Red Hat Decision Manager 7.3

Designing a decision service using DRL rules

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Abstract

This document describes how to design a decision service using DRL rules in Red Hat Decision Manager 7.3.

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PREFACE

As a business rules developer, you can define business rules using the DRL (Drools Rule Language) designer in Business Central. DRL rules are defined directly in free-form **.drl** text files instead of in a guided or tabular format like other types of rule assets in Business Central. These DRL files form the core of the decision service for your project.

Prerequisite

The team and project for the DRL rules have been created in Business Central. Each asset is associated with a project assigned to a team. For details, see *Getting started with decision services* .

CHAPTER 1. DECISION-AUTHORING ASSETS IN RED HAT DECISION MANAGER

Red Hat Decision Manager supports several assets that you can use to define business decisions for your decision service. Each decision-authoring asset has different advantages, and you might prefer to use one or a combination of multiple assets depending on your goals and needs.

The following table highlights the main decision-authoring assets supported in Red Hat Decision Manager projects to help you decide or confirm the best method for defining decisions in your decision service.

Table 1.1. Decision-authoring assets supported in Red Hat Decision Manager

Asset	Highlights	Authoring tools	Documentation
Decision Model and Notation (DMN) models	• Are decision models based on a notation standard defined by the Object Management Group (OMG) • Use graphical decision requirements diagrams (DRDs) with one or more decision requirements graphs (DRGs) to trace business decision flows • Use an XML schema that allows the DMN models to be shared between DMN-compliant platforms • Support Friendly Enough Expression Language (FEEL) to define decision logic in DMN decision tables and other DMN boxed expressions • Are optimal for creating comprehensive, illustrative, and stable decision flows	Business Central or other DMN-compliant editor	*Designing a decision service using DMN models*

Asset	Highlights	Authoring tools	Documentation
Guided decision tables	• Are tables of rules that you create in a UI-based table designer in Business Central • Are a wizard-led alternative to spreadsheet decision tables • Provide fields and options for acceptable input • Support template keys and values for creating rule templates • Support hit policies, real-time validation, and other additional features not supported in other assets • Are optimal for creating rules in a controlled tabular format to minimize compilation errors	Business Central	*Designing a decision service using guided decision tables*
Spreadsheet decision tables	• Are XLS or XLSX spreadsheet decision tables that you can upload into Business Central • Support template keys and values for creating rule templates • Are optimal for creating rules in decision tables already managed outside of Business Central • Have strict syntax requirements for rules to be compiled properly when uploaded	Spreadsheet editor	*Designing a decision service using spreadsheet decision tables*
Guided rules	• Are individual rules that you create in a UI-based rule designer in Business Central • Provide fields and options for acceptable input • Are optimal for creating single rules in a controlled format to minimize compilation errors	Business Central	*Designing a decision service using guided rules*

Asset	Highlights	Authoring tools	Documentation
Guided rule templates	• Are reusable rule structures that you create in a UI-based template designer in Business Central • Provide fields and options for acceptable input • Support template keys and values for creating rule templates (fundamental to the purpose of this asset) • Are optimal for creating many rules with the same rule structure but with different defined field values	Business Central	*Designing a decision service using guided rule templates*
DRL rules	• Are individual rules that you define directly in **.drl** text files • Provide the most flexibility for defining rules and other technicalities of rule behavior • Can be created in certain standalone environments and integrated with Red Hat Decision Manager • Are optimal for creating rules that require advanced DRL options • Have strict syntax requirements for rules to be compiled properly	Business Central or integrated development environment (IDE)	*Designing a decision service using DRL rules*

Asset	Highlights	Authoring tools	Documentation
Predictive Model Markup Language (PMML) models	• Are predictive data-analytic models based on a notation standard defined by the Data Mining Group (DMG) • Use an XML schema that allows the PMML models to be shared between PMML-compliant platforms • Support Regression, Scorecard, Tree, Mining, and other model types • Can be included with a standalone Red Hat Decision Manager project or imported into a project in Business Central • Are optimal for incorporating predictive data into decision services in Red Hat Decision Manager	PMML or XML editor	*Designing a decision service using PMML models*

CHAPTER 2. DRL (DROOLS RULE LANGUAGE) RULES

DRL (Drools Rule Language) rules are business rules that you define directly in **.drl** text files. These DRL files are the source in which all other rule assets in Business Central are ultimately rendered. You can create and manage DRL files within the Business Central interface, or create them externally using Red Hat Developer Studio, Java objects, or Maven archetypes. A DRL file can contain one or more rules that define at minimum the rule conditions (**when**) and actions (**then**). The DRL designer in Business Central provides syntax highlighting for Java, DRL, and XML.

All data objects related to a DRL rule must be in the same project package as the DRL rule in Business Central. Assets in the same package are imported by default. Existing assets in other packages can be imported with the DRL rule.

CHAPTER 3. DATA OBJECTS

Data objects are the building blocks for the rule assets that you create. Data objects are custom data types implemented as Java objects in specified packages of your project. For example, you might create a **Person** object with data fields **Name**, **Address**, and **DateOfBirth** to specify personal details for loan application rules. These custom data types determine what data your assets and your decision services are based on.

3.1. CREATING DATA OBJECTS

The following procedure is a generic overview of creating data objects. It is not specific to a particular business asset.

Procedure

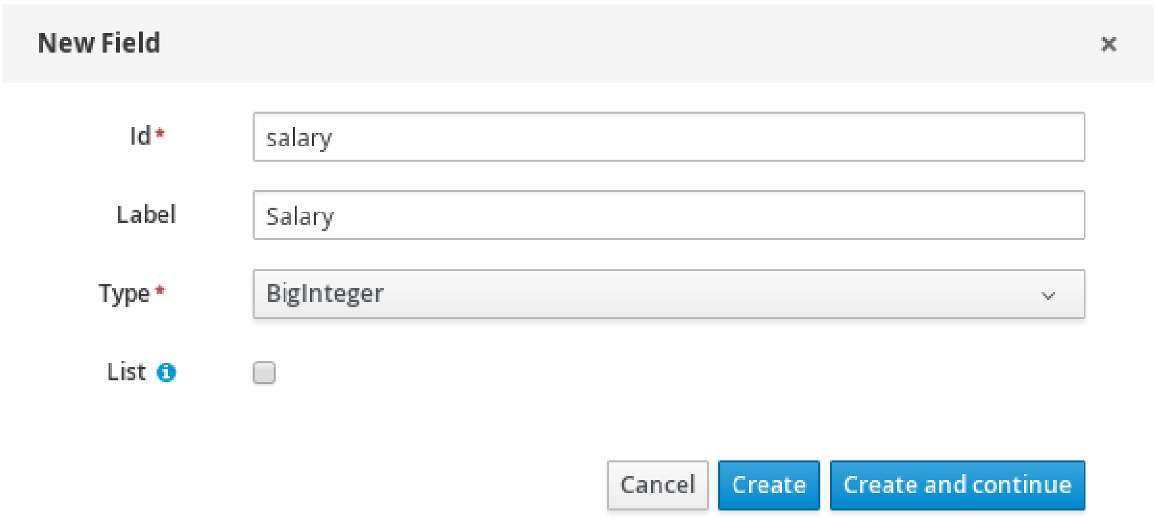
1. In Business Central, go to **Menu → Design → Projects** and click the project name.
2. Click **Add Asset → Data Object**.
3. Enter a unique **Data Object** name and select the **Package** where you want the data object to be available for other rule assets. Data objects with the same name cannot exist in the same package. In the specified DRL file, you can import a data object from any package.

   #### IMPORTING DATA OBJECTS FROM OTHER PACKAGES

   You can import an existing data object from another package directly into the asset designer. Select the relevant rule asset within the project and in the asset designer, go to **Data Objects → New item** to select the object to be imported.

4. To make your data object persistable, select the **Persistable** checkbox. Persistable data objects are able to be stored in a database according to the JPA specification. The default JPA is Hibernate.
5. Click **Ok**.
6. In the data object designer, click **add field** to add a field to the object with the attributes **Id**, **Label**, and **Type**. Required attributes are marked with an asterisk (*).
   - **Id:** Enter the unique ID of the field.
   - **Label:** (Optional) Enter a label for the field.
   - **Type:** Enter the data type of the field.
   - **List:** Select this check box to enable the field to hold multiple items for the specified type.

Figure 3.1. Add data fields to a data object


New Field

Id *: salary

Label: Salary

Type *: BigInteger

List: ☐

7. Click **Create** to add the new field, or click **Create and continue** to add the new field and continue adding other fields.

NOTE

To edit a field, select the field row and use the **general properties** on the right side of the screen.

CHAPTER 4. CREATING DRL RULES IN BUSINESS CENTRAL

You can create and manage DRL rules for your project in Business Central. In each DRL rule file, you define rule conditions, actions, and other components related to the rule, based on the data objects you create or import in the package.

Procedure

1. In Business Central, go to **Menu → Design → Projects** and click the project name.

2. Click **Add Asset → DRL file**.

3. Enter an informative **DRL file** name and select the appropriate **Package**. The package that you specify must be the same package where the required data objects have been assigned or will be assigned.
   You can also select **Show declared DSL sentences** if any domain specific language (DSL) assets have been defined in your project. These DSL assets will then become usable objects for conditions and actions that you define in the DRL designer.

4. Click **Ok** to create the rule asset.
   The new DRL file is now listed in the **DRL** panel of the **Project Explorer**, or in the **DSLR** panel if you selected the **Show declared DSL sentences** option. The package to which you assigned this DRL file is listed at the top of the file.

5. In the **Fact types** list in the left panel of the DRL designer, confirm that all data objects and data object fields (expand each) required for your rules are listed. If not, you can either import relevant data objects from other packages by using **import** statements in the DRL file, or create data objects within your package.

6. After all data objects are in place, return to the **Model** tab of the DRL designer and define the DRL file with any of the following components:

   Components of a DRL file

   ```
   package  //automatic

   import

   function  //optional

   query  //optional

   declare   //optional

   rule

   rule

   ...
   ```

   - **package**: (automatic) This was defined for you when you created the DRL file and selected the package.

- **import**: Use this to identify the data objects from either this package or another package that you want to use in the DRL file. Specify the package and data object in the format **package.name.object.name**, one import per line.

  Importing data objects

  ```
  import mortgages.mortgages.LoanApplication;
  ```

- **function**: (optional) Use this to include a function to be used by rules in the DRL file. Functions put semantic code in your rule source file. Functions are especially useful if an action (**then**) part of a rule is used repeatedly and only the parameters differ for each rule. Above the rules in the DRL file, you can declare the function or import a static method as a function, and then use the function by name in an action (**then**) part of the rule.

  Declaring and using a function with a rule (option 1)

  ```
  function String hello(String applicantName) {
      return "Hello " + applicantName + "!";
  }

  rule "Using a function"
    when
      eval( true )
    then
      System.out.println( hello( "James" ) );
  end
  ```

  Importing and using the function with a rule (option 2)

  ```
  import function my.package.applicant.hello;

  rule "Using a function"
    when
      eval( true )
    then
      System.out.println( hello( "James" ) );
  end
  ```

- **query**: (optional) Use this to search the decision engine for facts related to the rules in the DRL file. Queries search for a set of defined conditions and do not require **when** or **then** specifications. Query names are global to the KIE base and therefore must be unique among all other rule queries in the project. To return the results of a query, construct a traditional **QueryResults** definition using **ksession.getQueryResults("name")**, where **"name"** is the query name. This returns a list of query results, which enable you to retrieve the objects that matched the query. Define the query and query results parameters above the rules in the DRL file.

  Query and query results for people under the age of 21, with a rule

  ```
  query "people under the age of 21"
      person : Person( age < 21 )
  end

  QueryResults results = ksession.getQueryResults( "people under the age of 21" );
  ```

```
System.out.println( "we have " + results.size() + " people under the age  of 21" );

rule "Underage"
  when
    application : LoanApplication( )
    Applicant( age < 21 )
  then
    application.setApproved( false );
    application.setExplanation( "Underage" );
end
```

- **declare**: (optional) Use this to declare a new fact type to be used by rules in the DRL file. The default fact type in the **java.lang** package of Red Hat Decision Manager is **Object**, but you can declare other types in DRL files as needed. Declaring fact types in DRL files enables you to define a new fact model directly in the decision engine, without creating models in a lower-level language like Java.

  Declaring and using a new fact type

  ```
  declare Person
    name : String
    dateOfBirth : java.util.Date
    address : Address
  end

  rule "Using a declared type"
    when
      $p : Person( name == "James" )
    then   // Insert Mark, who is a customer of James.
      Person mark = new Person();
      mark.setName( "Mark" );
      insert( mark );
  end
  ```

- **rule**: Use this to define each rule in the DRL file. Rules consist of a rule name in the format **rule "name"**, followed by optional attributes that define rule behavior (such as **salience** or **no-loop**), followed by **when** and **then** definitions. The same rule name cannot be used more than once in the same package. The **when** part of the rule contains the conditions that must be met to execute an action. For example, if a bank requires loan applicants to have over 21 years of age, then the **when** condition for an **Underage** rule would be **Applicant(age < 21)**. The **then** part of the rule contains the actions to be performed when the conditional part of the rule has been met. For example, when the loan applicant is under 21 years old, the **then** action would be **setApproved(false)**, declining the loan because the applicant is under age. Conditions (**when**) and actions (**then**) consist of a series of stated fact patterns with optional constraints, bindings, and other supported DRL elements, based on the available data objects in the package. These patterns determine how defined objects are affected by the rule.

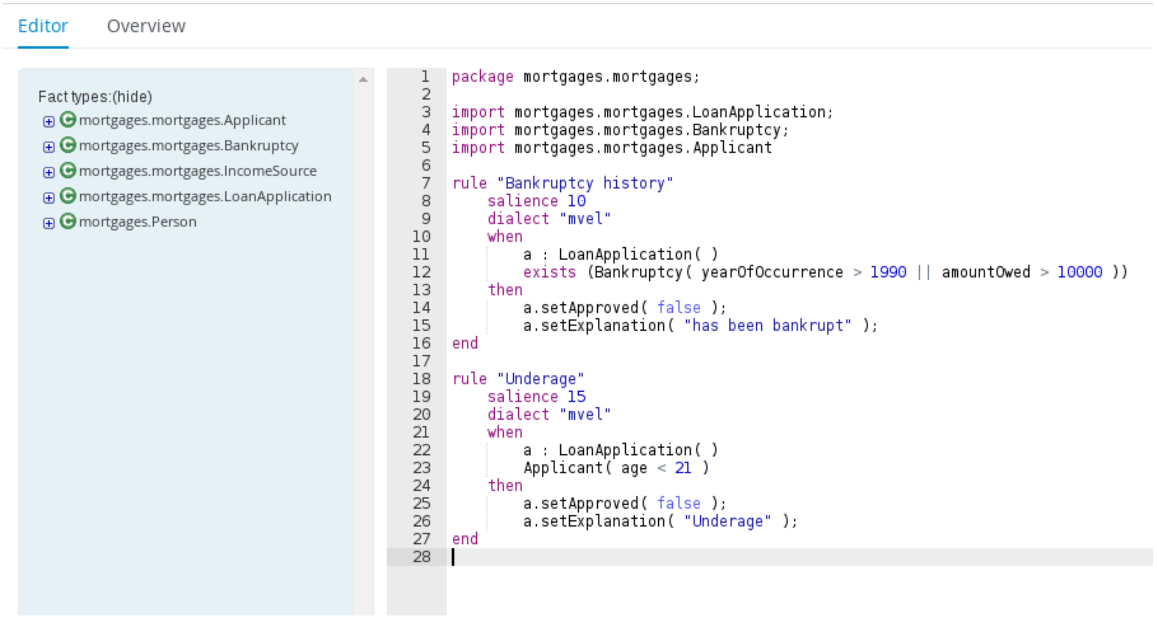
  Rule for loan application age limit

  ```
  rule "Underage"
    salience 15
    dialect "mvel"
    when
      application : LoanApplication( )
  ```

```
    Applicant( age < 21 )
  then
    application.setApproved( false );
    application.setExplanation( "Underage" );
end
```

At minimum, each DRL file must specify the **package**, **import**, and **rule** components. All other components are optional.

Figure 4.1. Sample DRL file with required components and optional rule attributes



Editor Overview

Fact types:(hide)
mortgages.mortgages.Applicant
mortgages.mortgages.Bankruptcy
mortgages.mortgages.IncomeSource
mortgages.mortgages.LoanApplication
mortgages.Person

```
package mortgages.mortgages;

import mortgages.mortgages.LoanApplication;
import mortgages.mortgages.Bankruptcy;
import mortgages.mortgages.Applicant

rule "Bankruptcy history"
    salience 10
    dialect "mvel"
    when
        a : LoanApplication( )
        exists (Bankruptcy( yearOfOccurrence > 1990 || amountOwed > 10000 ))
    then
        a.setApproved( false );
        a.setExplanation( "has been bankrupt" );
end

rule "Underage"
    salience 15
    dialect "mvel"
    when
        a : LoanApplication( )
        Applicant( age < 21 )
    then
        a.setApproved( false );
        a.setExplanation( "Underage" );
end
```

7. After you define all components of the rule, click **Validate** in the upper-right toolbar of the DRL designer to validate the DRL file. If the file validation fails, address any problems described in the error message, review all syntax and components in the DRL file, and try again to validate the file until the file passes.

8. Click **Save** in the DRL designer to save your work.

4.1. ADDING WHEN CONDITIONS IN DRL RULES

The **when** part of the rule contains the conditions that must be met to execute an action. For example, if a bank requires loan applicants to have over 21 years of age, then the **when** condition of an **Underage** rule would be **Applicant(age < 21)**. Conditions consist of a series of stated patterns and constraints, with optional bindings and other supported DRL elements, based on the available data objects in the package.

Prerequisites

- The **package** is defined at the top of the DRL file. This should have been done for you when you created the file.
- The **import** list of data objects used in the rule is defined below the **package** line of the DRL file. Data objects can be from this package or from another package in Business Central.
- The **rule** name is defined in the format **rule "name"** below the **package**, **import**, and other lines that apply to the entire DRL file. The same rule name cannot be used more than once in the same package. Optional rule attributes (such as **salience** or **no-loop**) that define rule behavior are below the rule name, before the **when** section.

Procedure

1. In the DRL designer, enter **when** within the rule to begin adding condition statements. The **when** section consists of zero or more fact patterns that define conditions for the rule.
   If the **when** section is empty, then actions in the **then** section are executed every time a **fireAllRules()** call is made in the decision engine. This is useful if you want to use rules to set up the decision engine state.

   #### Rule without conditions

   ```
   rule "bootstrap"
     when   // empty

     then   // actions to be executed once
       insert( new Applicant() );
   end

   // The above rule is internally rewritten as:

   rule "bootstrap"
     when
       eval( true )
     then
       insert( new Applicant() );
   end
   ```

2. Enter a pattern for the first condition to be met, with optional constraints, bindings, and other supported DRL elements. A basic pattern format is **patternBinding : patternType (constraints)**. Patterns are based on the available data objects in the package and define the conditions to be met in order to trigger actions in the **then** section.

   - **Simple pattern:** A simple pattern with no constraints matches against a fact of the given type. For example, the following condition is only that the applicant exists.

     ```
     when
       Applicant( )
     ```

   - **Pattern with constraints:** A pattern with constraints matches against a fact of the given type and the additional restrictions in parentheses that are true or false. For example, the following condition is that the applicant is under the age of 21.

     ```
     when
       Applicant( age < 21 )
     ```

   - **Pattern with binding:** A binding on a pattern is a shorthand reference that other components of the rule can use to refer back to the defined pattern. For example, the following binding **a** on **LoanApplication** is used in a related action for underage applicants.

     ```
     when
       a : LoanApplication( )
       Applicant( age < 21 )
     then
       a.setApproved( false );
       a.setExplanation( "Underage" )
     ```

3. Continue defining all condition patterns that apply to this rule. The following are some of the keyword options for defining DRL conditions:

   - **and**: Use this to group conditional components into a logical conjunction. Infix and prefix **and** are supported. By default, all listed conditions or actions are combined with **and** when no conjunction is specified.

     ```
     a : LoanApplication( ) and Applicant( age < 21 )

     a : LoanApplication( )
     and Applicant( age < 21 )

     a : LoanApplication( )
     Applicant( age < 21 )

     // All of the above are the same.
     ```

   - **or**: Use this to group conditional components into a logical disjunction. Infix and prefix **or** are supported.

     ```
     Bankruptcy( amountOwed == 100000 ) or IncomeSource( amount == 20000 )

     Bankruptcy( amountOwed == 100000 )
     or IncomeSource( amount == 20000 )
     ```

   - **exists**: Use this to specify facts and constraints that must exist. Note that this does not mean that a fact exists, but that a fact must exist. This option is triggered on only the first match, not subsequent matches.

     ```
     exists ( Bankruptcy( yearOfOccurrence > 1990 || amountOwed > 10000 ) )
     ```

   - **not**: Use this to specify facts and constraints that must not exist.

     ```
     not ( Applicant( age < 21 ) )
     ```

   - **forall**: Use this to set up a construct where all facts that match the first pattern match all the remaining patterns.

     ```
     forall( app : Applicant( age < 21 )
                   Applicant( this == app, status = 'underage' ) )
     ```

   - **from**: Use this to specify a source for data to be matched by the conditional pattern.

     ```
     Applicant( ApplicantAddress : address )
     Address( zipcode == "23920W" ) from ApplicantAddress
     ```

   - **entry-point**: Use this to define an **Entry Point** corresponding to a data source for the pattern. Typically used with **from**.

     ```
     Applicant( ) from entry-point "LoanApplication"
     ```

   - **collect**: Use this to define a collection of objects that the construct can use as part of the condition. In the example, all pending applications in the decision engine for each given mortgage are grouped in **ArrayLists**. If three or more pending applications are found, the rule is executed.

```
m : Mortgage()
a : ArrayList( size >= 3 )
   from collect( LoanApplication( Mortgage == m, status == 'pending' ) )
```

- **accumulate**: Use this to iterate over a collection of objects, execute custom actions for each of the elements, and return one or more result objects (if the constraints evaluate to **true**). This option is a more flexible and powerful form of **collect**. Use the format **accumulate(<source pattern>; <functions> [;<constraints>])**. In the example, **min**, **max**, and **average** are accumulate functions that calculate the minimum, maximum and average temperature values over all the readings for each sensor. Other supported functions include **count**, **sum**, **variance**, **standardDeviation**, **collectList**, and **collectSet**.

```
s : Sensor()
accumulate( Reading( sensor == s, temp : temperature );
         min : min( temp ),
         max : max( temp ),
         avg : average( temp );
         min < 20, avg > 70 )
```

ADVANCED DRL OPTIONS

These are examples of basic keyword options and pattern constructs for defining conditions. For more advanced DRL options and syntax supported in the DRL designer, see the Drools Documentation online.

4. After you define all condition components of the rule, click **Validate** in the upper-right toolbar of the DRL designer to validate the DRL file. If the file validation fails, address any problems described in the error message, review all syntax and components in the DRL file, and try again to validate the file until the file passes.

5. Click **Save** in the DRL designer to save your work.

4.2. ADDING THEN ACTIONS IN DRL RULES

The **then** part of the rule contains the actions to be performed when the conditional part of the rule has been met. For example, when a loan applicant is under 21 years old, the **then** action of an **Underage** rule would be **setApproved(false)**, declining the loan because the applicant is under age. Actions execute consequences based on the rule conditions and on available data objects in the package.

Prerequisites

- The **package** is defined at the top of the DRL file. This should have been done for you when you created the file.
- The **import** list of data objects used in the rule is defined below the **package** line of the DRL file. Data objects can be from this package or from another package in Business Central.
- The **rule** name is defined in the format **rule "name"** below the **package**, **import**, and other lines that apply to the entire DRL file. The same rule name cannot be used more than once in the same package. Optional rule attributes (such as **salience** or **no-loop**) that define rule behavior are below the rule name, before the **when** section.

Procedure

1. In the DRL designer, enter **then** after the **when** section of the rule to begin adding action statements.

2. Enter one or more actions to be executed on fact patterns based on the conditions for the rule. The following are some of the keyword options for defining DRL actions:

   - **and**: Use this to group action components into a logical conjunction. Infix and prefix **and** are supported. By default, all listed conditions or actions are combined with **and** when no conjunction is specified.

     ```
     application.setApproved ( false ) and application.setExplanation( "has been bankrupt" );

     application.setApproved ( false );
     and application.setExplanation( "has been bankrupt" );

     application.setApproved ( false );
     application.setExplanation( "has been bankrupt" );

     // All of the above are the same.
     ```

   - **set**: Use this to set the value of a field.

     ```
     application.setApproved ( false );
     application.setExplanation( "has been bankrupt" );
     ```

   - **modify**: Use this to specify fields to be modified for a fact and to notify the decision engine of the change.

     ```
     modify( LoanApplication ) {
             setAmount( 100 )
     }
     ```

   - **update**: Use this to specify fields and the entire related fact to be modified and to notify the decision engine of the change. After a fact has changed, you must call **update** before changing another fact that might be affected by the updated values. The **modify** keyword avoids this added step.

     ```
     update( LoanApplication ) {
             setAmount( 100 )
     }
     ```

   - **delete**: Use this to remove an object from the decision engine. The keyword **retract** is also supported in the DRL designer and executes the same action, but **delete** is preferred for consistency with the keyword **insert**.

     ```
     delete( LoanApplication );
     ```

   - **insert**: Use this to insert a **new** fact and define resulting fields and values as needed for the fact.

     ```
     insert( new Applicant() );
     ```

- **insertLogical**: Use this to insert a **new** fact logically into the decision engine and define resulting fields and values as needed for the fact. The decision engine is responsible for logical decisions on insertions and retractions of facts. After regular or stated insertions, facts have to be retracted explicitly. After logical insertions, facts are automatically retracted when the conditions that originally asserted the facts are no longer true.

```
insertLogical( new Applicant() );
```

ADVANCED DRL OPTIONS

These are examples of basic keyword options and pattern constructs for defining actions. For more advanced DRL options and syntax supported in the DRL designer, see the Drools Documentation online.

3. After you define all action components of the rule, click **Validate** in the upper-right toolbar of the DRL designer to validate the DRL file. If the file validation fails, address any problems described in the error message, review all syntax and components in the DRL file, and try again to validate the file until the file passes.

