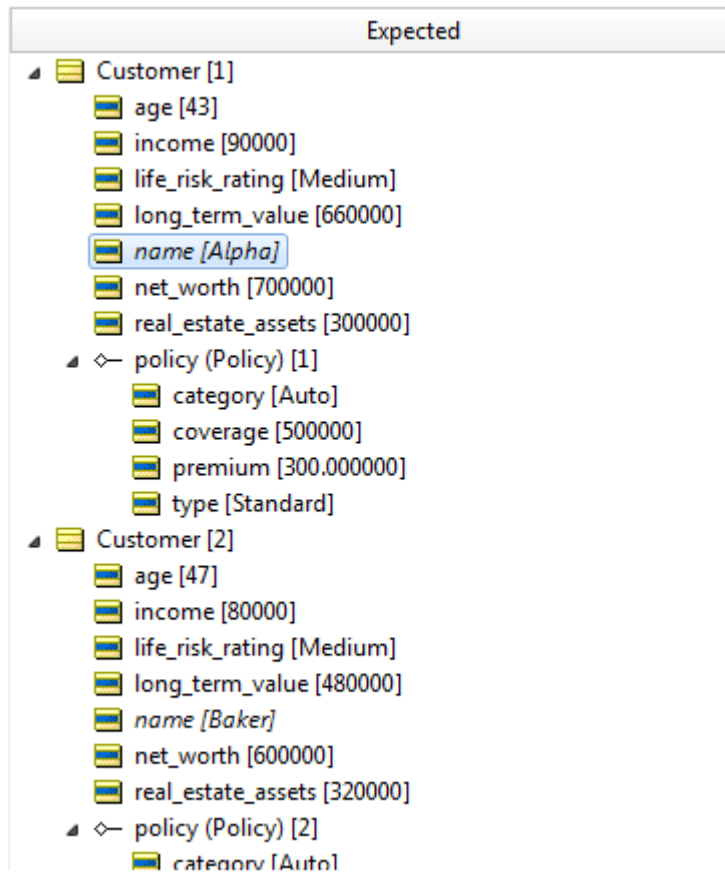
Use key attributes to improve difference detection in Ruletests

The execution of Ruletests can, in some cases, erroneously detect differences between the Output and Expected results. This typically occurs in Rulesheets that add new entities to collections. The unsorted nature of collections makes it impossible to match the collections in the Output and Expected results with complete accuracy. An optional feature is available when you encounter problems with test failures due to the randomness of entity ordering. To avoid this problem, you can specify certain attributes as *key attributes* that will assist the comparison algorithm, that the validation linking entities in both panels are chosen based on the key values.

To set a key attribute, right click on it in the Expected panel, and then choose **Key Attribute**, as shown:



Key attributes are shown in italics in the current entity as well as all other corresponding entities in the **Expected** panel, as shown:



To remove a key attribute, right click on it again in the **Expected** panel, and then choose **Key Attribute** to clear the setting.

Setting multiple key attributes will attempt to match the full set.

Set how whitespace is handled

Leading or trailing blanks on String values (often called *whitespace*) might cause imprecise matching to the output from rules. While the default behavior of trimming whitespaces is often preferred, you can add `com.corticon.tester.trimstringvalues=false` to your `brms.properties` file to tell Corticon Studio to not perform trimming, and thus reduce validation mismatches. The default behavior is apparent when copying the output to the Expected column, as that action strips whitespaces, and often reveals apparent mismatches immediately.


Numerical equivalence

When comparing expected results with output results during the validation stage of testing, two values that have a different number of trailing zeros to the right of the decimal place will validate correctly. However, you should avoid introducing rounding errors and inconsistent use of big decimal data types as they can produce unintended differences during comparisons.

How to optimize Rulesheets

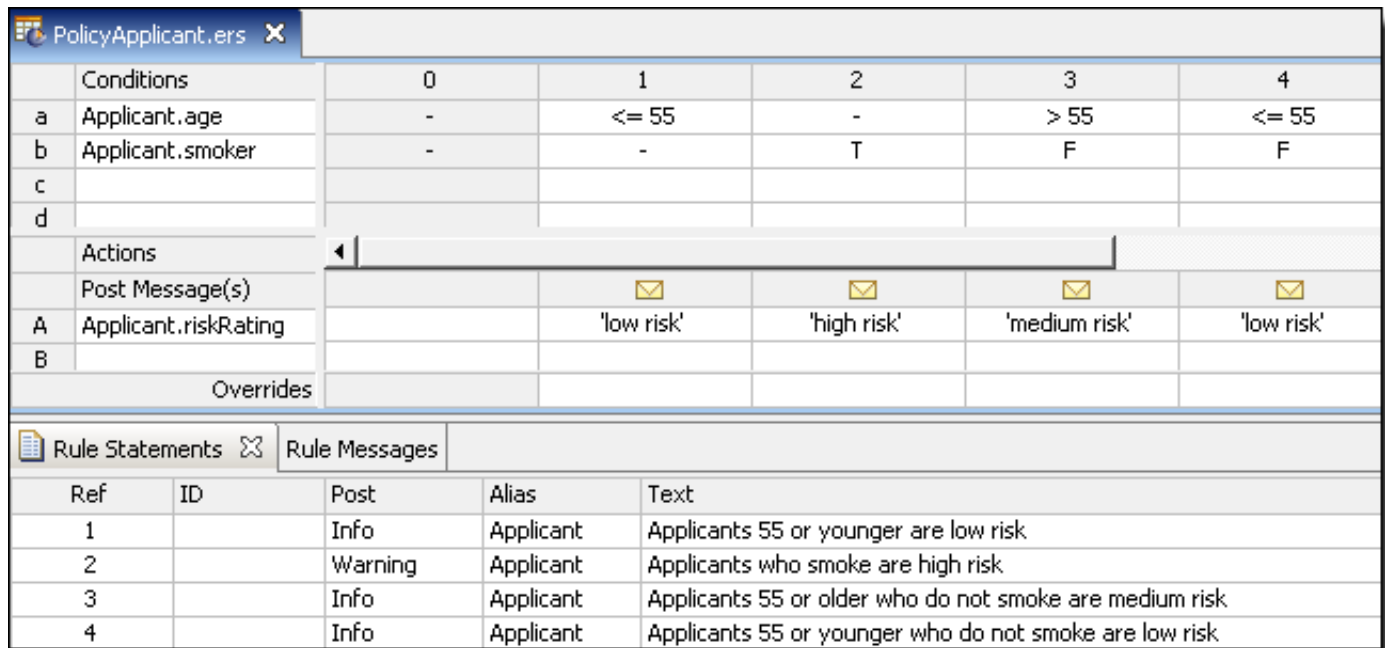
The tools that evaluate completeness and that perform compression can be reviewed to ensure that the decision service will execute them efficiently .

The compress tool

Corticon Studio helps improve performance by removing redundancies within Rulesheets. There are two types of redundancies the **Compress Tool**  detects and removes:

1. **Rule or sub-rule duplication.** The Compress Tool will search a Rulesheet for duplicate columns (including sub-rules that may not be visible unless the rule columns are expanded), and delete extra copies. Picking up where we left off in [New Rule Added by Completeness Check](#), let's add another rule (column #4), as shown in the following figure:

Figure 220: New Rule (#4) Added



Conditions		0	1	2	3	4
a	Applicant.age	-	<= 55	-	> 55	<= 55
b	Applicant.smoker	-	-	T	F	F
c						
d						
Actions						
Post Message(s)			☑	☑	☑	☑
A	Applicant.riskRating		'low risk'	'high risk'	'medium risk'	'low risk'
B						
Overrides						

Rule Statements		Rule Messages		
Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk
3		Info	Applicant	Applicants 55 or older who do not smoke are medium risk
4		Info	Applicant	Applicants 55 or younger who do not smoke are low risk


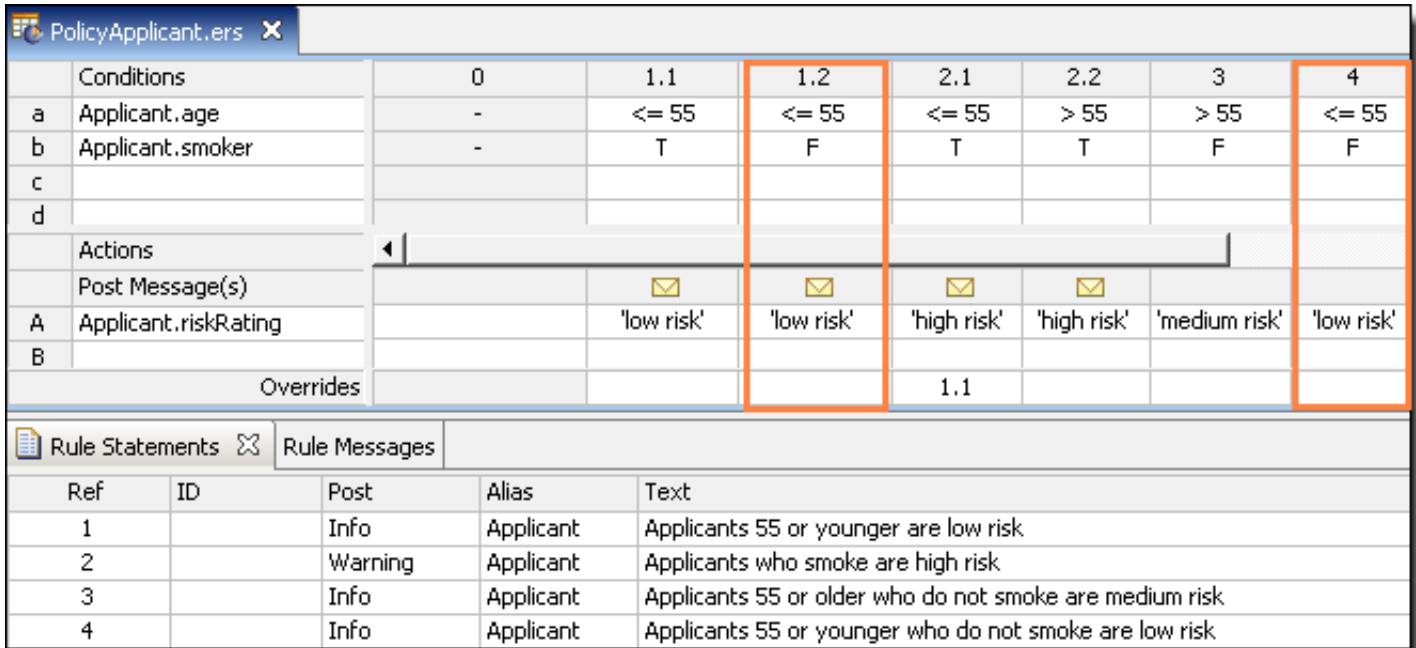
While these 4 rules use only 2 Conditions and take just 2 Actions (an assignment to `riskRating` and a posted message), they already contain a redundancy problem. Using the **Expand Tool**  this redundancy is visible in the following figure:

Figure 221: Redundancy Problem Exposed



Conditions		0	1.1	1.2	2.1	2.2	3	4
a	Applicant.age	-	<= 55	<= 55	<= 55	> 55	> 55	<= 55
b	Applicant.smoker	-	T	F	T	T	F	F
c								
d								
Actions								
Post Message(s)			✉	✉	✉	✉		
A	Applicant.riskRating		'low risk'	'low risk'	'high risk'	'high risk'	'medium risk'	'low risk'
B								
Overrides					1.1			

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
2		Warning	Applicant	Applicants who smoke are high risk
3		Info	Applicant	Applicants 55 or older who do not smoke are medium risk
4		Info	Applicant	Applicants 55 or younger who do not smoke are low risk


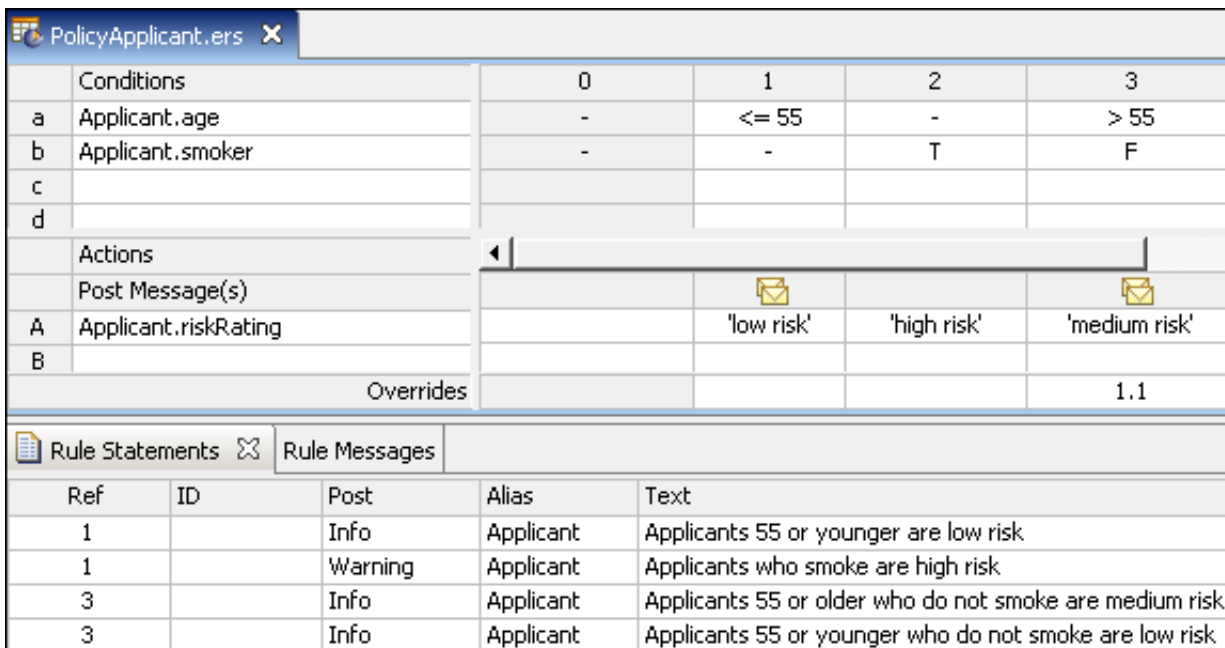
Clicking on the **Compress Tool**  has the effect shown in the following figure:

Figure 222: Rulesheet After Compression



Conditions		0	1	2	3
a	Applicant.age	-	<= 55	-	> 55
b	Applicant.smoker	-	-	T	F
c					
d					
Actions					
Post Message(s)			✉		✉
A	Applicant.riskRating		'low risk'	'high risk'	'medium risk'
B					
Overrides					1.1

Ref	ID	Post	Alias	Text
1		Info	Applicant	Applicants 55 or younger are low risk
1		Warning	Applicant	Applicants who smoke are high risk
3		Info	Applicant	Applicants 55 or older who do not smoke are medium risk
3		Info	Applicant	Applicants 55 or younger who do not smoke are low risk

Looking at the compressed Rulesheet in this figure, we see that column #4 has disappeared entirely. More accurately, the Compress Tool determined that column 4 was a duplicate of one of the sub-rules in column 1 (1.2) and simply removed it.

Compression does not, however, alter the *text* of the rule statement; that task is left to the rule writer.

It is important to note that the compression does not alter the Rulesheet's logic; it simply affects the way the rules **appear** in the Rulesheet – the number of columns, Values sets in the columns, and such. Compression also streamlines rule execution by ensuring that no rules are processed more than necessary.

2. **Combining Values sets to simplify and shorten Rulesheets.** Recall our shipping charge example. By using the Compress Tool, Rulesheet columns are combined wherever possible by creating Values sets in Condition cells. For example, rule 6 in the figure **Compressed Shipping Charge Rulesheet** (highlighted below) is the combination of rule 6 and 8 from [Rulesheet with Renumbered Rules](#).

Figure 223: Compressed Shipping Charge Rulesheet

	Conditions	0	1	2	3	4	5	6
a	Manifest.sendingAddress	-	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 1'	'Zone 2'
b	Manifest.receivingAddress	-	'Zone 1'	'Zone 2'	'Zone 3'	'Zone 4'	'Zone 5'	{ 'Zone 1', 'Zone 3' }
c								
d								
	Actions							
	Post Message(s)							
A	Manifest.shipCharge		0.25	0.35	0.45	0.55	0.65	0.35

Value sets in Condition cells are equivalent to the logical operator **OR**. Rule 6 therefore reads:

6. A manifest with a Zone 2 sending address **AND** a Zone 1 **OR** Zone 3 receiving address costs \$0.35 per pound to ship.

In deployment, the decision service will execute this new rule 6 faster than the previous rule 6 and 8 together.

How to produce characteristic Rulesheet patterns

Because Corticon Studio is a visual environment, patterns often appear in the Rulesheet that provide insight into the decision logic. Once rule writers recognize and understand what these patterns mean, they can often accelerate rule modeling in the Rulesheet. The Compression Tool is designed to reproduce Rulesheet patterns in some common cases.

For example, take the following rule statement:

1. An aircraft with max cargo volume greater than 300 **AND** max cargo weight greater than 200,000 **AND** tail number of N123UA must be a 747.
2. Otherwise it must be a DC-10.

Applying our modeling techniques, we might implement rule 1 as:

Figure 224: Implementing the 747 Rule

Conditions		0	1	2
a	Aircraft.maxCargoVolume		> 300	
b	Aircraft.maxCargoWeight		> 200000	
c	Aircraft.tailNumber		'N123UA'	
d				
e				
f				
Actions		<		
Post Message(s)			✉	
K	Aircraft.aircraftType		'747'	
L				
M				

Now let's have the Completeness Checker populate any missing columns:

Figure 225: Remaining Columns Produced by the Completeness Checker

Conditions		2	3	4	5
a	Aircraft.maxCargoVolume	> 300	> 300	{<= 300, null}	
b	Aircraft.maxCargoWeight	> 200000	{<= 200000, null}	-	
c	Aircraft.tailNumber	not 'N123UA'	-	-	
d					
Actions		<			
Post Message(s)					
K	Aircraft.aircraftType				
L					

Progress Corticon Studio

i Completeness check has added 17 missing scenarios which have been automatically compressed in to 3 non-overlapping columns.

✉ Rule Messages

Text
An aircraft with a maximum cargo volume of 300,000 lbs and a maximum cargo weight of 200,000 lbs can transport 747 aircraft.
A Boeing 747 can transport 747 aircraft.

Click **Expand** to fill out the Rulesheet so you can examine the 17 cross-product sub-rules:

Figure 226: Underlying Sub-Rules Produced by the Completeness Checker

0	1	2	3.1	3.2	3.3	3.4	4.1	4.2	4.3
	> 300	> 300	> 300	> 300	> 300	> 300	<= 300	<= 300	<= 300
	> 200000	> 200000	<= 200000	<= 200000	null	null	<= 200000	<= 200000	> 200000
	'N123UA'	not 'N123UA'	'N123UA'	not 'N123UA'	'N123UA'	not 'N123UA'	'N123UA'	not 'N123UA'	'N123UA'

The 17 new columns (counting both rules and sub-rules) include an optimization that combined <> 'N312UA' and null into not 'N312UA'. So the number of combinations is 3*3*2 = 18. Subtracting the rule in column 1, we expect 17 new columns to be added.

Now, click **Compress**: 

There are now just 4 rules. Fill in the Actions for the new columns, DC-10, as shown:

Figure 227: Missing Rules with Actions Assigned

Conditions	0	1	2	3	4
a Aircraft.maxCargoVolume		> 300	-	-	{<= 300, null}
b Aircraft.maxCargoWeight		> 200000	-	{<= 200000, null}	-
c Aircraft.tailNumber		'N123UA'	not 'N123UA'	-	-
d					
e					
f					
Actions					
Post Message(s)	<				
K Aircraft.aircraftType		'747'	'DC-10'	'DC-10'	'DC-10'
L					
M					
N					
O					
Overrides					

Because the added rules are non-overlapping, we can be sure they won't introduce any ambiguities into the Rulesheet.

To be sure, click the **Conflict Checker**: 

Figure 228: Proof that no New Conflicts have been Introduced by the Completeness Check

Conditions	0	1	2	3	4
a Aircraft.maxCargoVolume		> 300	-	-	{<= 300, null}
b Aircraft.maxCargoWeight		> 200000	-	{<= 200000, null}	-
c Aircraft.tailNumber		'N123UA'	not 'N123UA'	-	-
d					
e					
f					
Actions					
Post Message(s)	<				
K Aircraft.aircraftType		'747'			
L					
M					
N					
O					
Overrides					

Progress Corticon Studio ✕

i

No conflicts detected

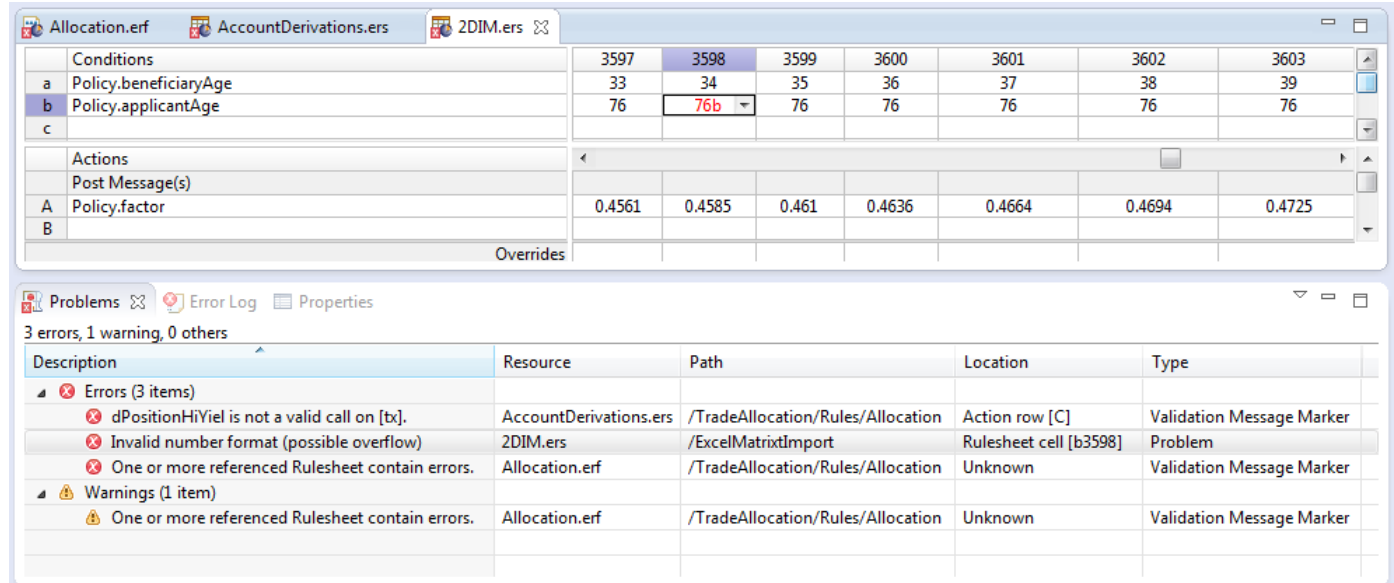
This pattern tells us that the only case where the aircraft type is a 747 is when max cargo volume is greater than 300 **AND** max cargo weight is greater than 200,000 **AND** tail number is N123UA. This rule is expressed in column 1. In all other cases, specifically where max cargo volume is 300 or less **OR** max cargo weight is 200,000 or less **OR** tail number is something other than N123UA will the aircraft type be a DC-10.

The characteristic diagonal line of Condition values in columns 2-4, surrounded by dashes indicates a classic **OR** relationship between the 3 Conditions in these columns. The Compression algorithm was designed to produce this characteristic pattern whenever the underlying rule logic is present. It helps the rule writer to better “see” how the rules relate to each other.

Precise location of problem markers in editors

Problems experienced in Corticon editors are easily located when you click on each annotated error line in the **Problems** view to open the corresponding file in its editor, then bring the specific location into view and give it the focus.

In the following illustration, the problem location is Rulesheet cell [b3598] of the 2DIM Rulesheet. Double-clicking the problem line opened the file to that precise location, as shown:





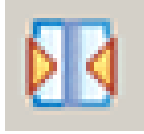


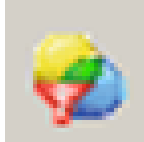
This functionality applies to Vocabularies, Rulesheets, Ruleflows, and Ruletests.

Note: When migrating projects from earlier releases, the marker metadata has not been captured. When you clear the existing problem list, and then perform a full build of the project, the location metadata that enables this feature will be established.

Test Yourself questions for Logical analysis and optimization

Note: Try this test, and then go to [Test Yourself answers for Logical analysis and optimization](#) on page 343 to correct yourself.

1. What does it mean for two rules to be ambiguous?
2. What does it mean for a Rulesheet to be complete?
3. Are all ambiguous rules wrong, and must all ambiguities be resolved before deployment? Why or why not?
4. Are all incomplete Rulesheets wrong, and must all incompletenesses be resolved before deployment? Why or why not?
5. Match the Corticon Studio tool name with its toolbar icon

Conflict Checker	
Compression Tool	
Expansion Tool	
Collapse Tool	
Conflict Filter	
Completeness Checker	

6. Explain the different ways in which an Ambiguity/Conflict between two rules can be resolved.
7. True or False. Defining an override enforces a specific execution sequence of the two ambiguous rules
8. True or False. A Conditions row with an incomplete values set will always result in an incomplete Rulesheet.
9. If a Rulesheet is incomplete due to an incomplete values set, will the Completeness Checker detect the problem? Why or why not?
10. Can a rule column define more than one override?
11. If rule 1 overrides rule 2, and rule 2 overrides rule 3, does rule 1 automatically override rule 3?
12. Are rules created by the Completeness Checker always legitimate?
13. In a rule column, what does a dash (-) character mean?
14. True or False. The Expansion Tool permanently changes the rule models in a Rulesheet. If false, how can it be reversed?
15. True or False. The Compression Tool permanently changes the rule models in a Rulesheet. If false, how can it be reversed?
16. If a rule has 3 condition rows, and each condition row has a Values set with 4 elements, what is the size of the Cross Product?
17. In above question, is it necessary to assign actions for every set of conditions (i.e., for every column)?
18. If you do not want to assign actions for every column, what can be done to/with these columns?
19. Which Corticon Studio tool helps to improve Rulesheet performance?

Expansion Tool	Compression Tool	Completeness Checker	Collapse Tool	Squeeze Tool
----------------	------------------	----------------------	---------------	--------------

20. How is the compression performed by the Completeness Checker different from that performed by the Compression Tool?
21. What's wrong with using databases of test data to discover Rulesheet incompleteness?
22. If you expand a rule column and change the Actions for one of the sub-rules, what will Corticon Studio force you to do before saving the changes?
23. What does it mean for one rule to subsume another?

Advanced Ruleflow techniques and tools

Ruleflows provide techniques for combining, branching, and graphing. You can also use versioning and effective dating to precisely manage your Ruleflows when they are compiled into Decision Services.

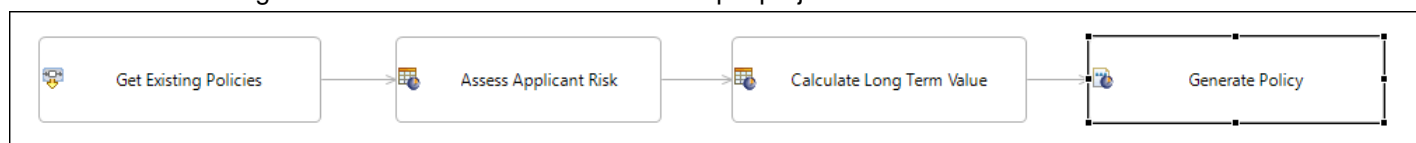
For details, see the following topics:

- [How to use a Ruleflow in another Ruleflow](#)
- [Conditional branching in Ruleflows](#)
- [How to generate Ruleflow dependency graphs](#)
- [Ruleflow versions and effective dates](#)
- [TestYourself questions for Ruleflow versions and effective dates](#)

How to use a Ruleflow in another Ruleflow

You can reduce the complexity and testing of large Ruleflows by breaking a Ruleflow into smaller Ruleflows, and then constructing the larger Ruleflow from them. The resulting modularity simplifies unit testing and collaboration.

Consider the following Ruleflow from the Life Insurance sample project:



The Ruleflow editor shows the `iSample_policy_pricing.erf` canvas with four objects in sequence. The first three apply the risk assessment rules and the other object is altogether separate Ruleflow file, as you can see in the object's properties:

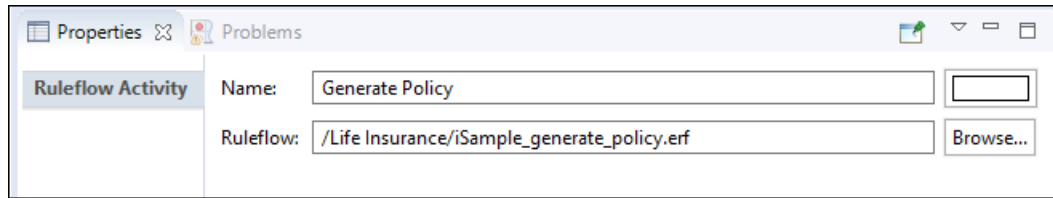
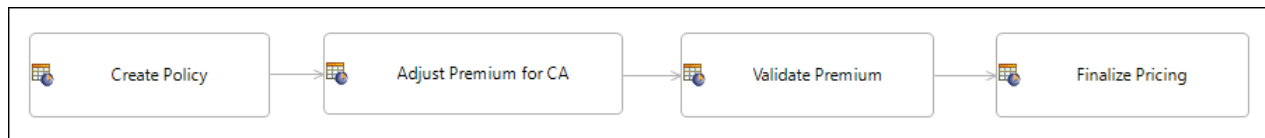


Figure 230: A Ruleflow overrides settings on an embedded Ruleflow

A Ruleflow file's **Properties** provide settings for versioning and effective date stamping of the Decision Service that will be created. (See the topic [Ruleflow versions and effective dates](#) on page 309 for details.) However, when a Ruleflow is added to another Ruleflow's canvas, it ignores its **Ruleflow Properties** and takes on **Ruleflow Activity Properties** that are local to its role as a component of another Ruleflow, as illustrated.

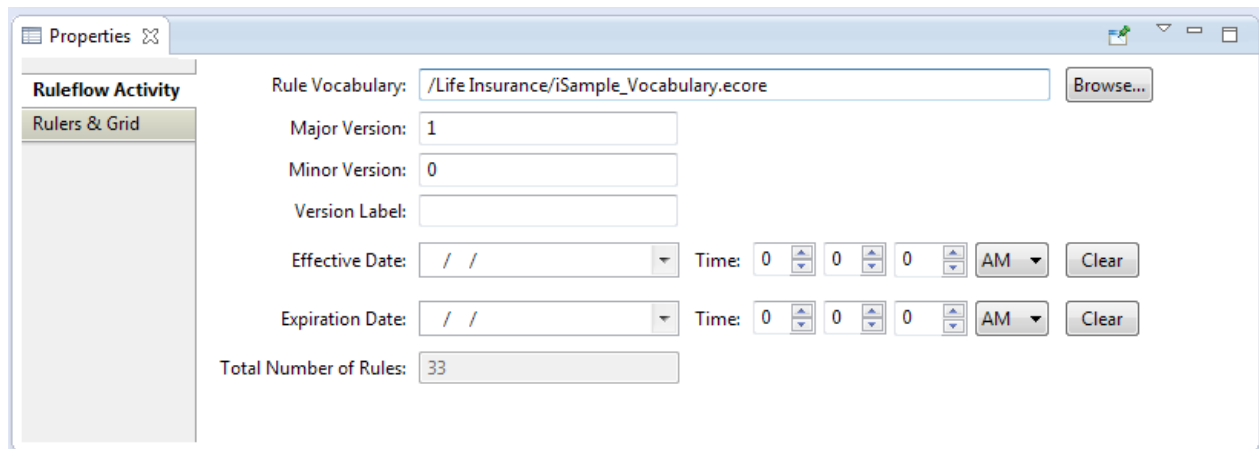
You can change the name of the Ruleflow on the canvas in this context so that it provides meaning, and you can add comments. None of these actions change the Ruleflow properties of the original Ruleflow.

The referenced Ruleflow, `iSample_generate_policy.erf`, contains four Rulesheets, as shown:



With these two Ruleflows, each can be updated and tested independently, and -- as long as you ensure that the Vocabulary stays consistent -- separate teams can collaborate on developing risk rules and policy rules. That makes it easy to *reuse* either of these Ruleflows. For example, if policy pricing varies in different markets, you can create a new Ruleflow that brings in the same risk assessment rules to provide the data to process against a modified policy pricing Ruleflow for the other market.

The parent Ruleflow provides its own settings for versioning and effective date stamping of the Decision Service that will be created, as illustrated:

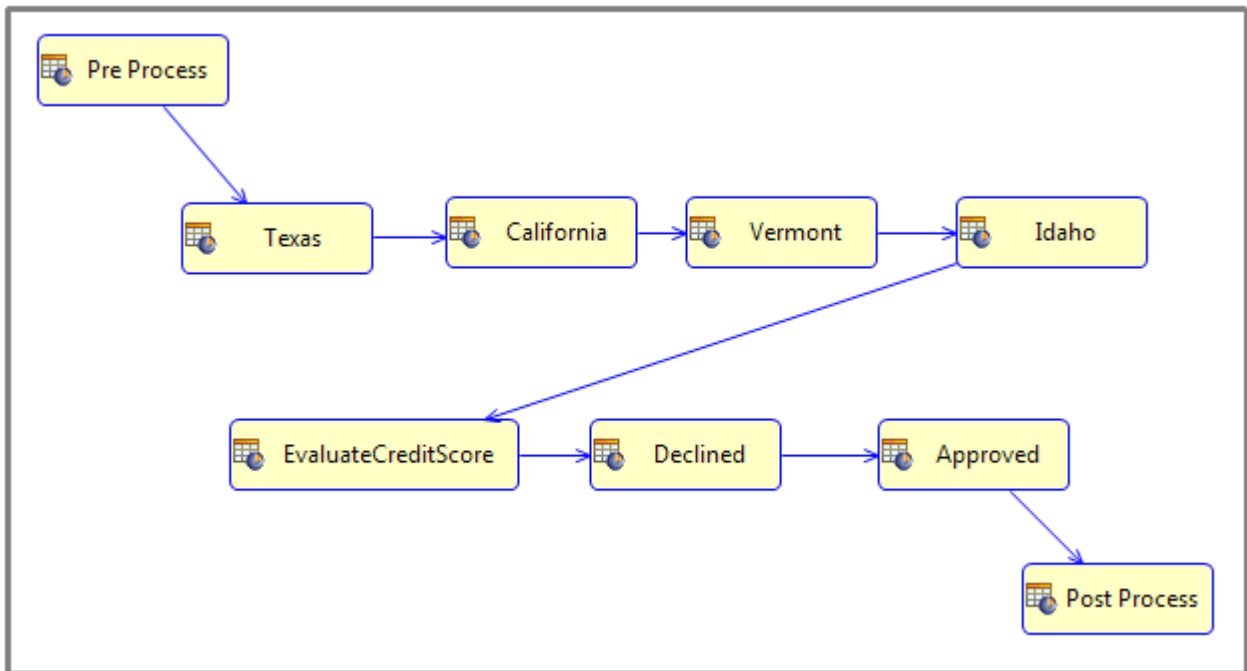


Note: Deploying Ruleflows within a Ruleflow - When this Ruleflow is deployed, the generated Decision Service will include the content of both Ruleflows. However, when either of the included Ruleflows changes, Ruleflows that include one of them are not automatically updated -- each must be redeployed to include the changes.

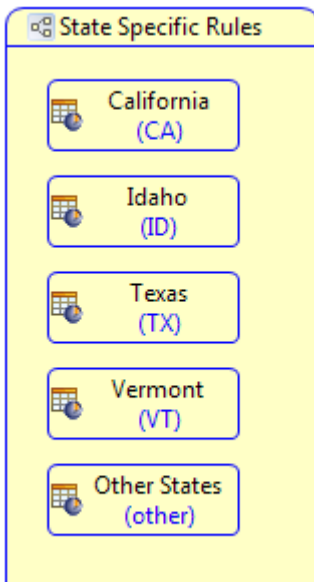
For more information, see *the "Ruleflows" section of the Quick Reference Guide*

Conditional branching in Ruleflows

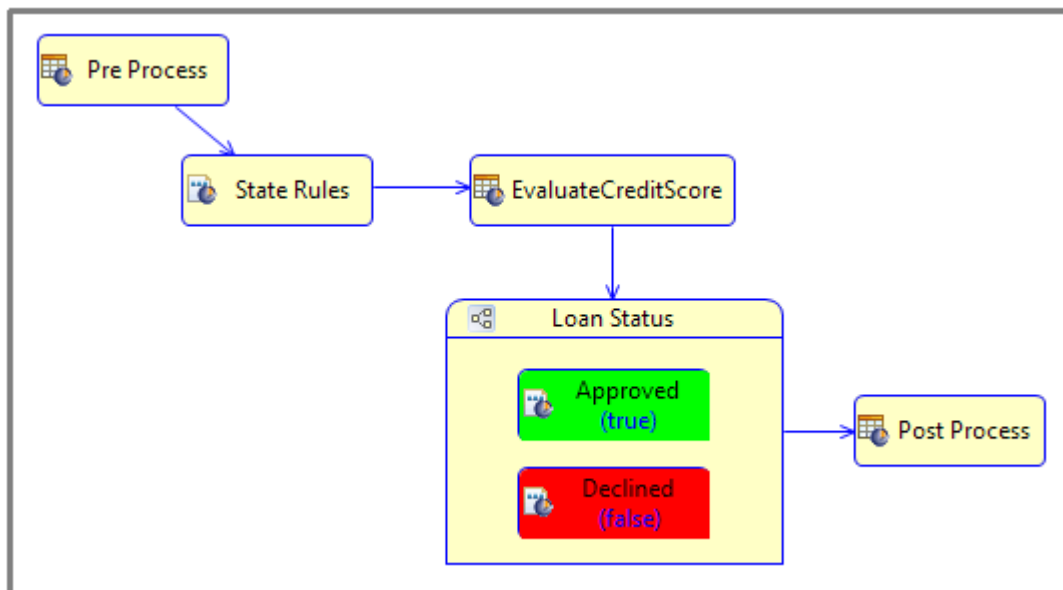
In a Ruleflow, you often have steps which should only process an entity with a specific attribute value. You can accomplish this by using *preconditions* on a Rulesheet, but the resulting logic, or flow, is difficult to perceive when looking at the Ruleflow. The following Ruleflow shows a progression of processing from the upper left to the lower right. But the rules to decide whether a loan is approved or declined are one-or-the-other, and the Rulesheets for the US states do not really represent a progression because the applicant's state is going to trigger only one of these Rulesheets to fire its rules:



Looking at this Ruleflow the real flow is somewhat hidden. If the Rulesheets for Texas, California, Vermont, and Idaho each had a precondition such that only matching states were processed, then they represent a set of mutually exclusive options, not the linear flow depicted in the Ruleflow. We'll see how we can create a branch in a Ruleflow like this:



And then bring that Ruleflow into another Ruleflow where we will also create a branch for the Declined and Approved Rulesheets that also might have needed to use preconditions. The completed Ruleflow looks like this:



A branch node can be Rulesheet, Ruleflow, Service Call Out, Subflow, or another Branch container.