4. Click **Save** in the DRL designer to save your work.

4.2.1. Rule attributes

Rule attributes are additional specifications that you can add to business rules to modify rule behavior. The following table lists the names and supported values of the attributes that you can assign to rules:

Table 4.1. Rule attributes

Attribute	Value
salience	An integer defining the priority of the rule. Rules with a higher salience value are given higher priority when ordered in the activation queue. Example: **salience 10**
enabled	A Boolean value. When the option is selected, the rule is enabled. When the option is not selected, the rule is disabled. Example: **enabled true**
date-effective	A string containing a date and time definition. The rule can be activated only if the current date and time is after a **date-effective** attribute. Example: **date-effective "4-Sep-2018"**
date-expires	A string containing a date and time definition. The rule cannot be activated if the current date and time is after the **date-expires** attribute. Example: **date-expires "4-Oct-2018"**

Attribute	Value
no-loop	A Boolean value. When the option is selected, the rule cannot be reactivated (looped) if a consequence of the rule re-triggers a previously met condition. When the condition is not selected, the rule can be looped in these circumstances. Example: **no-loop true**
agenda-group	A string identifying an agenda group to which you want to assign the rule. Agenda groups allow you to partition the agenda to provide more execution control over groups of rules. Only rules in an agenda group that has acquired a focus are able to be activated. Example: **agenda-group "GroupName"**
activation-group	A string identifying an activation (or XOR) group to which you want to assign the rule. In activation groups, only one rule can be activated. The first rule to fire will cancel all pending activations of all rules in the activation group. Example: **activation-group "GroupName"**
duration	A long integer value defining the duration of time in milliseconds after which the rule can be activated, if the rule conditions are still met. Example: **duration 10000**
timer	A string identifying either **int** (interval) or **cron** timer definition for scheduling the rule. Example: **timer "*/5 * * * *"** (every 5 minutes)
calendar	A Quartz calendar definition for scheduling the rule. Example: **calendars "* * 0-7,18-23 ? * *"** (exclude non-business hours)
auto-focus	A Boolean value, applicable only to rules within agenda groups. When the option is selected, the next time the rule is activated, a focus is automatically given to the agenda group to which the rule is assigned. Example: **auto-focus true**
lock-on-active	A Boolean value, applicable only to rules within rule flow groups or agenda groups. When the option is selected, the next time the ruleflow group for the rule becomes active or the agenda group for the rule receives a focus, the rule cannot be activated again until the ruleflow group is no longer active or the agenda group loses the focus. This is a stronger version of the **no-loop** attribute, because the activation of a matching rule is discarded regardless of the origin of the update (not only by the rule itself). This attribute is ideal for calculation rules where you have a number of rules that modify a fact and you do not want any rule re-matching and firing again. Example: **lock-on-active true**

Attribute	Value
ruleflow-group	A string identifying a rule flow group. In rule flow groups, rules can fire only when the group is activated by the associated rule flow. Example: **ruleflow-group "GroupName"**
dialect	A string identifying either **JAVA** or **MVEL** as the language to be used for code expressions in the rule. By default, the rule uses the dialect specified at the package level. Any dialect specified here overrides the package dialect setting for the rule. Example: **dialect "JAVA"** NOTE When you use Red Hat Decision Manager without the executable model, the **dialect "JAVA"** rule consequences support only Java 5 syntax. For more information about executable models, see *Packaging and deploying a Red Hat Decision Manager project*.

CHAPTER 5. EXECUTING RULES

After you identify example rules or create your own rules in Business Central, you can build and deploy the associated project and execute rules locally or on Decision Server to test the rules.

Prerequisites

- Business Central and Decision Server are installed and running. For installation options, see *Planning a Red Hat Decision Manager installation* .

Procedure

1. In Business Central, go to **Menu** → **Design** → **Projects** and click the project name.
2. In the upper-right corner of the project **Assets** page, click **Deploy** to build the project and deploy it to Decision Server. If the build fails, address any problems described in the **Alerts** panel at the bottom of the screen.
   For more information about project deployment options, see *Packaging and deploying a Red Hat Decision Manager project*.
3. Create a Maven or Java project outside of Business Central, if not created already, that you can use for executing rules locally or that you can use as a client application for executing rules on Decision Server. The project must contain a **pom.xml** file and any other required components for executing the project resources.
   For example test projects, see "Other methods for creating and executing DRL rules".
4. Open the **pom.xml** file of your test project or client application and add the following dependencies, if not added already:
   - **kie-ci**: Enables your client application to load Business Central project data locally using **ReleaseId**
   - **kie-server-client**: Enables your client application to interact remotely with assets on Decision Server
   - **slf4j**: (Optional) Enables your client application to use Simple Logging Facade for Java (SLF4J) to return debug logging information after you interact with Decision Server

   Example dependencies for Red Hat Decision Manager 7.3 in a client application **pom.xml** file:

```
<!-- For local execution -->
<dependency>
  <groupId>org.kie</groupId>
  <artifactId>kie-ci</artifactId>
  <version>7.18.0.Final-redhat-00002</version>
</dependency>

<!-- For remote execution on Decision Server -->
<dependency>
  <groupId>org.kie.server</groupId>
  <artifactId>kie-server-client</artifactId>
  <version>7.18.0.Final-redhat-00002</version>
</dependency>

<!-- For debug logging (optional) -->
<dependency>
```

```
  <groupId>org.slf4j</groupId>
  <artifactId>slf4j-simple</artifactId>
  <version>1.7.25</version>
</dependency>
```

For available versions of these artifacts, search the group ID and artifact ID in the Nexus Repository Manager online.

NOTE

Instead of specifying a Red Hat Decision Manager **<version>** for individual dependencies, consider adding the Red Hat Business Automation bill of materials (BOM) dependency to your project **pom.xml** file. The Red Hat Business Automation BOM applies to both Red Hat Decision Manager and Red Hat Process Automation Manager. When you add the BOM files, the correct versions of transitive dependencies from the provided Maven repositories are included in the project.

Example BOM dependency:

```
<dependency>
  <groupId>com.redhat.ba</groupId>
  <artifactId>ba-platform-bom</artifactId>
  <version>7.3.0.GA-redhat-00002</version>
  <scope>import</scope>
  <type>pom</type>
</dependency>
```

For more information about the Red Hat Business Automation BOM, see What is the mapping between Red Hat Decision Manager and the Maven library version?.

5. Ensure that the dependencies for artifacts containing model classes are defined in the client application **pom.xml** file exactly as they appear in the **pom.xml** file of the deployed project. If dependencies for model classes differ between the client application and your projects, execution errors can occur.
   To access the project **pom.xml** file in Business Central, select any existing asset in the project and then in the **Project Explorer** menu on the left side of the screen, click the **Customize View** gear icon and select **Repository View** → **pom.xml**.

   For example, the following **Person** class dependency appears in both the client and deployed project **pom.xml** files:

```
<dependency>
  <groupId>com.sample</groupId>
  <artifactId>Person</artifactId>
  <version>1.0.0</version>
</dependency>
```

6. If you added the **slf4j** dependency to the client application **pom.xml** file for debug logging, create a **simplelogger.properties** file on the relevant classpath (for example, in **src/main/resources/META-INF** in Maven) with the following content:

```
org.slf4j.simpleLogger.defaultLogLevel=debug
```

7. In your client application, create a **.java** main class containing the necessary imports and a **main()** method to load the KIE base, insert facts, and execute the rules.
   For example, a **Person** object in a project contains getter and setter methods to set and retrieve the first name, last name, hourly rate, and the wage of a person. The following **Wage** rule in a project calculates the wage and hourly rate values and displays a message based on the result:

```
package com.sample;

import com.sample.Person;

dialect "java"

rule "Wage"
  when
    Person(hourlyRate * wage > 100)
    Person(name : firstName, surname : lastName)
  then
    System.out.println("Hello" + " " + name + " " + surname + "!");
    System.out.println("You are rich!");
end
```

   To test this rule locally outside of Decision Server (if desired), configure the **.java** class to import KIE services, a KIE container, and a KIE session, and then use the **main()** method to fire all rules against a defined fact model:

   Executing rules locally

```
import org.kie.api.KieServices;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;

public class RulesTest {

  public static final void main(String[] args) {
    try {
      // Identify the project in the local repository:
      ReleaseId rid = new ReleaseId();
      rid.setGroupId("com.myspace");
      rid.setArtifactId("MyProject");
      rid.setVersion("1.0.0");

      // Load the KIE base:
      KieServices ks = KieServices.Factory.get();
      KieContainer kContainer = ks.newKieContainer(rid);
      KieSession kSession = kContainer.newKieSession();

      // Set up the fact model:
      Person p = new Person();
      p.setWage(12);
      p.setFirstName("Tom");
      p.setLastName("Summers");
      p.setHourlyRate(10);

      // Insert the person into the session:
```

```
      kSession.insert(p);

      // Fire all rules:
      kSession.fireAllRules();
      kSession.dispose();
    }

    catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

To test this rule on Decision Server, configure the **.java** class with the imports and rule execution information similarly to the local example, and additionally specify KIE services configuration and KIE services client details:

Executing rules on Decision Server

```
package com.sample;

import java.util.ArrayList;
import java.util.HashSet;
import java.util.List;
import java.util.Set;

import org.kie.api.command.BatchExecutionCommand;
import org.kie.api.command.Command;
import org.kie.api.KieServices;
import org.kie.api.runtime.ExecutionResults;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;
import org.kie.server.api.marshalling.MarshallingFormat;
import org.kie.server.api.model.ServiceResponse;
import org.kie.server.client.KieServicesClient;
import org.kie.server.client.KieServicesConfiguration;
import org.kie.server.client.KieServicesFactory;
import org.kie.server.client.RuleServicesClient;

import com.sample.Person;

public class RulesTest {

  private static final String containerName = "testProject";
  private static final String sessionName = "myStatelessSession";

  public static final void main(String[] args) {
    try {
      // Define KIE services configuration and client:
      Set<Class<?>> allClasses = new HashSet<Class<?>>();
      allClasses.add(Person.class);
      String serverUrl = "http://$HOST:$PORT/kie-server/services/rest/server";
      String username = "$USERNAME";
      String password = "$PASSWORD";
      KieServicesConfiguration config =
        KieServicesFactory.newRestConfiguration(serverUrl,
                                          username,
                                          password);
      config.setMarshallingFormat(MarshallingFormat.JAXB);
      config.addExtraClasses(allClasses);
      KieServicesClient kieServicesClient =
        KieServicesFactory.newKieServicesClient(config);

      // Set up the fact model:
      Person p = new Person();
      p.setWage(12);
      p.setFirstName("Tom");
      p.setLastName("Summers");
      p.setHourlyRate(10);

      // Insert Person into the session:
      KieCommands kieCommands = KieServices.Factory.get().getCommands();
      List<Command> commandList = new ArrayList<Command>();
      commandList.add(kieCommands.newInsert(p, "personReturnId"));

      // Fire all rules:
      commandList.add(kieCommands.newFireAllRules("numberOfFiredRules"));
      BatchExecutionCommand batch = kieCommands.newBatchExecution(commandList,
sessionName);

      // Use rule services client to send request:
      RuleServicesClient ruleClient =
kieServicesClient.getServicesClient(RuleServicesClient.class);
      ServiceResponse<ExecutionResults> executeResponse =
ruleClient.executeCommandsWithResults(containerName, batch);
      System.out.println("number of fired rules:" +
executeResponse.getResult().getValue("numberOfFiredRules"));
    }

    catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

8. Run the configured **.java** class from your project directory. You can run the file in your development platform (such as Red Hat JBoss Developer Studio) or in the command line.
   Example Maven execution (within project directory):

   ```
   mvn clean install exec:java -Dexec.mainClass="com.sample.app.RulesTest"
   ```

   Example Java execution (within project directory)

   ```
   javac -classpath "./$DEPENDENCIES/*:." RulesTest.java
   java -classpath "./$DEPENDENCIES/*:." RulesTest
   ```

9. Review the rule execution status in the command line and in the server log. If any rules do not execute as expected, review the configured rules in the project and the main class configuration to validate the data provided.

CHAPTER 6. OTHER METHODS FOR CREATING AND EXECUTING DRL RULES

As an alternative to creating and managing DRL rules within the Business Central interface, you can create DRL rule files in external standalone projects using Red Hat Developer Studio, Java objects, or Maven archetypes. These standalone projects can then be integrated as knowledge JAR (KJAR) dependencies in existing Red Hat Decision Manager projects in Business Central. The DRL files in your standalone project must contain at minimum the required **package** specification, **import** lists, and **rule** definitions. Any other DRL components, such as global variables and functions, are optional. All data objects related to a DRL rule must be included with your standalone DRL project or deployment.

You can also use executable rule models in your Maven or Java projects to provide a Java-based representation of a rule set for execution at build time. The executable model is a more efficient alternative to the standard asset packaging in Red Hat Decision Manager and enables KIE containers and KIE bases to be created more quickly, especially when you have large lists of DRL (Drools Rule Language) files and other Red Hat Decision Manager assets.

6.1. CREATING AND EXECUTING DRL RULES IN RED HAT JBOSS DEVELOPER STUDIO

You can use Red Hat JBoss Developer Studio to create DRL files with rules and integrate the files with your Red Hat Decision Manager decision service. This method of creating DRL rules is helpful if you already use Red Hat Developer Studio for your decision service and want to continue with the same work flow. If you do not already use this method, then the Business Central interface of Red Hat Decision Manager is recommended for creating DRL files and other rule assets.

Prerequisite

Red Hat JBoss Developer Studio has been installed from the Red Hat Customer Portal .

Procedure

1. In the Red Hat JBoss Developer Studio, click **File → New → Project**.
2. In the **New Project** window that opens, select **Drools → Drools Project** and click **Next**.
3. Click the second icon to **Create a project and populate it with some example files to help you get started quickly**. Click **Next**.
4. Enter a **Project name** and select the **Maven** radio button as the project building option. The GAV values are generated automatically. You can update these values as needed for your project:
    - Group ID: **com.sample**
    - Artifact ID: **my-project**
    - Version: **1.0.0-SNAPSHOT**
5. Click **Finish** to create the project.
   This configuration sets up a basic project structure, class path, and sample rules. The following is an overview of the project structure:

```
my-project
 `-- src/main/java
```

```
  | `-- com.sample
  |    `-- DecisionTableTest.java
  |    `-- DroolsTest.java
  |    `-- ProcessTest.java
  |
`-- src/main/resources
  | `-- dtables
  |    `-- Sample.xls
  | `-- process
  |    `-- sample.bpmn
  | `-- rules
  |    `-- Sample.drl
  | `-- META-INF
  |
`-- JRE System Library
  |
`-- Maven Dependencies
  |
`-- Drools Library
  |
`-- src
  |
`-- target
  |
`-- pom.xml
```

Notice the following elements:

- A **Sample.drl** rule file in the **src/main/resources** directory, containing an example **Hello World** and **GoodBye** rules.
- A **DroolsTest.java** file under the **src/main/java** directory in the **com.sample** package. The **DroolsTest** class can be used to execute the **Sample.drl** rule.
- The **Drools Library** directory, which acts as a custom class path containing JAR files necessary for execution.

You can edit the existing **Sample.drl** file and **DroolsTest.java** files with new configurations as needed, or create new rule and object files. In this procedure, you are creating a new rule and new Java objects.

6. Create a Java object on which the rule or rules will operate.
In this example, a **Person.java** file is created in **my-project/src/main/java/com.sample**. The **Person** class contains getter and setter methods to set and retrieve the first name, last name, hourly rate, and the wage of a person:

```
public class Person {
  private String firstName;
  private String lastName;
  private Integer hourlyRate;
  private Integer wage;

  public String getFirstName() {
    return firstName;
  }
```

```
    public void setFirstName(String firstName) {
      this.firstName = firstName;
    }

    public String getLastName() {
      return lastName;
    }

    public void setLastName(String lastName) {
      this.lastName = lastName;
    }

    public Integer getHourlyRate() {
      return hourlyRate;
    }

    public void setHourlyRate(Integer hourlyRate) {
      this.hourlyRate = hourlyRate;
    }

    public Integer getWage(){
      return wage;
    }

    public void setWage(Integer wage){
      this.wage = wage;
    }
  }
```

7. Click **File → Save** to save the file.

8. Create a rule file in **.drl** format in **my-project/src/main/resources/rules**. The DRL file must contain at minimum a package specification, an import list of data objects to be used by the rule or rules, and one or more rules with **when** conditions and **then** actions.
   The following **Wage.drl** file contains a **Wage** rule that imports the **Person** class, calculates the wage and hourly rate values, and displays a message based on the result:

```
package com.sample;

import com.sample.Person;

dialect "java"

rule "Wage"
  when
    Person(hourlyRate * wage > 100)
    Person(name : firstName, surname : lastName)
  then
    System.out.println("Hello" + " " + name + " " + surname + "!");
    System.out.println("You are rich!");
end
```

9. Click **File → Save** to save the file.

10. Create a main class and save it to the same directory as the Java object that you created. The main class will load the KIE base and execute rules.

    NOTE

    You can also add the **main()** method and **Person** class within a single Java object file, similar to the **DroolsTest.java** sample file.

11. In the main class, add the required **import** statements to import KIE services, a KIE container, and a KIE session. Then load the KIE base, insert facts, and execute the rule from the **main()** method that passes the fact model to the rule.
    In this example, a **RulesTest.java** file is created in **my-project/src/main/java/com.sample** with the required imports and **main()** method:

```
package com.sample;

import org.kie.api.KieServices;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;

public class RulesTest {
  public static final void main(String[] args) {
    try {
      // Load the KIE base:
      KieServices ks = KieServices.Factory.get();
      KieContainer kContainer = ks.getKieClasspathContainer();
      KieSession kSession = kContainer.newKieSession();

      // Set up the fact model:
      Person p = new Person();
      p.setWage(12);
      p.setFirstName("Tom");
      p.setLastName("Summers");
      p.setHourlyRate(10);

      // Insert the person into the session:
      kSession.insert(p);

      // Fire all rules:
      kSession.fireAllRules();
      kSession.dispose();
    }

    catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

12. Click **File** → **Save** to save the file.

13. After you create and save all DRL assets in your project, right-click your project folder and select **Run As** → **Java Application** to build the project. If the project build fails, address any problems described in the **Problems** tab of the lower window in Developer Studio, and try again to validate the project until the project builds.

IF THE RUN AS → JAVA APPLICATION OPTION IS NOT AVAILABLE

If **Java Application** is not an option when you right-click your project and select **Run As**, then go to **Run As → Run Configurations**, right-click **Java Application**, and click **New**. Then in the **Main** tab, browse for and select your **Project** and the associated **Main class**. Click **Apply** and then click **Run** to test the project. The next time you right-click your project folder, the **Java Application** option will appear.

To integrate the new rule assets with an existing project in Red Hat Decision Manager, you can compile the new project as a knowledge JAR (KJAR) and add it as a dependency in the **pom.xml** file of the project in Business Central. To access the project **pom.xml** file in Business Central, you can select any existing asset in the project and then in the **Project Explorer** menu on the left side of the screen, click the **Customize View** gear icon and select **Repository View → pom.xml**.

6.2. CREATING AND EXECUTING DRL RULES USING JAVA

You can use Java objects to create DRL files with rules and integrate the objects with your Red Hat Decision Manager decision service. This method of creating DRL rules is helpful if you already use external Java objects for your decision service and want to continue with the same work flow. If you do not already use this method, then the Business Central interface of Red Hat Decision Manager is recommended for creating DRL files and other rule assets.

Procedure

1. Create a Java object on which the rule or rules will operate.
   In this example, a **Person.java** file is created in a directory **my-project**. The **Person** class contains getter and setter methods to set and retrieve the first name, last name, hourly rate, and the wage of a person:

```
public class Person {
  private String firstName;
  private String lastName;
  private Integer hourlyRate;
  private Integer wage;

  public String getFirstName() {
    return firstName;
  }

  public void setFirstName(String firstName) {
    this.firstName = firstName;
  }

  public String getLastName() {
    return lastName;
  }

  public void setLastName(String lastName) {
    this.lastName = lastName;
  }

  public Integer getHourlyRate() {
    return hourlyRate;
  }
  public void setHourlyRate(Integer hourlyRate) {
    this.hourlyRate = hourlyRate;
  }

  public Integer getWage(){
    return wage;
  }

  public void setWage(Integer wage){
    this.wage = wage;
  }
}
```

2. Create a rule file in **.drl** format under the **my-project** directory. The DRL file must contain at minimum a package specification (if applicable), an import list of data objects to be used by the rule or rules, and one or more rules with **when** conditions and **then** actions.
   The following **Wage.drl** file contains a **Wage** rule that calculates the wage and hourly rate values and displays a message based on the result:

```
package com.sample;

import com.sample.Person;

dialect "java"

rule "Wage"
  when
    Person(hourlyRate * wage > 100)
    Person(name : firstName, surname : lastName)
  then
    System.out.println("Hello" + " " + name + " " + surname + "!");
    System.out.println("You are rich!");
end
```

3. Create a main class and save it to the same directory as the Java object that you created. The main class will load the KIE base and execute rules.

4. In the main class, add the required **import** statements to import KIE services, a KIE container, and a KIE session. Then load the KIE base, insert facts, and execute the rule from the **main()** method that passes the fact model to the rule.
   In this example, a **RulesTest.java** file is created in **my-project** with the required imports and **main()** method:

```
import org.kie.api.KieServices;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;

public class RulesTest {
  public static final void main(String[] args) {
    try {
      // Load the KIE base:
      KieServices ks = KieServices.Factory.get();
      KieContainer kContainer = ks.getKieClasspathContainer();
      KieSession kSession = kContainer.newKieSession();
```

```
        // Set up the fact model:
        Person p = new Person();
        p.setWage(12);
        p.setFirstName("Tom");
        p.setLastName("Summers");
        p.setHourlyRate(10);

        // Insert the person into the session:
        kSession.insert(p);

        // Fire all rules:
        kSession.fireAllRules();
        kSession.dispose();
      }

      catch (Throwable t) {
        t.printStackTrace();
      }
    }
  }
```

5. Download the **Red Hat Decision Manager 7.3.0 Source Distribution**ZIP file from the Red Hat Customer Portal and extract it under **my-project/dm-engine-jars/**.

6. In the **my-project/META-INF** directory, create a **kmodule.xml** metadata file with the following content:

   ```
   <?xml version="1.0" encoding="UTF-8"?>
   <kmodule xmlns="http://www.drools.org/xsd/kmodule">
   </kmodule>
   ```

   This **kmodule.xml** file is a KIE module descriptor that selects resources to KIE bases and configures sessions. This file enables you to define and configure one or more KIE bases, and to include DRL files from specific **packages** in a specific KIE base. You can also create one or more KIE sessions from each KIE base.

   The following example shows a more advanced **kmodule.xml** file:

   ```
   <?xml version="1.0" encoding="UTF-8"?>
   <kmodule xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns="http://www.drools.org/xsd/kmodule">
     <kbase name="KBase1" default="true" eventProcessingMode="cloud"
   equalsBehavior="equality" declarativeAgenda="enabled" packages="org.domain.pkg1">
       <ksession name="KSession1_1" type="stateful" default="true" />
       <ksession name="KSession1_2" type="stateful" default="true" beliefSystem="jtms" />
     </kbase>
     <kbase name="KBase2" default="false" eventProcessingMode="stream"
   equalsBehavior="equality" declarativeAgenda="enabled" packages="org.domain.pkg2,
   org.domain.pkg3" includes="KBase1">
       <ksession name="KSession2_1" type="stateless" default="true" clockType="realtime">
         <fileLogger file="debugInfo" threaded="true" interval="10" />
         <workItemHandlers>
           <workItemHandler name="name" type="new org.domain.WorkItemHandler()" />
         </workItemHandlers>
         <listeners>
   ```

```
        <ruleRuntimeEventListener type="org.domain.RuleRuntimeListener" />
        <agendaEventListener type="org.domain.FirstAgendaListener" />
        <agendaEventListener type="org.domain.SecondAgendaListener" />
        <processEventListener type="org.domain.ProcessListener" />
      </listeners>
    </ksession>
  </kbase>
</kmodule>
```

This example defines two KIE bases. Two KIE sessions are instantiated from the **KBase1** KIE base, and one KIE session from **KBase2**. The KIE session from **KBase2** is a **stateless** KIE session, which means that data from a previous invocation of the KIE session (the previous session state) is discarded between session invocations. Specific **packages** of rule assets are included with both KIE bases. When you specify packages in this way, you must organize your DRL files in a folder structure that reflects the specified packages.

7. After you create and save all DRL assets in your Java object, navigate to the **my-project** directory in the command line and run the following command to build your Java files. Replace **RulesTest.java** with the name of your Java main class.

   ```
   javac -classpath "./dm-engine-jars/*:." RulesTest.java
   ```

   If the build fails, address any problems described in the command line error messages and try again to validate the Java object until the object passes.

8. After your Java files build successfully, run the following command to execute the rules locally. Replace **RulesTest** with the prefix of your Java main class.

   ```
   java -classpath "./dm-engine-jars/*:." RulesTest
   ```

9. Review the rules to ensure that they executed properly, and address any needed changes in the Java files.

To integrate the new rule assets with an existing project in Red Hat Decision Manager, you can compile the new Java project as a knowledge JAR (KJAR) and add it as a dependency in the **pom.xml** file of the project in Business Central. To access the project **pom.xml** file in Business Central, you can select any existing asset in the project and then in the **Project Explorer** menu on the left side of the screen, click the **Customize View** gear icon and select **Repository View** → **pom.xml**.

6.3. CREATING AND EXECUTING DRL RULES USING MAVEN

You can use Maven archetypes to create DRL files with rules and integrate the archetypes with your Red Hat Decision Manager decision service. This method of creating DRL rules is helpful if you already use external Maven archetypes for your decision service and want to continue with the same work flow. If you do not already use this method, then the Business Central interface of Red Hat Decision Manager is recommended for creating DRL files and other rule assets.

Procedure

1. Navigate to a directory where you want to create a Maven archetype and run the following command:

   ```
   mvn archetype:generate -DgroupId=com.sample.app -DartifactId=my-app -
   DarchetypeArtifactId=maven-archetype-quickstart -DinteractiveMode=false
   ```

This creates a directory **my-app** with the following structure:

```
my-app
|-- pom.xml
`-- src
    |-- main
    |   `-- java
    |       `-- com
    |           `-- sample
    |               `-- app
    |                   `-- App.java
    `-- test
        `-- java
            `-- com
                `-- sample
                    `-- app
                        `-- AppTest.java
```

The **my-app** directory contains the following key components:

- A **src/main** directory for storing the application sources
- A **src/test** directory for storing the test sources
- A **pom.xml** file with the project configuration

2. Create a Java object on which the rule or rules will operate within the Maven archetype.
In this example, a **Person.java** file is created in the directory **my-app/src/main/java/com/sample/app**. The **Person** class contains getter and setter methods to set and retrieve the first name, last name, hourly rate, and the wage of a person:

```
package com.sample.app;

  public class Person {

    private String firstName;
    private String lastName;
    private Integer hourlyRate;
    private Integer wage;

    public String getFirstName() {
      return firstName;
    }

    public void setFirstName(String firstName) {
      this.firstName = firstName;
    }

    public String getLastName() {
      return lastName;
    }

    public void setLastName(String lastName) {
      this.lastName = lastName;
    }
    public Integer getHourlyRate() {
      return hourlyRate;
    }

    public void setHourlyRate(Integer hourlyRate) {
      this.hourlyRate = hourlyRate;
    }

    public Integer getWage(){
      return wage;
    }

    public void setWage(Integer wage){
      this.wage = wage;
    }
  }
```

3. Create a rule file in **.drl** format in **my-app/src/main/resources/rules**. The DRL file must contain at minimum a package specification, an import list of data objects to be used by the rule or rules, and one or more rules with **when** conditions and **then** actions.
   The following **Wage.drl** file contains a **Wage** rule that imports the **Person** class, calculates the wage and hourly rate values, and displays a message based on the result:

```
package com.sample.app;

import com.sample.app.Person;

dialect "java"

rule "Wage"
  when
    Person(hourlyRate * wage > 100)
    Person(name : firstName, surname : lastName)
  then
    System.out.println("Hello " + name + " " + surname + "!");
    System.out.println("You are rich!");
end
```

4. In the **my-app/src/main/resources/META-INF** directory, create a **kmodule.xml** metadata file with the following content:

```
<?xml version="1.0" encoding="UTF-8"?>
<kmodule xmlns="http://www.drools.org/xsd/kmodule">
</kmodule>
```

   This **kmodule.xml** file is a KIE module descriptor that selects resources to KIE bases and configures sessions. This file enables you to define and configure one or more KIE bases, and to include DRL files from specific **packages** in a specific KIE base. You can also create one or more KIE sessions from each KIE base.

   The following example shows a more advanced **kmodule.xml** file:

```
<?xml version="1.0" encoding="UTF-8"?>
<kmodule xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns="http://www.drools.org/xsd/kmodule">
```

```
  <kbase name="KBase1" default="true" eventProcessingMode="cloud"
equalsBehavior="equality" declarativeAgenda="enabled" packages="org.domain.pkg1">
    <ksession name="KSession1_1" type="stateful" default="true" />
    <ksession name="KSession1_2" type="stateful" default="true" beliefSystem="jtms" />
  </kbase>
  <kbase name="KBase2" default="false" eventProcessingMode="stream"
equalsBehavior="equality" declarativeAgenda="enabled" packages="org.domain.pkg2,
org.domain.pkg3" includes="KBase1">
    <ksession name="KSession2_1" type="stateless" default="true" clockType="realtime">
      <fileLogger file="debugInfo" threaded="true" interval="10" />
      <workItemHandlers>
        <workItemHandler name="name" type="new org.domain.WorkItemHandler()" />
      </workItemHandlers>
      <listeners>
        <ruleRuntimeEventListener type="org.domain.RuleRuntimeListener" />
        <agendaEventListener type="org.domain.FirstAgendaListener" />
        <agendaEventListener type="org.domain.SecondAgendaListener" />
        <processEventListener type="org.domain.ProcessListener" />
      </listeners>
    </ksession>
  </kbase>
</kmodule>
```

This example defines two KIE bases. Two KIE sessions are instantiated from the **KBase1** KIE base, and one KIE session from **KBase2**. The KIE session from **KBase2** is a **stateless** KIE session, which means that data from a previous invocation of the KIE session (the previous session state) is discarded between session invocations. Specific **packages** of rule assets are included with both KIE bases. When you specify packages in this way, you must organize your DRL files in a folder structure that reflects the specified packages.

5. In the **my-app/pom.xml** configuration file, specify the libraries that your application requires. Provide the Red Hat Decision Manager dependencies as well as the **group ID**, **artifact ID**, and **version** (GAV) of your application.

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://maven.apache.org/POM/4.0.0
http://maven.apache.org/xsd/maven-4.0.0.xsd">
<modelVersion>4.0.0</modelVersion>
<groupId>com.sample.app</groupId>
<artifactId>my-app</artifactId>
<version>1.0.0</version>
<repositories>
  <repository>
    <id>jboss-ga-repository</id>
    <url>http://maven.repository.redhat.com/ga/</url>
  </repository>
</repositories>
<dependencies>
  <dependency>
    <groupId>org.drools</groupId>
    <artifactId>drools-compiler</artifactId>
    <version>VERSION</version>
  </dependency>
  <dependency>
```

```
      <groupId>org.kie</groupId>
      <artifactId>kie-api</artifactId>
      <version>VERSION</version>
    </dependency>
    <dependency>
      <groupId>junit</groupId>
      <artifactId>junit</artifactId>
      <version>4.11</version>
      <scope>test</scope>
    </dependency>
  </dependencies>
</project>
```

For information about Maven dependencies and the BOM (Bill of Materials) in Red Hat Decision Manager, see What is the mapping between Red Hat Decision Manager and Maven library version?.

6. Use the **testApp** method in **my-app/src/test/java/com/sample/app/AppTest.java** to test the rule. The **AppTest.java** file is created by Maven by default.

7. In the **AppTest.java** file, add the required **import** statements to import KIE services, a KIE container, and a KIE session. Then load the KIE base, insert facts, and execute the rule from the **testApp()** method that passes the fact model to the rule.

```
import org.kie.api.KieServices;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;

public void testApp() {

  // Load the KIE base:
  KieServices ks = KieServices.Factory.get();
  KieContainer kContainer = ks.getKieClasspathContainer();
  KieSession kSession = kContainer.newKieSession();

  // Set up the fact model:
  Person p = new Person();
  p.setWage(12);
  p.setFirstName("Tom");
  p.setLastName("Summers");
  p.setHourlyRate(10);

  // Insert the person into the session:
  kSession.insert(p);

  // Fire all rules:
  kSession.fireAllRules();
  kSession.dispose();
}
```

8. After you create and save all DRL assets in your Maven archetype, navigate to the **my-app** directory in the command line and run the following command to build your files:

```
mvn clean install
```

If the build fails, address any problems described in the command line error messages and try again to validate the files until the build is successful.

9. After your files build successfully, run the following command to execute the rules locally. Replace **com.sample.app** with your package name.

```
mvn exec:java -Dexec.mainClass="com.sample.app"
```

10. Review the rules to ensure that they executed properly, and address any needed changes in the files.

To integrate the new rule assets with an existing project in Red Hat Decision Manager, you can compile the new Maven project as a knowledge JAR (KJAR) and add it as a dependency in the **pom.xml** file of the project in Business Central. To access the project **pom.xml** file in Business Central, you can select any existing asset in the project and then in the **Project Explorer** menu on the left side of the screen, click the **Customize View** gear icon and select **Repository View → pom.xml**.

6.4. EXECUTABLE RULE MODELS

Executable rule models are embeddable models that provide a Java-based representation of a rule set for execution at build time. The executable model is a more efficient alternative to the standard asset packaging in Red Hat Decision Manager and enables KIE containers and KIE bases to be created more quickly, especially when you have large lists of DRL (Drools Rule Language) files and other Red Hat Decision Manager assets. The model is low level and enables you to provide all necessary execution information, such as the lambda expressions for the index evaluation.

Executable rule models provide the following specific advantages for your projects:

- **Compile time:** Traditionally, a packaged Red Hat Decision Manager project (KJAR) contains a list of DRL files and other Red Hat Decision Manager artifacts that define the rule base together with some pre-generated classes implementing the constraints and the consequences. Those DRL files must be parsed and compiled when the KJAR is downloaded from the Maven repository and installed in a KIE container. This process can be slow, especially for large rule sets. With an executable model, you can package within the project KJAR the Java classes that implement the executable model of the project rule base and re-create the KIE container and its KIE bases out of it in a much faster way. In Maven projects, you use the **kie-maven-plugin** to automatically generate the executable model sources from the DRL files during the compilation process.

- **Run time:** In an executable model, all constraints are defined as Java lambda expressions. The same lambda expressions are also used for constraints evaluation, so you no longer need to use **mvel** expressions for interpreted evaluation nor the just-in-time (JIT) process to transform the **mvel**-based constraints into bytecode. This creates a quicker and more efficient run time.

- **Development time:** An executable model enables you to develop and experiment with new features of the decision engine without needing to encode elements directly in the DRL format or modify the DRL parser to support them.

NOTE

For query definitions in executable rule models, you can use up to 10 arguments only.

For variables within rule consequences in executable rule models, you can use up to 12 bound variables only (including the built-in **drools** variable). For example, the following rule consequence uses more than 12 bound variables and creates a compilation error:

```
...
then
  $input.setNo13Count(functions.sumOf(new Object[]{$no1Count_1, $no2Count_1,
$no3Count_1, ..., $no13Count_1}).intValue());
  $input.getFirings().add("fired");
  update($input);
```

6.4.1. Embedding an executable rule model in a Maven project

You can embed an executable rule model in your Maven project to compile your rule assets more efficiently at build time.

Prerequisite

You have a Mavenized project that contains Red Hat Decision Manager business assets.

Procedure

1. In the **pom.xml** file of your Maven project, ensure that the packaging type is set to **kjar** and add the **kie-maven-plugin** build component:

```
<packaging>kjar</packaging>
...
<build>
  <plugins>
    <plugin>
      <groupId>org.kie</groupId>
      <artifactId>kie-maven-plugin</artifactId>
      <version>${rhdm.version}</version>
      <extensions>true</extensions>
    </plugin>
  </plugins>
</build>
```

The **kjar** packaging type activates the **kie-maven-plugin** component to validate and pre-compile artifact resources. The **<version>** is the Maven artifact version for Red Hat Decision Manager currently used in your project (for example, 7.18.0.Final-redhat-00002). These settings are required to properly package the Maven project.

NOTE

Instead of specifying a Red Hat Decision Manager **<version>** for individual dependencies, consider adding the Red Hat Business Automation bill of materials (BOM) dependency to your project **pom.xml** file. The Red Hat Business Automation BOM applies to both Red Hat Decision Manager and Red Hat Process Automation Manager. When you add the BOM files, the correct versions of transitive dependencies from the provided Maven repositories are included in the project.

Example BOM dependency:

```
<dependency>
  <groupId>com.redhat.ba</groupId>
  <artifactId>ba-platform-bom</artifactId>
  <version>7.3.0.GA-redhat-00002</version>
  <scope>import</scope>
  <type>pom</type>
</dependency>
```

For more information about the Red Hat Business Automation BOM, see What is the mapping between RHDM product and maven library version?.

2. Add the following dependencies to the **pom.xml** file to enable rule assets to be built from an executable model:

   - **drools-canonical-model**: Enables an executable canonical representation of a rule set model that is independent from Red Hat Decision Manager

   - **drools-model-compiler**: Compiles the executable model into Red Hat Decision Manager internal data structures so that it can be executed by the decision engine

```
<dependency>
  <groupId>org.drools</groupId>
  <artifactId>drools-canonical-model</artifactId>
  <version>${rhdm.version}</version>
</dependency>

<dependency>
  <groupId>org.drools</groupId>
  <artifactId>drools-model-compiler</artifactId>
  <version>${rhdm.version}</version>
</dependency>
```

3. In a command terminal, navigate to your Maven project directory and run the following command to build the project from an executable model:

```
mvn clean install -DgenerateModel=<VALUE>
```

The **-DgenerateModel=<VALUE>** property enables the project to be built as a model-based KJAR instead of a DRL-based KJAR.

Replace **<VALUE>** with one of three values:

- **YES**: Generates the executable model corresponding to the DRL files in the original project and excludes the DRL files from the generated KJAR.
- **WITHDRL**: Generates the executable model corresponding to the DRL files in the original project and also adds the DRL files to the generated KJAR for documentation purposes (the KIE base is built from the executable model regardless).
- **NO**: Does not generate the executable model.

Example build command:

```
mvn clean install -DgenerateModel=YES
```

For more information about packaging Maven projects, see *Packaging and deploying a Red Hat Decision Manager project*.

6.4.2. Embedding an executable rule model in a Java application

You can embed an executable rule model programmatically within your Java application to compile your rule assets more efficiently at build time.

Prerequisite

You have a Java application that contains Red Hat Decision Manager business assets.

Procedure

1. Add the following dependencies to the relevant classpath for your Java project:

   - **drools-canonical-model**: Enables an executable canonical representation of a rule set model that is independent from Red Hat Decision Manager
   - **drools-model-compiler**: Compiles the executable model into Red Hat Decision Manager internal data structures so that it can be executed by the decision engine

```
<dependency>
  <groupId>org.drools</groupId>
  <artifactId>drools-canonical-model</artifactId>
  <version>${rhdm.version}</version>
</dependency>

<dependency>
  <groupId>org.drools</groupId>
  <artifactId>drools-model-compiler</artifactId>
  <version>${rhdm.version}</version>
</dependency>
```

The **<version>** is the Maven artifact version for Red Hat Decision Manager currently used in your project (for example, 7.18.0.Final-redhat-00002).

NOTE

Instead of specifying a Red Hat Decision Manager **<version>** for individual dependencies, consider adding the Red Hat Business Automation bill of materials (BOM) dependency to your project **pom.xml** file. The Red Hat Business Automation BOM applies to both Red Hat Decision Manager and Red Hat Process Automation Manager. When you add the BOM files, the correct versions of transitive dependencies from the provided Maven repositories are included in the project.

Example BOM dependency:

```
<dependency>
  <groupId>com.redhat.ba</groupId>
  <artifactId>ba-platform-bom</artifactId>
  <version>7.3.0.GA-redhat-00002</version>
  <scope>import</scope>
  <type>pom</type>
</dependency>
```

For more information about the Red Hat Business Automation BOM, see What is the mapping between RHDM product and maven library version?.

2. Add rule assets to the KIE virtual file system **KieFileSystem** and use **KieBuilder** with **buildAll(ExecutableModelProject.class)** specified to build the assets from an executable model:

```
import org.kie.api.KieServices;
import org.kie.api.builder.KieFileSystem;
import org.kie.api.builder.KieBuilder;

 KieServices ks = KieServices.Factory.get();
 KieFileSystem kfs = ks.newKieFileSystem()
 kfs.write("src/main/resources/KBase1/ruleSet1.drl", stringContainingAValidDRL)
 .write("src/main/resources/dtable.xls",
   kieServices.getResources().newInputStreamResource(dtableFileStream));

 KieBuilder kieBuilder = ks.newKieBuilder( kfs );
 // Build from an executable model
 kieBuilder.buildAll( ExecutableModelProject.class )
 assertEquals(0, kieBuilder.getResults().getMessages(Message.Level.ERROR).size());
```

After **KieFileSystem** is built from the executable model, the resulting **KieSession** uses constraints based on lambda expressions instead of less-efficient **mvel** expressions. If **buildAll()** contains no arguments, the project is built in the standard method without an executable model.

As a more manual alternative to using **KieFileSystem** for creating executable models, you can define a **Model** with a fluent API and create a **KieBase** from it:

```
Model model = new ModelImpl().addRule( rule );
KieBase kieBase = KieBaseBuilder.createKieBaseFromModel( model );
```

For more information about packaging projects programmatically within a Java application, see *Packaging and deploying a Red Hat Decision Manager project* .

CHAPTER 7. EXAMPLE DECISIONS IN RED HAT DECISION MANAGER FOR AN IDE

Red Hat Decision Manager provides example decisions distributed as Java classes that you can import into your integrated development environment (IDE). You can use these examples to better understand decision engine capabilities or use them as a reference for the decisions that you define in your own Red Hat Decision Manager projects.

The following example decision sets are some of the examples available in Red Hat Decision Manager:

- **Hello World example**: Demonstrates basic rule execution and use of debug output
- **State example**: Demonstrates forward chaining and conflict resolution through rule salience and agenda groups
- **Fibonacci example**: Demonstrates recursion and conflict resolution through rule salience
- **Banking example**: Demonstrates pattern matching, basic sorting, and calculation
- **Pet Store example**: Demonstrates rule agenda groups, global variables, callbacks, and GUI integration
- **Sudoku example**: Demonstrates complex pattern matching, problem solving, callbacks, and GUI integration
- **House of Doom example**: Demonstrates backward chaining and recursion

NOTE

For optimization examples provided with Red Hat Business Optimizer, see *Getting started with Red Hat Business Optimizer*.

7.1. IMPORTING AND EXECUTING RED HAT DECISION MANAGER EXAMPLE DECISIONS IN AN IDE

You can import Red Hat Decision Manager example decisions into your integrated development environment (IDE) and execute them to explore how the rules and code function. You can use these examples to better understand decision engine capabilities or use them as a reference for the decisions that you define in your own Red Hat Decision Manager projects.

Prerequisites

- Java 8 or later is installed.
- Maven 3.5.x or later is installed.
- An IDE is installed, such as Red Hat JBoss Developer Studio.

Procedure

1. Download and unzip the **Red Hat Decision Manager 7.3.0 Source Distribution**from the Red Hat Customer Portal to a temporary directory, such as **/rhdm-7.3.0-sources**.

2. Open your IDE and select **File → Import → Maven → Existing Maven Projects**, or the equivalent option for importing a Maven project.

3. Click **Browse**, navigate to **~/rhdm-7.3.0-sources/src/drools-$VERSION/drools-examples** (or, for the Conway's Game of Life example, **~/rhdm-7.3.0-sources/src/droolsjbpm-integration-$VERSION/droolsjbpm-integration-examples**), and import the project.

4. Navigate to the example package that you want to run and find the Java class with the **main** method.

5. Right-click the Java class and select **Run As → Java Application** to run the example.
   To run all examples through a basic user interface, run the **DroolsExamplesApp.java** class (or, for Conway's Game of Life, the **DroolsJbpmIntegrationExamplesApp.java** class) in the **org.drools.examples** main class.

Figure 7.1. Interface for all examples in drools-examples (DroolsExamplesApp.java)

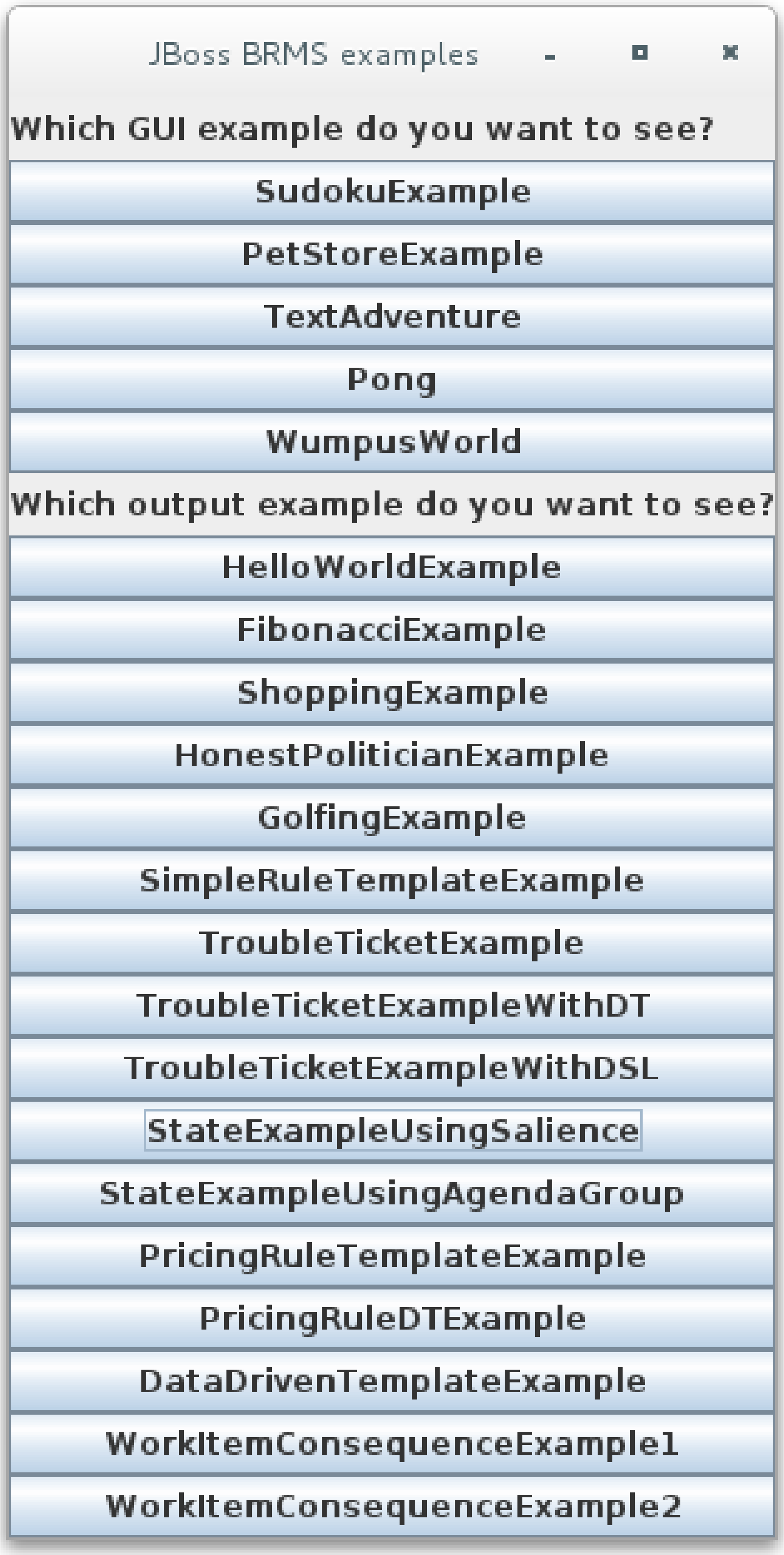
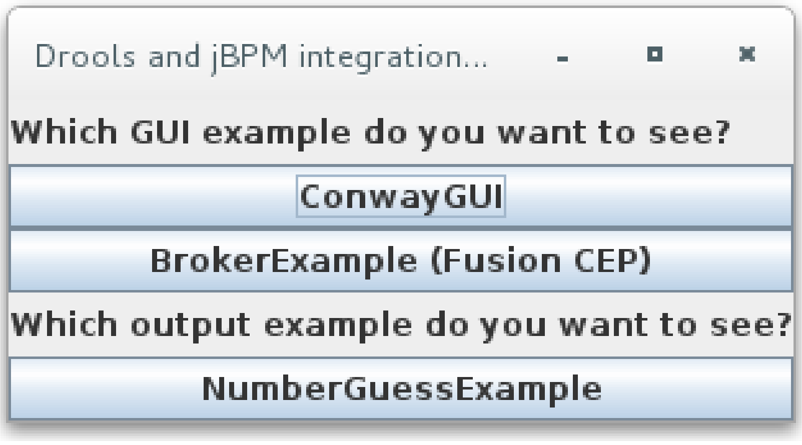

JBoss BRMS examples
Which GUI example do you want to see?
SudokuExample
PetStoreExample
TextAdventure
Pong
WumpusWorld
Which output example do you want to see?
HelloWorldExample
FibonacciExample
ShoppingExample
HonestPoliticianExample
GolfingExample
SimpleRuleTemplateExample
TroubleTicketExample
TroubleTicketExampleWithDT
TroubleTicketExampleWithDSL
StateExampleUsingSalience
StateExampleUsingAgendaGroup
PricingRuleTemplateExample
PricingRuleDTExample
DataDrivenTemplateExample
WorkItemConsequenceExample1
WorkItemConsequenceExample2

Figure 7.2. Interface for all examples in droolsjbpm-integration-examples (DroolsJbpmIntegrationExamplesApp.java)


Drools and jBPM integration...
Which GUI example do you want to see?
ConwayGUI
BrokerExample (Fusion CEP)
Which output example do you want to see?
NumberGuessExample

7.2. HELLO WORLD EXAMPLE DECISIONS (BASIC RULES AND DEBUGGING)

The Hello World example decision set demonstrates how to insert objects into the decision engine working memory, how to match the objects using rules, and how to configure logging to trace the internal activity of the decision engine.

The following is an overview of the Hello World example:

- Name: **helloworld**
- Main class: **org.drools.examples.helloworld.HelloWorldExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule file: **org.drools.examples.helloworld.HelloWorld.drl** (in **src/main/resources**)
- **Objective**: Demonstrates basic rule execution and use of debug output

In the Hello World example, a KIE session is generated to enable rule execution. All rules require a KIE session for execution.

KIE session for rule execution

```
KieServices ks = KieServices.Factory.get(); 1
KieContainer kc = ks.getKieClasspathContainer(); 2
KieSession ksession = kc.newKieSession("HelloWorldKS"); 3
```

1 Obtains the **KieServices** factory. This is the main interface that applications use to interact with the decision engine.

2 Creates a **KieContainer** from the project class path. This detects a **/META-INF/kmodule.xml** file from which it configures and instantiates a **KieContainer** with a **KieModule**.

3 Creates a **KieSession** based on the **"HelloWorldKS"** KIE session configuration defined in the **/META-INF/kmodule.xml** file.

NOTE

For more information about Red Hat Decision Manager project packaging, see *Packaging and deploying a Red Hat Decision Manager project*.

Red Hat Decision Manager has an event model that exposes internal engine activity. Two default debug listeners, **DebugAgendaEventListener** and **DebugWorkingMemoryEventListener**, print debug event information to the **System.err** output. The **KieRuntimeLogger** provides execution auditing, the result of which you can view in a graphical viewer.

Debug listeners and audit loggers

```
// Set up listeners.
ksession.addEventListener( new DebugAgendaEventListener() );
ksession.addEventListener( new DebugRuleRuntimeEventListener() );

// Set up a file-based audit logger.
KieRuntimeLogger logger = KieServices.get().getLoggers().newFileLogger( ksession,
"./target/helloworld" );

// Set up a ThreadedFileLogger so that the audit view reflects events while debugging.
KieRuntimeLogger logger = ks.getLoggers().newThreadedFileLogger( ksession, "./target/helloworld",
1000 );
```

The logger is a specialized implementation built on the **Agenda** and **RuleRuntime** listeners. When the decision engine has finished executing, **logger.close()** is called.

The example creates a single **Message** object with the message **"Hello World"**, inserts the status **HELLO** into the **KieSession**, executes rules with **fireAllRules()**.

Data insertion and execution

```
// Insert facts into the KIE session.
final Message message = new Message();
message.setMessage( "Hello World" );
message.setStatus( Message.HELLO );
ksession.insert( message );

// Fire the rules.
ksession.fireAllRules();
```

Rule execution uses a data model to pass data as inputs and outputs to the **KieSession**. The data model in this example has two fields: the **message**, which is a **String**, and the **status**, which can be **HELLO** or **GOODBYE**.