Note: Multiple branches can be assigned to the same target activity. These values are shown as a set in the Ruleflow canvas.

Refresher on enumerations and Booleans

Branching can occur on either enumerated or boolean attribute types. Only these are allowed because they have a set of known possible values. These possible values can be used to identify a branch. Using branches in a Ruleflow lets you clearly identify the set of options, or branches, for processing an entity based on an attribute value. In our example, using branching for the set of state options and whether the loan is approved or declined makes the flow more apparent. It will also be easier to create and maintain.

This topic covers general concepts of branching. First, let's review enumerations and Booleans as they are essential to branching definitions.

When defining elements of a Vocabulary, each attribute is specified as one of seven data types in the Corticon Vocabulary.

Property Name	Property Value
Attribute Name	state
Data Type	String

Boolean
Decimal
DateTime
Date
Integer
String
Time

These can be extended by Constraints or Enumerations. In this illustration, States are extending their String type to be qualified as a list of labels and corresponding values that delimit the expected values yet offer the listed items in pulldowns when you are defining Ruletests. Notice that the Boolean Data Type is not listed as it is implicitly an enumeration.

Data Type Name	Base Data Type	Enumeration	Constraint...	Label	Value
States	String	Yes		AK	'AK'
				AL	'AL'
				AR	'AR'
				AZ	'AZ'
				CA	'CA'
				CO	'CO'
				CT	'CT'
				DC	'DC'
				DE	'DE'
				FL	'FL'
				GA	'GA'
				HI	'HI'
				IA	'IA'
				ID	'ID'
				IL	'IL'
				IN	'IN'

The Vocabulary definition then chooses the States data type, a subset of String, as its data type.

Property Name	Property Value
Attribute Name	state
Data Type	States

Boolean
 Decimal
 DateTime
 Date
 Integer
 String
 States
 Time

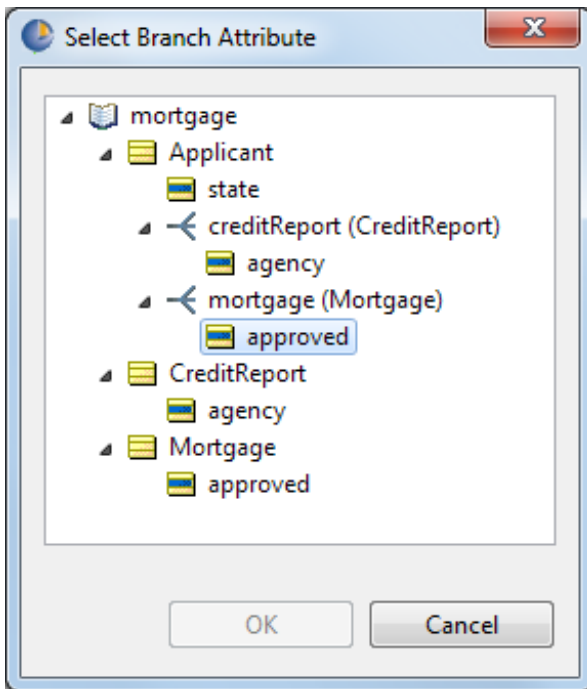
Every attribute that is an enumerated data type or a Boolean is available for branching. For more information, see [Enumerations](#) on page 36 in this guide.

Example of branching based on a Boolean

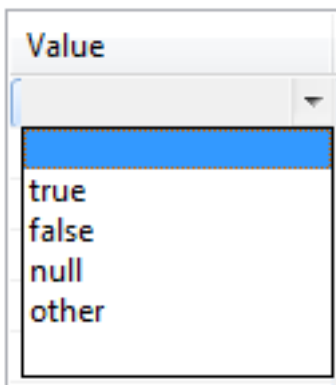
In the example, loan status does not pass through being declined on its way to being approved; it is one or the other. This true/false decision point (actually Ruleflows that might contain several Rulesheets) provides an easy introduction to branching.

To create a Branch on a Ruleflow canvas for a Boolean attribute:

1. On the Ruleflow canvas where you want to create a branch, click **Branch** on the Palette, and then click on the canvas where you want to place the branch. A Branch container is created with your cursor in the name label area.
2. Enter a name such as `Loan Status`, and press **Enter**. You can change the name later.
3. Drag the Rulesheets `Approved.erf` and `Declined.erf` from the Project Explorer to the branch compartment.
4. On the Branch's **Properties** tab for **Branch Activity**, click . The **Select Branch Attributes** for the Ruleflow's Vocabulary identifies three attributes that are candidates for branching (state, agency, and approved), and the associations that apply to these attributes. For this branch, `approved` is the Boolean attribute appropriate for loan status. More specifically the attribute preferred is, `Applicant.mortgage.approved`. Click on that attribute as shown:

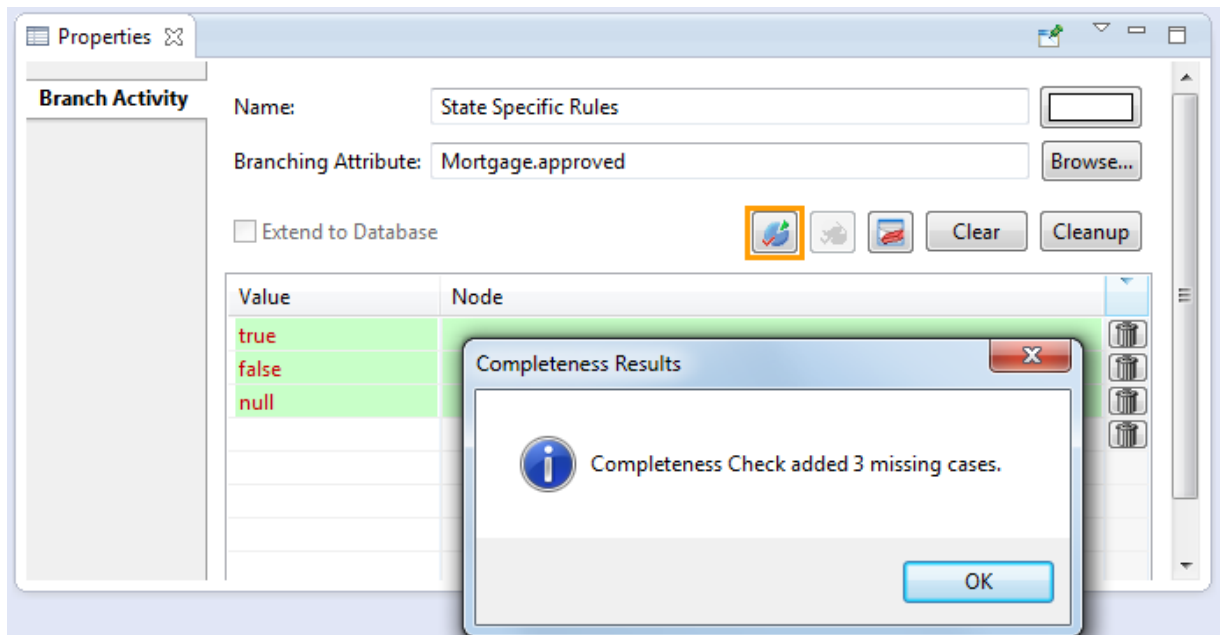


5. Click **OK**.
6. You can define the Boolean branches in a few ways:
 - Click on the **Value** pulldown, as shown:



Notice that there four choices for a Boolean. The null value is offered the attribute is not set as Mandatory so null is allowable. The other value is demonstrated below.

- Choose `true` on the first line and then choose `other` on the second line.
- Click **Check for completeness**, as shown, to populate the **Value** list from the attribute:



Notice that it does not add `other` to the list. If you set `true` and `other` as shown above, clicking **Check for completeness** would have nothing to add because `other` implies completeness. You can clear green highlights by clicking the **Clear analysis results** button.

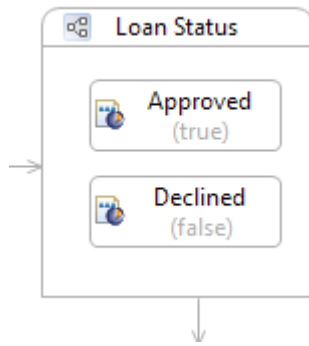
The values listed are in red until we bind each one to a node. You can delete any or all but a minimal number of these lines if you do not have nodes that will handle specific cases. For this example, keep only `true` and `false`. Then click **Cleanup** to remove lines that no assigned node.

- In the **Branch Activity** section, the **Node** column lets you click on a Value line and then use the pulldown to choose the appropriate target node for the value. When the request in process matches this value, it will be passed to this branch in the branch container:

Value	Node
true	
false	
	Declined
	Approved

When both `true` and `false` have nodes specified, we have defined the required branches for this rule flow.

- Connect the incoming and outgoing connections to the branch to complete the flow on the canvas.



Multiple values can direct to the same target node, as shown in this colored examples, where all the 'not true' possibilities are assigned to the **Declined** node:

The screenshot displays the Corticon Rule Modeler interface. The top pane shows a ruleflow diagram with three nodes: 'Pre Process' (purple), 'Idaho' (yellow), and 'Loan Status' (grey). The 'Loan Status' node is a branch activity containing two sub-nodes: 'Approved (true)' (green) and 'Declined (false,null,other)' (pink). The bottom pane shows the 'Properties' window for the 'Loan Status' branch activity.

Branch Activity Properties:

- Name: Loan Status
- Branching Attribute: Applicant.mortgage.approved
- Extend to Database
- Buttons: Fill, Clear, Cleanup

Value	Node
true	Approved
false	Declined

That completes the creation of this Boolean-based branch.

Example of branching based on an enumeration

In the example, four US states each have specific rules defined. Processing policy might require graceful rejection of requests that do not specify one of these four states. And, over time, the included states might expand or contract. This branch for State Specific Rules will be created as a separate Ruleflow, `State Rules`, so that it can be reused in other Ruleflows.

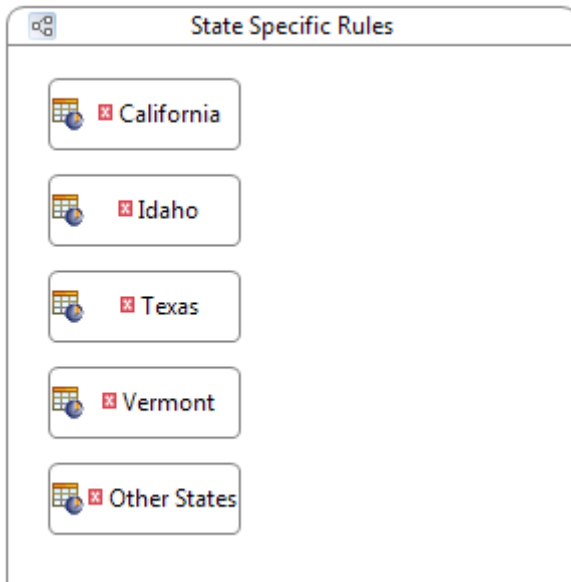
To create a Branch on a Ruleflow canvas for an attribute that is an enumerated list:

1. On the Ruleflow canvas, click **Branch** on the Palette, and then click on the canvas where you want to place the branch. A Branch compartment is created with your cursor in the name label area.
2. Enter a name such as `State Specific Rules`, and press **Enter**.
3. On the Branch's **Properties** tab for **Branch Activity**, click . The **Select Branch Attributes** for the Ruleflow's Vocabulary identifies three attributes that are candidates for branching (state, agency, and approved), and the associations that apply to these attributes.
4. Choose `Applicant.state`. The list of all US state abbreviations that is used by this attribute defines the enumeration in the Vocabulary, as shown:

Data Type Name	Base Data Type	Enumeration	Constraint...	Label	Value
States	String	Yes		AK	'AK'
Agency	String	Yes		AL	'AL'
				AR	'AR'
				AZ	'AZ'
				CA	'CA'
				CO	'CO'
				CT	'CT'
				DC	'DC'
				DE	'DE'
				FL	'FL'
				GA	'GA'
				HI	'HI'
				IA	'IA'
				ID	'ID'
				IL	'IL'
				IN	'IN'

Note: See [Enumerations](#) on page 36 for information on entering or pasting enumeration labels and values as well importing them from a connected database.

5. Drag the Rulesheets `California.ers`, `Idaho.ers`, `Texas.ers`, `Vermont.ers`, and `Other States.ers` into the branch compartment on the canvas. You can use **Ctrl+Click** to select multiples and then drag them as a group. Each Rulesheet is marked with a error flag at this point, as shown:



6. On the canvas, click on the branch to open its **Properties** tab. You can define the enumeration branches in a few ways:
 - Click on the **Value** pulldown. On separate value lines, choose each of the defined states and then `other`.
 - Click **Check for completeness**, as shown, to populate the **Value** list from the attribute:

Name:

Branching Attribute:

Extend to Database

Value	Node
WY	
WV	
WI	
WA	
VT	
VA	
UT	
TX	

Completeness Results

Completeness Check added 51 missing cases.

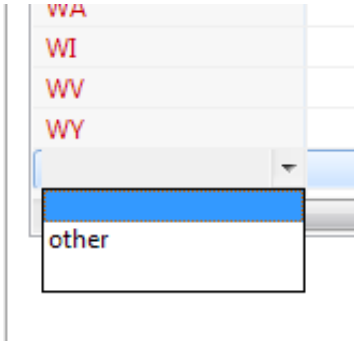
Notice that it does not add `other` to the list. If you set `true` and `other` as shown above, clicking **Check for completeness** would have nothing to add because `other` implies completeness. You can clear green highlights by clicking the **Clear analysis results** button.

The values listed are in red until we bind each one to a node.

7. Click on state value, then use the pulldown to select the appropriate node. In the following image, notice that the California node was assigned to the CA value, so that value turned black, the node on the canvas cleared the error, and the branching value is indicated in parentheses.

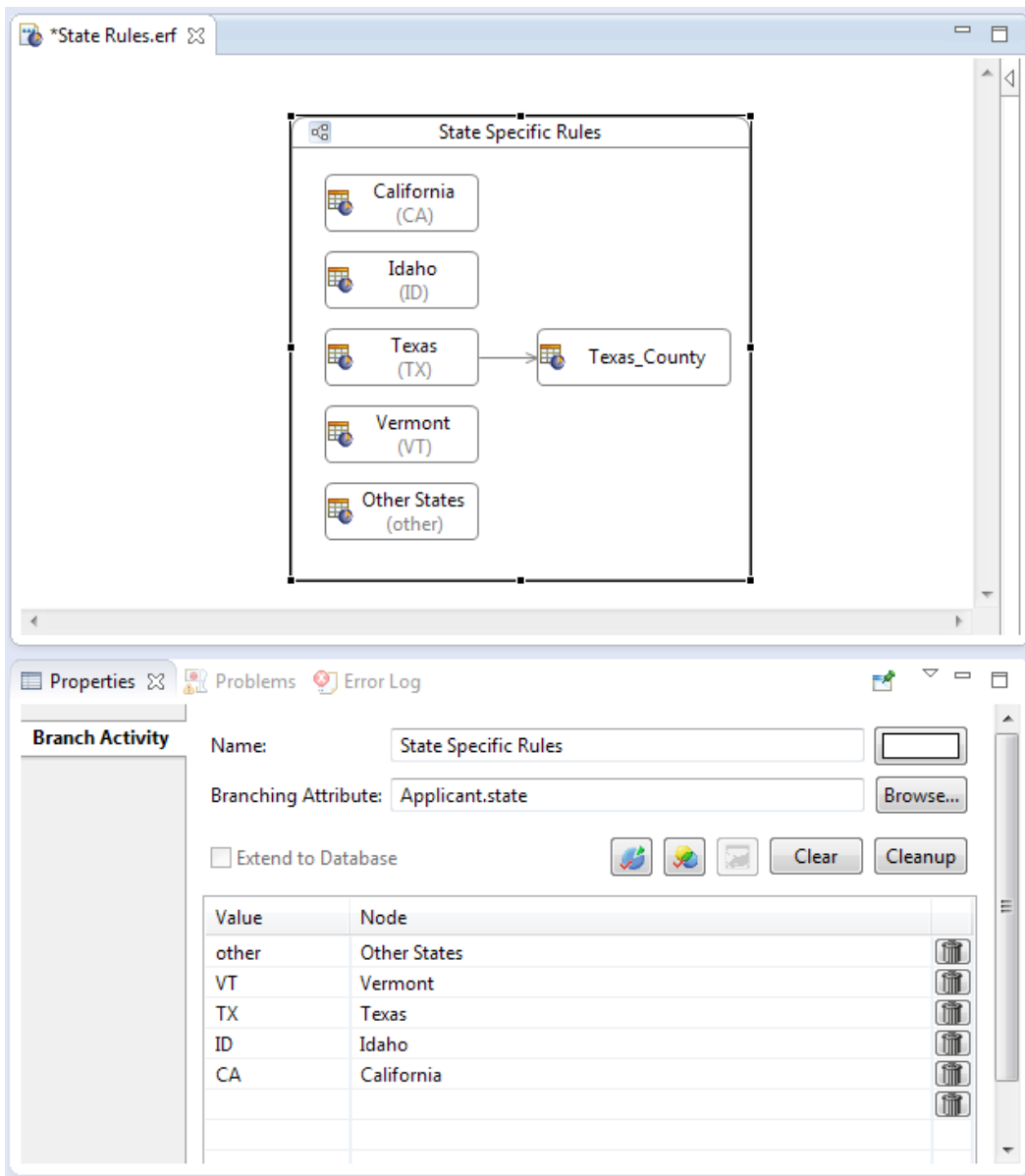
Note: An additional node was added to the canvas but because it is connected to a node, it is not offered in the pulldown list as a branch.

8. After matching the states with appropriate nodes, the `Other States` Rulesheet is unassigned. To handle this, a special purpose value is added. At the bottom of the value list, click on the down arrow and choose `other`.



Assign the `Other States` Rulesheet to that value.

9. Once all the nodes have been assigned to values, click **Cleanup** to clear all the unassigned values, as shown:



The unassigned values that were removed will all be handled by the `other` value's node. If you click **Check for Completeness** now, you will get the branch is complete.

That completes the creation of this enumeration-based branch.

Note: Other features of the user interface for defining Branch Activity are:

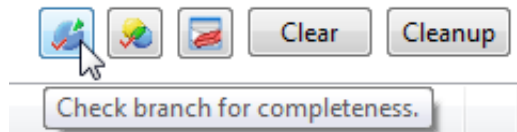
- Clicking a trashcan button on the right side of a branch line, deletes that line.
 - Clicking the **Clear** button removes all lines (the branch and components on the canvas are not removed).
 - The **Extend to Database** option is offered when the branching attribute is defined to connect to a database table and columns. The option is enabled in the Vocabulary editor by setting the attribute's Entity property **Datastore Persistent** to **Yes**. Choosing the option when it is available pulls the entities out of the defined and connected database and then processes the branch; when cleared, it tests against only the payload.
-

Logical analysis of a branch container

A Ruleflow branch container is subject to two significant types of logical errors: *completeness* and *conflicts*.

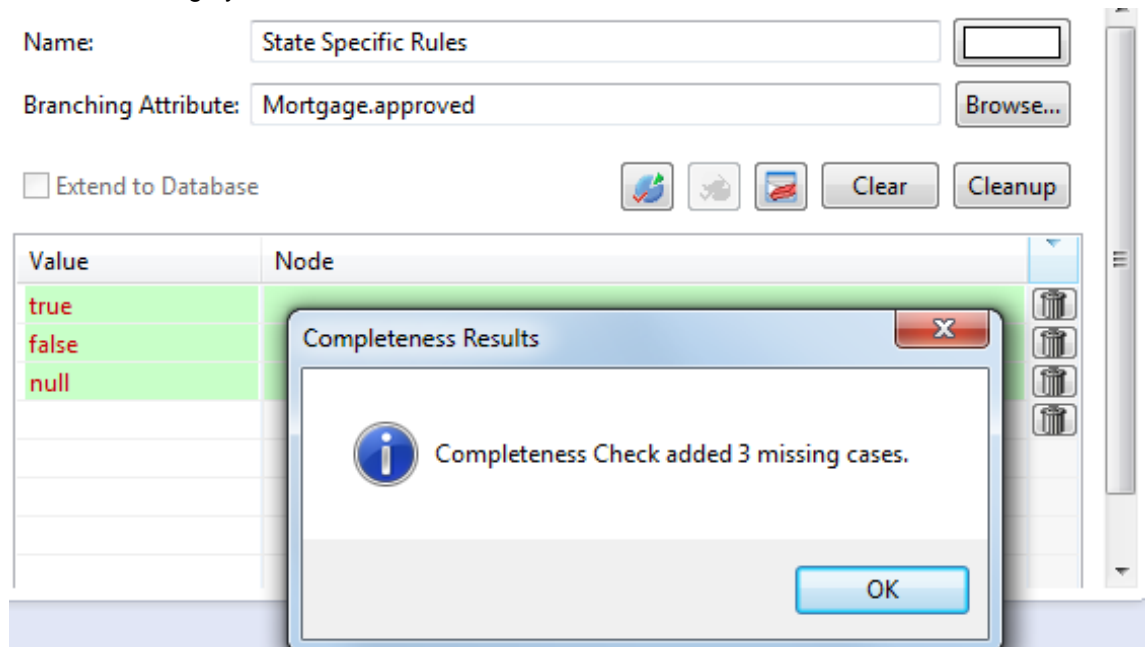
Completeness in a branch

A branch is complete when all of its possible values have been accounted for in branch nodes. When first defining branch activity, instead of selecting each possible value on each line, you can click **Check branch for completeness**, as shown:

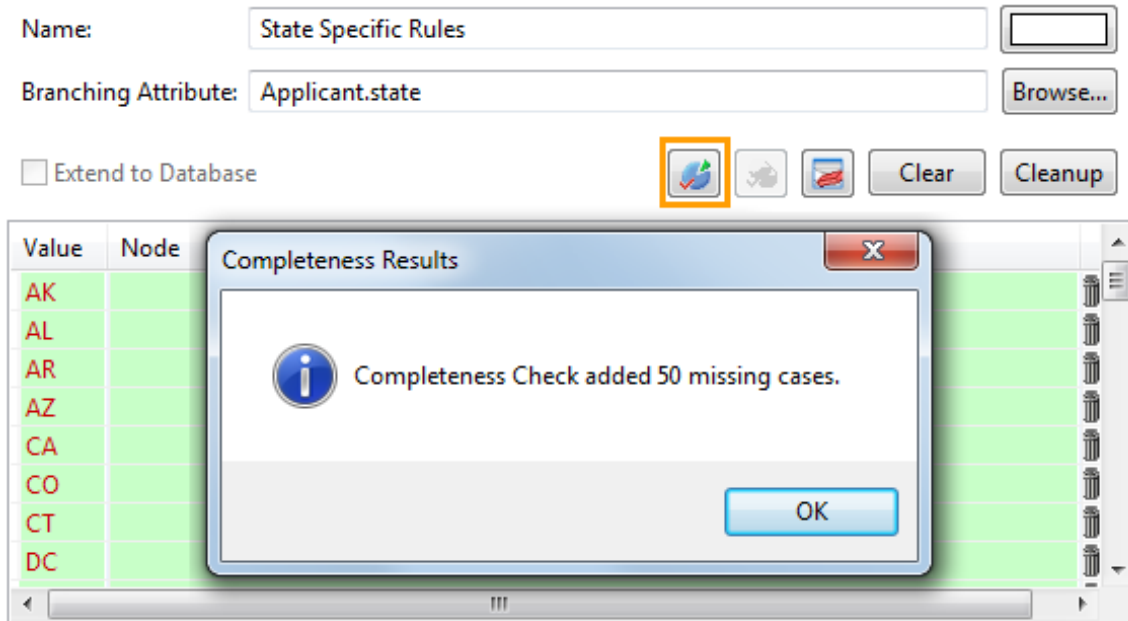


This will add all missing values as branch targets.

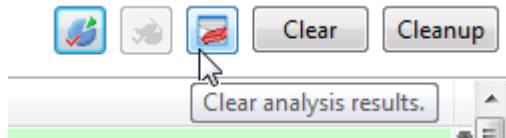
When branching by a Boolean attribute, three values are added, as shown:



When branching by an enumerated Custom Data Type attribute, each label in the enumeration is added, as illustrated:



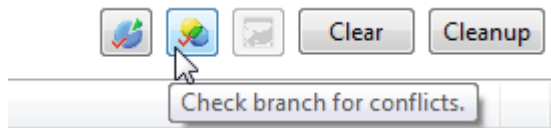
If the completeness check adds additional branch values, these will be highlighted in green. Clicking **Clear analysis results** removes color highlighting:



Assign nodes in the branch to appropriate listed value values. When you are done, click **Cleanup** to remove any branch values which do not have corresponding branch nodes. Unless you specify the keyword `other` as a branch value and assign it a branch node, your branch would be incomplete; you have not accounted for some of the possible branch values.

Conflicts in a branch

When branch nodes include logic that creates conflicts or ambiguities, those conflicts are difficult to identify. You can evaluate whether there are logical conflicts in a branch by clicking **Check branch for conflicts**, as shown:



Conflict or ambiguity in a Ruleflow branch container might be:

- **Different branches modify a shared entity** - You are informed of the attribute/association being modified.
- **A branch accesses the branch entity through an association that is not being filtered by the branch** - For example, the branch is on `Policy.type` while some rules act on `Customer.policy.type`. That creates a conflicting branch node, each of which is highlighted in red, as illustrated:

The screenshot illustrates a conflict in a Ruleflow branch container. It shows three windows from the Ruleflow editor:

- DirectAccounts.ers**: Shows a condition 'Policy.type' highlighted in orange.
- PartnerAccounts.ers**: Shows a condition 'Customer.policy.type' highlighted in orange.
- *AccountDistribution.eref**: Shows a diagram of an 'Accounts' container with two nodes: 'DirectAccounts (Elite, Preferred)' and 'PartnerAccounts (Standard)'.
- Properties**: Shows the 'Branch Activity' for the 'Accounts' container. The 'Branching Attribute' is 'Policy.type'. Below is a table showing the mapping of values to nodes:

Value	Node
Elite	DirectAccounts
Preferred	DirectAccounts
Standard	PartnerAccounts

The 'Standard' row in the table is highlighted in red, indicating a conflict because the 'PartnerAccounts' node is associated with the 'Policy.type' attribute, which is not filtered by the 'Customer.policy.type' condition.

Note: For more about this type of conflict, see the topic, *"How branches in a Ruleflow are processed"*.

Click the **Clear analysis results** button to remove the highlights.

How branches in a Ruleflow are processed

Branch selection

Data is assigned to each branch before any branch execution occurs, so if an attribute in the branch condition changes value during a branch activity execution, it will not change the branch assignment. Further downstream, the new value is presented for subsequent branch activity execution.

Consider the following example. When branching by `Customer.smoker`, the value of `smoker` determines which branch is executed. Changing the value of `smoker` within a branch will not alter which branch processes the Customer.

Suppose you had the payload:

```
Customer 1 (smoker = "Yes")
Customer 2 (smoker = "No")
```

Changing the `smoker` for Customer 1 from "Yes" to "No" would not, within the current branch condition, cause it to be passed to the "No" `smoker` branch. Subsequent branching by `smoker` would use its current value.

Branching by associated attributes

When associations are involved, the data passed into the branch activity is the full association traversal of the branch condition. The entity (with possible associated parents) that satisfies the branch condition is passed into the branch activity. Child associations will be available during activity execution. Unrelated entities are part of the branch payload.

Consider the following example of branching by `Customer.policy.type`. All the policies for an order of some `type` will be passed into the matching branch.

Suppose you had the payload:

```
- Customer 1
  - policy 1 (type="standard")
  - policy 2 (type="preferred")
- Customer 2
  - policy 3 (type="standard")
  - policy 4 (type="preferred")
```

The branch for "standard" would be passed:

```
- Customer 1
  - policy 1 (type="standard")
- Customer 2
  - policy 3 (type="standard")
```

The branch for "preferred" would be passed:

```
- Customer 1
  - policy 2 (type="preferred")
- Customer 2
  - policy 4 (type="preferred")
```

Branch consistency

When a root entity is used for the branch and the branch activities use associations, care must be taken to ensure consistent results in a Ruleflow branch. It is important to use the same association traversals in the branch Rulesheets as used in the branch attribute. Thus, if the branch Rulesheets reference entities like `Customer.policy.type` and the branch attribute is on entity `policy.type`, the branch attribute in the branch container properties should be defined as `Customer.policy.type`, not `Policy.type`. If the branch container is the root entity `Policy.type`, the branch Rulesheets will still allow for references through the association `Customer.policy.type` to `Policy` entities that did not survive the branch.

Consider the following example of branching on `Policy.type`.

Suppose the payload had `Policy.type`:

```
- Customer 1
  - policy 1 (type="standard")
  - policy 2 (type="preferred")
- Customer 2
  - policy 3 (type="standard")
  - policy 4 (type="preferred")
```

The branch for "standard" would be passed:

```
- Policy 1 (type="standard")
- Policy 3 (type="standard")
```

The branch for "preferred" would be passed:

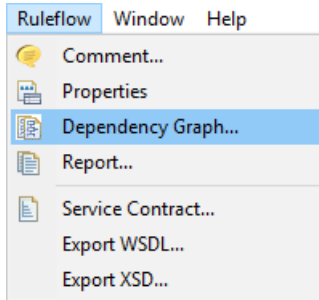
```
- Policy 2 (type="preferred")
- Policy 4 (type="preferred")
```

However in both branches, `Customer 1` and `Customer 2` (with associations) will also be available. So if rules in those branches reference `Customer.policy`, the rules will execute on every `Customer.policy`, not just the branched ones. Since the branch was on `Policy`, rules that reference `Policy` will only execute on the branched ones.

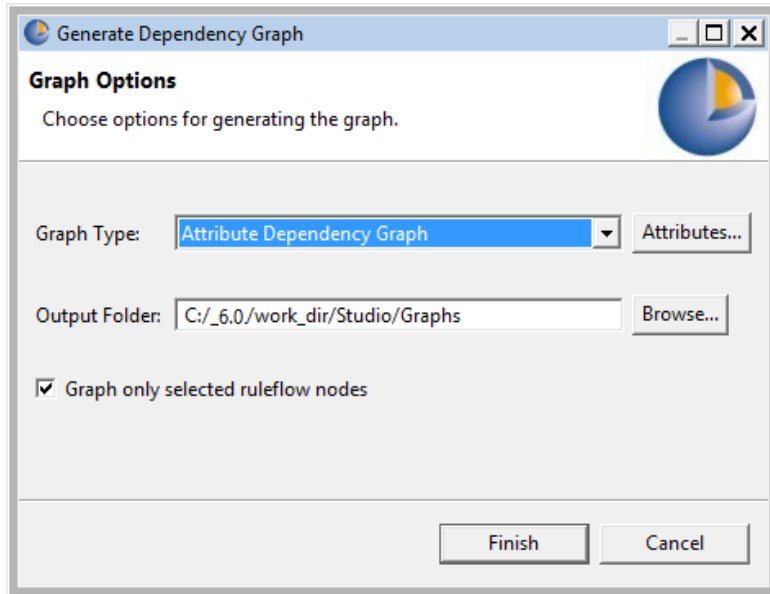
How to generate Ruleflow dependency graphs

When working on large Ruleflows you often want to know the dependencies between the nodes in the Ruleflow. This can help you determine how best to order the nodes or detect unanticipated dependencies. Dependencies are identified by the attributes that are set or referenced in the nodes of a Ruleflow. You also often want to know how one or more attributes are used in a Ruleflow. Ruleflow graphing lets you see the dependencies and where attributes are used. This is useful for understanding a Ruleflow, debugging problems, and performing impact analysis when changing a vocabulary.

With the Ruleflow you want to graph open in its Studio editor, select the **Ruleflow** menu command **Dependency Graph**, as shown:



The **Generate Dependency Graph** dialog box opens:



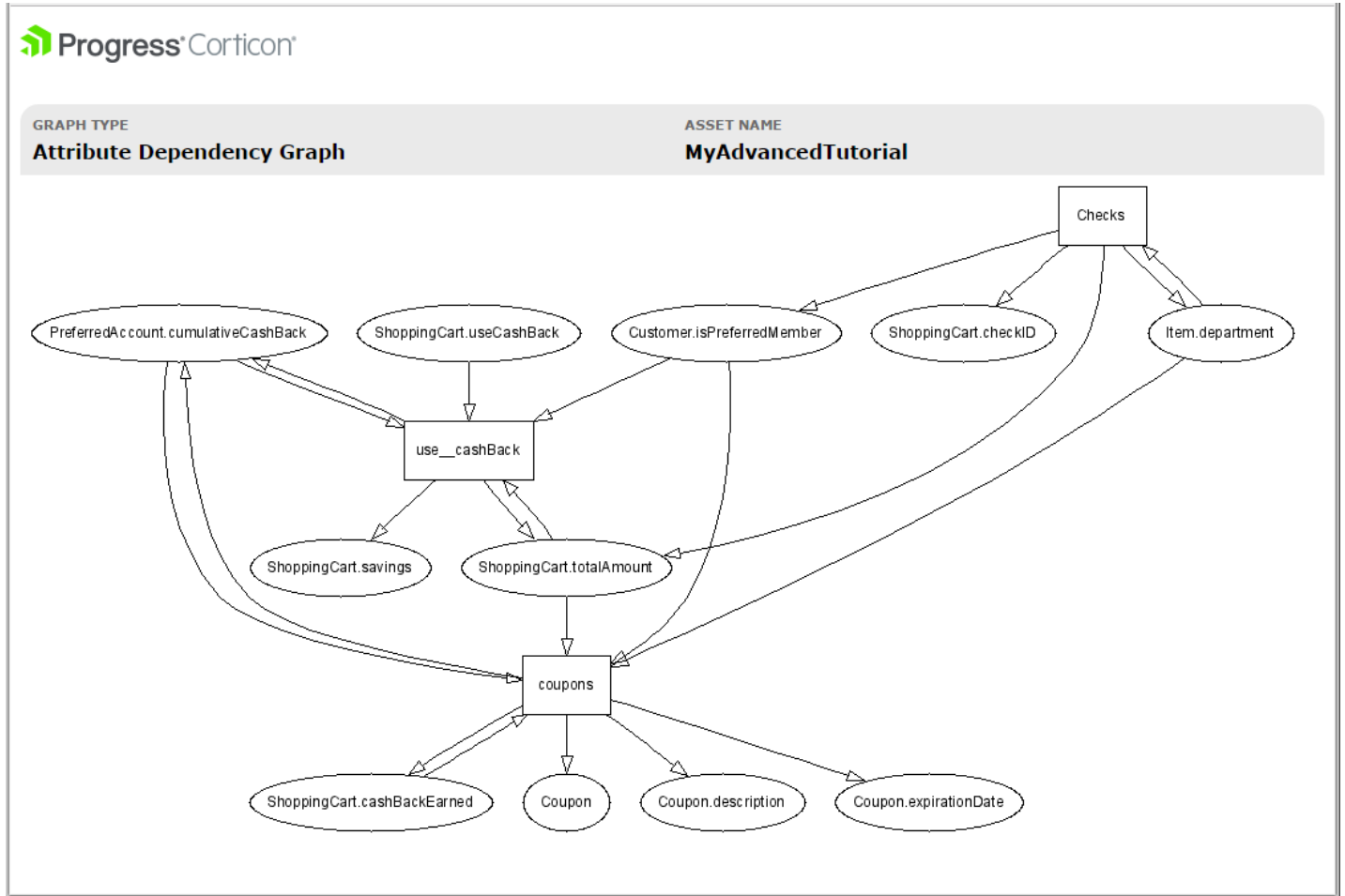
Choose the type of graph you want, and the output folder. You can focus the analysis on just nodes you selected before opening the dialog, or all nodes on the Ruleflow canvas.

Note: When no objects on the Ruleflow canvas are preselected, the option to graph only selected nodes has no effect.