Data model class

```
public static class Message {
    public static final int HELLO   = 0;
    public static final int GOODBYE = 1;

    private String        message;
    private int           status;
    ...
}
```

The two rules are located in the file **src/main/resources/org/drools/examples/helloworld/HelloWorld.drl**.

The **when** condition of the **"Hello World"** rule states that the rule is activated for each **Message** object inserted into the KIE session that has the status **Message.HELLO**. Additionally, two variable bindings are created: the variable **message** is bound to the **message** attribute and the variable **m** is bound to the matched **Message** object itself.

The **then** action of the rule is written using the MVEL expression language, as declared by the rule **dialect** attribute. After printing the content of the bound variable **message** to **System.out**, the rule changes the values of the **message** and **status** attributes of the **Message** object bound to **m**. The rule uses the MVEL **modify** statement to apply a block of assignments in one statement and to notify the decision engine of the changes at the end of the block.

"Hello World" rule

```
rule "Hello World"
    dialect "mvel"
  when
    m : Message( status == Message.HELLO, message : message )
  then
    System.out.println( message );
    modify ( m ) { message = "Goodbye cruel world",
                   status = Message.GOODBYE };
end
```

The **"Good Bye"** rule, which specifies the **java** dialect, is similar to the **"Hello World"** rule except that it matches **Message** objects that have the status **Message.GOODBYE**.

"Good Bye" rule

```
rule "Good Bye"
    dialect "java"
  when
    Message( status == Message.GOODBYE, message : message )
  then
    System.out.println( message );
end
```

To execute the example, run the **org.drools.examples.helloworld.HelloWorldExample** class as a Java application in your IDE. The rule writes to **System.out**, the debug listener writes to **System.err**, and the audit logger creates a log file in **target/helloworld.log**.

System.out output in the IDE console

```
Hello World
Goodbye cruel world
```

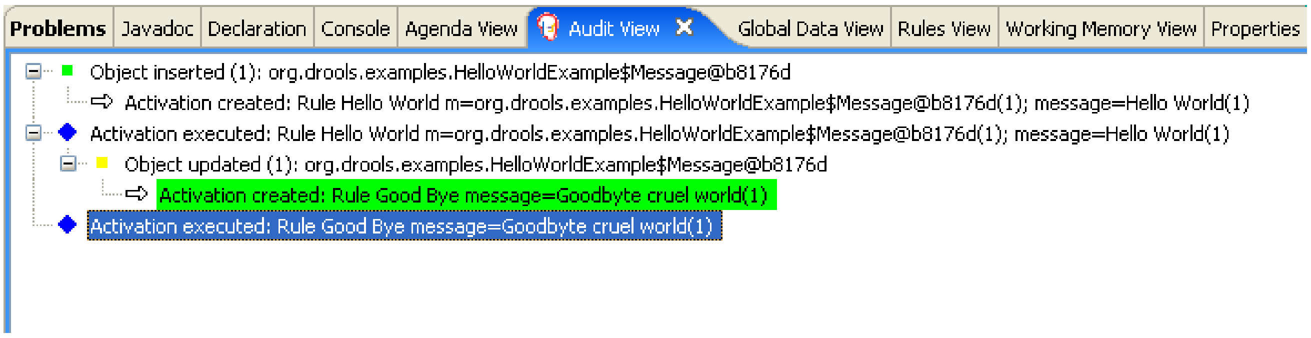
System.err output in the IDE console

```
==>[ActivationCreated(0): rule=Hello World;
                   tuple=[fid:1:1:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]]
[ObjectInserted: handle=
[fid:1:1:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96];
                 object=org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]
[BeforeActivationFired: rule=Hello World;
                   tuple=[fid:1:1:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]]
==>[ActivationCreated(4): rule=Good Bye;
                   tuple=[fid:1:2:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]]
[ObjectUpdated: handle=
[fid:1:2:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96];
                old_object=org.drools.examples.helloworld.HelloWorldExample$Message@17cec96;
                new_object=org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]
[AfterActivationFired(0): rule=Hello World]
[BeforeActivationFired: rule=Good Bye;
                   tuple=[fid:1:2:org.drools.examples.helloworld.HelloWorldExample$Message@17cec96]]
[AfterActivationFired(4): rule=Good Bye]
```

To better understand the execution flow of this example, you can load the audit log file from **target/helloworld.log** into your IDE debug view or **Audit View**, if available (for example, in **Window → Show View** in some IDEs).

In this example, the **Audit view** shows that the object is inserted, which creates an activation for the **"Hello World"** rule. The activation is then executed, which updates the **Message** object and causes the **"Good Bye"** rule to activate. Finally, the **"Good Bye"** rule is executed. When you select an event in the **Audit View**, the origin event, which is the **"Activation created"** event in this example, is highlighted in green.

Figure 7.3. Hello World example Audit View



```
Object inserted (1): org.drools.examples.HelloWorldExample$Message@b8176d
    Activation created: Rule Hello World m=org.drools.examples.HelloWorldExample$Message@b8176d(1); message=Hello World(1)
Activation executed: Rule Hello World m=org.drools.examples.HelloWorldExample$Message@b8176d(1); message=Hello World(1)
    Object updated (1): org.drools.examples.HelloWorldExample$Message@b8176d
        Activation created: Rule Good Bye message=Goodbyte cruel world(1)
Activation executed: Rule Good Bye message=Goodbyte cruel world(1)
```

7.3. STATE EXAMPLE DECISIONS (FORWARD CHAINING AND CONFLICT RESOLUTION)

The State example decision set demonstrates how the decision engine uses forward chaining and any changes to facts in the working memory to resolve execution conflicts for rules in a sequence. The example focuses on resolving conflicts through salience values or through agenda groups that you can define in rules.

The following is an overview of the State example:

- Name: **state**
- Main classes: **org.drools.examples.state.StateExampleUsingSalience**, **org.drools.examples.state.StateExampleUsingAgendaGroup** (in **src/main/java**)

- Module: **drools-examples**
- **Type**: Java application
- Rule files: **org.drools.examples.state.*.drl** (in **src/main/resources**)
- **Objective**: Demonstrates forward chaining and conflict resolution through rule salience and agenda groups

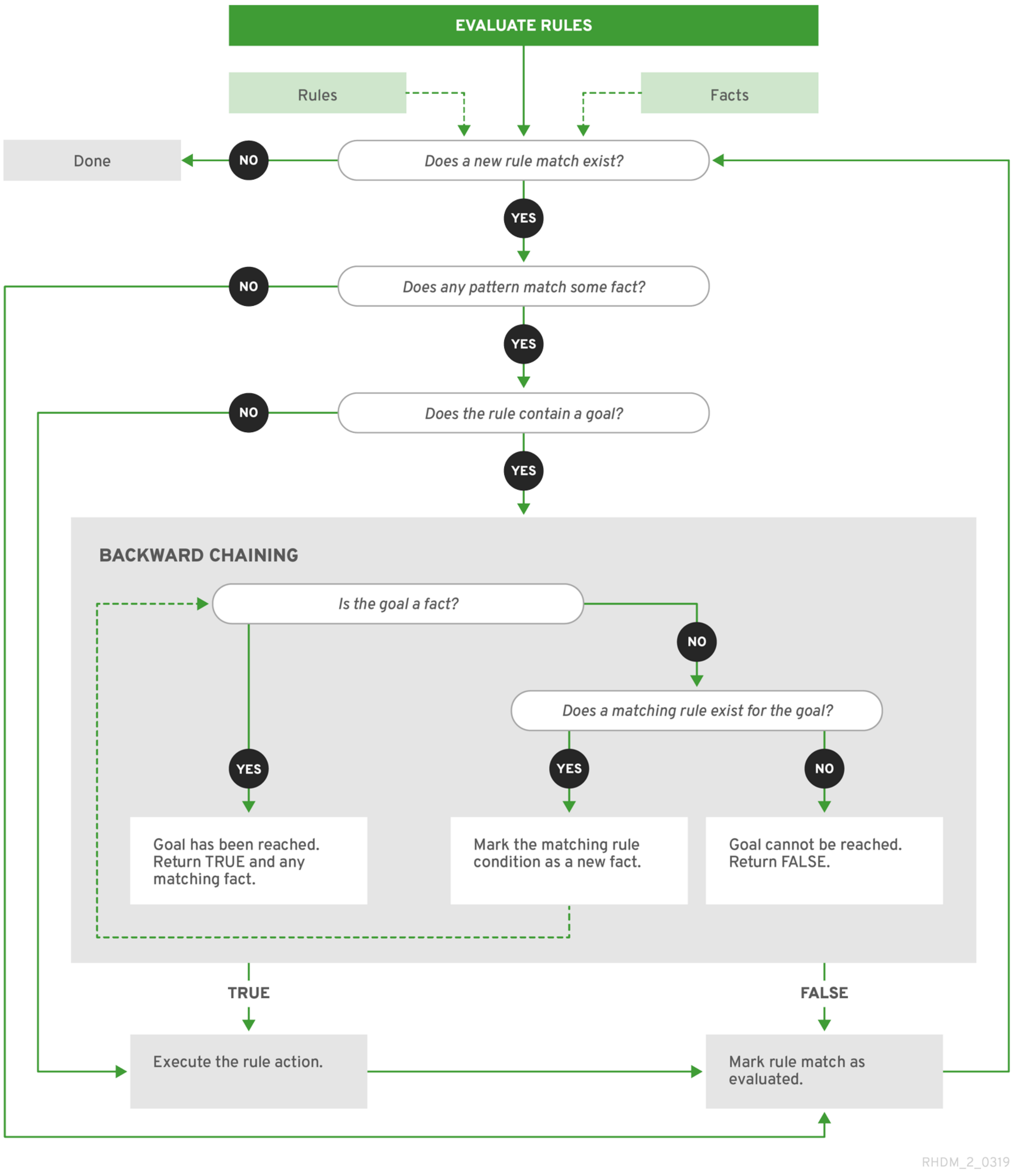
A forward-chaining rule system is a data-driven system that starts with a fact in the working memory of the decision engine and reacts to changes to that fact. When objects are inserted into working memory, any rule conditions that become true as a result of the change are scheduled for execution by the agenda.

In contrast, a backward-chaining rule system is a goal-driven system that starts with a conclusion that the decision engine attempts to satisfy, often using recursion. If the system cannot reach the conclusion or goal, it searches for subgoals, which are conclusions that complete part of the current goal. The system continues this process until either the initial conclusion is satisfied or all subgoals are satisfied.

The decision engine in Red Hat Decision Manager uses both forward and backward chaining to evaluate rules.

The following diagram illustrates how the decision engine evaluates rules using forward chaining overall with a backward-chaining segment in the logic flow:

Figure 7.4. Rule evaluation logic using forward and backward chaining


EVALUATE RULES
Rules
Facts
Done
NO
Does a new rule match exist?
YES
NO
Does any pattern match some fact?
YES
NO
Does the rule contain a goal?
YES
BACKWARD CHAINING
Is the goal a fact?
NO
Does a matching rule exist for the goal?
YES
YES
NO
Goal has been reached. Return TRUE and any matching fact.
Mark the matching rule condition as a new fact.
Goal cannot be reached. Return FALSE.
TRUE
FALSE
Execute the rule action.
Mark rule match as evaluated.
RHDM_2_0319

In the State example, each **State** class has fields for its name and its current state (see the class **org.drools.examples.state.State**). The following states are the two possible states for each object:

- **NOTRUN**
- **FINISHED**

State class

```
public class State {
    public static final int NOTRUN   = 0;
    public static final int FINISHED = 1;

    private final PropertyChangeSupport changes =
        new PropertyChangeSupport( this );

    private String name;
    private int    state;

    ... setters and getters go here...
}
```

The State example contains two versions of the same example to resolve rule execution conflicts:

- A **StateExampleUsingSalience** version that resolves conflicts by using rule salience
- A **StateExampleUsingAgendaGroups** version that resolves conflicts by using rule agenda groups

Both versions of the state example involve four **State** objects: **A**, **B**, **C**, and **D**. Initially, their states are set to **NOTRUN**, which is the default value for the constructor that the example uses.

State example using salience

The **StateExampleUsingSalience** version of the State example uses salience values in rules to resolve rule execution conflicts. Rules with a higher salience value are given higher priority when ordered in the activation queue.

The example inserts each **State** instance into the KIE session and then calls **fireAllRules()**.

Salience State example execution

```
final State a = new State( "A" );
final State b = new State( "B" );
final State c = new State( "C" );
final State d = new State( "D" );

ksession.insert( a );
ksession.insert( b );
ksession.insert( c );
ksession.insert( d );

ksession.fireAllRules();

// Dispose KIE session if stateful (not required if stateless).
ksession.dispose();
```

To execute the example, run the **org.drools.examples.state.StateExampleUsingSalience** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window:

Salience State example output in the IDE console

```
A finished
B finished
```

```
C finished
D finished
```

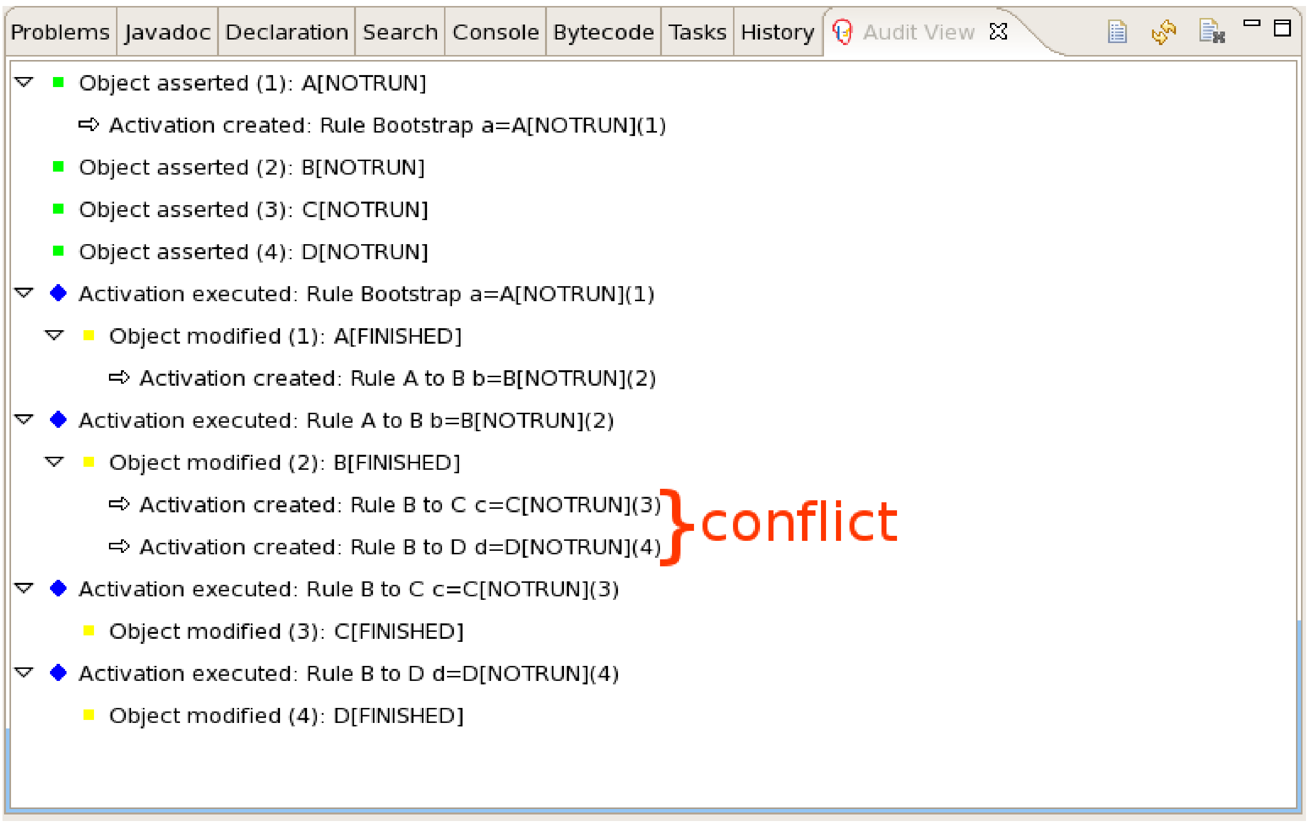
Four rules are present.

First, the **"Bootstrap"** rule fires, setting **A** to state **FINISHED**, which then causes **B** to change its state to **FINISHED**. Objects **C** and **D** are both dependent on **B**, causing a conflict that is resolved by the salience values.

To better understand the execution flow of this example, you can load the audit log file from **target/state.log** into your IDE debug view or **Audit View**, if available (for example, in **Window → Show View** in some IDEs).

In this example, the **Audit View** shows that the assertion of the object **A** in the state **NOTRUN** activates the **"Bootstrap"** rule, while the assertions of the other objects have no immediate effect.

Figure 7.5. Salience State example Audit View



```
Object asserted (1): A[NOTRUN]
    Activation created: Rule Bootstrap a=A[NOTRUN](1)
Object asserted (2): B[NOTRUN]
Object asserted (3): C[NOTRUN]
Object asserted (4): D[NOTRUN]
Activation executed: Rule Bootstrap a=A[NOTRUN](1)
    Object modified (1): A[FINISHED]
        Activation created: Rule A to B b=B[NOTRUN](2)
Activation executed: Rule A to B b=B[NOTRUN](2)
    Object modified (2): B[FINISHED]
        Activation created: Rule B to C c=C[NOTRUN](3)
        Activation created: Rule B to D d=D[NOTRUN](4)
Activation executed: Rule B to C c=C[NOTRUN](3)
    Object modified (3): C[FINISHED]
Activation executed: Rule B to D d=D[NOTRUN](4)
    Object modified (4): D[FINISHED]
```

Rule "Bootstrap" in salience State example

```
rule "Bootstrap"
  when
    a : State(name == "A", state == State.NOTRUN )
  then
    System.out.println(a.getName() + " finished" );
    a.setState( State.FINISHED );
end
```

The execution of the **"Bootstrap"** rule changes the state of **A** to **FINISHED**, which activates rule **"A to B"**.

Rule "A to B" in salience State example

```
rule "A to B"
  when
    State(name == "A", state == State.FINISHED )
    b : State(name == "B", state == State.NOTRUN )
  then
    System.out.println(b.getName() + " finished" );
    b.setState( State.FINISHED );
end
```

The execution of rule **"A to B"** changes the state of **B** to **FINISHED**, which activates both rules **"B to C"** and **"B to D"**, placing their activations onto the decision engine agenda.

Rules "B to C" and "B to D" in salience State example

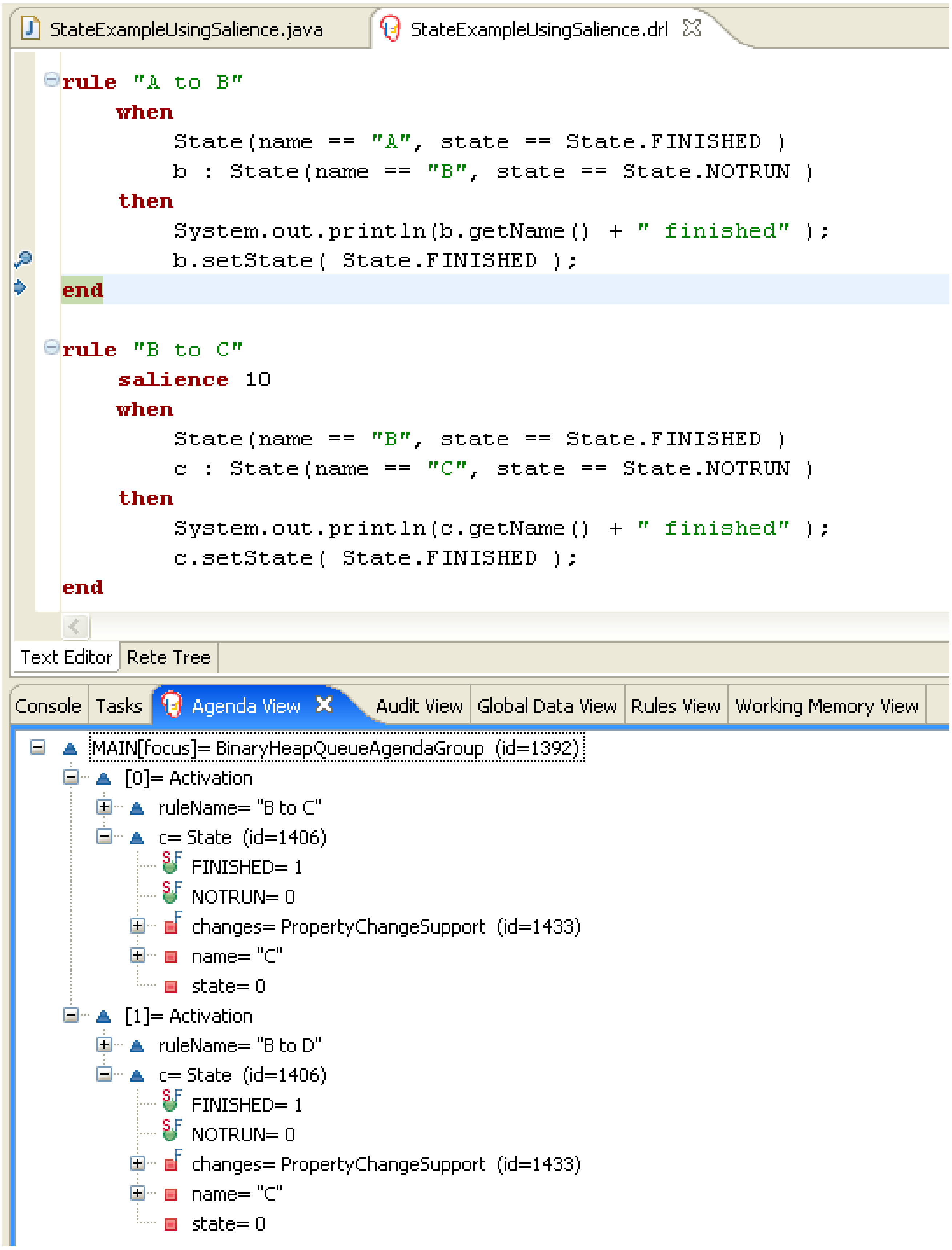
```
rule "B to C"
    salience 10
  when
    State(name == "B", state == State.FINISHED )
    c : State(name == "C", state == State.NOTRUN )
  then
    System.out.println(c.getName() + " finished" );
    c.setState( State.FINISHED );
end

rule "B to D"
  when
    State(name == "B", state == State.FINISHED )
    d : State(name == "D", state == State.NOTRUN )
  then
    System.out.println(d.getName() + " finished" );
    d.setState( State.FINISHED );
end
```

From this point on, both rules may fire and, therefore, the rules are in conflict. The conflict resolution strategy enables the decision engine agenda to decide which rule to fire. Rule **"B to C"** has the higher salience value (**10** versus the default salience value of **0**), so it fires first, modifying object **C** to state **FINISHED**.

The **Audit View** in your IDE shows the modification of the **State** object in the rule **"A to B"**, which results in two activations being in conflict.

You can also use the **Agenda View** in your IDE to investigate the state of the decision engine agenda. In this example, the **Agenda View** shows the breakpoint in the rule **"A to B"** and the state of the agenda with the two conflicting rules. Rule **"B to D"** fires last, modifying object **D** to state **FINISHED**.

Figure 7.6. Salience State example Agenda View



```
rule "A to B"
    when
        State(name == "A", state == State.FINISHED )
        b : State(name == "B", state == State.NOTRUN )
    then
        System.out.println(b.getName() + " finished" );
        b.setState( State.FINISHED );
end

rule "B to C"
    salience 10
    when
        State(name == "B", state == State.FINISHED )
        c : State(name == "C", state == State.NOTRUN )
    then
        System.out.println(c.getName() + " finished" );
        c.setState( State.FINISHED );
end
```

```
MAIN[focus]= BinaryHeapQueueAgendaGroup  (id=1392)
    [0]= Activation
        ruleName= "B to C"
        c= State  (id=1406)
            FINISHED= 1
            NOTRUN= 0
            changes= PropertyChangeSupport  (id=1433)
            name= "C"
            state= 0
    [1]= Activation
        ruleName= "B to D"
        c= State  (id=1406)
            FINISHED= 1
            NOTRUN= 0
            changes= PropertyChangeSupport  (id=1433)
            name= "C"
            state= 0
```

State example using agenda groups

The **StateExampleUsingAgendaGroups** version of the State example uses agenda groups in rules to resolve rule execution conflicts. Agenda groups enable you to partition the decision engine agenda to provide more execution control over groups of rules. By default, all rules are in the agenda group **MAIN**. You can use the **agenda-group** attribute to specify a different agenda group for the rule.

Initially, a working memory has its focus on the agenda group **MAIN**. Rules in an agenda group only fire when the group receives the focus. You can set the focus either by using the method **setFocus()** or the rule attribute **auto-focus**. The **auto-focus** attribute enables the rule to be given a focus automatically for its agenda group when the rule is matched and activated.

In this example, the **auto-focus** attribute enables rule **"B to C"** to fire before **"B to D"**.

Rule "B to C" in agenda group State example

```
rule "B to C"
    agenda-group "B to C"
    auto-focus true
  when
    State(name == "B", state == State.FINISHED )
    c : State(name == "C", state == State.NOTRUN )
  then
    System.out.println(c.getName() + " finished" );
    c.setState( State.FINISHED );
    kcontext.getKnowledgeRuntime().getAgenda().getAgendaGroup( "B to D" ).setFocus();
end
```

The rule **"B to C"** calls **setFocus()** on the agenda group **"B to D"**, enabling its active rules to fire, which then enables the rule **"B to D"** to fire.

Rule "B to D" in agenda group State example

```
rule "B to D"
    agenda-group "B to D"
  when
    State(name == "B", state == State.FINISHED )
    d : State(name == "D", state == State.NOTRUN )
  then
    System.out.println(d.getName() + " finished" );
    d.setState( State.FINISHED );
end
```

To execute the example, run the **org.drools.examples.state.StateExampleUsingAgendaGroups** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window (same as the salience version of the State example):

Agenda group State example output in the IDE console

```
A finished
B finished
C finished
D finished
```

Dynamic facts in the State example

Another notable concept in this State example is the use of *dynamic facts*, based on objects that implement a **PropertyChangeListener** object. In order for the decision engine to see and react to changes of fact properties, the application must notify the decision engine that changes occurred. You can configure this communication explicitly in the rules by using the **modify** statement, or implicitly by specifying that the facts implement the **PropertyChangeSupport** interface as defined by the JavaBeans specification.