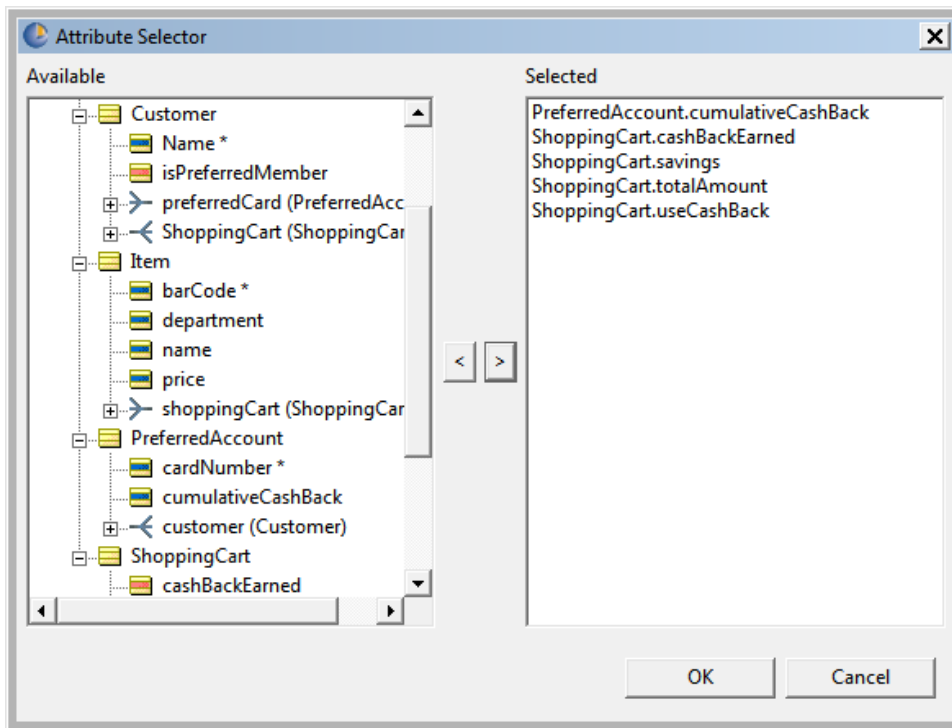
Attribute Dependency Graph

An *attribute dependency graph* shows the attributes that establish dependencies – that is, when a Rulesheet uses an attribute set by another Rulesheet, the former has a dependency on the latter.

When you just generate a graph right away, all the attributes are included, as in this graph of the advanced tutorial's Ruleflow:

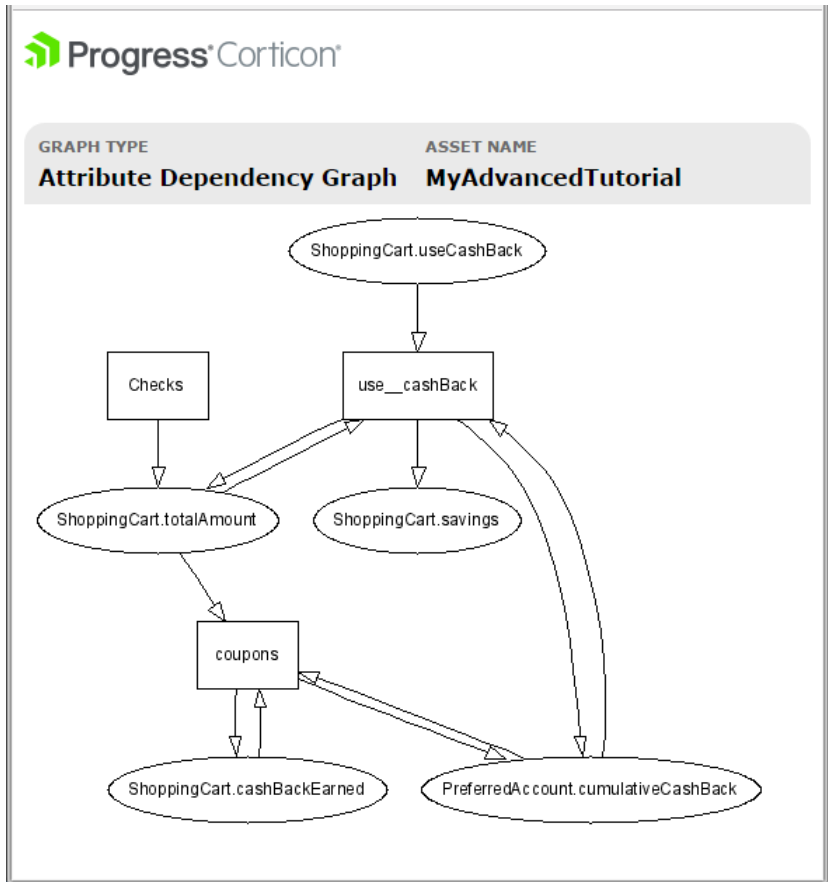


For large projects, graphs with all the attributes and dependencies can be difficult to work with. You can specify that only selected attributes are to be analyzed. Click **Attributes** to open the **Attribute Selector** dialog box, as shown:



In this illustration, five attributes were selected, so clicking **OK** returns to the graph options where clicking **Finish** generates the graph.

The graph opens in your default browser, as illustrated:

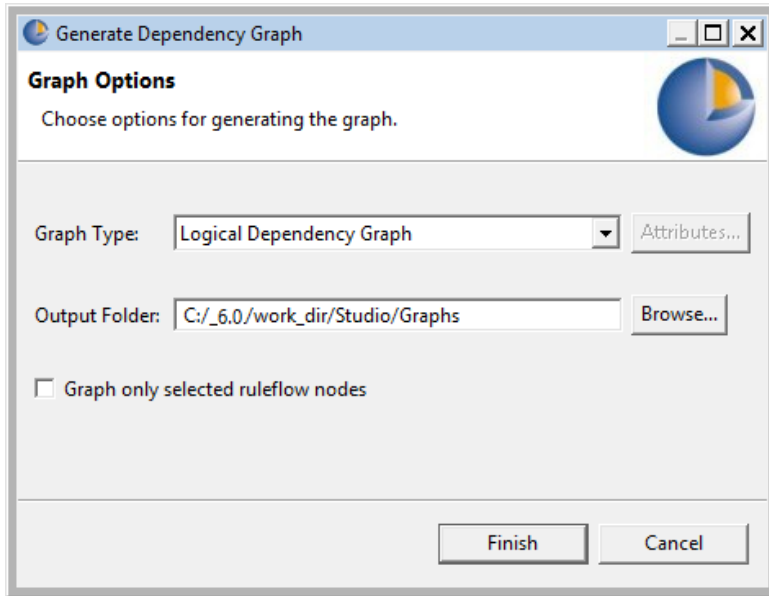


The graph image and its supporting files are saved in the output folder.

Note: When you next generate an attribute graph from the same Ruleflow, it overwrites the existing file unless you relocate generated files or specify unique output folders.

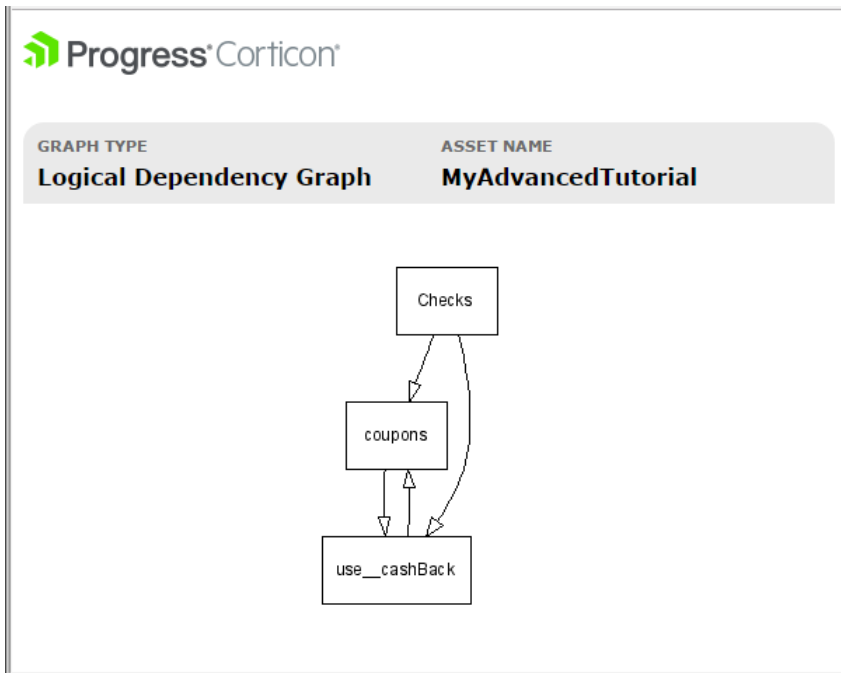
Logical Dependency Graph

A *logical dependency graph* shows the dependency between the Rulesheets in a Ruleflow. Change the graph type to **Logical Dependency Graph**, as shown:



You can set the output folder to your preference and if Ruleflow nodes were selected before opening the dialog box, the analysis is limited to those nodes. The option to specify attributes is not relevant and not available.

Clicking **Finish** generates the graph. The following illustration is the logical dependency graph for Rulesheets in the advanced tutorial's Ruleflow:



The graph image and its supporting files are saved in the output folder.

Note: When you again generate a dependency graph from the same Ruleflow, it overwrites the existing file unless you relocate generated files or specify unique output folders.

Ruleflow versions and effective dates

Ruleflow version

Major and minor version numbers for Ruleflows are optional. With the Ruleflow open in its editor, select the menu command **Ruleflow > Properties**, and then enter the **Major Version** and **Minor Version** as integer values:

Figure 231: Assigning a Version Number to a Ruleflow

The screenshot shows a 'Properties' dialog box for a Ruleflow. The 'Ruleflow' tab is selected. The 'Rule Vocabulary' field contains '/Training/Advanced/lifePolicy.ecore'. The 'Work Document Entity' is a dropdown menu. The 'Major Version' field is set to '1' and the 'Minor Version' field is set to '0'. The 'Version Label' field is empty. The 'Effective Date' and 'Expiration Date' fields are both set to '/ /'. The 'Time' fields for both dates are set to '0' for hours, '0' for minutes, and '0' for seconds, with a dropdown set to 'AM'. There are 'Clear' buttons for each time field. The 'Total Number of Rules' field is set to '3'.

When you use different Version numbers to describe identically named Ruleflows, the Corticon Server keeps each Decision Service distinguished in its memory, so it can respond correctly to requests for a specified version. In other words, an application or process can use (or call) different versions of the same Decision Service depending on certain criteria. The details of how this works at the Server level are discussed in the topics at *"Decision Service versioning and effective dating"* in the *Deployment Guide*.

Major and minor versions

Minor and Major version designations are arbitrary and may be adapted to fit the version naming conventions used in different environments. As an example, Ruleflow minor versions may be incremented whenever a component Rulesheet is modified. Major Ruleflow versions may be incremented when more substantial changes are made to it, such as adding, replacing, or removing a Rulesheet from the Ruleflow.

Version numbers can be incremented, but not decremented.

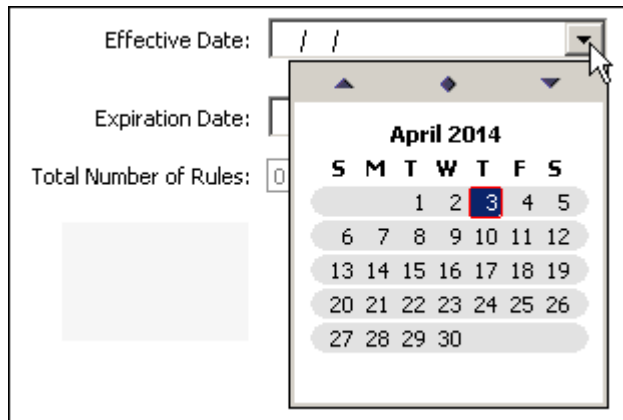
For details on how to invoke a Ruleflow by version number, see the topic *"Decision Service versioning and effective dating"* in the *Deployment Guide*.

Effective and expiration dates

Effective and Expiration dateTimes are optional for Ruleflows and can be assigned singly or in pairs. When you use different Effective and Expiration dateTimes to describe identically named Ruleflows, the Corticon Server keeps them straight in memory, and responds correctly to requests for the different dates. In other words, an application or process can use different versions of the same Ruleflow depending on dateTime criteria. The details of how this works at the Corticon Server level is described in the *Deployment Guide*.

Effective and Expiration Dates may be assigned using the same window as for the version numbers. Clicking on the **Effective Date** or **Expiration Date** drop-down displays a calendar and clock interface, as shown below:

Figure 232: Setting Effective and Expiration Dates



Setting a specific target date for a Ruletest

When you execute a Ruletest against a corresponding Decision Service that is deployed and running on a Corticon Server that was deployed with effective and expiration dates, the day you are testing the Decision Service could be impacted by the data constraints. The ability to set a *target date* lets you execute the test as though it were sent at a specific date and time. Using this feature enables setting the clock back to see how past date ranges would have handled a request, as well as setting the clock forward to test deployed Decision Services in pre-production staging.

To set a version and effective target date for a Ruletest:

1. With the Ruletest in its editor, choose the menu command **Ruletest > Testsheet > Select Test Subject**.
2. Select the **Run against Server** tab, select a Server URL, and then click **Refresh**.
3. Click on a Decision Service in the list.
4. In the **Optional Overrides** section, specify the Decision Service's version identity and effective target date to use for the Ruletest, as illustrated:

5. Click **OK**. The dialog closes. The details of the deployed Decision Service and its overrides are displayed at the top of the Testsheet:

untitled_1
<http://localhost:8850/axis?name=Cargo,major version=1,effective target date=01/29/16 12:00:01 AM>

6. Run the Ruletest.

The test executes against the specified Decision Service on the selected server using the overrides you entered.

TestYourself questions for Ruleflow versions and effective dates

Note: Try this test, and then go to [TestYourself answers for Ruleflow versioning and effective dating](#) on page 344 to correct yourself.

1. True or False. If a Ruleflow has an Effective date, it must also have an Expiration date.
2. True or False. If a Ruleflow has an Expiration date, it must also have an Effective date.
3. True or False. Ruleflow Version numbers are mandatory
4. Which Corticon Studio menu contains the Ruleflow Properties settings?
5. True or False. A Ruleflow Minor or Major Version number may be raised or lowered.
6. True or False. Ruleflow Effective and Expiration dates are mandatory.

Troubleshooting Corticon Studio problems

In addition to being a convenient way to test your Rulesheets with real business scenarios, the Corticon Studio Ruletest facility is also the best way to troubleshoot rule, Rulesheet, and Ruleflow operation. Corticon Ruletest are designed to replicate exactly the data handling, translation, and rule execution by Corticon Server when deployed as a Java component or web service in a production environment.

This means that if your rules function correctly when executed in a Corticon Ruletest, you can be confident they will also function correctly when executed by Corticon Server. If they do not, then the trouble is most likely in the way data is sent to Corticon Server – in other words, in the technical integration. This is such a fundamental tenet of rule modeling with Corticon, we'll repeat it again:

If your rules function correctly when executed in a Corticon Studio, they will also function correctly when executed by Corticon Server. If they do not, then the trouble is most likely your client application's integration/invocation with/of Corticon Server.

We offer the following methodology to guide your rule troubleshooting and debugging efforts. The basic technique is known generically as “half-splitting” or “binary chopping”, in other words, dividing a decision into smaller logical pieces, then setting aside the known-good pieces systematically until the problem is isolated.

This guide is not intended to be an in-depth cookbook for correcting specific problems since, as an expression language, the Corticon Rule Language offers too many syntactical combinations to address each in any detail.

For details, see the following topics:

- [Where did the problem occur](#)
- [Use Corticon Studio to reproduce the behavior](#)
- [Studio license expiration](#)
- [How to compare and report on Rulesheet differences](#)
- [TestYourself questions for Troubleshooting rulesheets and ruleflows](#)

Where did the problem occur

Regardless of the environment the error or problem occurred in, we will always first attempt to reproduce the behavior in Studio. If the error occurred while you were building and testing rules in Corticon Studio, then you're already in the right place. If the error occurred while the rules were running on Corticon Server (in a test or production environment), then you will want to obtain a copy of the Ruleflow (.erf file) and open it, its constituent Rulesheets (.ers files) and its Vocabulary (.ecore file) in Studio.

Use Corticon Studio to reproduce the behavior

It is always helpful to build and save “known-good” Ruletests (.ert files) for the Corticon Rulesheets and Ruleflows you intend to deploy. A known-good Ruletest not only verifies your Rulesheet or Ruleflow is producing the expected results for a given scenario, it also enables you to re-test and re-verify these results at any time in future.

If you do not have a known-good Ruletest, you will want to build one now to verify that the Ruleflow, as it exists right now, is producing the expected results. If you have access to the actual data set or scenario that produced the error in the first place, it is especially helpful to use it here now. Run the Ruletest.

Observe constraint violations or severe errors

When you run a Ruletest in Studio, it might produce error messages. Error messages are distinct from **Post** messages you specified in Rulesheet **Rule Statements** to generate info, warning, and violation statements that are posted by normal operation of the rules.

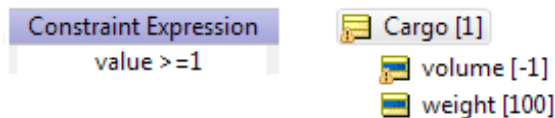
Constraint Violation

A constraint violation indicates that values in the test's attributes are not within numeric constraint ranges or not included in enumerated lists that have been set in the Vocabulary's Custom Data Types. A constraint violation might look like this:

Figure 233: A Constraint Violation in a Ruletest

Severity	Message
Violation	An unexpected error occurred in Input Data: com.corticon.cdo.ConstraintViolationException: constraint violation setting Cargo.volume to value [-1]

In the example, the constraint is shown, and its violation is marked on the attribute and its entity in the Input column:



Running the test halts at the first constraint violation. The log lists the first constraint exception and its detailed trace. No response is generated.

You can revise the input to have valid values, or choose to relax enforcement of such violations through a setting in the brms.properties file, com.corticon.vocabulary.cdt.relaxEnforcement=true.

When the option is enabled, a response is generated that includes each of constraint violation warnings. For example:

```
<CorticonResponse xmlns="urn:Corticon"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  decisionServiceName="Cargo.ers_null_ALL">
  <WorkDocuments>
    <Cargo id="Cargo_id_1">
      <weight>0</weight>
      <volume>-1</volume>
      <container>standard</container>
    </Cargo>
  </WorkDocuments>
  <Messages version="0.0">
    <Message postOrder="cc00000001">
      <severity>Warning</severity>
      <text>constraint violation setting Cargo.weight to value [0]</text>
      <entityReference href="Cargo_id_1" />
    </Message>
    ...
  </Messages>
</CorticonResponse>
```

See [How to relax enforcement of Custom Data Types](#) on page 47 for details about constraints and the option to relax enforcement.

Note: The output example shown reflects the execution properties in a Ruletest output file. If you extract the same response for a Ruletest from your Studio log when the RULETRACE logging filter is enabled, you reveal several additional execution properties that can be helpful in support efforts but they are otherwise not meaningful to users.

Severe errors

Some errors indicate problems with how the rules engine is handling the Decision Service: Null Pointer Exception, Reactor Exception, Fatal Exception. Let's hope that you don't see any of these alerts ever! These error conditions are important to resolve as soon as possible.

Immediately capture and save any advanced information in the alert, and then copy and save the logs. You might want to try closing Corticon Studio and running the Ruletest again. If it reliably fails with a severe error, you will need to engage Corticon Support. Package the current project and logs, and then contact support. If you have been following the best practice of retaining offline backups of the project as well as saving your work, you might be able to resume with most-recent in a different project workspace.

Note: Next step in troubleshooting - If you did not encounter constraint violations or severe errors, any other problems are within your rules. Proceed to [Analyzing Test Results](#). To work around a problem in rules, you can identify the expression syntax that produces it, and then try to express the logic in a different way. The Corticon Rule Language is very flexible and usually allows the same logic to be expressed in many different ways.

Analyze Ruletest results

This section assumes:

- Your Ruletest produced none of the errors listed above, or
- You or Corticon Technical Support identified workarounds that overcame these errors

Does the Rulesheet produce the expected test results? In other words, does the *actual* output match the *expected* output?

- If so, and you were using the same scenario that caused the original problem, then the problem is not with the rules or with Studio, but instead with the data integration or Corticon Server deployment.

The Corticon Server log captures errors and exceptions caused by certain rule and request errors. These log messages are detailed in the *Using Corticon Server logs section of the Server Guide*.

- If not, the problem is with the rules themselves. Continue in this section.

Trace rule execution

A first step in analyzing results of executing Decision Services is to gain visibility to the rules that fired. With rule tracing, you can see what rules and Rulesheets fired in processing a work document. Rule tracing can be used during development time in the Studio Tester or with deployed Decision Services. The following example uses the Advanced Tutorial's Ruleflow as the test subject. The Ruleflow has three Rulesheets, each with conditional and non-conditional rules.

Figure 234: Rule messages when metadata is enabled in Studio

Severity	Message	Entity
Info	[Checks,2] The customer is a Preferred Cardholder	Customer[1]
Info	[coupons,2] \$2 off next purchase when 3 or more Soda/Juice items are purchased in a single visit.	ShoppingCart[1]
Info	[coupons,3] 10% off next gas purchase when total is over \$75.	ShoppingCart[1]
Info	[coupons,B0] \$1.649800 cashBack bonus earned today, new cashBack balance is \$10.889800.	ShoppingCart[1]
Info	[use__cashBack,1] cashback.bonus has been deducted from the total. New total = \$71.600200. Today's savings = \$10.889800.	ShoppingCart[1]

The metadata can be expressed in natural language, such as, for line 1: "In Rulesheet Checks.ers, rule 2 generated this statement", and, for line 4 "In Rulesheet coupons.ers, line B's non-conditional (column 0) action generated this statement."

To enable this function, add a line to the `brms.properties` as:

```
com.corticon.reactor.rulestatement.metadata=true
```

Note: See "Server properties and settings" in the *Server Guide* for more information.

Identify the breakpoint

To understand why your rules are producing incorrect results, it's important to know where in the Rulesheet or Ruleflow the rules stop behaving as expected. At some point, the rules stop acting normally and start acting abnormally – they "break". Once we identify where the rule breaks, the next step is to determine why it breaks.

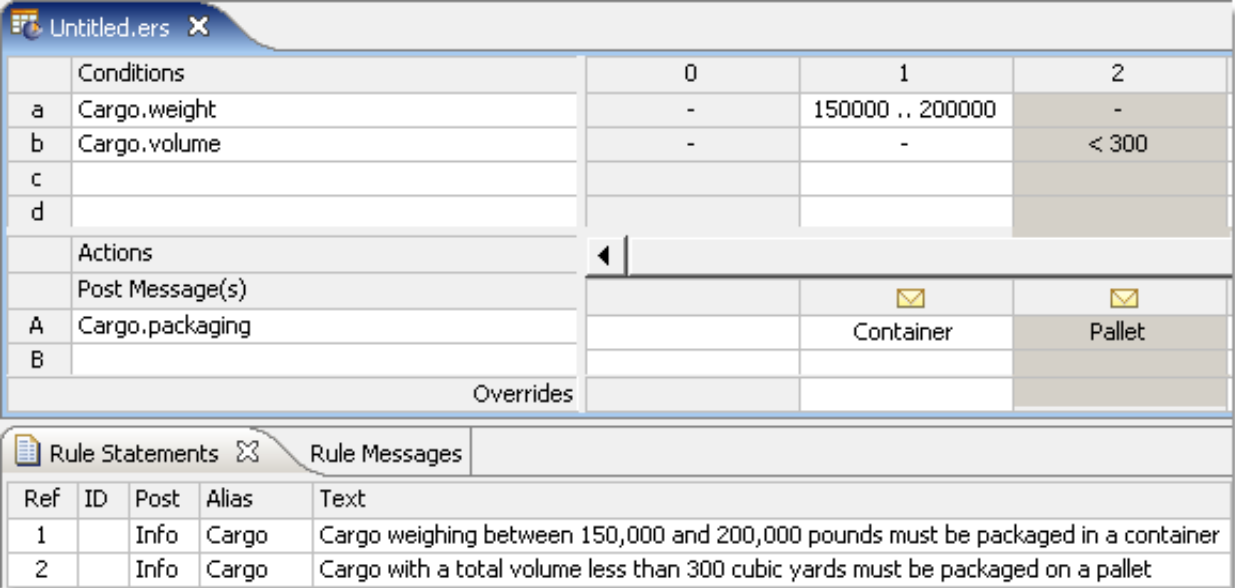
An important tool to help identify the breakpoint is the Ruletest's message box. By choosing values for `Post` and `Alias` columns in the **Rule Messages** window, you can generate a trace or log of the rules that fire during execution. The message box in a Ruletest will display those messages in the order they were generated by Corticon Server. In other words, the order of the messages in the box (top to bottom) corresponds to the order in which the rules were fired by Corticon Server. While messages in the message box can also be sorted by Severity or Entity by clicking on the header of those columns, clicking on the Message column header will always sequence according to the order in which the rules fired. Inserting attribute values into rule statements can also provide good insight into rule operation. But beware; a non-existent entity inserted into a rule statement will prevent the rule from firing, becoming the cause of another failure!

Disable/Enable

Disabling and then re-enabling individual Condition/Action rows, entire rule columns, Filter rows, and even whole Rulesheets is a powerful way to isolate problems:

- **Rulesheet elements** - Right-click active Condition or Action row headers, column headers, or Filter row headers to display a pop-up menu containing enable/disable options. Disabled rows and columns will be shaded in gray on the Rulesheet.

Figure 235: Rulesheet with Rule Column #2 Disabled.




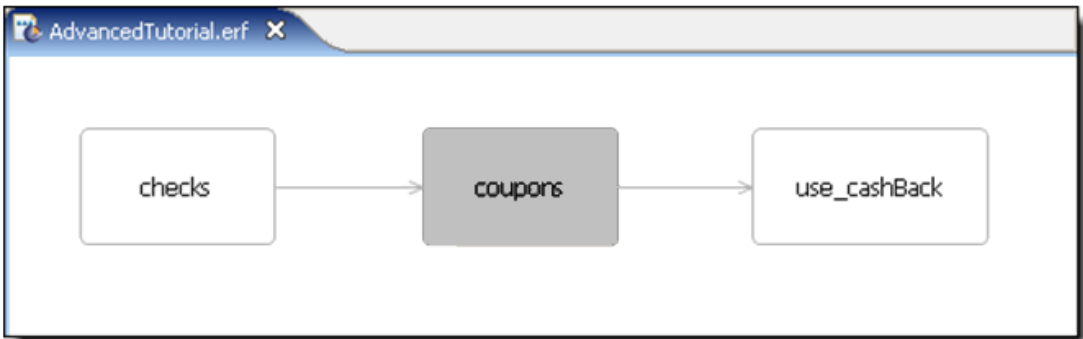
- **Ruleflow objects** - Select objects on a Ruleflow canvas, and then click the Disable/Enable toolbar button  to toggle the disabled objects to dark gray. Redo the action to re-enable the object.

Figure 236: Ruleflow with coupons object disabled



Be sure to save these changes before running a Ruletest to ensure the changes take effect. Disable and re-enable Rulesheet elements and Ruleflow objects until the strange or unexpected behavior stops.

At the breakpoint

At the point at which abnormal behavior begins, what results is the breakpoint rule producing?

- No results at all – the breakpoint rule *should* fire (given the data in the Ruletest) but does not. Proceed to the [No Results](#) section.
- Incorrect results – the breakpoint rule *does* fire, but without the expected result. Proceed to the [Incorrect Results](#) section.

No results

Failure of a rule to produce any results at all indicates the rule is telling the rule engine to do something it can't do. (This assumes, of course, that the rule *should* fire under normal circumstances.) Frequently, this means the engine tries to perform an operation on a term that does not exist or isn't defined at time of rule execution. For example, trying to:

- Increment or decrement an attribute (using the += or -= operators, respectively) whose value does not exist (in other words, has a `null` value).
- “Post” a message to an entity that does not exist, either because it was not part of the Ruletest to begin with, or because it was deleted or re-associated by prior rules.
- “Post” a message with an embedded term from the Vocabulary whose value does not exist in the Ruletest, or was deleted by prior rules.
- Create (using the `.new` operator) a collection child element where no parent exists, either because it was not part of the Ruletest to begin with, or because it was deleted or re-associated by prior rules.
- Trying to *forward-chain* -- using the results of one expression as the input to another -- within the same rule. For example, if Action row B in a given rule derives a value that is required in Action row C, then the rule may not fire. Both Actions must be executable independently in order for the rule to fire. If forward-chaining is required in the decision logic, then the chaining steps should be expressed as separate rules.

Incorrect results in Studio

Once the breakpoint rule has been isolated, it is often helpful to copy the relevant logic into another Rulesheet for more focused testing. Refer to the *Rule Language Guide* to ensure you have expressed your rules correctly. Be sure to review the usage restrictions for the operator(s) in question.

If, after isolating and verifying the suspicious expression syntax, you are unable to fix the problem, please call Progress Corticon Technical Support. As always, be prepared to send us a) the product version used, and b) the set of Corticon files (`.ecore`, `.ers`, `.erf`, and `.ert`) that will allow us to reproduce the problem.

Partial rule firing

A Condition/Action rule column might partially fire, meaning Action 1 is executed but Action 2 is not. If Action A cannot execute, then Action B will not execute either, even if there is nothing wrong with Action B by itself. An Action containing any one of the problems listed above is sufficient to prevent a rule from firing, even if all other Actions in the rule are valid.

There are two exceptions to this rule:

Nonconditional actions

In the special Nonconditional rule column, column 0, each Action row in column 0 acts as its own separate, independent rule, so Action row A may fire even if Action row B does not.

Partial execution of rules with relationships and null attributes

When a *relationship* is null, the rule does not fire. When an *attribute* is null, and the relationship aspects of the rule can be evaluated, the rule fires partially: The actions related to the association do fire but the action related to a null attribute does not. Consider a Rulesheet and test on the Cargo sample where the `Aircraft` information is set from its ID, and the total cargo weight computed. If there is no associated `Aircraft.flightPlan` or `Aircraft.flightPlan.cargo` in the test, then the rule does not execute (even though those associations are not referenced in the Rulesheet's Conditions section). However, if the associations exist but the attribute `Aircraft.flightPlan.cargo.volume` is null, the rule *does* fire partially -- all the `Aircraft` values are computed but the weight is not computed from the null value of the attribute.

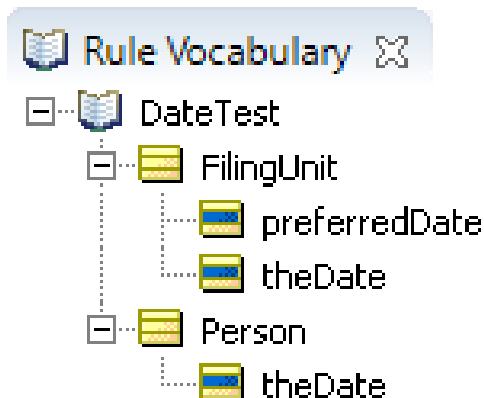
How to initialize null attributes

Attributes that are used in calculations must have a non-null value to prevent test rule failure. More specifically, attributes used on the right-hand-side of equations (that is, an attribute on the right side of an assignment operator, such as `=` or `+=`) are *initialized* prior to performing calculations. It is not necessary for attributes on the left-hand-side of an equation to be initialized – it is assigned the result of the calculation. For example, when you are calculating `Force=Mass*Acceleration`, you must provide values for `Mass` and `Acceleration`. `Force` is the result of a valid calculation.

Initialization of attributes is often performed in Nonconditional rules, or in rules expressed in Rulesheets that execute beforehand. That was often because an Attribute that was set to Transient mode could not be added as Input to Ruletests. The limitation has been removed: You can add Transients to the Input column of a Ruletest. Then, as stated, you must provide a value to such attributes in their Input locations in Ruletests to enable valid firing of the rule.

How to handle nulls in compare operations

Unless the application that formed the request ensured that a value was provided before submission, one (or both) of the attributes used in a comparison test might have a null value. You might need to define rules to handle such cases. An example that describes the workaround for these cases uses the following Vocabulary:



Here are two scenarios:

1. Two dates are passed from the application and one of them is null. When given the rule ``[If FilingUnit.theDate is null] or [[FilingUnit.theDate = Null] and [FilingUnit.theDate >= Person.theDate]]'`, then the appropriate action triggers.
2. In Actions, one date value is set to another date's value which happens to be null. If the date is null, then it is used in the subsequent Rulesheets in their Conditions section. However, since the value is null, a warning will be generated in the Corticon logs.

For the first scenario, the logic in subsequent Rulesheets needs to determine whether a value is null, so it can apply appropriate actions. The following Rulesheet shows that you can avoid the error message by only setting the preferred date when you have a non-null filing date or person date.

Conditions		0	1	2	3	4	5
a	FilingUnit.theDate = null		T	F	T	F	F
b	Person.theDate = null		F	T	T	F	F
c	FilingUnit.theDate >= Person.theDate		-	-	-	T	F
d							
e							
f							

Actions		0	1	2	3	4	5
Post Message(s)							
A	FilingUnit.preferredDate = FilingUnit.theDate						
B	FilingUnit.preferredDate = Person.theDate						
C							
D							

Ref	Post	Alias	Text
1	Warning	FilingUnit	Filing unit date is null - use person date as the preferred date
2	Warning	Person	Person date is null - use filing unit date as the preferred date
3	Violation	FilingUnit	Both dates are null - unable to determine preferred date
4	Info	FilingUnit	Filing data is greater than or equal to the person date - use filing date
5	Info	FilingUnit	Filing date is less than person date - use person date

Note: If null values would prevent subsequent rules from continuing reasonable further processing, then perhaps validation sheets should be used before rule processing to check the data, and then terminate execution of the decision if the data is bad. That could be accomplished by setting an attribute that can be tested in the filter section of subsequent Rulesheets. Then, every subsequent Rulesheet is assured of dealing only with "clean" data.

For the scenario where both values being compared are null, you could set the resulting value to a default value or to null, as shown here:

Conditions		0	1	2	3	4	5
a	FilingUnit.theDate = null		T	F	T	F	F
b	Person.theDate = null		F	T	T	F	F
c	FilingUnit.theDate >= Person.theDate		-	-	-	T	F
d							

Actions		0	1	2	3	4	5
Post Message(s)							
A	FilingUnit.preferredDate = FilingUnit.theDate						
B	FilingUnit.preferredDate = Person.theDate						
C	FilingUnit.preferredDate = null						
D							

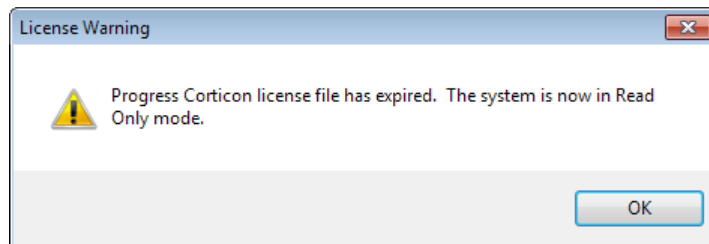
Ref	Post	Alias	Text
1	Warning	FilingUnit	Filing unit date is null - use person date as the preferred date
2	Warning	Person	Person date is null - use filing unit date as the preferred date
3	Violation	FilingUnit	Both dates are null - set preferred date to null
4	Info	FilingUnit	Filing data is greater than or equal to the person date - use filing date
5	Info	FilingUnit	Filing date is less than person date - use person date

As highlighted, Rule 3 explicitly sets the preferred date to null when both incoming dates are null.

Studio license expiration

If your license indicates that it has expired, contact your Progress Corticon representative to obtain an updated license file. Corticon Studio alerts the user at startup, and then limits functionality:

Figure 237: License Expiration alert at Studio startup



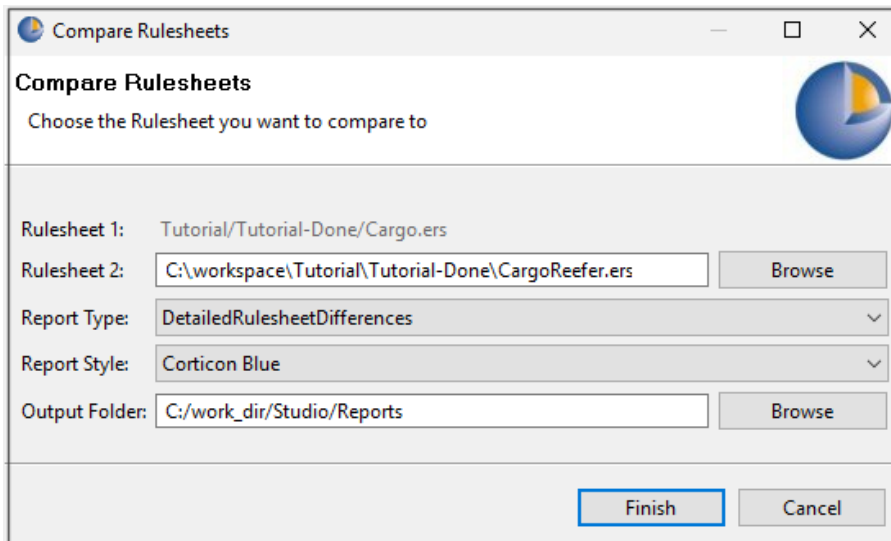
How to compare and report on Rulesheet differences

When the execution of your rules is not producing the expected results and you are not sure what changed, Corticon Studio provides difference reports to help identify changes. Two versions of a Rulesheet can have modest changes, yet it can be difficult to see all the differences during a visual inspection of the two Rulesheets. Reporting on differences between Rulesheets provides help in debugging mistaken rule changes, and inconsistent rule definitions. For example:

- **Diagnosing a Ruletest failure** - When a Ruletest fails because of changes in newer Rulesheets, you can use Rulesheet difference reports to determine what changed, and then make changes to a Rulesheet to fix bad rules, or to indicate changes to make to your Ruletest expected results.
- **Resolving merge conflicts** - When using a source control system such as git, you may encounter situations where you want to commit a Rulesheet that someone else has changed, and discover a merge conflict. Using Rulesheet difference analysis and reports, you can see what has changed and decide how to manually merge the differences so you can commit your changes.