This example demonstrates how to use the **PropertyChangeSupport** interface to avoid the need for explicit **modify** statements in the rules. To make use of this interface, ensure that your facts implement **PropertyChangeSupport** in the same way that the class **org.drools.example.State** implements it, and then use the following code in the DRL rule file to configure the decision engine to listen for property changes on those facts:

Declaring a dynamic fact

```
declare type State
  @propertyChangeSupport
end
```

When you use **PropertyChangeListener** objects, each setter must implement additional code for the notification. For example, the following setter for **state** is in the class **org.drools.examples**:

Setter example with PropertyChangeSupport

```
public void setState(final int newState) {
    int oldState = this.state;
    this.state = newState;
    this.changes.firePropertyChange( "state",
                                     oldState,
                                     newState );
}
```

7.4. FIBONACCI EXAMPLE DECISIONS (RECURSION AND CONFLICT RESOLUTION)

The Fibonacci example decision set demonstrates how the decision engine uses recursion to resolve execution conflicts for rules in a sequence. The example focuses on resolving conflicts through salience values that you can define in rules.

The following is an overview of the Fibonacci example:

- Name: **fibonacci**
- Main class: **org.drools.examples.fibonacci.FibonacciExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule file: **org.drools.examples.fibonacci.Fibonacci.drl** (in **src/main/resources**)
- **Objective**: Demonstrates recursion and conflict resolution through rule salience

The Fibonacci Numbers form a sequence starting with 0 and 1. The next Fibonacci number is obtained by adding the two preceding Fibonacci numbers: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765, 10946, and so on.

The Fibonacci example uses the single fact class **Fibonacci** with the following two fields:

- **sequence**
- **value**

The **sequence** field indicates the position of the object in the Fibonacci number sequence. The **value** field shows the value of that Fibonacci object for that sequence position, where **-1** indicates a value that still needs to be computed.

Fibonacci class

```
public static class Fibonacci {
    private int  sequence;
    private long value;

    public Fibonacci( final int sequence ) {
        this.sequence = sequence;
        this.value = -1;
    }

    ... setters and getters go here...
}
```

To execute the example, run the **org.drools.examples.fibonacci.FibonacciExample** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window:

Fibonacci example output in the IDE console

```
recurse for 50
recurse for 49
recurse for 48
recurse for 47
...
recurse for 5
recurse for 4
recurse for 3
recurse for 2
1 == 1
2 == 1
3 == 2
4 == 3
5 == 5
6 == 8
...
47 == 2971215073
48 == 4807526976
49 == 7778742049
50 == 12586269025
```

To achieve this behavior in Java, the example inserts a single **Fibonacci** object with a sequence field of **50**. The example then uses a recursive rule to insert the other 49 **Fibonacci** objects.

Instead of implementing the **PropertyChangeSupport** interface to use dynamic facts, this example uses the MVEL dialect **modify** keyword to enable a block setter action and notify the decision engine of changes.

Fibonacci example execution

```
ksession.insert( new Fibonacci( 50 ) );
ksession.fireAllRules();
```

This example uses the following three rules:

- **"Recurse"**
- **"Bootstrap"**
- **"Calculate"**

The rule **"Recurse"** matches each asserted **Fibonacci** object with a value of **-1**, creating and asserting a new **Fibonacci** object with a sequence of one less than the currently matched object. Each time a Fibonacci object is added while the one with a sequence field equal to **1** does not exist, the rule re-matches and fires again. The **not** conditional element is used to stop the rule matching once you have all 50 Fibonacci objects in memory. The rule also has a **salience** value because you need to have all 50 **Fibonacci** objects asserted before you execute the **"Bootstrap"** rule.

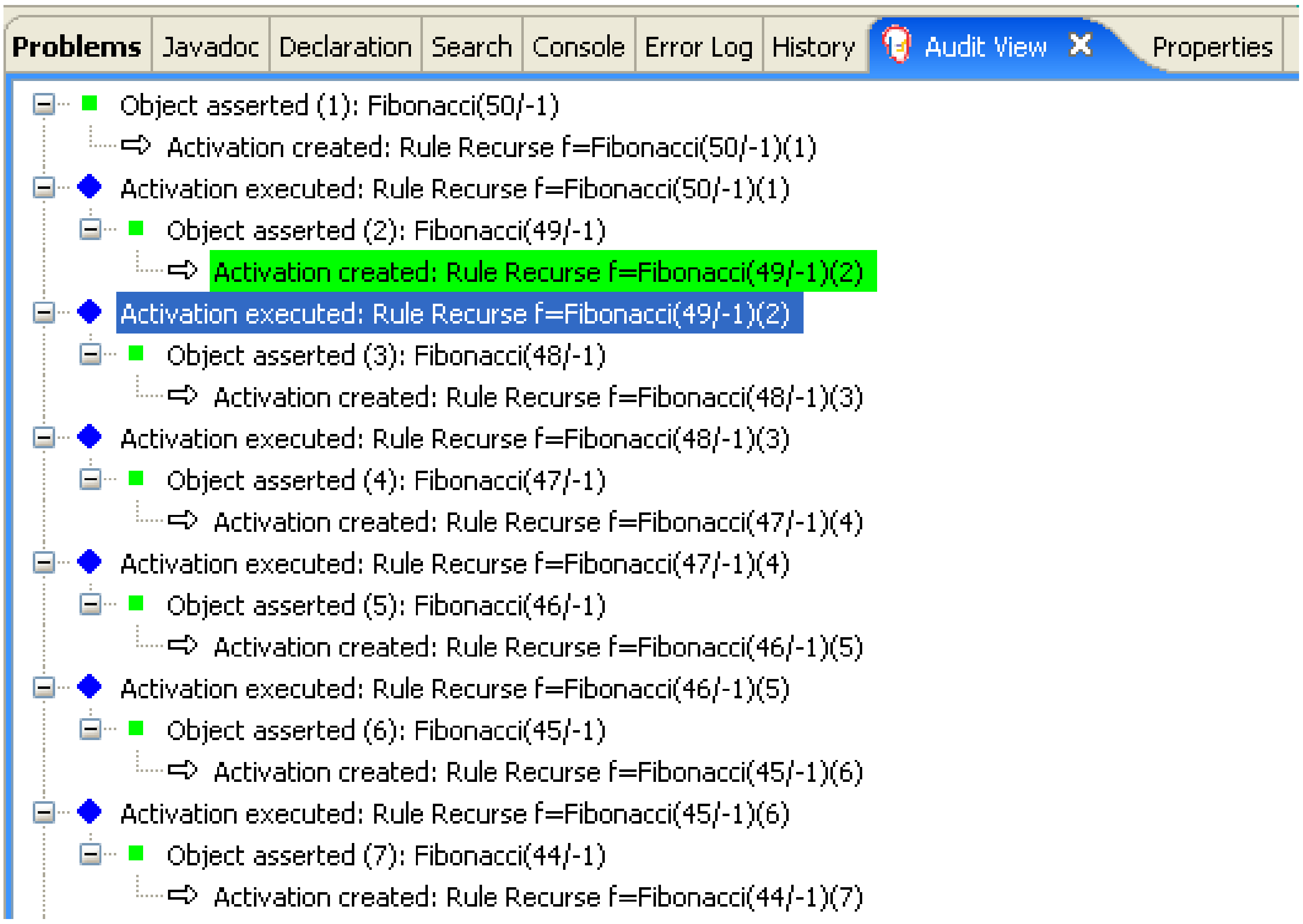
Rule "Recurse"

```
rule "Recurse"
    salience 10
  when
    f : Fibonacci ( value == -1 )
    not ( Fibonacci ( sequence == 1 ) )
  then
    insert( new Fibonacci( f.sequence - 1 ) );
    System.out.println( "recurse for " + f.sequence );
end
```

To better understand the execution flow of this example, you can load the audit log file from **target/fibonacci.log** into your IDE debug view or **Audit View**, if available (for example, in **Window → Show View** in some IDEs).

In this example, the **Audit View** shows the original assertion of the **Fibonacci** object with a **sequence** field of **50**, done from Java code. From there on, the **Audit View** shows the continual recursion of the rule, where each asserted **Fibonacci** object causes the **"Recurse"** rule to become activated and to fire again.

Figure 7.7. Rule "Recurse" in Audit View



```
Object asserted (1): Fibonacci(50/-1)
    Activation created: Rule Recurse f=Fibonacci(50/-1)(1)
Activation executed: Rule Recurse f=Fibonacci(50/-1)(1)
    Object asserted (2): Fibonacci(49/-1)
        Activation created: Rule Recurse f=Fibonacci(49/-1)(2)
Activation executed: Rule Recurse f=Fibonacci(49/-1)(2)
    Object asserted (3): Fibonacci(48/-1)
        Activation created: Rule Recurse f=Fibonacci(48/-1)(3)
Activation executed: Rule Recurse f=Fibonacci(48/-1)(3)
    Object asserted (4): Fibonacci(47/-1)
        Activation created: Rule Recurse f=Fibonacci(47/-1)(4)
Activation executed: Rule Recurse f=Fibonacci(47/-1)(4)
    Object asserted (5): Fibonacci(46/-1)
        Activation created: Rule Recurse f=Fibonacci(46/-1)(5)
Activation executed: Rule Recurse f=Fibonacci(46/-1)(5)
    Object asserted (6): Fibonacci(45/-1)
        Activation created: Rule Recurse f=Fibonacci(45/-1)(6)
Activation executed: Rule Recurse f=Fibonacci(45/-1)(6)
    Object asserted (7): Fibonacci(44/-1)
        Activation created: Rule Recurse f=Fibonacci(44/-1)(7)
```

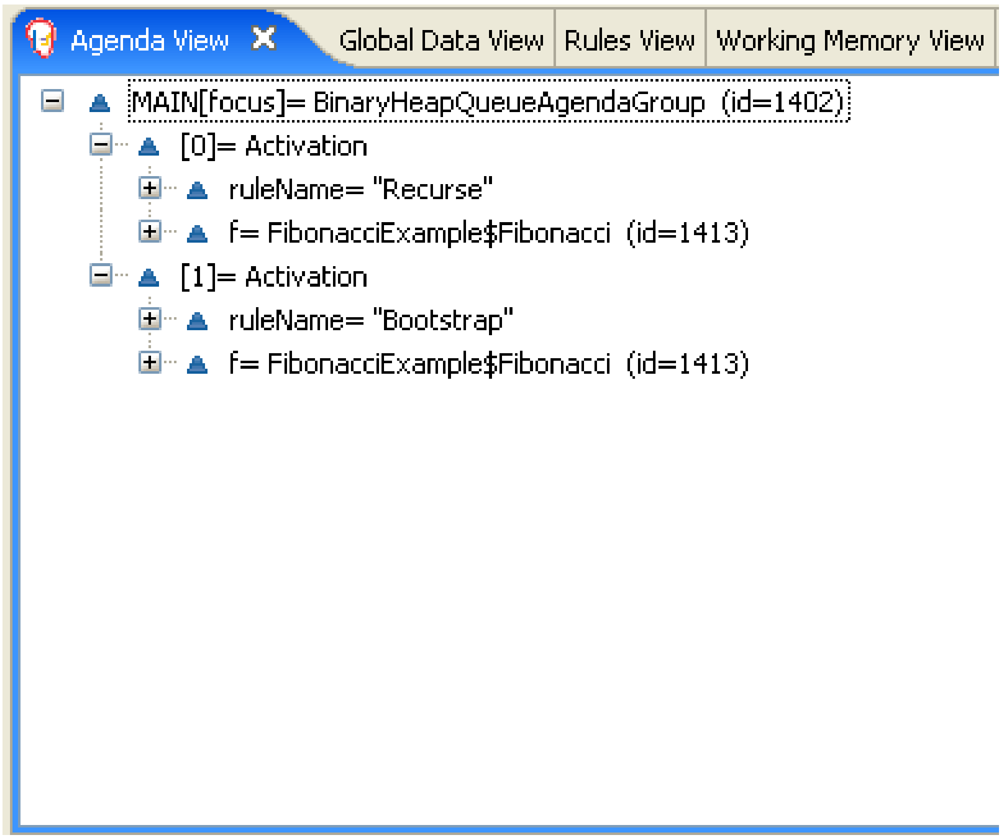
When a **Fibonacci** object with a **sequence** field of **2** is asserted, the **"Bootstrap"** rule is matched and activated along with the **"Recurse"** rule. Notice the multiple restrictions on field **sequence** that test for equality with **1** or **2**:

Rule "Bootstrap"

```
rule "Bootstrap"
  when
    f : Fibonacci( sequence == 1 || == 2, value == -1 ) // multi-restriction
  then
    modify ( f ){ value = 1 };
    System.out.println( f.sequence + " == " + f.value );
end
```

You can also use the **Agenda View** in your IDE to investigate the state of the decision engine agenda. The **"Bootstrap"** rule does not fire yet because the **"Recurse"** rule has a higher salience value.

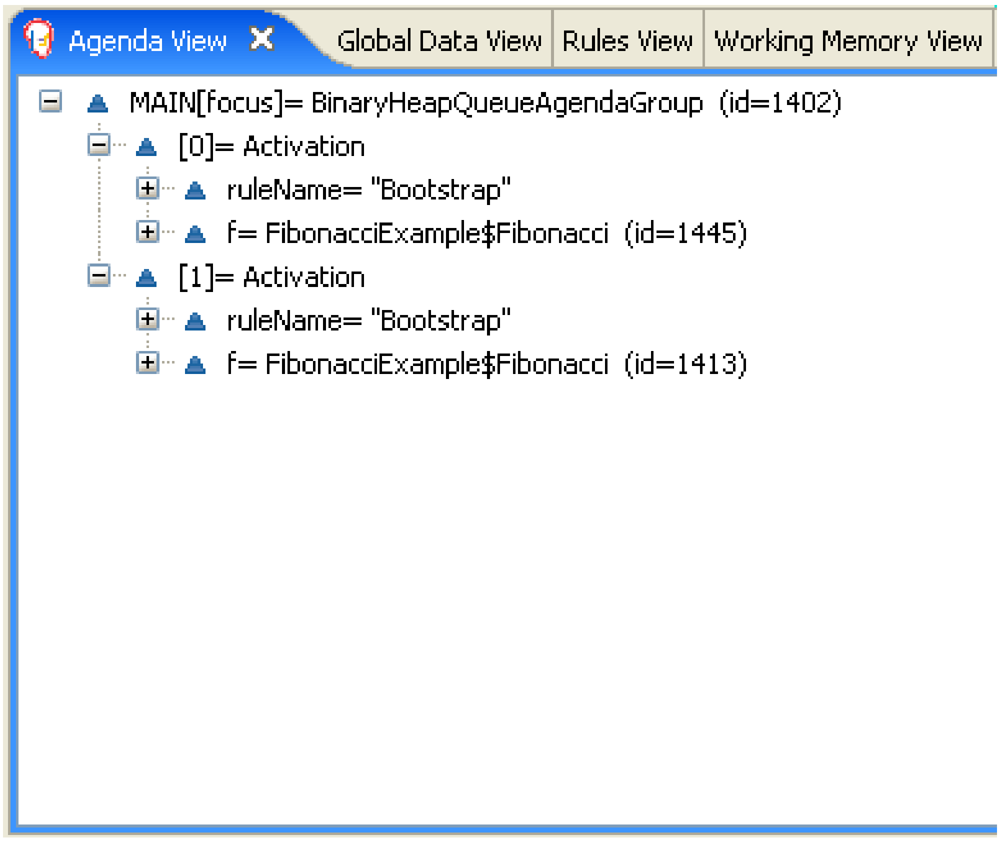
Figure 7.8. Rules "Recurse" and "Bootstrap" in Agenda View 1



```
MAIN[focus]= BinaryHeapQueueAgendaGroup  (id=1402)
    [0]= Activation
        ruleName= "Recurse"
        f= FibonacciExample$Fibonacci  (id=1413)
    [1]= Activation
        ruleName= "Bootstrap"
        f= FibonacciExample$Fibonacci  (id=1413)
```

When a **Fibonacci** object with a **sequence** of **1** is asserted, the **"Bootstrap"** rule is matched again, causing two activations for this rule. The **"Recurse"** rule does not match and activate because the **not** conditional element stops the rule matching as soon as a **Fibonacci** object with a **sequence** of **1** exists.

Figure 7.9. Rules "Recurse" and "Bootstrap" in Agenda View 2



```
MAIN[focus]= BinaryHeapQueueAgendaGroup  (id=1402)
    [0]= Activation
        ruleName= "Bootstrap"
        f= FibonacciExample$Fibonacci  (id=1445)
    [1]= Activation
        ruleName= "Bootstrap"
        f= FibonacciExample$Fibonacci  (id=1413)
```

The **"Bootstrap"** rule sets the objects with a **sequence** of **1** and **2** to a value of **1**. Now that you have two **Fibonacci** objects with values not equal to **-1**, the **"Calculate"** rule is able to match.

At this point in the example, nearly 50 **Fibonacci** objects exist in the working memory. You need to select a suitable triple to calculate each of their values in turn. If you use three Fibonacci patterns in a rule without field constraints to confine the possible cross products, the result would be 50x49x48 possible combinations, leading to about 125,000 possible rule firings, most of them incorrect.

The **"Calculate"** rule uses field constraints to evaluate the three Fibonacci patterns in the correct order. This technique is called *cross-product matching*.

The first pattern finds any **Fibonacci** object with a value **!= -1** and binds both the pattern and the field. The second **Fibonacci** object does the same thing, but adds an additional field constraint to ensure that its sequence is greater by one than the **Fibonacci** object bound to **f1**. When this rule fires for the first time, you know that only sequences **1** and **2** have values of **1**, and the two constraints ensure that **f1** references sequence **1** and that **f2** references sequence **2**.

The final pattern finds the **Fibonacci** object with a value equal to **-1** and with a sequence one greater than **f2**.

At this point in the example, three **Fibonacci** objects are correctly selected from the available cross products, and you can calculate the value for the third **Fibonacci** object that is bound to **f3**.

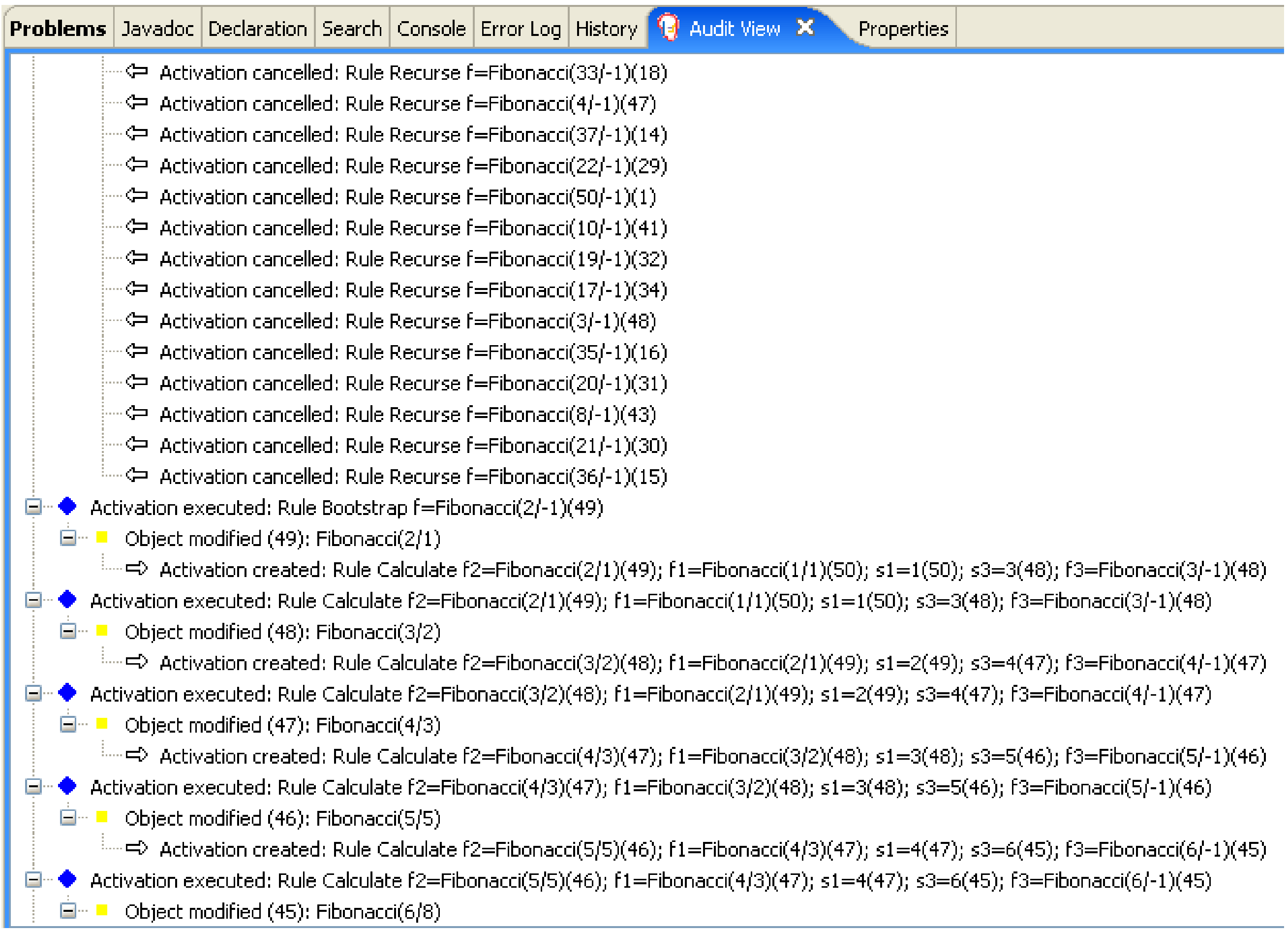
Rule "Calculate"

```
rule "Calculate"
  when
    // Bind f1 and s1.
    f1 : Fibonacci( s1 : sequence, value != -1 )
    // Bind f2 and v2, refer to bound variable s1.
    f2 : Fibonacci( sequence == (s1 + 1), v2 : value != -1 )
    // Bind f3 and s3, alternative reference of f2.sequence.
    f3 : Fibonacci( s3 : sequence == (f2.sequence + 1 ), value == -1 )
  then
    // Note the various referencing techniques.
    modify ( f3 ) { value = f1.value + v2 };
    System.out.println( s3 + " == " + f3.value );
end
```

The **modify** statement updates the value of the **Fibonacci** object bound to **f3**. This means that you now have another new **Fibonacci** object with a value not equal to **-1**, which allows the **"Calculate"** rule to re-match and calculate the next Fibonacci number.

The debug view or **Audit View** of your IDE shows how the firing of the last **"Bootstrap"** rule modifies the **Fibonacci** object, enabling the **"Calculate"** rule to match, which then modifies another **Fibonacci** object that enables the **"Calculate"** rule to match again. This process continues until the value is set for all **Fibonacci** objects.

Figure 7.10. Rules in Audit View



```
Activation cancelled: Rule Recurse f=Fibonacci(33/-1)(18)
Activation cancelled: Rule Recurse f=Fibonacci(4/-1)(47)
Activation cancelled: Rule Recurse f=Fibonacci(37/-1)(14)
Activation cancelled: Rule Recurse f=Fibonacci(22/-1)(29)
Activation cancelled: Rule Recurse f=Fibonacci(50/-1)(1)
Activation cancelled: Rule Recurse f=Fibonacci(10/-1)(41)
Activation cancelled: Rule Recurse f=Fibonacci(19/-1)(32)
Activation cancelled: Rule Recurse f=Fibonacci(17/-1)(34)
Activation cancelled: Rule Recurse f=Fibonacci(3/-1)(48)
Activation cancelled: Rule Recurse f=Fibonacci(35/-1)(16)
Activation cancelled: Rule Recurse f=Fibonacci(20/-1)(31)
Activation cancelled: Rule Recurse f=Fibonacci(8/-1)(43)
Activation cancelled: Rule Recurse f=Fibonacci(21/-1)(30)
Activation cancelled: Rule Recurse f=Fibonacci(36/-1)(15)
Activation executed: Rule Bootstrap f=Fibonacci(2/-1)(49)
  Object modified (49): Fibonacci(2/1)
    Activation created: Rule Calculate f2=Fibonacci(2/1)(49); f1=Fibonacci(1/1)(50); s1=1(50); s3=3(48); f3=Fibonacci(3/-1)(48)
Activation executed: Rule Calculate f2=Fibonacci(2/1)(49); f1=Fibonacci(1/1)(50); s1=1(50); s3=3(48); f3=Fibonacci(3/-1)(48)
  Object modified (48): Fibonacci(3/2)
    Activation created: Rule Calculate f2=Fibonacci(3/2)(48); f1=Fibonacci(2/1)(49); s1=2(49); s3=4(47); f3=Fibonacci(4/-1)(47)
Activation executed: Rule Calculate f2=Fibonacci(3/2)(48); f1=Fibonacci(2/1)(49); s1=2(49); s3=4(47); f3=Fibonacci(4/-1)(47)
  Object modified (47): Fibonacci(4/3)
    Activation created: Rule Calculate f2=Fibonacci(4/3)(47); f1=Fibonacci(3/2)(48); s1=3(48); s3=5(46); f3=Fibonacci(5/-1)(46)
Activation executed: Rule Calculate f2=Fibonacci(4/3)(47); f1=Fibonacci(3/2)(48); s1=3(48); s3=5(46); f3=Fibonacci(5/-1)(46)
  Object modified (46): Fibonacci(5/5)
    Activation created: Rule Calculate f2=Fibonacci(5/5)(46); f1=Fibonacci(4/3)(47); s1=4(47); s3=6(45); f3=Fibonacci(6/-1)(45)
Activation executed: Rule Calculate f2=Fibonacci(5/5)(46); f1=Fibonacci(4/3)(47); s1=4(47); s3=6(45); f3=Fibonacci(6/-1)(45)
  Object modified (45): Fibonacci(6/8)
```

7.5. PRICING EXAMPLE DECISIONS (DECISION TABLES)

The Pricing example decision set demonstrates how to use a spreadsheet decision table for calculating the retail cost of an insurance policy in tabular format instead of directly in a DRL file.

The following is an overview of the Pricing example:

- Name: **decisiontable**
- Main class: **org.drools.examples.decisiontable.PricingRuleDTExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule file: **org.drools.examples.decisiontable.ExamplePolicyPricing.xls** (in **src/main/resources**)
- **Objective**: Demonstrates use of spreadsheet decision tables to define rules

Spreadsheet decision tables are XLS or XLSX spreadsheets that contain business rules defined in a tabular format. You can include spreadsheet decision tables with standalone Red Hat Decision Manager projects or upload them to projects in Business Central. Each row in a decision table is a rule, and each column is a condition, an action, or another rule attribute. After you create and upload your decision tables into your Red Hat Decision Manager project, the rules you defined are compiled into Drools Rule Language (DRL) rules as with all other rule assets.