To compare two versions of a Rulesheet:

1. Right-click within a Rulesheet, and then choose the menu command **Compare Rulesheets**.
2. The **Compare Rulesheets** dialog box opens, as illustrated.



Rulesheet 1 is the Rulesheet currently in the editor.

3. Locate **Rulesheet 2**, a variation of Rulesheet 1, typically produced earlier in development or by another developer.
4. Choose a preferred **Report Type**
5. Choose a preferred **Report Style** - The CSS stylesheet to use for the report. The basic stylesheets are **Corticon Blue** and **Corticon Green**.
6. Choose a preferred **Output Folder** - The location where the report will be stored on disk. The default location is `[CORTICON_WORK_DIR]/Studio/Reports`. You can create a root location such as `C:\CorticonStudioReports` and then append subfolder names to sort out your projects, tasks, clients, or versions.
7. Click **Finish**.

Customized difference reports

Advanced users might want to create alternative report types and styles:

- The type files are located at `[CORTICON_WORK_DIR]\Studio\Reports\XSLT\` in folders according to the asset types. You can copy the files to use as templates or change them to create report types that are then offered in the Report Type dropdown menu for the asset type.
- The style files are located at `[CORTICON_WORK_DIR]\Studio\Reports\CSS\`. You can copy a stylesheet file to use as a template to create custom report styles that are then offered in the **Report Style** dropdown menu.

Reading a differences report

The Rulesheet difference report evaluates what's changed -- additions, deletions, and modifications as well as items set as disabled. Presentation differences -- colors, fonts, natural language, and widths -- between the Rulesheets are ignored.

A report lists all the data in both Rulesheets. Items that are the same in both Rulesheets are not highlighted while those that are different are highlighted. The reason could be because the item changed. These need to be researched to see if they pair with an item on the other Rulesheet that has a variation of the item in that location.

Examples of how differences are reported

The following examples use the basic tutorial's Cargo Rulesheet as the Rulesheet to which variations are compared:

Conditions		0	1	2	3	4
a	Cargo.weight		<= 20000	-	> 20000	
b	Cargo.volume		-	> 30	<= 30	
c						
Actions						
Post Message(s)			☑	☑	☑	
A	Cargo.container		standard	oversize	heavyweight	
B						
Overrides				1		

EXAMPLE: Extra Condition

Conditions		0	1	2	3	4
a	Cargo.weight		<= 20000	-	> 20000	-
b	Cargo.volume		-	> 30	<= 30	-
c	Cargo.needsRefrigeration		-	-	-	T
d						
Actions						
Post Message(s)			☑	☑	☑	☑
A	Cargo.container		standard	oversize	heavyweight	reefer
R						
Overrides				{1, 4}		{1, 3}

Conditions a and b are matched; however, Rulesheet 2 has an extra Condition, c.

Conditions	
Rulesheet1	Rulesheet2
a. Cargo.weight	a. Cargo.weight
b. Cargo.volume	b. Cargo.volume
	c. Cargo.needsRefrigeration

EXAMPLE: One match that is in sequence and one that is out of sequence

Conditions		0	1	2	3	4
a						
b						
c	Cargo.volume		-	> 30	<= 30	
d	Cargo.weight		<= 20000	-	> 20000	
e						
Actions						
Post Message(s)			✉	✉	✉	
A	Cargo.container		standard	oversize	heavyweight	
n						
Overrides				1		

There are a few differences illustrated in this example:

- In-sequence match: Condition *c* in Rulesheet 1 matches condition *b* in Rulesheet 2.
- Out-of-sequence match: Condition *d* in Rulesheet 1 is marked as different because Condition *a* in Rulesheet 2 is out of sequence, and is marked as different.
- Extra: Condition: *c* in Rulesheet 2 is extra, and therefore different.
- Empty Condition Rows: Rulesheet1 has two empty Condition rows *a* and *b* are highlighted.

Conditions	
Rulesheet1	Rulesheet2
a.	
b.	
c. Cargo.volume	b. Cargo.volume
d. Cargo.weight	
	a. Cargo.weight
	c. Cargo.needsRefrigeration

EXAMPLE: A Condition has been disabled

Conditions		0	1	2	3	4
a						
b						
c	Cargo.volume		-	> 30	<= 30	
d	Cargo.weight		<= 20000	-	> 20000	
Actions		< [] >				
Post Message(s)			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
A	Cargo.container		standard	oversize	heavyweight	
B						
C						
Overrides				1		

When the *state* of the condition is different, the conditions are matched, but marked as different, as shown. Condition c is disabled in Rulesheet 1 -- it is highlighted but matched.

Conditions	
Rulesheet1	Rulesheet2
a.	
b.	
c. <i>Cargo.volume Disabled</i>	b. Cargo.volume
d. Cargo.weight	
	a. Cargo.weight
	c. Cargo.needsRefrigeration

TestYourself questions for Troubleshooting rulesheets and ruleflows

Note: Try this test, and then go to [TestYourself answers for Troubleshooting rulesheets](#) on page 344 to correct yourself.

1. Troubleshooting is based on the principle that Rulesheets behave the same way when tested in Corticon Studio as when executed on _____.
2. The first step in troubleshooting a suspected rule problem is to reproduce the behavior in a Corticon Studio _____ (test)
3. If the Rulesheet executes correctly in Corticon Studio, then where does the problem most likely occur?
4. Which of the following problems requires you to contact Progress Corticon Support for help?

Fatal Error	Null Pointer Exception	Reactor Error	Expired License
-------------	------------------------	---------------	-----------------

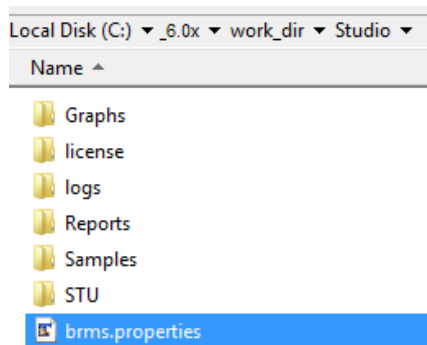
5. The specific rule where execution behavior begins acting abnormally is called the _____.
6. True or False. When a rule fires, some of its Actions may execute and some may not.
7. What Corticon Studio tools help you to identify the Rulesheet's breakpoint?
8. A dark gray-colored Rulesheet box within a Ruleflow indicates that the Rulesheet has been _____.
9. A disabled rule:
 - a. executes in a Corticon Studio Test but not on the Corticon Server
 - b. executes on the Corticon Studio but not in a Corticon Studio Test
 - c. executes in both Corticon Studio Tests and on the Corticon Server
 - d. executes neither in a Corticon Studio Test nor on the Corticon Server
10. Where are the Corticon Studio logging features set?
11. Where are the Corticon Studio override properties set?
12. True or False. The Corticon Server license file needs to be located everywhere the Corticon Server is installed.
13. If you are reporting a possible Corticon Studio bug to Corticon Support, what minimum information is needed to troubleshoot?
14. Which of the following cannot be disabled?
 - a. a Condition row
 - b. an Action row
 - c. a Filter row
 - d. a leaf of the Scope tree
 - e. a Noncondition row (i.e., an Action row in Column 0)
 - f. a rule column
 - g. a Rulesheet
 - h. a Ruleflow

A

Studio properties and settings

Corticon Studio provides properties that specify property names and default values of user-configurable behaviors in Corticon Studios.

The settings file `brms.properties` is installed at the root of `[CORTICON_WORK_DIR]` for each Studio installation. If you install Studio and Server on one machine and accept the default colocating paths, one `brms.properties` file is installed to be shared by Studio and Server:



About the `brms.properties` file

- It is good practice to back up the file before you start to make changes.
- When installed separately, the Studio and Server `brms.properties` files are identical.
- If you delete the file, it does not get recreated at restart. However, as these are overrides to default properties, there is no loss of features or functionality when the file is not present.
- In the absence of a `brms.properties` file, you can simply list property settings in a text file, and then save it to its proper location as `brms.properties`.
- An update of the installation will preserve a modified `brms.properties` file, and will add the default file if none is present.

Enabling settings listed in the default `brms.properties` file

The file lists properties that users commonly want to change. Each group of properties provides descriptive comments and the commented default `name=value` pair.

To specify a preferred value for a listed property, edit the file, remove the `#` from the beginning of a property's line, and then add your preferred value after the equals sign. For example, to express a preference for decimal values displayed and rounded to two places instead of the six places preset for this property, locate the line:

```
#decimalscale=6
```

and then change it to

```
decimalscale=2
```

Adding unlisted settings to `brms.properties` file

Some locations in the documentation tell you about other property settings that you might want to add to the settings file. Or you might be directed by technical support or your Progress representative to add or change settings to provide certain behaviors or functions.

For example, to change interval of diagnostic readings from five minutes to two minutes, add the following line to the `brms.properties` file -- it does not matter where in the file as long as it is on a separate line:

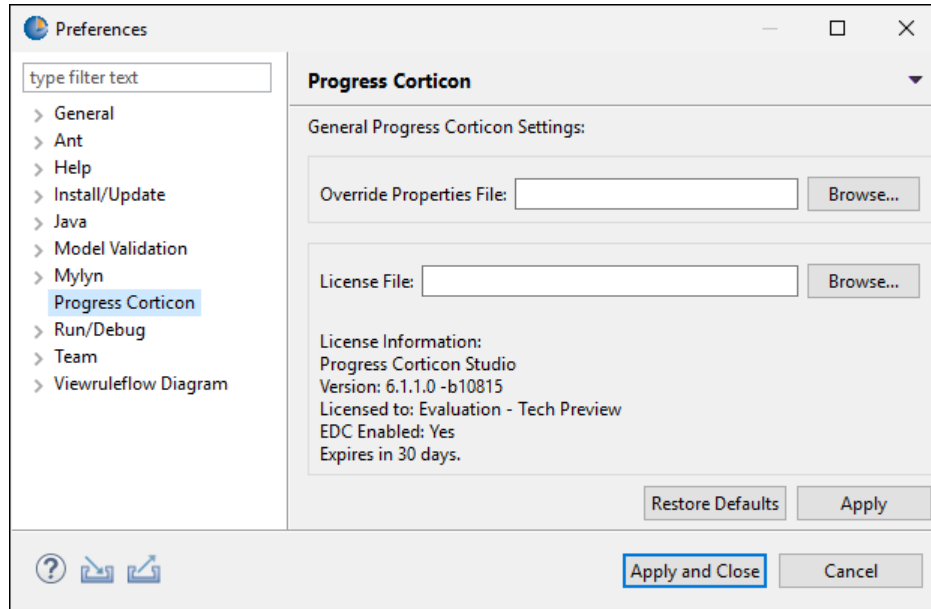
```
com.corticon.server.DiagnosticWaitTime=120000
```

If you add the same property more than once in the settings file, the last instance takes precedence.

Saving and applying the revised Studio property settings

When your changes are complete, you can choose to save the settings file with its default name and location, but you could save a copy with a useful name, such as `debuggingLogSettingsbrms.properties`.

In Studio, you can save multiple settings files, and then use Studio's **Preferences** to specify the **Override Properties File** for the `brms.properties` to use, as illustrated:



Note: The overrides and license specified are stored in the Studio Workspace. If you change the Workspace, those overrides or defaults will take effect.

For the revised settings to take effect, save the edited file, and then restart the Corticon Studio.

Note: Property settings you list in your `brms.properties` *replace* corresponding properties that have default settings. They do not *append* to an existing list. For example, if you want to add a new `DateTime` mask to the built-in list, be sure to include *all* the masks you intend to use, not just the new one. If your `brms.properties` file contains only the new mask, then it will be the only mask Corticon uses.

The following properties are settings you can apply to your Corticon Studio installation by adding the properties and appropriate values as lines in its `brms.properties` file, and then restarting Studio.

GENERAL

Decimal scale sets the default precision for Decimal values. All Decimal values are rounded to the specified number of decimal places. Default value is 6. For example, `4.6059556` will be rounded, displayed, and/or returned as `4.605957`. In the `brms.properties` file, set the Studio Test's decimal scale:

```
decimalscale=6
```

When set to 2, the rounded value is `4.61`.

Default character encoding for objects, such as Vocabulary, Rulesheet and Ruletest XML files. Examples: UTF-8, UTF-16, ISO-8859-1, US-ASCII. Default value is UTF-8.

```
com.corticon.encoding.standard=UTF-8
```

RULESHEETS

Determines the number of rows that are added to the end of a Rulesheet section when **Rulesheet > Add Rows to End** is selected from the Corticon Studio menubar or popup menu. Default is 10.

```
com.corticon.designer.corticon.insertrowstoend=10
```

Determines the number of columns that are added to the end of a Rulesheet section when **Rulesheet > Add Columns to End** is selected from the Corticon Studio menubar or popup menu. Default is 10.

```
com.corticon.designer.corticon.insertcolumnstoend=10
```

When there are any null attributes on the right hand side of a clone assignment expression, the assignment does not occur; it will not override the cloned value. If the null result is preferred, add this property set to `true` so that the null checks are removed. Be aware that using this setting on a Studio machine should be applied on any other machine that will work on a related project, and that Decision Services created when the property is `true` have the setting embedded in the Decision Service. Default is `false`.

```
com.corticon.reactor.rulebuilder.DisableNullCheckingOnClone=false
```

RULETESTS

Specifies how the Rule Messages are displayed in the Tester after execution based on the data in the columns. Options are `ExecutionOrder`, `Severity`, and `Entity`. Default value is `ExecutionOrder`.

```
com.corticon.testers.result.messages.sorting=ExecutionOrder
```

Option to specify how many variable substitutions could be applied to an ADC PreparedStatement. The restriction on how many PreparedStatement variables is controlled by the Database Driver. Different Databases have different maximums.

Default value is 1000

```
com.corticon.server.adc.preparedstatements.maxvariables=1000
```

Specifies whether String attribute values should be trimmed in the Tester Expected tree. When set to `false`, suppresses trimming of leading and trailing whitespaces.

Default value is `true`.

```
com.corticon.testers.trimstringvalues=true
```

By default, Corticon Studio uses the Corticon Server's REST API to run ruletests against a remote server. You can change this to use the SOAP API by setting the following property (Default value is `JSON`):

```
com.corticon.testers.cserver.execute.format=XML
```

When using the SOAP API and testing against an IIS server you also need to set this property for Corticon Studio (Default value is JAVA):

```
com.corticon.studio.client.soap.clienttype=IIS
```

Sets the Studio Test's XML messaging style: Hier (hierarchical), Flat, or Autodetect. Default value is Hier.

```
com.corticon.designer.test.xmlmessagingstyle=Hier
```

RULEFLOWS: Packaging

Corticon Studio uses the following properties when compiling assets into a Decision Service through the "Package and Deploy" wizard. (Corticon Server utilities also use these properties when compiling a Decision Service.)

Compile option: This property lets you configure memory settings for compiling the Rule Assets into an EDS file.

Default value is `-Xms256m -Xmx1g`

```
com.corticon.ccsrver.compile.memorysettings=-Xms256m -Xmx1g
```

Compile option: Add the Rule Asset's Report to the compiled EDS file. By having the Report inside the EDS file, any user can get the report for a deployed Decision Service through an in-process or a SOAP call to the Corticon Server. Including the Report in the EDS file will increase the EDS file significantly.

Default value is false

```
com.corticon.server.compile.add.report=true
```

Compile option: Add the Rule Asset's WSDL to the compiled EDS file. By having the WSDL inside the EDS file, any user can get the WSDL for a deployed Decision Service through an in-process or a SOAP call to the Corticon Server. Including the WSDL in the EDS file will increase the EDS file significantly.

Default value is false

```
com.corticon.server.compile.add.wsdl=true
```

Note: In prior releases, the default action was to automatically produce the WSDL and reports to add to the EDS. Given the techniques to produce WSDL and reports without having them in the EDS, the option to suppress the WSDL and reports in packaging unless explicitly requested, results in smaller packages and better compilation performance.

GRAPHIC VISUALIZER

Sets the font type and size used by the Graphic Visualizer. Default values are `Helvetica-Narrow.ttc` and `9`, respectively.

```
com.corticon.crml.CrmlGraphVisualizer.fontname=Helvetica-Narrow.ttc
com.corticon.crml.CrmlGraphVisualizer.fontname.ja=msgothic.ttc
com.corticon.crml.CrmlGraphVisualizer.fontsize=9
```

B

Answers to TestYourself questions

Check out your results from the tests at the end of each section.

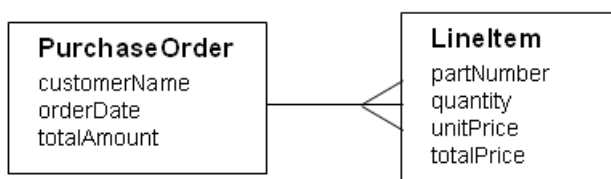
For details, see the following topics:

- [TestYourself answers for Building the vocabulary](#)
- [TestYourself answers for Rule scope and context](#)
- [TestYourself answers for Rule writing techniques and logical equivalents](#)
- [TestYourself answers for Collections](#)
- [TestYourself answers for Rules containing calculations and equations](#)
- [TestYourself answers for Rule dependency and inferencing](#)
- [TestYourself answers for Filters and preconditions](#)
- [TestYourself answers for Recognizing and modeling parameterized rules](#)
- [TestYourself answers for Writing rules to access external data](#)
- [TestYourself answers for Logical analysis and optimization](#)
- [TestYourself answers for Ruleflow versioning and effective dating](#)
- [TestYourself answers for Troubleshooting rulesheets](#)

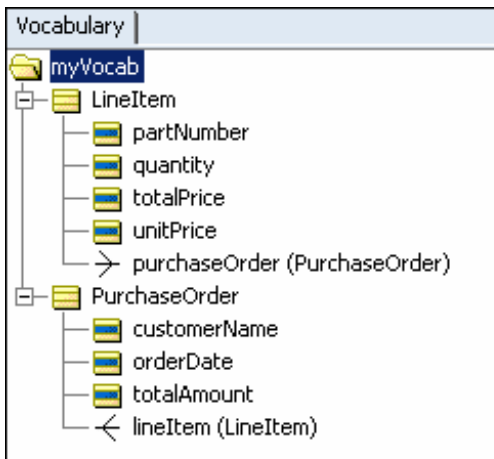
TestYourself answers for Building the vocabulary

[Show me this set of test questions.](#)

1. Any three of the following:
 - a. provides terms that represent business “things”
 - b. provides terms that are used to hold transient (temporary) values within Corticon Studio
 - c. provides a federated data model that consolidates entities and attributes from various enterprise data resources
 - d. provides a built-in library of literal terms and operators that can be applied to entities and attributes
 - e. defines a schema that supplies the contract for sending data to and from a Corticon Decision Service
2. False. The Vocabulary may include transient terms that are used only in rules and that don't exist in the data model.
3. False. Terms in the data model that are not used by rules do not need to be included in the Vocabulary.
4. False. A Vocabulary may be created before its corresponding object or data model exists.
5. The Vocabulary is an **abstract** model, meaning many of the real complexities of an underlying data model are hidden so that the rule author can focus on only those terms relevant to the rules.
6. The UML model that contains the same types of information as a Vocabulary is called a **Class Diagram**
7. Entities, Attributes, Associations
8. hairColor
9. yellow
10. Attributes
11. Boolean, DateTime, Decimal, Integer, String
12. blue and yellow
13. orange and yellow
14. A Transient Vocabulary term is used when the term is needed to hold a temporary value that is not required to be stored in external data.
15. Associations are **bidirectional** by default
16. cardinality
17.
18.
19. Target.source.attribute
20. target



21.