The purpose of the Pricing example is to provide a set of business rules to calculate the base price and a discount for a car driver applying for a specific type of insurance policy. The driver's age and history and the policy type all contribute to calculate the basic premium, and additional rules calculate potential discounts for which the driver might be eligible.

To execute the example, run the **org.drools.examples.decisiontable.PricingRuleDTExample** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window:

```
Cheapest possible
BASE PRICE IS: 120
DISCOUNT IS: 20
```

The code to execute the example follows the typical execution pattern: the rules are loaded, the facts are inserted, and a stateless KIE session is created. The difference in this example is that the rules are defined in an **ExamplePolicyPricing.xls** file instead of a DRL file or other source. The spreadsheet file is loaded into the decision engine using templates and DRL rules.

Spreadsheet decision table setup

The **ExamplePolicyPricing.xls** spreadsheet contains two decision tables in the first tab:

- **Base pricing rules**
- **Promotional discount rules**

As the example spreadsheet demonstrates, you can use only the first tab of a spreadsheet to create decision tables, but multiple tables can be within a single tab. Decision tables do not necessarily follow top-down logic, but are more of a means to capture data resulting in rules. The evaluation of the rules is not necessarily in the given order, because all of the normal mechanics of the decision engine still apply. This is why you can have multiple decision tables in the same tab of a spreadsheet.

The decision tables are executed through the corresponding rule template files **BasePricing.drt** and **PromotionalPricing.drt**. These template files reference the decision tables through their template parameter and directly reference the various headers for the conditions and actions in the decision tables.

BasePricing.drt rule template file

```
template header
age[]
profile
priorClaims
policyType
base
reason

package org.drools.examples.decisiontable;

template "Pricing bracket"
age
policyType
base

rule "Pricing bracket_@{row.rowNumber}"
  when
```

```
    Driver(age >= @{age0}, age <= @{age1}
        , priorClaims == "@{priorClaims}"
        , locationRiskProfile == "@{profile}"
    )
    policy: Policy(type == "@{policyType}")
  then
    policy.setBasePrice(@{base});
    System.out.println("@{reason}");
end
end template
```

PromotionalPricing.drt rule template file

```
template header
age[]
priorClaims
policyType
discount

package org.drools.examples.decisiontable;

template "discounts"
age
priorClaims
policyType
discount

rule "Discounts_@{row.rowNumber}"
  when
    Driver(age >= @{age0}, age <= @{age1}, priorClaims == "@{priorClaims}")
    policy: Policy(type == "@{policyType}")
  then
    policy.applyDiscount(@{discount});
end
end template
```

The rules are executed through the **kmodule.xml** reference of the KIE Session **DTableWithTemplateKB**, which specifically mentions the **ExamplePolicyPricing.xls** spreadsheet and is required for successful execution of the rules. This execution method enables you to execute the rules as a standalone unit (as in this example) or to include the rules in a packaged knowledge JAR (KJAR) file, so that the spreadsheet is packaged along with the rules for execution.

The following section of the **kmodule.xml** file is required for the execution of the rules and spreadsheet to work successfully:

```
    <kbase name="DecisionTableKB" packages="org.drools.examples.decisiontable">
        <ksession name="DecisionTableKS" type="stateless"/>
    </kbase>

    <kbase name="DTableWithTemplateKB" packages="org.drools.examples.decisiontable-template">
        <ruleTemplate dtable="org/drools/examples/decisiontable-
template/ExamplePolicyPricingTemplateData.xls"
                      template="org/drools/examples/decisiontable-template/BasePricing.drt"
                      row="3" col="3"/>
        <ruleTemplate dtable="org/drools/examples/decisiontable-
```

```
template/ExamplePolicyPricingTemplateData.xls"
                 template="org/drools/examples/decisiontable-template/PromotionalPricing.drt"
                 row="18" col="3"/>
      <ksession name="DTableWithTemplateKS"/>
   </kbase>
```

As an alternative to executing the decision tables using rule template files, you can use the **DecisionTableConfiguration** object and specify an input spreadsheet as the input type, such as **DecisionTableInputType.xls**:

```
DecisionTableConfiguration dtableconfiguration =
   KnowledgeBuilderFactory.newDecisionTableConfiguration();
      dtableconfiguration.setInputType( DecisionTableInputType.XLS );

      KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();

      Resource xlsRes = ResourceFactory.newClassPathResource( "ExamplePolicyPricing.xls",
                                                            getClass() );
      kbuilder.add( xlsRes,
                 ResourceType.DTABLE,
                 dtableconfiguration );
```

The Pricing example uses two fact types:

- **Driver**
- **Policy**.

The example sets the default values for both facts in their respective Java classes **Driver.java** and **Policy.java**. The **Driver** is 30 years old, has had no prior claims, and currently has a risk profile of **LOW**. The **Policy** that the driver is applying for is **COMPREHENSIVE**.

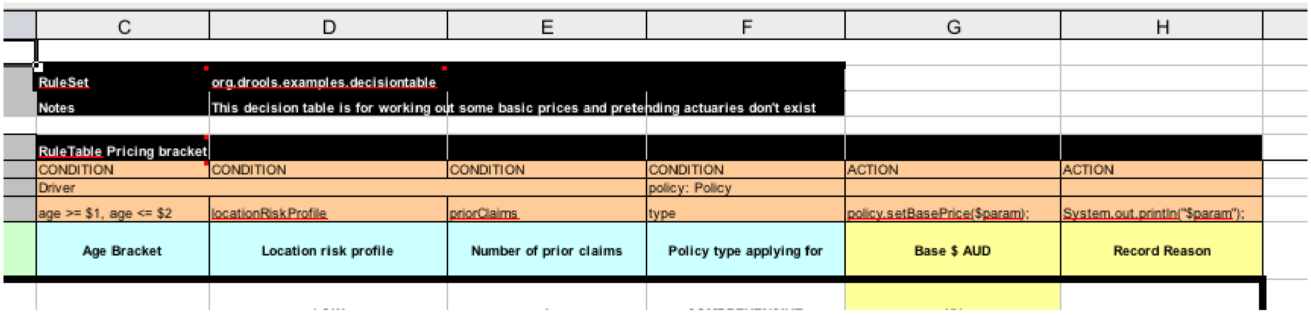
In any decision table, each row is considered a different rule and each column is a condition or an action. Each row is evaluated in a decision table unless the agenda is cleared upon execution.

Decision table spreadsheets (XLS or XLSX) require two key areas that define rule data:

- A **RuleSet** area
- A **RuleTable** area

The **RuleSet** area of the spreadsheet defines elements that you want to apply globally to all rules in the same package (not only the spreadsheet), such as a rule set name or universal rule attributes. The **RuleTable** area defines the actual rules (rows) and the conditions, actions, and other rule attributes (columns) that constitute that rule table within the specified rule set. A decision table spreadsheet can contain multiple **RuleTable** areas, but only one **RuleSet** area.

Figure 7.11. Decision table configuration



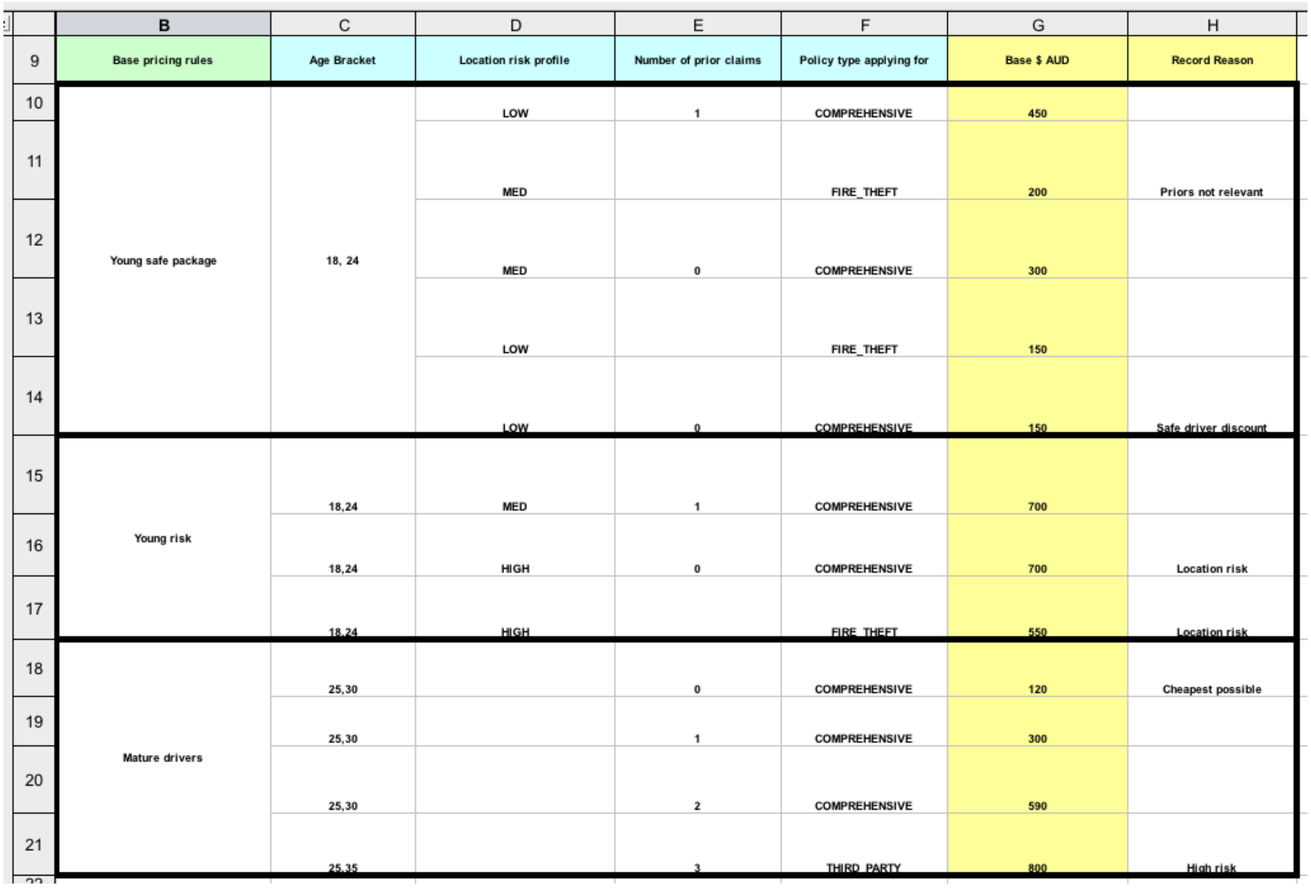
C	D	E	F	G	H
RuleSet	org.drools.examples.decisiontable				
Notes	This decision table is for working out some basic prices and pretending actuaries don't exist				
RuleTable Pricing bracket					
CONDITION	CONDITION	CONDITION	CONDITION	ACTION	ACTION
Driver			policy: Policy		
age >= $1, age <= $2	locationRiskProfile	priorClaims	type	policy.setBasePrice($param);	System.out.println("$param");
Age Bracket	Location risk profile	Number of prior claims	Policy type applying for	Base $ AUD	Record Reason

The **RuleTable** area also defines the objects to which the rule attributes apply, in this case **Driver** and **Policy**, followed by constraints on the objects. For example, the **Driver** object constraint that defines the **Age Bracket** column is **age >= $1, age <= $2**, where the comma-separated range is defined in the table column values, such as **18,24**.

Base pricing rules

The **Base pricing rules** decision table in the Pricing example evaluates the age, risk profile, number of claims, and policy type of the driver and produces the base price of the policy based on these conditions.

Figure 7.12. Base price calculation



	B	C	D	E	F	G	H
9	Base pricing rules	Age Bracket	Location risk profile	Number of prior claims	Policy type applying for	Base $ AUD	Record Reason
10	Young safe package	18, 24	LOW	1	COMPREHENSIVE	450	
11			MED		FIRE_THEFT	200	Priors not relevant
12			MED	0	COMPREHENSIVE	300	
13			LOW		FIRE_THEFT	150	
14			LOW	0	COMPREHENSIVE	150	Safe driver discount
15	Young risk	18,24	MED	1	COMPREHENSIVE	700	
16		18,24	HIGH	0	COMPREHENSIVE	700	Location risk
17		18,24	HIGH		FIRE_THEFT	550	Location risk
18	Mature drivers	25,30		0	COMPREHENSIVE	120	Cheapest possible
19		25,30		1	COMPREHENSIVE	300	
20		25,30		2	COMPREHENSIVE	590	
21		25,35		3	THIRD_PARTY	800	High risk

The **Driver** attributes are defined in the following table columns:

- **Age Bracket**: The age bracket has a definition for the condition **age >=$1, age <=$2**, which defines the condition boundaries for the driver's age. This condition column highlights the use of **$1 and $2**, which is comma delimited in the spreadsheet. You can write these values as **18,24** or **18, 24** and both formats work in the execution of the business rules.

- **Location risk profile**: The risk profile is a string that the example program passes always as **LOW** but can be changed to reflect **MED** or **HIGH**.
- **Number of prior claims**: The number of claims is defined as an integer that the condition column must exactly equal to trigger the action. The value is not a range, only exact matches.

The **Policy** of the decision table is used in both the conditions and the actions of the rule and has attributes defined in the following table columns:

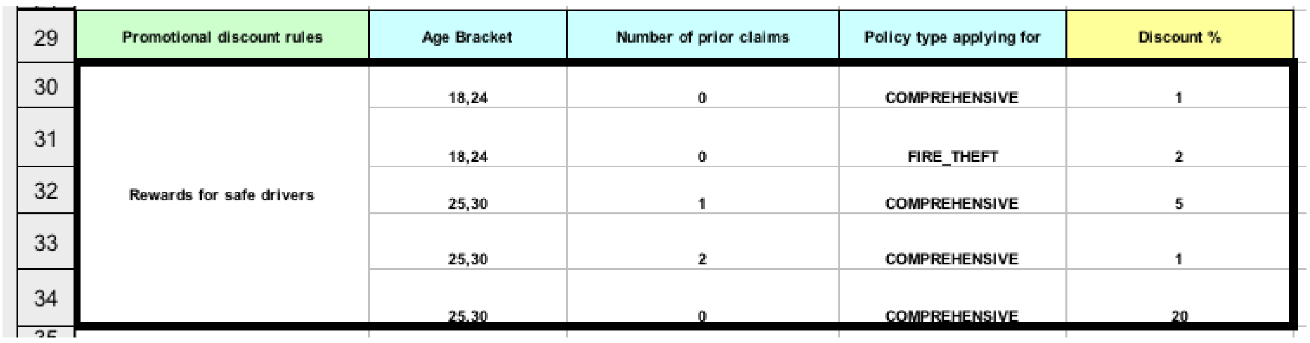
- **Policy type applying for**: The policy type is a condition that is passed as a string that defines the type of coverage: **COMPREHENSIVE**, **FIRE_THEFT**, or **THIRD_PARTY**.
- **Base $ AUD**: The **basePrice** is defined as an **ACTION** that sets the price through the constraint **policy.setBasePrice($param);** based on the spreadsheet cells corresponding to this value. When you execute the corresponding DRL rule for this decision table, the **then** portion of the rule executes this action statement on the true conditions matching the facts and sets the base price to the corresponding value.
- **Record Reason**: When the rule successfully executes, this action generates an output message to the **System.out** console reflecting which rule fired. This is later captured in the application and printed.

The example also uses the first column on the left to categorize rules. This column is for annotation only and has no affect on rule execution.

Promotional discount rules

The **Promotional discount rules** decision table in the Pricing example evaluates the age, number of prior claims, and policy type of the driver to generate a potential discount on the price of the insurance policy.

Figure 7.13. Discount calculation



29	Promotional discount rules	Age Bracket	Number of prior claims	Policy type applying for	Discount %
30	Rewards for safe drivers	18,24	0	COMPREHENSIVE	1
31		18,24	0	FIRE_THEFT	2
32		25,30	1	COMPREHENSIVE	5
33		25,30	2	COMPREHENSIVE	1
34		25,30	0	COMPREHENSIVE	20

This decision table contains the conditions for the discount for which the driver might be eligible. Similar to the base price calculation, this table evaluates the **Age**, **Number of prior claims** of the driver, and the **Policy type applying for** to determine a **Discount %** rate to be applied. For example, if the driver is 30 years old, has no prior claims, and is applying for a **COMPREHENSIVE** policy, the driver is given a discount of **20** percent.

7.6. PET STORE EXAMPLE DECISIONS (AGENDA GROUPS, GLOBAL VARIABLES, CALLBACKS, AND GUI INTEGRATION)

The Pet Store example decision set demonstrates how to use agenda groups and global variables in rules and how to integrate Red Hat Decision Manager rules with a graphical user interface (GUI), in this case a Swing-based desktop application. The example also demonstrates how to use callbacks to interact with a running decision engine to update the GUI based on changes in the working memory at run time.

The following is an overview of the Pet Store example:

- Name: **petstore**
- Main class: **org.drools.examples.petstore.PetStoreExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule file: **org.drools.examples.petstore.PetStore.drl** (in **src/main/resources**)
- **Objective**: Demonstrates rule agenda groups, global variables, callbacks, and GUI integration

In the Pet Store example, the sample **PetStoreExample.java** class defines the following principal classes (in addition to several classes to handle Swing events):

- **Petstore** contains the **main()** method.
- **PetStoreUI** is responsible for creating and displaying the Swing-based GUI. This class contains several smaller classes, mainly for responding to various GUI events, such as user mouse clicks.
- **TableModel** holds the table data. This class is essentially a JavaBean that extends the Swing class **AbstractTableModel**.
- **CheckoutCallback** enables the GUI to interact with the rules.
- **Ordershow** keeps the items that you want to buy.
- **Purchase** stores details of the order and the products that you are buying.
- **Product** is a JavaBean containing details of the product available for purchase and its price.

Much of the Java code in this example is either plain JavaBean or Swing based. For more information about Swing components, see the Java tutorial on Creating a GUI with JFC/Swing.

Rule execution behavior in the Pet Store example

Unlike other example decision sets where the facts are asserted and fired immediately, the Pet Store example does not execute the rules until more facts are gathered based on user interaction. The example executes rules through a **PetStoreUI** object, created by a constructor, that accepts the **Vector** object **stock** for collecting the products. The example then uses an instance of the **CheckoutCallback** class containing the rule base that was previously loaded.

Pet Store KIE container and fact execution setup

```
// KieServices is the factory for all KIE services.
KieServices ks = KieServices.Factory.get();

// Create a KIE container on the class path.
KieContainer kc = ks.getKieClasspathContainer();

// Create the stock.
Vector<Product> stock = new Vector<Product>();
stock.add( new Product( "Gold Fish", 5 ) );
stock.add( new Product( "Fish Tank", 25 ) );
stock.add( new Product( "Fish Food", 2 ) );
```

```
// A callback is responsible for populating the working memory and for firing all rules.
PetStoreUI ui = new PetStoreUI( stock,
                                new CheckoutCallback( kc ) );
ui.createAndShowGUI();
```

The Java code that fires the rules is in the **CheckoutCallBack.checkout()** method. This method is triggered when the user clicks **Checkout** in the UI.

Rule execution from CheckoutCallBack.checkout()

```
public String checkout(JFrame frame, List<Product> items) {
    Order order = new Order();

    // Iterate through list and add to cart.
    for ( Product p: items ) {
        order.addItem( new Purchase( order, p ) );
    }

    // Add the JFrame to the ApplicationData to allow for user interaction.

    // From the KIE container, a KIE session is created based on
    // its definition and configuration in the META-INF/kmodule.xml file.
    KieSession ksession = kcontainer.newKieSession("PetStoreKS");

    ksession.setGlobal( "frame", frame );
    ksession.setGlobal( "textArea", this.output );

    ksession.insert( new Product( "Gold Fish", 5 ) );
    ksession.insert( new Product( "Fish Tank", 25 ) );
    ksession.insert( new Product( "Fish Food", 2 ) );

    ksession.insert( new Product( "Fish Food Sample", 0 ) );

    ksession.insert( order );

    // Execute rules.
    ksession.fireAllRules();

    // Return the state of the cart
    return order.toString();
}
```

The example code passes two elements into the **CheckoutCallBack.checkout()** method. One element is the handle for the **JFrame** Swing component surrounding the output text frame, found at the bottom of the GUI. The second element is a list of order items, which comes from the **TableModel** that stores the information from the **Table** area at the upper-right section of the GUI.

The **for** loop transforms the list of order items coming from the GUI into the **Order** JavaBean, also contained in the file **PetStoreExample.java**.

In this case, the rule is firing in a stateless KIE session because all of the data is stored in Swing components and is not executed until the user clicks **Checkout** in the UI. Each time the user clicks **Checkout**, the content of the list is moved from the Swing **TableModel** into the KIE session working memory and is then executed with the **ksession.fireAllRules()** method.

Within this code, there are nine calls to **KieSession**. The first of these creates a new **KieSession** from the **KieContainer** (the example passed in this **KieContainer** from the **CheckoutCallBack** class in the **main()** method). The next two calls pass in the two objects that hold the global variables in the rules: the Swing text area and the Swing frame used for writing messages. More inserts put information on products into the **KieSession**, as well as the order list. The final call is the standard **fireAllRules()**.

Pet Store rule file imports, global variables, and Java functions

The **PetStore.drl** file contains the standard package and import statements to make various Java classes available to the rules. The rule file also includes *global variables* to be used within the rules, defined as **frame** and **textArea**. The global variables hold references to the Swing components **JFrame** and **JTextArea** components that were previously passed on by the Java code that called the **setGlobal()** method. Unlike standard variables in rules, which expire as soon as the rule has fired, global variables retain their value for the lifetime of the KIE session. This means the contents of these global variables are available for evaluation on all subsequent rules.

PetStore.drl package, imports, and global variables

```
package org.drools.examples;

import org.kie.api.runtime.KieRuntime;
import org.drools.examples.petstore.PetStoreExample.Order;
import org.drools.examples.petstore.PetStoreExample.Purchase;
import org.drools.examples.petstore.PetStoreExample.Product;
import java.util.ArrayList;
import javax.swing.JOptionPane;

import javax.swing.JFrame;

global JFrame frame
global javax.swing.JTextArea textArea
```

The **PetStore.drl** file also contains two functions that the rules in the file use:

PetStore.drl Java functions

```
function void doCheckout(JFrame frame, KieRuntime krt) {
        Object[] options = {"Yes",
                            "No"};

        int n = JOptionPane.showOptionDialog(frame,
                                             "Would you like to checkout?",
                                             "",
                                             JOptionPane.YES_NO_OPTION,
                                             JOptionPane.QUESTION_MESSAGE,
                                             null,
                                             options,
                                             options[0]);

       if (n == 0) {
            krt.getAgenda().getAgendaGroup( "checkout" ).setFocus();
       }
}

function boolean requireTank(JFrame frame, KieRuntime krt, Order order, Product fishTank, int total)
{
        Object[] options = {"Yes",
                            "No"};

        int n = JOptionPane.showOptionDialog(frame,
                                             "Would you like to buy a tank for your " + total + " fish?",
                                             "Purchase Suggestion",
                                             JOptionPane.YES_NO_OPTION,
                                             JOptionPane.QUESTION_MESSAGE,
                                             null,
                                             options,
                                             options[0]);

       System.out.print( "SUGGESTION: Would you like to buy a tank for your "
                         + total + " fish? - " );

       if (n == 0) {
             Purchase purchase = new Purchase( order, fishTank );
             krt.insert( purchase );
             order.addItem( purchase );
             System.out.println( "Yes" );
       } else {
            System.out.println( "No" );
       }
       return true;
}
```

The two functions perform the following actions:

- **doCheckout()** displays a dialog that asks the user if she or he wants to check out. If the user does, the focus is set to the **checkout** agenda group, enabling rules in that group to (potentially) fire.
- **requireTank()** displays a dialog that asks the user if she or he wants to buy a fish tank. If the user does, a new fish tank **Product** is added to the order list in the working memory.

NOTE

For this example, all rules and functions are within the same rule file for efficiency. In a production environment, you typically separate the rules and functions in different files or build a static Java method and import the files using the import function, such as **import function my.package.name.hello**.

Pet Store rules with agenda groups

Most of the rules in the Pet Store example use agenda groups to control rule execution. Agenda groups allow you to partition the decision engine agenda to provide more execution control over groups of rules. By default, all rules are in the agenda group **MAIN**. You can use the **agenda-group** attribute to specify a different agenda group for the rule.

Initially, a working memory has its focus on the agenda group **MAIN**. Rules in an agenda group only fire when the group receives the focus. You can set the focus either by using the method **setFocus()** or the rule attribute **auto-focus**. The **auto-focus** attribute enables the rule to be given a focus automatically for its agenda group when the rule is matched and activated.

The Pet Store example uses the following agenda groups for rules:

- **"init"**
- **"evaluate"**
- **"show items"**
- **"checkout"**

For example, the sample rule **"Explode Cart"** uses the **"init"** agenda group to ensure that it has the option to fire and insert shopping cart items into the KIE session working memory:

Rule "Explode Cart"

```
// Insert each item in the shopping cart into the working memory.
rule "Explode Cart"
    agenda-group "init"
    auto-focus true
    salience 10
    dialect "java"
  when
    $order : Order( grossTotal == -1 )
    $item : Purchase() from $order.items
  then
    insert( $item );
    kcontext.getKnowledgeRuntime().getAgenda().getAgendaGroup( "show items" ).setFocus();
    kcontext.getKnowledgeRuntime().getAgenda().getAgendaGroup( "evaluate" ).setFocus();
end
```

This rule matches against all orders that do not yet have their **grossTotal** calculated. The execution loops for each purchase item in that order.

The rule uses the following features related to its agenda group:

- **agenda-group "init"** defines the name of the agenda group. In this case, only one rule is in the group. However, neither the Java code nor a rule consequence sets the focus to this group, and therefore it relies on the **auto-focus** attribute for its chance to fire.
- **auto-focus true** ensures that this rule, while being the only rule in the agenda group, gets a chance to fire when **fireAllRules()** is called from the Java code.
- **kcontext….setFocus()** sets the focus to the **"show items"** and **"evaluate"** agenda groups, enabling their rules to fire. In practice, you loop through all items in the order, insert them into memory, and then fire the other rules after each insertion.

The **"show items"** agenda group contains only one rule, **"Show Items"**. For each purchase in the order currently in the KIE session working memory, the rule logs details to the text area at the bottom of the GUI, based on the **textArea** variable defined in the rule file.