22.

23. identify terms, separate terms, assemble and relate terms, diagram vocabulary remove answer from question

24. a

25. operators

26. Rule Language Guide

27. False. Custom Data Types must be based on the 7 base data types. They extend the 7 base data types.

28. b. May match other Custom Data Type Names

29. True

30. value < 10

31. True

32. No

33. 'Airbus'

34. Attribute values are pre-populated in pulldowns based on the enumerated values.

35. Allow you to re-use entities by "bundling" or creating a "sub-set" within the vocabulary. (technically equivalent to packages in Java or namespaces in XML.)

36. True.

37. True.

38. All entities have native attributes, but Bicycle = 100% native, the others have 1 native attribute each and 3 inherited. Entities with inherited attributes = MountainBike, RoadBike, TandemBike

39. cadence, gear, or speed

40. True.

TestYourself answers for Rule scope and context

[Show me this set of test questions.](#)

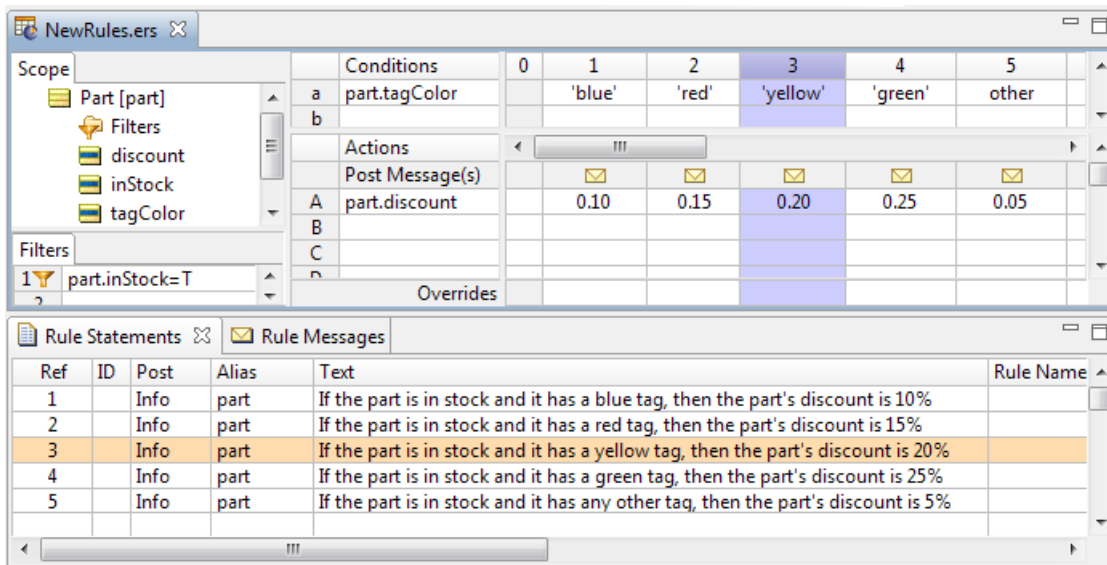
1. 7 root-level entities are present
2. all terms are allowed **except** DVD.actor
3. Movie.supplier

4.
 - a. Movie.oscar
 - b. Movie.roles
 - c. Actor.roles
 - d. DVD.supplier
 - e. Movie.dvd.extras
 - f. Actor.roles.movie.oscar
5. Actor.roles.movie
6. Since the association between Actor and Role is bidirectional, we can use both Actor.roles and **Roles.actor** in our rules.
7. Movie and Award
8. from Movie to Award: goldenGlobe and oscar. From Award to Movie: two unique rolenames exist for this perspective, too, but are not visible in the Vocabulary diagram.
9. The Award entity could be split into two separate entities, or an attribute could be added to Award to identify the *type* of award.
10. Using roles helps to clarify rule context.
11. unique
12. True
13. all examples shown are Boolean expressions
14. can use Movie if it is the root term, or DVD.movie if DVD is the root term The root term can either be Movie or DVD – no conditions in the rule prevent either one from being the root term
15. can use Movie.dvd if Movie is the root term, or DVD if it is the root term The root term can either be Movie or DVD – no conditions in the rule prevent either one from being the root term
16. False. Both Movie and DVD terms in this example are root terms with no relationship to each other.
17. Once for the Movie satisfying the rule conditions and its *associated* DVD
18. Twice: once for each DVD (i.e. the cross product of the DVDs and the Movie satisfying the rule conditions)
19.
 - a. High
 - b. Low
 - c. Low for each DVD
 - d. Twice: once for each DVD
 - e. Four: each of the 2 rules fired 2 times
 - f. cross product
 - g. no, each rule should only fire once for the DVD *associated* with the Movie
 - h. change the Movie and DVD terms to share the same scope, starting either with Movie as the root term (Movie and Movie.dvd) or DVD as the root term (DVD and DVD.movie)
20. False. Aliases are only *required* to be used in certain circumstances, but they can be used at any time and provide a good way of simplifying rule expressions.
21. Scope is another way of defining a specific **context** or **perspective** in the Vocabulary
22. be updated
23. False. Each alias must be unique and cannot have the same spelling as any term in the Vocabulary.

TestYourself answers for Rule writing techniques and logical equivalents

[Show me this set of test questions.](#)

1. Preconditions act as master rules for all other rules in the same Rulesheet that share the same **scope**
2. An expression that evaluates to a True or False value is called a **Boolean** expression
3. True
4. False. The requirement for complete Values sets only applies to Condition rows.
5. The special term **other** can be used to complete any Condition row values set.
6. not
7. {T, F}
8. all **except** Entity.boolean=F are equivalent, however some expressions are more clear than others!
9. Entity.boolean is probably the best choice since it is the simplest and most straightforward. The other two choices use double negatives which are harder for most people to understand.
10. **a.** OK as is
 - b.** if the value range is supposed to contain Integer values, then a does not belong. If the range is supposed to contain String values then 1 and a need to be surrounded by single quotes as in {'1'..'a', other}
 - c.** the special word other can't be used as a range endpoint.
 - d.** the range contains overlaps between 5 and 10, but this is acceptable in v5.
 - e.** the range contains an overlap at 10, but this is acceptable in v5.
 - f.** this is an incomplete set and should be {'red', 'green', 'blue', other}
 - g.** the range contains overlaps between 3 and 15, but this is acceptable in v5.
11. False. The term other may **not** be used in Action row Values sets since Actions can only assign *specific* values.
12. The Rulesheet would be modeled as shown:



13. True

14. False. Nonconditional rules are governed by Preconditions on the same Rulesheet only if they share the same scope as the Preconditions.

TestYourself answers for Collections

[Show me this set of test questions.](#)

1. Children of a Parent entity are also known as **elements** of a collection.
2. False. A collection can contain root-level entities.
3. True
4. True
5. Refer to the Rule Language Guide for a full list and description of all collection operators.
6. Rule Language Guide
7. Order total is equal to the sum of the line item prices on the order.
8. items
9. one-to-many (1->*)
10. It is not an acceptable replacement since the use of any collection operator requires that the collection be represented by an alias.
11. set the navigability of the association between Order and Lineltem to Order->lineltem. In other words, make the association one-directional from Order to Lineltem.
12. Optional, Convenient
13. A collection alias is not required in this case because no collection operator is being applied to the collection.
14. ->forAll
15. ->exists

16.
 - a. aroles ->size > 3 where aroles is an alias for Actor.roles
 - b. mdvd ->isEmpty where mdvd is an alias for Movie.dvd
 - c. mdextras ->exists(deletedScenes=T) where mdextras is an alias for Movie.dvd.extras
 - d. mgglobes ->exists(win=T) where mgglobes is an alias for Movie.goldenGlobe
 - e. mroles ->size > 15 where mroles is an alias for Movie.roles
 - f. mdvd.quantityAvailable ->sum >= 100 where mdvd is an alias for Movie.dvd
 - g. mdvd.quantityAvailable ->sum < 2 where mdvd is an alias for Movie.dvd
 - h. mdsuppliers ->size > 1 where mdsuppliers is an alias for Movie.dvd.supplier
17. Actor, Distributor, DVDExtras
18. Actor, Movie
19. The ->forAll operator tests whether **all** elements of a collection satisfy a condition. The ->exists operator tests whether **at least one** element of a collection satisfies a condition.
20. The ->notEmpty operator tests whether a collection is not empty, meaning there is at least one element in the collection. The ->isEmpty operator tests whether a collection is empty, meaning there are no elements in the collection.
21. To ensure that the system knows precisely which collection (or copy) you are referring to in your rules, it's necessary to use a unique alias to refer to each collection.

TestYourself answers for Rules containing calculations and equations

[Show me this set of test questions.](#)

1. comparison in Preconditions and Conditions, assignment in Nonconditionals and Actions
2. The results of the equations are:
 - a. 10
 - b. 13
 - c. 22
 - d. 24
 - e. 0
3. This assignment is not valid since an Integer attribute cannot contain the digits to the right of the decimal point in a Decimal attribute value.
4. The data types are:
 - a. Integer
 - b. String
 - c. Boolean
 - d. Decimal
 - e. Boolean

- f. Boolean
 - g. Boolean
5. The validity of the assignments are:
- a. valid
 - b. invalid
 - c. valid
 - d. valid
 - e. valid
 - f. invalid
 - g. valid
6. The part of Corticon Studio that checks for syntactical problems is called the **Parser**.
7. False. Although the Parser in Corticon Studio is very effective at finding syntactical errors, it is not perfect and can't anticipate all possible combinations of the rule language.
8. This Filter tests if the difference between the current year and the year a movie was released is more than 10 years.
9. This Condition tests if the total quantity of DVDs available divided by the number of DVD versions of a movie is less than or equal to 50,000 or greater than 50,000. This same calculation could be performed by using the `->avg` operator by itself.
10. If the average quantity available of a DVD is greater than 50,000 for a movie that is more than 10 years old, then flag the movie with a warning.
11. The sections of a Rulesheet that accept equations and calculations are:
- a. Scope: False
 - b. Rule statements: False
 - c. Condition rows: True
 - d. Action rows: True
 - e. Column 0: True
 - f. Condition cells: False
 - g. Action cells: False
 - h. Filters: True

TestYourself answers for Rule dependency and inferencing

[Show me this set of test questions.](#)

- 1. Inferencing involves only a single pass through rules while looping involves multiple passes.
- 2. A loop that does not end by itself is known as an **infinite** loop.
- 3. A loop that depends logically on itself is known as a single-rule or **trivial** loop.

4. False. The Rulesheet must have looping enabled in order for the loop detector to notice mutual dependencies.
5. False. The Check for Logical Loops tool can only detect and highlight loops, not fix them.
6. No, looping is neither required nor wanted for these rules. Normal inferencing will ensure the correct sequence of execution of these rules.
7. Yes, having this Rulesheet configured to Process All Logical Loops enables an infinite loop between rule 1 and rule 2 for DVDs meeting the conditions for that rule.
8. Rule 1 would change the DVD's price tier value to Medium, and then rule 2 and rule 1 would execute in an infinite loop, incrementing the DVD's quantity available by 25,000 repeatedly until terminating after the maxloop property setting number of iterations.
9. Process all logical loops
10. Process multi-rule loops only
11. A *dependency network* determines the sequence of rule execution and is generated when a Rulesheet is saved.

TestYourself answers for Filters and preconditions

[Show me this set of test questions.](#)

1. True
2. False - precondition behavior is optional
3. True - a filter will only "apply" to other rules that share the same scope. This means that other rules acting on data outside the filter's scope will be unaffected.
4. and'ed
5. False. Preconditions/Filters are not stand-alone rules.
6. c
7. a
8. no
9. True
10. full
11. full filter only
12. precondition AND full filter
13. f and d
14. a
15. Oscars:
 - a. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
 - b. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
 - c. Movie 1; DVD 1; Oscar 2
 - d. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
 - e. Movie 1; DVD 1; Oscars 1, 2
 - f. none

- g. none
- h. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
- i. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
- j. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
- k. none
- l. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5
- m. none
- n. none
- o. Movie 1; DVD 1; Oscars 1, 2, 3, 4, 5

TestYourself answers for Recognizing and modeling parameterized rules

[Show me this set of test questions.](#)

1. When several rules use the same set of Conditions and Actions, but different values for each, we say that these rules share a common **pattern**.
2. Another name for the different values in these expressions is **parameter**.
3. False. It is usually easier to model them as Conditions and Actions that use values sets.
4. You may accidentally introduce ambiguities into your rules.
5. **X** customers buy more than **\$Y** of product each year
6. Type of customer: {'Platinum', 'Gold', 'Silver', 'Bronze'} and spend amount: {25000..50000, (50000..75000), (75000..100000), >100000}. Depending on how the rules are modeled, one of these values sets will be part of a Condition and should be completed with the special word `other`.
7. These parameters may be maintained in the values sets of an individual Rulesheet, which is easy to perform, but makes reuse more difficult. They may be maintained as Custom Data Types (Enumerated) in the Vocabulary, which makes reuse easier.

TestYourself answers for Writing rules to access external data

[Show me this set of test questions.](#)

1. Rule scope determines which data is processed during rule execution.
2. So a Database-enabled Rulesheet does not inadvertently retrieve all the corresponding data in a database, which could be a lot of data!
3. It is extended to the database
4. True. Only root-level entities need to be extended – all other entities are extended automatically because their scope is reduced enough to not be as concerned about massive amounts of retrieved data.
5. See the *Data Integration Guide*.

6. No. In general, the rule modeler does not need to worry about where data is stored.
7. Yes. The exception is when rules are written using root-level terms. If the Rule Set is Database-enabled, then these root-level terms may need to be extended to the database.

TestYourself answers for Logical analysis and optimization

[Show me this set of test questions.](#)

1. They have the same Conditions but different Actions.
2. All combinations of possible values from the Conditions' values sets are covered in rules on the Rulesheet.
3. No, not all ambiguous rules are wrong or need to be resolved before deployment. Ambiguities may exist in Rulesheets where there are rules that are completely unrelated to each other. In those cases, it may be appropriate for both rules to fire if the Conditions for both are met.
4. No, not all incompletenesses are wrong or need to be resolved before deployment. Incomplete Rulesheets may be missing combinations of Conditions that cannot or should not occur in real data. In those cases, rules for such combinations may not make sense at all.
5. Conflict Checker – second icon; Compression Tool – fifth icon; Expansion Tool – first icon; Collapse Tool – third icon; Conflict Filter – sixth icon.
6. An ambiguity can be resolved by 1) making the Actions match for both rules, or 2) by setting an override for one of the rules.
7. False. Defining an override does not specify an execution sequence, but rather specifies that the rule with the override will always fire **instead of** the rule being overridden when the Conditions they share are satisfied.
8. False. The Completeness Checker will auto-complete the Condition's value set prior to inserting missing rules. This ensures the Rulesheet, post-application of the Completeness Check, is truly complete.
9. The Completeness Checker will detect Rulesheet incompleteness caused by an incomplete values set because it will automatically complete the value set first before inserting missing columns.
10. Yes. One rule can override multiple other rules by holding the **Ctrl** key to multi-select overrides from the drop-down.
11. No, overrides are not transitive and must be specified directly between all applicable rules.
12. No, rules created by the Completeness Checker may be made up of combinations of Conditions that cannot or should not occur in real data. In those cases, rules for such combinations may not make sense at all.
13. A dash specifies that the Condition should be ignored for this rule.
14. False. The Expansion Tool merely expands a Rulesheet so that all sub-rules are visible. The results can be reversed by using the Collapse Tool.
15. True. It *may* be reversible using **Undo**, or by manually removing redundant sub-rules after expansion.
16. 64 (4 x 4 x 4)
17. It is not necessary to assign actions for a rule column if that combination of conditions cannot or should not exist in real data. We recommend disabling columns added by the Completeness Check that you determine need no Actions.
18. They may be disabled, deleted, or just left as-is with no Actions (but this last option is not recommended since it will still cause activity which can impact performance).
19. Compression Tool

20. The compression performed by the Completeness Checker is designed to reduce a large set of missing rules into the smallest set of *non-overlapping* columns, while the compression performed by the Compression Tool is designed to reduce the number of rules into the smallest set of general rules (i.e. create columns with the most dashes).
21. Even very large databases may still not contain all possible combinations of data necessary to verify Rulesheet completeness. In short, they may be incomplete themselves.
22. Renumber the rules and potentially ask you to consolidate Rule Statements if duplicate row numbers result from the renumbering.
23. Subsumation occurs when the Compression Tool detects that a more general rule expression includes the logic of a more specific rule expression. In this case, the more specific rule can be removed.

TestYourself answers for Ruleflow versioning and effective dating

[Show me this set of test questions.](#)

1. False. Ruleflow Effective and Expiration dates may be assigned singly.
2. False. Ruleflow Effective and Expiration dates may be assigned singly.
3. False. Ruleflow Version numbers are optional.
4. Ruleflow > Properties, or click on the Properties window in Corticon Studio.
5. False. A Ruleflow Version number may only be raised, not lowered.
6. False. Ruleflow Effective and Expiration dates are optional.

TestYourself answers for Troubleshooting rulesheets

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1. Troubleshooting is based on the principle that Rulesheets behave the same way when tested in Corticon Studio as when executed on **Server**
2. The first step in troubleshooting a suspected rule problem is to reproduce the behavior in a Corticon Studio **Test**.
3. In the integration with Corticon Server.
4. All of them!
5. The specific rule where execution behavior begins acting abnormally is called the **breakpoint**.
6. True. Partial rule firing is allowed.
7. Disabling Rulesheets; Filters, Nonconditions, Conditions, Action rows; or rule columns
8. A dark gray-colored Rulesheet tab indicates that Rulesheet has been **disabled**.
9. d
10. In the `brms.properties` file at `[CORTICON_WORK_DIR]` root.
11. In the `brms.properties` file at `[CORTICON_WORK_DIR]` root.
12. True.

13. Vocabulary (.ecore), Rulesheet (.ers), and a Ruletest (.ert) and the Ruleflow (.erf) if any. We also need to know the Corticon Studio version you are using.
14. d and h