Rule "Show Items"

```
rule "Show Items"
    agenda-group "show items"
    dialect "mvel"
  when
    $order : Order( )
    $p : Purchase( order == $order )
  then
   textArea.append( $p.product + "\n");
end
```

The **"evaluate"** agenda group also gains focus from the **"Explode Cart"** rule. This agenda group contains two rules, **"Free Fish Food Sample"** and **"Suggest Tank"**, which are executed in that order.

Rule "Free Fish Food Sample"

```
// Free fish food sample when users buy a goldfish if they did not already buy
// fish food and do not already have a fish food sample.
rule "Free Fish Food Sample"
    agenda-group "evaluate" (1)
    dialect "mvel"
  when
    $order : Order()
    not ( $p : Product( name == "Fish Food") && Purchase( product == $p ) ) (2)
    not ( $p : Product( name == "Fish Food Sample") && Purchase( product == $p ) ) (3)
    exists ( $p : Product( name == "Gold Fish") && Purchase( product == $p ) ) (4)
    $fishFoodSample : Product( name == "Fish Food Sample" );
  then
    System.out.println( "Adding free Fish Food Sample to cart" );
    purchase = new Purchase($order, $fishFoodSample);
    insert( purchase );
    $order.addItem( purchase );
end
```

The rule **"Free Fish Food Sample"** fires only if all of the following conditions are true:

1. The agenda group **"evaluate"** is being evaluated in the rules execution.
2. User does not already have fish food.
3. User does not already have a free fish food sample.
4. User has a goldfish in the order.

If the order facts meet all of these requirements, then a new product is created (Fish Food Sample) and is added to the order in working memory.

Rule "Suggest Tank"

```
// Suggest a fish tank if users buy more than five goldfish and
// do not already have a tank.
rule "Suggest Tank"
    agenda-group "evaluate"
    dialect "java"
  when
    $order : Order()
    not ( $p : Product( name == "Fish Tank") && Purchase( product == $p ) ) (1)
    ArrayList( $total : size > 5 ) from collect( Purchase( product.name == "Gold Fish" ) ) (2)
    $fishTank : Product( name == "Fish Tank" )
  then
    requireTank(frame, kcontext.getKieRuntime(), $order, $fishTank, $total);
end
```

The rule **"Suggest Tank"** fires only if the following conditions are true:

1. User does not have a fish tank in the order.
2. User has more than five fish in the order.

When the rule fires, it calls the **requireTank()** function defined in the rule file. This function displays a dialog that asks the user if she or he wants to buy a fish tank. If the user does, a new fish tank **Product** is added to the order list in the working memory. When the rule calls the **requireTank()** function, the rule passes the **frame** global variable so that the function has a handle for the Swing GUI.

The **"do checkout"** rule in the Pet Store example has no agenda group and no **when** conditions, so the rule is always executed and considered part of the default **MAIN** agenda group.

Rule "do checkout"

```
rule "do checkout"
    dialect "java"
  when
  then
    doCheckout(frame, kcontext.getKieRuntime());
end
```

When the rule fires, it calls the **doCheckout()** function defined in the rule file. This function displays a dialog that asks the user if she or he wants to check out. If the user does, the focus is set to the **checkout** agenda group, enabling rules in that group to (potentially) fire. When the rule calls the **doCheckout()** function, the rule passes the **frame** global variable so that the function has a handle for the Swing GUI.

NOTE

This example also demonstrates a troubleshooting technique if results are not executing as you expect: You can remove the conditions from the **when** statement of a rule and test the action in the **then** statement to verify that the action is performed correctly.

The **"checkout"** agenda group contains three rules for processing the order checkout and applying any discounts: **"Gross Total"**, **"Apply 5% Discount"**, and **"Apply 10% Discount"**.

Rules "Gross Total", "Apply 5% Discount", and "Apply 10% Discount"

```
rule "Gross Total"
    agenda-group "checkout"
    dialect "mvel"
  when
    $order : Order( grossTotal == -1)
    Number( total : doubleValue ) from accumulate( Purchase( $price : product.price ),
                                                   sum( $price ) )
  then
    modify( $order ) { grossTotal = total }
    textArea.append( "\ngross total=" + total + "\n" );
```

```
end

rule "Apply 5% Discount"
    agenda-group "checkout"
    dialect "mvel"
  when
    $order : Order( grossTotal >= 10 && < 20 )
  then
    $order.discountedTotal = $order.grossTotal * 0.95;
    textArea.append( "discountedTotal total=" + $order.discountedTotal + "\n" );
end

rule "Apply 10% Discount"
    agenda-group "checkout"
    dialect "mvel"
  when
    $order : Order( grossTotal >= 20 )
  then
    $order.discountedTotal = $order.grossTotal * 0.90;
    textArea.append( "discountedTotal total=" + $order.discountedTotal + "\n" );
end
```

If the user has not already calculated the gross total, the **Gross Total** accumulates the product prices into a total, puts this total into the KIE session, and displays it through the Swing **JTextArea** using the **textArea** global variable.

If the gross total is between **10** and **20** (currency units), the **"Apply 5% Discount"** rule calculates the discounted total, adds it to the KIE session, and displays it in the text area.

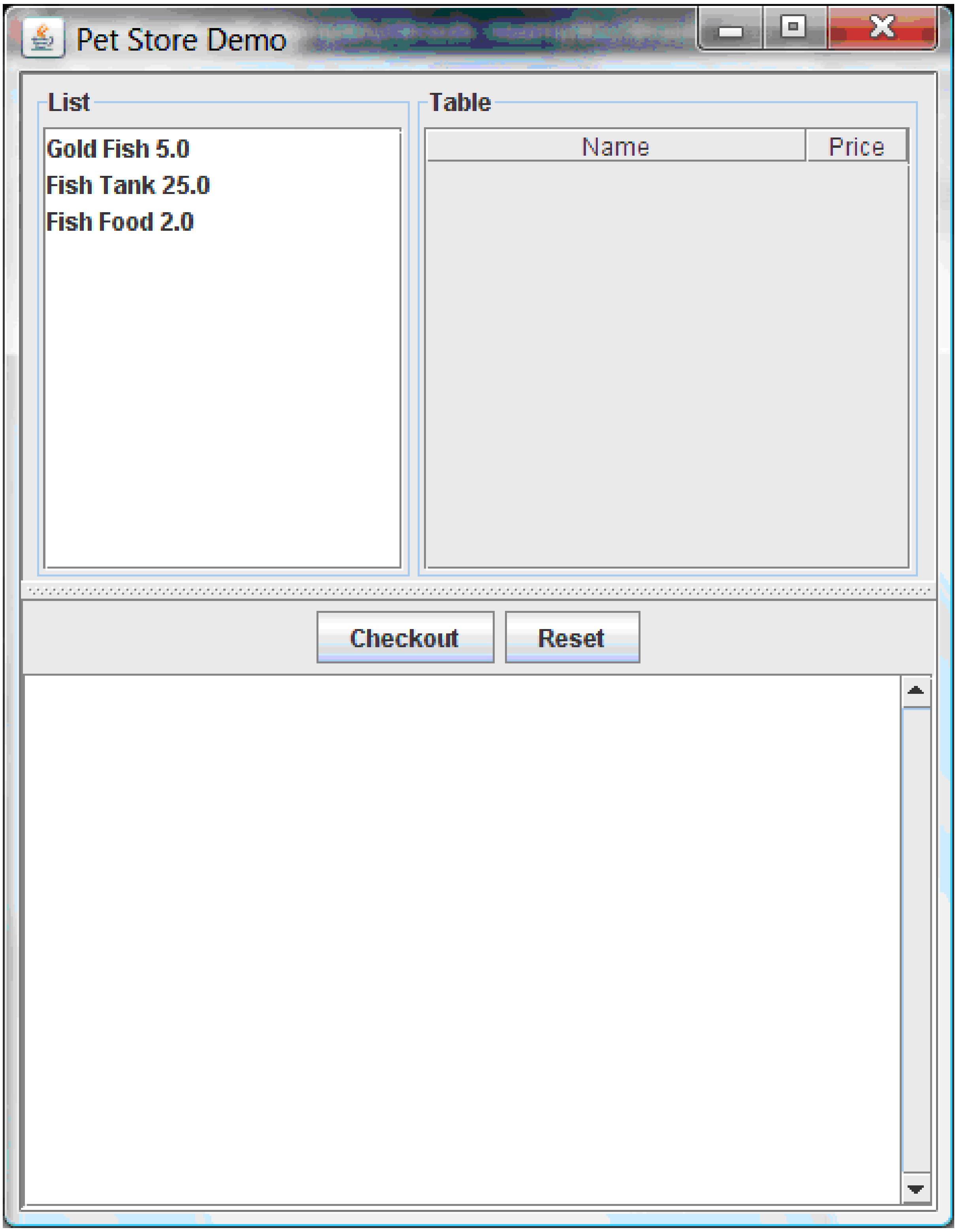
If the gross total is not less than **20**, the **"Apply 10% Discount"** rule calculates the discounted total, adds it to the KIE session, and displays it in the text area.

Pet Store example execution

Similar to other Red Hat Decision Manager decision examples, you execute the Pet Store example by running the **org.drools.examples.petstore.PetStoreExample** class as a Java application in your IDE.

When you execute the Pet Store example, the **Pet Store Demo** GUI window appears. This window displays a list of available products (upper left), an empty list of selected products (upper right), **Checkout** and **Reset** buttons (middle), and an empty system messages area (bottom).

Figure 7.14. Pet Store example GUI after launch



The following events occurred in this example to establish this execution behavior:

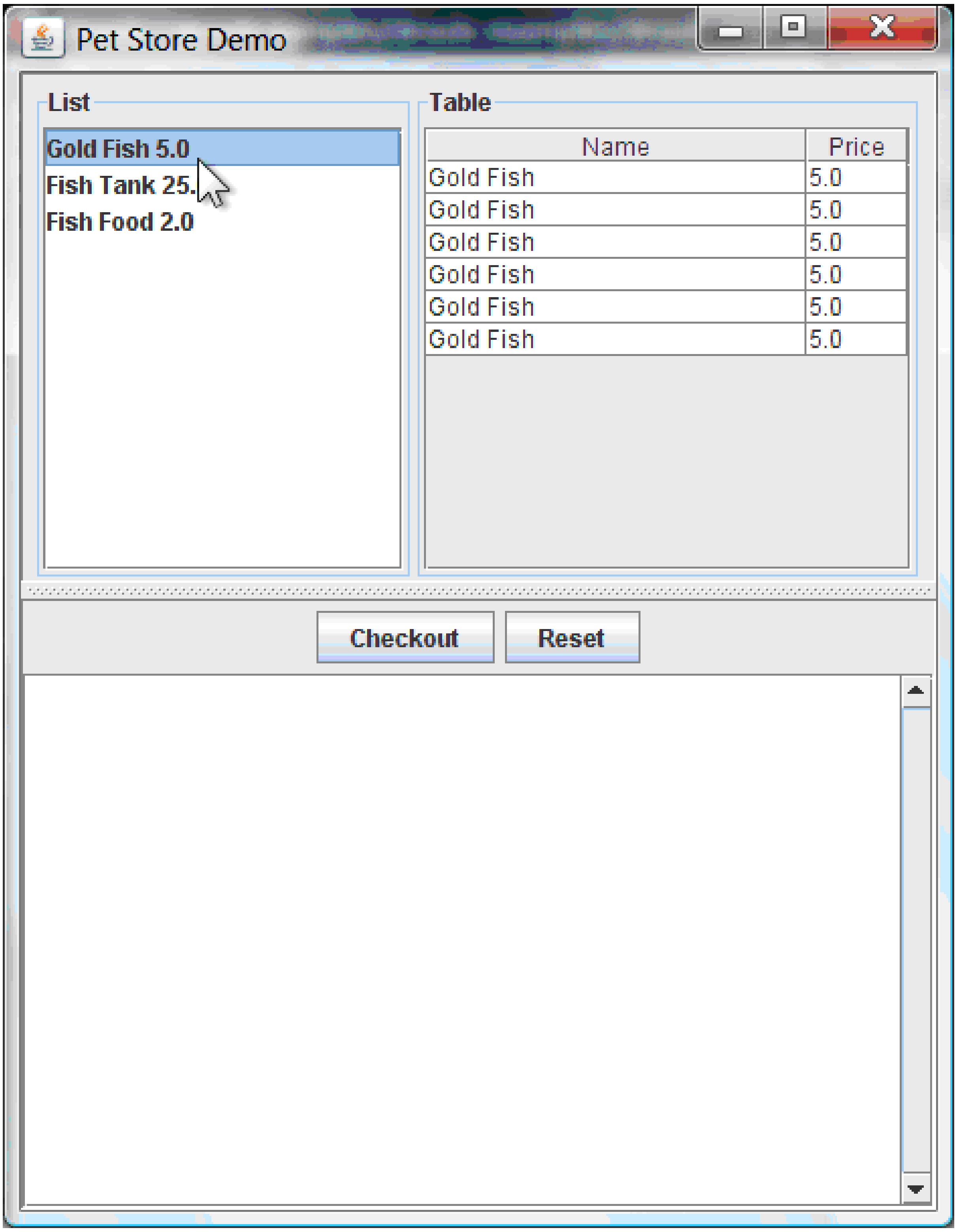
1. The **main()** method has run and loaded the rule base but has not yet fired the rules. So far, this is the only code in connection with rules that has been run.

2. A new **PetStoreUI** object has been created and given a handle for the rule base, for later use.

3. Various Swing components have performed their functions, and the initial UI screen is displayed and waits for user input.

You can click on various products from the list to explore the UI setup:

Figure 7.15. Explore the Pet Store example GUI



Gold Fish 5.0
Fish Tank 25.
Fish Food 2.0

Name	Price
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0

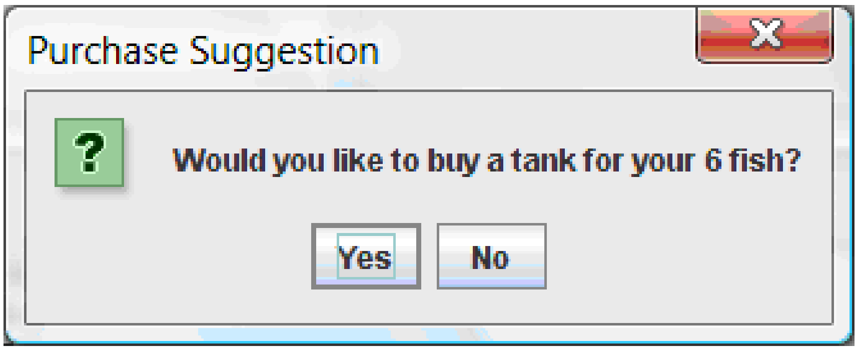
No rules code has been fired yet. The UI uses Swing code to detect user mouse clicks and add selected products to the **TableModel** object for display in the upper-right corner of the UI. This example illustrates the Model-View-Controller design pattern.

When you click **Checkout**, the rules are then fired in the following way:

1. Method **CheckOutCallBack.checkout()** is called (eventually) by the Swing class waiting for the click on **Checkout**. This inserts the data from the **TableModel** object (upper-right corner of the UI) into the KIE session working memory. The method then fires the rules.

2. The **"Explode Cart"** rule is the first to fire, with the **auto-focus** attribute set to **true**. The rule loops through all of the products in the cart, ensures that the products are in the working memory, and then gives the **"show Items"** and **"evaluate"** agenda groups the option to fire. The rules in these groups add the contents of the cart to the text area (bottom of the UI), evaluate if you are eligible for free fish food, and determine whether to ask if you want to buy a fish tank.

   Figure 7.16. Fish tank qualification

   Purchase Suggestion

   Would you like to buy a tank for your 6 fish?

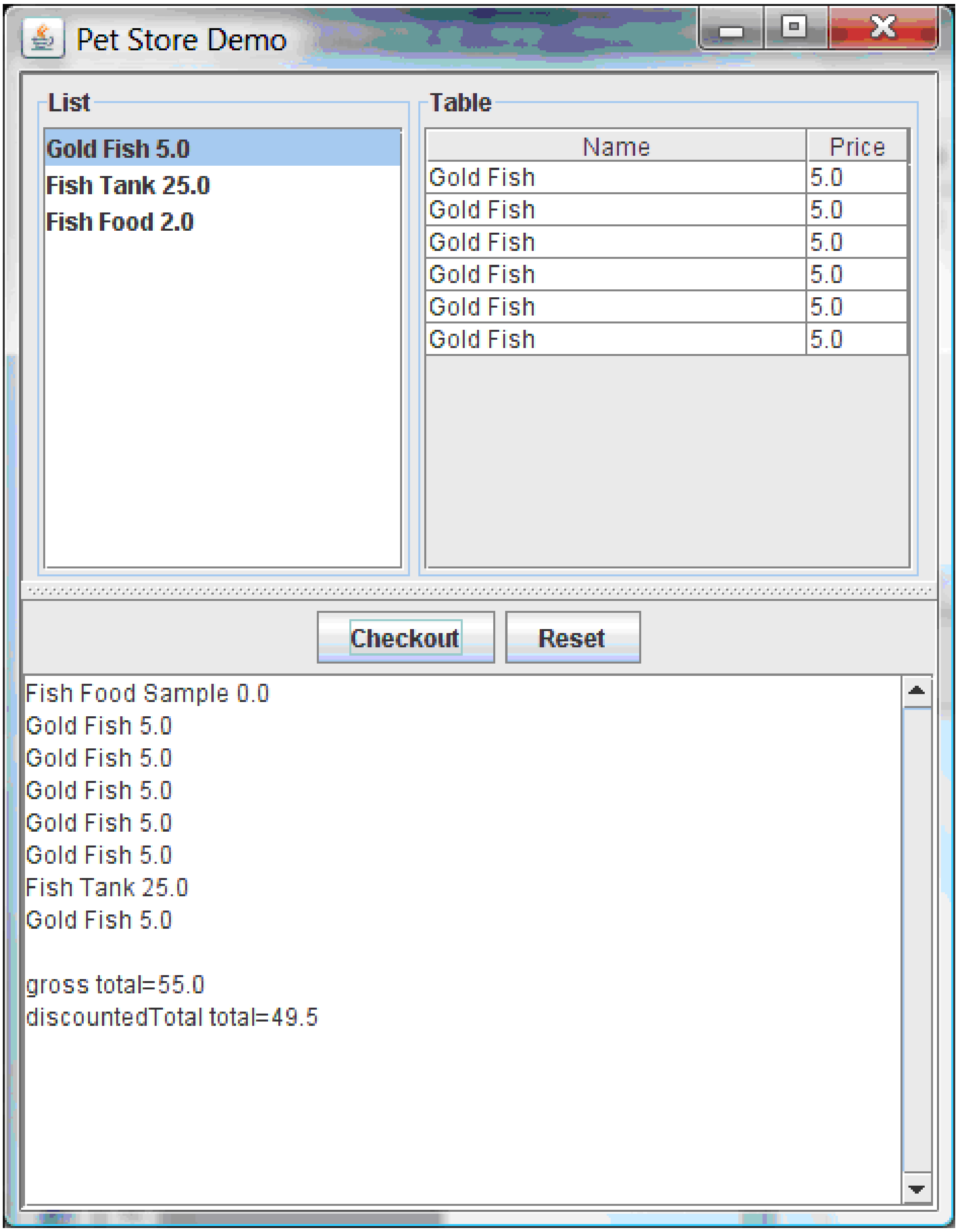
3. The **"do checkout"** rule is the next to fire because no other agenda group currently has focus and because it is part of the default **MAIN** agenda group. This rule always calls the **doCheckout()** function, which asks you if you want to check out.

4. The **doCheckout()** function sets the focus to the **"checkout"** agenda group, giving the rules in that group the option to fire.

5. The rules in the **"checkout"** agenda group display the contents of the cart and apply the appropriate discount.

6. Swing then waits for user input to either select more products (and cause the rules to fire again) or to close the UI.

Figure 7.17. Pet Store example GUI after all rules have fired



Gold Fish 5.0
Fish Tank 25.0
Fish Food 2.0

Name	Price
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0
Gold Fish	5.0

```
Fish Food Sample 0.0
Gold Fish 5.0
Gold Fish 5.0
Gold Fish 5.0
Gold Fish 5.0
Gold Fish 5.0
Fish Tank 25.0
Gold Fish 5.0

gross total=55.0
discountedTotal total=49.5
```

You can add more **System.out** calls to demonstrate this flow of events in your IDE console:

System.out output in the IDE console

```
Adding free Fish Food Sample to cart
SUGGESTION: Would you like to buy a tank for your 6 fish? - Yes
```

7.7. HONEST POLITICIAN EXAMPLE DECISIONS (TRUTH MAINTENANCE AND SALIENCE)

The Honest Politician example decision set demonstrates the concept of truth maintenance with logical insertions and the use of salience in rules.

The following is an overview of the Honest Politician example:

- Name: **honestpolitician**
- Main class: **org.drools.examples.honestpolitician.HonestPoliticianExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule file: **org.drools.examples.honestpolitician.HonestPolitician.drl** (in **src/main/resources**)
- **Objective**: Demonstrates the concept of truth maintenance based on the logical insertion of facts and the use of salience in rules

The basic premise of the Honest Politician example is that an object can only exist while a statement is true. A rule consequence can logically insert an object with the **insertLogical()** method. This means the object remains in the KIE session working memory as long as the rule that logically inserted it remains true. When the rule is no longer true, the object is automatically retracted.

In this example, rule execution causes a group of politicians to change from being honest to being dishonest as a result of a corrupt corporation. As each politician is evaluated, they start out with their honesty attribute being set to **true**, but a rule fires that makes the politicians no longer honest. As they switch their state from being honest to dishonest, they are then removed from the working memory. The rule salience notifies the decision engine how to prioritize any rules that have a salience defined for them, otherwise utilizing the default salience value of **0**. Rules with a higher salience value are given higher priority when ordered in the activation queue.

Politician and Hope classes

The sample class **Politician** in the example is configured for an honest politician. The **Politician** class is made up of a String item **name** and a Boolean item **honest**:

Politician class

```
public class Politician {
    private String name;
    private boolean honest;
    ...
}
```

The **Hope** class determines if a **Hope** object exists. This class has no meaningful members, but is present in the working memory as long as society has hope.

Hope class

```
public class Hope {

    public Hope() {

    }
  }
```

Rule definitions for politician honesty

In the Honest Politician example, when at least one honest politician exists in the working memory, the **"We have an honest Politician"** rule logically inserts a new **Hope** object. As soon as all politicians become dishonest, the **Hope** object is automatically retracted. This rule has a **salience** attribute with a value of **10** to ensure that it fires before any other rule, because at that stage the **"Hope is Dead"** rule is true.

Rule "We have an honest politician"

```
rule "We have an honest Politician"
    salience 10
  when
    exists( Politician( honest == true ) )
  then
    insertLogical( new Hope() );
end
```

As soon as a **Hope** object exists, the **"Hope Lives"** rule matches and fires. This rule also has a **salience** value of **10** so that it takes priority over the **"Corrupt the Honest"** rule.

Rule "Hope Lives"

```
rule "Hope Lives"
    salience 10
  when
    exists( Hope() )
  then
    System.out.println("Hurrah!!! Democracy Lives");
end
```

Initially, four honest politicians exist so this rule has four activations, all in conflict. Each rule fires in turn, corrupting each politician so that they are no longer honest. When all four politicians have been corrupted, no politicians have the property **honest == true**. The rule **"We have an honest Politician"** is no longer true and the object it logically inserted (due to the last execution of **new Hope()**) is automatically retracted.

Rule "Corrupt the Honest"

```
rule "Corrupt the Honest"
  when
    politician : Politician( honest == true )
    exists( Hope() )
  then
    System.out.println( "I'm an evil corporation and I have corrupted " + politician.getName() );
    modify ( politician ) { honest = false };
end
```

With the **Hope** object automatically retracted through the truth maintenance system, the conditional element **not** applied to **Hope** is no longer true so that the **"Hope is Dead"** rule matches and fires.

Rule "Hope is Dead"

```
rule "Hope is Dead"
  when
```

```
    not( Hope() )
  then
    System.out.println( "We are all Doomed!!! Democracy is Dead" );
end
```

Example execution and audit trail

In the **HonestPoliticianExample.java** class, the four politicians with the honest state set to **true** are inserted for evaluation against the defined business rules:

HonestPoliticianExample.java class execution

```
public static void execute( KieContainer kc ) {
        KieSession ksession = kc.newKieSession("HonestPoliticianKS");

        final Politician p1 = new Politician( "President of Umpa Lumpa", true );
        final Politician p2 = new Politician( "Prime Minster of Cheeseland", true );
        final Politician p3 = new Politician( "Tsar of Pringapopaloo", true );
        final Politician p4 = new Politician( "Omnipotence Om", true );

        ksession.insert( p1 );
        ksession.insert( p2 );
        ksession.insert( p3 );
        ksession.insert( p4 );

        ksession.fireAllRules();

        ksession.dispose();
    }
```

To execute the example, run the **org.drools.examples.honestpolitician.HonestPoliticianExample** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window:

Execution output in the IDE console

```
Hurrah!!! Democracy Lives
I'm an evil corporation and I have corrupted President of Umpa Lumpa
I'm an evil corporation and I have corrupted Prime Minster of Cheeseland
I'm an evil corporation and I have corrupted Tsar of Pringapopaloo
I'm an evil corporation and I have corrupted Omnipotence Om
We are all Doomed!!! Democracy is Dead
```

The output shows that, while there is at least one honest politician, democracy lives. However, as each politician is corrupted by some corporation, all politicians become dishonest, and democracy is dead.

To better understand the execution flow of this example, you can modify the **HonestPoliticianExample.java** class to include a **RuleRuntime** listener and an audit logger to view execution details:

HonestPoliticianExample.java class with an audit logger

```
package org.drools.examples.honestpolitician;

import org.kie.api.KieServices;
import org.kie.api.event.rule.DebugAgendaEventListener; ①
import org.kie.api.event.rule.DebugRuleRuntimeEventListener;
import org.kie.api.runtime.KieContainer;
import org.kie.api.runtime.KieSession;

public class HonestPoliticianExample {

    /**
     * @param args
     */
    public static void main(final String[] args) {
     KieServices ks = KieServices.Factory.get(); ②
     //ks = KieServices.Factory.get();
        KieContainer kc = KieServices.Factory.get().getKieClasspathContainer();
        System.out.println(kc.verify().getMessages().toString());
        //execute( kc );
        execute( ks, kc); ③
    }

    public static void execute( KieServices ks, KieContainer kc ) { ④
        KieSession ksession = kc.newKieSession("HonestPoliticianKS");

        final Politician p1 = new Politician( "President of Umpa Lumpa", true );
        final Politician p2 = new Politician( "Prime Minster of Cheeseland", true );
        final Politician p3 = new Politician( "Tsar of Pringapopaloo", true );
        final Politician p4 = new Politician( "Omnipotence Om", true );

        ksession.insert( p1 );
        ksession.insert( p2 );
        ksession.insert( p3 );
        ksession.insert( p4 );

        // The application can also setup listeners ⑤
        ksession.addEventListener( new DebugAgendaEventListener() );
        ksession.addEventListener( new DebugRuleRuntimeEventListener() );

        // Set up a file-based audit logger.
        ks.getLoggers().newFileLogger( ksession, "./target/honestpolitician" ); ⑥

        ksession.fireAllRules();

        ksession.dispose();
    }

}
```

① Adds to your imports the packages that handle the **DebugAgendaEventListener** and **DebugRuleRuntimeEventListener**

② Creates a **KieServices Factory** and a **ks** element to produce the logs because this audit log is not available at the **KieContainer** level

③ Modifies the **execute** method to use both **KieServices** and **KieContainer**

④ Modifies the **execute** method to pass in **KieServices** in addition to the **KieContainer**

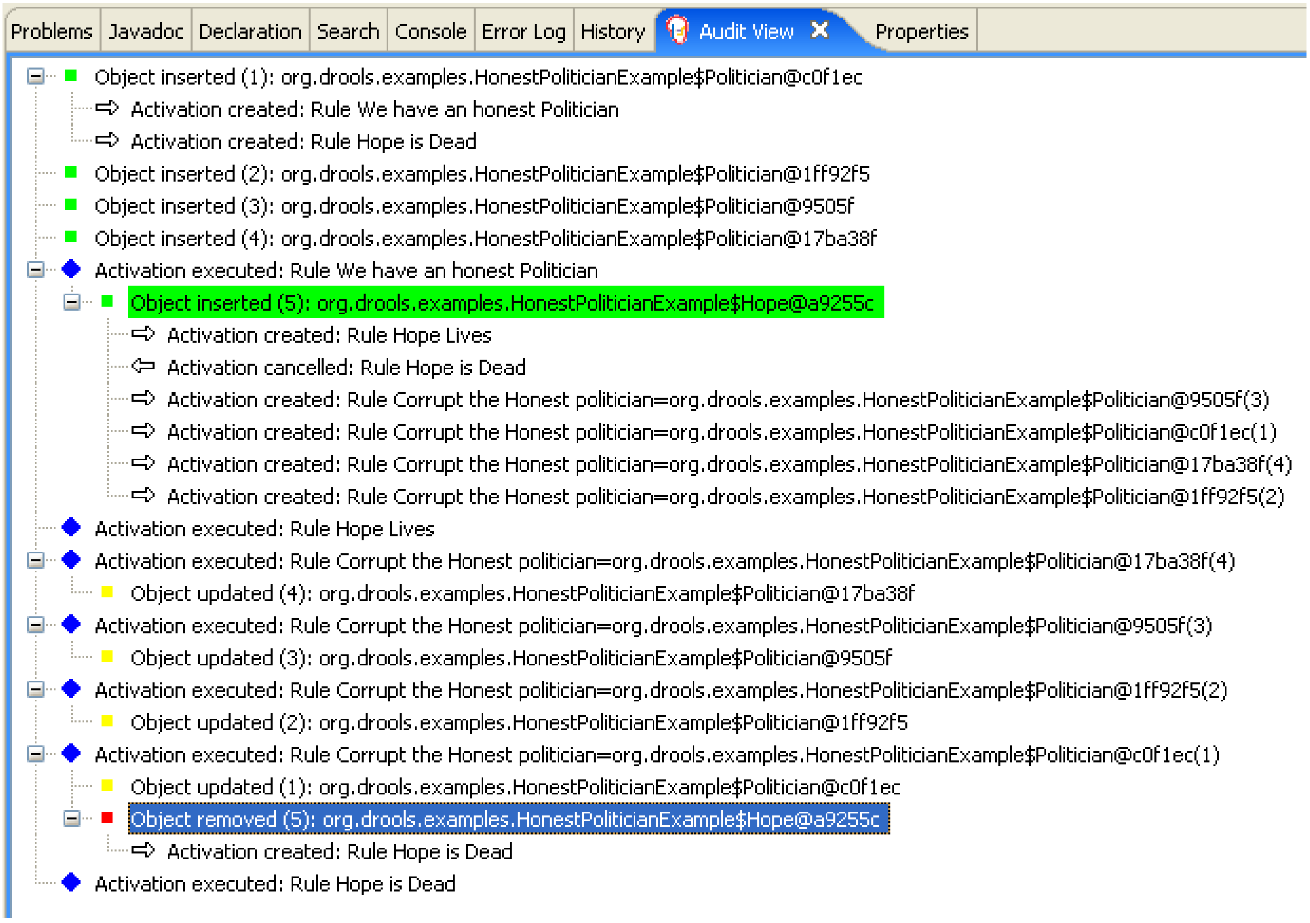
5 Creates the listeners

6 Builds the log that can be passed into the debug view or **Audit View** or your IDE after executing of the rules

When you run the Honest Politician with this modified logging capability, you can load the audit log file from **target/honestpolitician.log** into your IDE debug view or **Audit View**, if available (for example, in **Window → Show View** in some IDEs).

In this example, the **Audit View** shows the flow of executions, insertions, and retractions as defined in the example classes and rules:

Figure 7.18. Honest Politician example Audit View



```
Object inserted (1): org.drools.examples.HonestPoliticianExample$Politician@c0f1ec
    Activation created: Rule We have an honest Politician
    Activation created: Rule Hope is Dead
Object inserted (2): org.drools.examples.HonestPoliticianExample$Politician@1ff92f5
Object inserted (3): org.drools.examples.HonestPoliticianExample$Politician@9505f
Object inserted (4): org.drools.examples.HonestPoliticianExample$Politician@17ba38f
Activation executed: Rule We have an honest Politician
    Object inserted (5): org.drools.examples.HonestPoliticianExample$Hope@a9255c
        Activation created: Rule Hope Lives
        Activation cancelled: Rule Hope is Dead
        Activation created: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@9505f(3)
        Activation created: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@c0f1ec(1)
        Activation created: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@17ba38f(4)
        Activation created: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@1ff92f5(2)
Activation executed: Rule Hope Lives
Activation executed: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@17ba38f(4)
    Object updated (4): org.drools.examples.HonestPoliticianExample$Politician@17ba38f
Activation executed: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@9505f(3)
    Object updated (3): org.drools.examples.HonestPoliticianExample$Politician@9505f
Activation executed: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@1ff92f5(2)
    Object updated (2): org.drools.examples.HonestPoliticianExample$Politician@1ff92f5
Activation executed: Rule Corrupt the Honest politician=org.drools.examples.HonestPoliticianExample$Politician@c0f1ec(1)
    Object updated (1): org.drools.examples.HonestPoliticianExample$Politician@c0f1ec
    Object removed (5): org.drools.examples.HonestPoliticianExample$Hope@a9255c
        Activation created: Rule Hope is Dead
Activation executed: Rule Hope is Dead
```

When the first politician is inserted, two activations occur. The rule **"We have an honest Politician"** is activated only one time for the first inserted politician because it uses an **exists** conditional element, which matches when at least one politician is inserted. The rule **"Hope is Dead"** is also activated at this stage because the **Hope** object is not yet inserted. The rule **"We have an honest Politician"** fires first because it has a higher **salience** value than the rule **"Hope is Dead"**, and inserts the **Hope** object (highlighted in green). The insertion of the **Hope** object activates the rule **"Hope Lives"** and deactivates the rule **"Hope is Dead"**. The insertion also activates the rule **"Corrupt the Honest"** for each inserted honest politician. The rule **"Hope Lives"** is executed and prints **"Hurrah!!! Democracy Lives"**.

Next, for each politician, the rule **"Corrupt the Honest"** fires, printing **"I'm an evil corporation and I have corrupted X"**, where **X** is the name of the politician, and modifies the politician honesty value to **false**. When the last honest politician is corrupted, **Hope** is automatically retracted by the truth maintenance system (highlighted in blue). The green highlighted area shows the origin of the currently selected blue highlighted area. After the **Hope** fact is retracted, the rule **"Hope is dead"** fires, printing **"We are all Doomed!!! Democracy is Dead"**.

7.8. SUDOKU EXAMPLE DECISIONS (COMPLEX PATTERN MATCHING, CALLBACKS, AND GUI INTEGRATION)

The Sudoku example decision set, based on the popular number puzzle Sudoku, demonstrates how to use rules in Red Hat Decision Manager to find a solution in a large potential solution space based on various constraints. This example also shows how to integrate Red Hat Decision Manager rules into a graphical user interface (GUI), in this case a Swing-based desktop application, and how to use callbacks to interact with a running decision engine to update the GUI based on changes in the working memory at run time.

The following is an overview of the Sudoku example:

- Name: **sudoku**
- Main class: **org.drools.examples.sudoku.SudokuExample** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application
- Rule files: **org.drools.examples.sudoku.*.drl** (in **src/main/resources**)
- **Objective**: Demonstrates complex pattern matching, problem solving, callbacks, and GUI integration

Sudoku is a logic-based number placement puzzle. The objective is to fill a 9x9 grid so that each column, each row, and each of the nine 3x3 zones contains the digits from 1 to 9 only one time. The puzzle setter provides a partially completed grid and the puzzle solver’s task is to complete the grid with these constraints.

The general strategy to solve the problem is to ensure that when you insert a new number, it must be unique in its particular 3x3 zone, row, and column. This Sudoku example decision set uses Red Hat Decision Manager rules to solve Sudoku puzzles from a range of difficulty levels, and to attempt to resolve flawed puzzles that contain invalid entries.

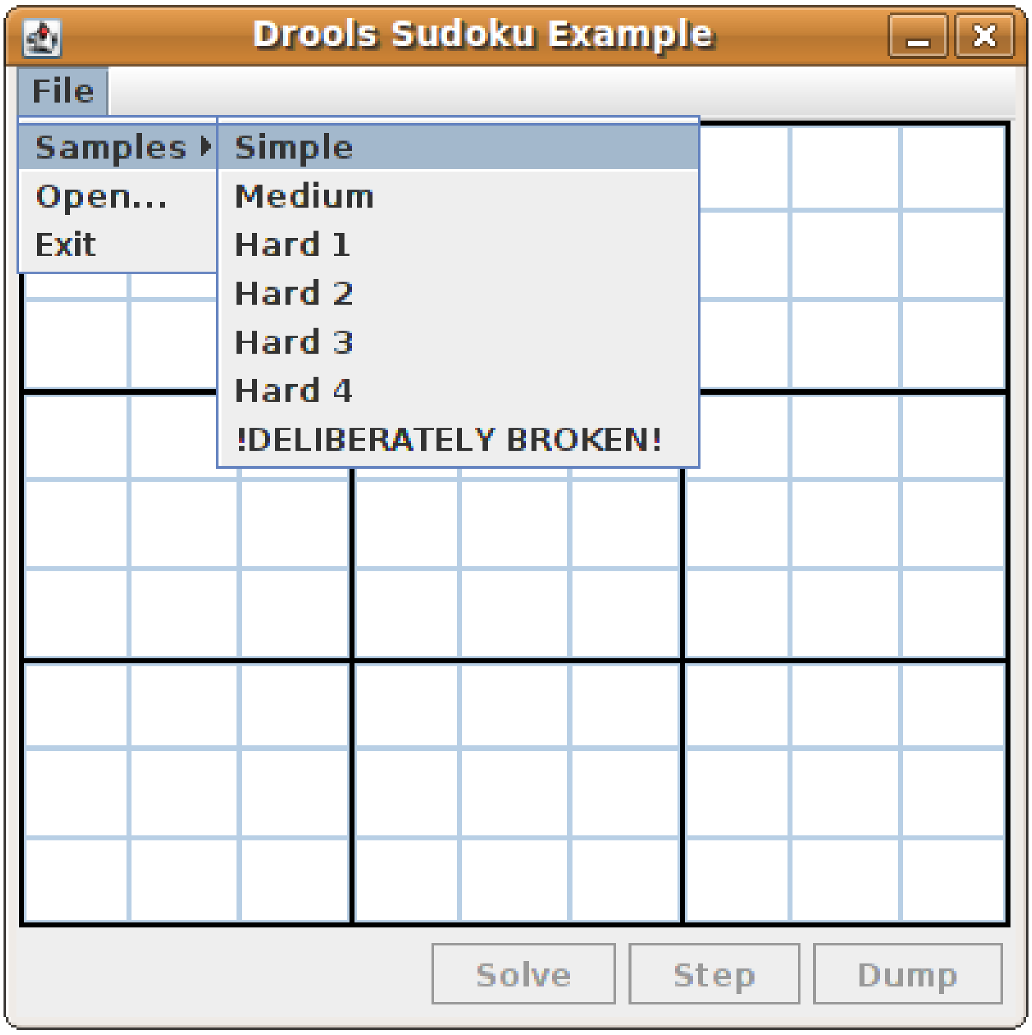
Sudoku example execution and interaction

Similar to other Red Hat Decision Manager decision examples, you execute the Sudoku example by running the **org.drools.examples.sudoku.SudokuExample** class as a Java application in your IDE.

When you execute the Sudoku example, the **Drools Sudoku Example** GUI window appears. This window contains an empty grid, but the program comes with various grids stored internally that you can load and solve.

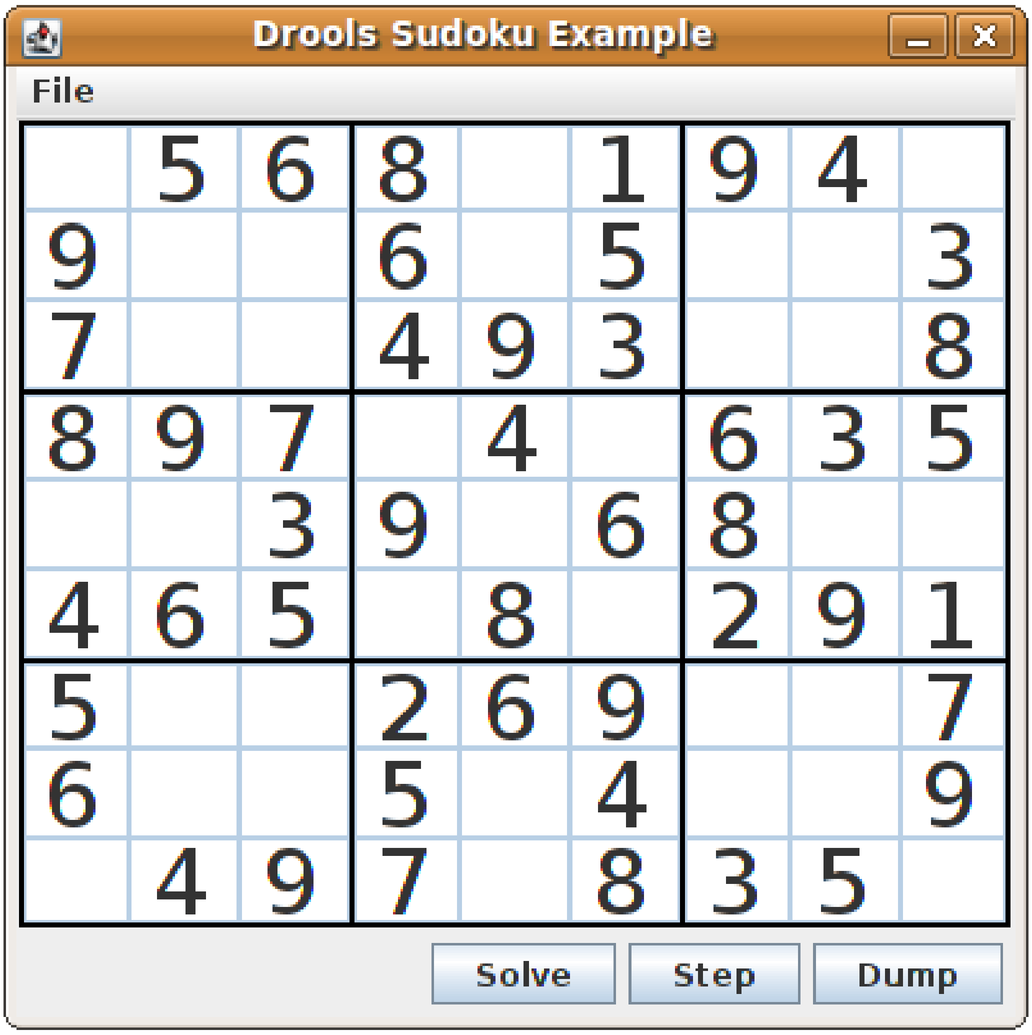
Click **File → Samples → Simple** to load one of the examples. Notice that all buttons are disabled until a grid is loaded.

Figure 7.19. Sudoku example GUI after launch



When you load the **Simple** example, the grid is filled according to the puzzle's initial state.

Figure 7.20. Sudoku example GUI after loading Simple sample

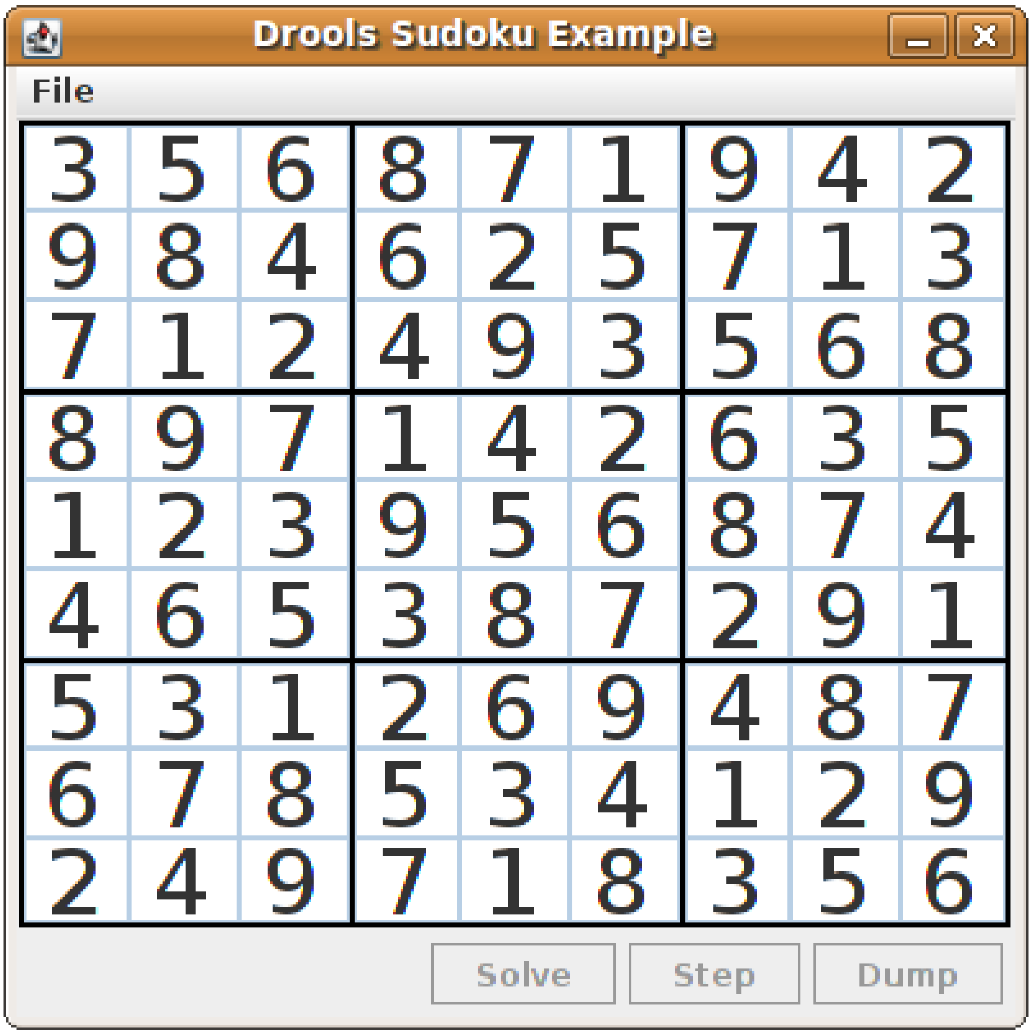


	5	6	8		1	9	4	
9			6		5			3
7			4	9	3			8
8	9	7		4		6	3	5
		3	9		6	8		
4	6	5		8		2	9	1
5			2	6	9			7
6			5		4			9
	4	9	7		8	3	5	

Choose from the following options:

- Click **Solve** to fire the rules defined in the Sudoku example that fill out the remaining values and that make the buttons inactive again.

Figure 7.21. Simple sample solved



3	5	6	8	7	1	9	4	2
9	8	4	6	2	5	7	1	3
7	1	2	4	9	3	5	6	8
8	9	7	1	4	2	6	3	5
1	2	3	9	5	6	8	7	4
4	6	5	3	8	7	2	9	1
5	3	1	2	6	9	4	8	7
6	7	8	5	3	4	1	2	9
2	4	9	7	1	8	3	5	6

- Click **Step** to see the next digit found by the rule set. The console window in your IDE displays detailed information about the rules that are executing to solve the step.

Step execution output in the IDE console

```
single 8 at [0,1]
column elimination due to [1,2]: remove 9 from [4,2]
hidden single 9 at [1,2]
row elimination due to [2,8]: remove 7 from [2,4]
remove 6 from [3,8] due to naked pair at [3,2] and [3,7]
hidden pair in row at [4,6] and [4,4]
```

- Click **Dump** to see the state of the grid, with cells showing either the established value or the remaining possibilities.

Dump execution output in the IDE console

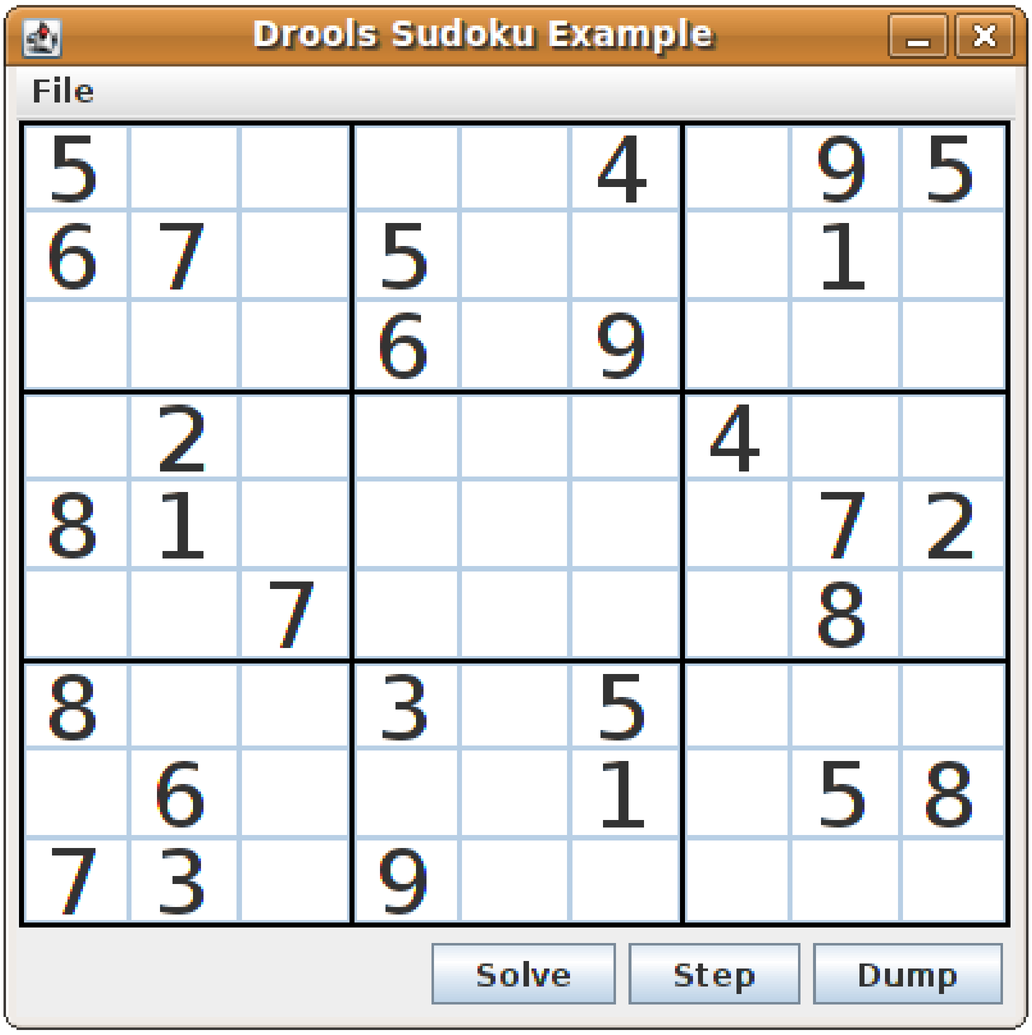
```
        Col: 0     Col: 1     Col: 2     Col: 3     Col: 4     Col: 5     Col: 6     Col: 7     Col: 8
Row 0:  123456789  --- 5 ---  --- 6 ---  --- 8 ---  123456789  --- 1 ---  --- 9 ---  --- 4 ---
123456789
Row 1:  --- 9 ---  123456789  123456789  --- 6 ---  123456789  --- 5 ---  123456789
123456789  --- 3 ---
Row 2:  --- 7 ---  123456789  123456789  --- 4 ---  --- 9 ---  --- 3 ---  123456789  123456789
--- 8 ---
```

```
Row 3:  --- 8 ---  --- 9 ---  --- 7 ---  123456789  --- 4 ---  123456789  --- 6 ---  --- 3 ---  --- 5 ---
Row 4:  123456789  123456789  --- 3 ---  --- 9 ---  123456789  --- 6 ---  --- 8 ---  123456789
123456789
Row 5:  --- 4 ---  --- 6 ---  --- 5 ---  123456789  --- 8 ---  123456789  --- 2 ---  --- 9 ---  --- 1 ---
Row 6:  --- 5 ---  123456789  123456789  --- 2 ---  --- 6 ---  --- 9 ---  123456789  123456789
--- 7 ---
Row 7:  --- 6 ---  123456789  123456789  --- 5 ---  123456789  --- 4 ---  123456789
123456789  --- 9 ---
Row 8:  123456789  --- 4 ---  --- 9 ---  --- 7 ---  123456789  --- 8 ---  --- 3 ---  --- 5 ---
123456789
```

The Sudoku example includes a deliberately broken sample file that the rules defined in the example can resolve.

Click **File** → **Samples** → **!DELIBERATELY BROKEN!** to load the broken sample. The grid starts with some issues, for example, the value **5** appears two times in the first row, which is not allowed.

Figure 7.22. Broken Sudoku example initial state



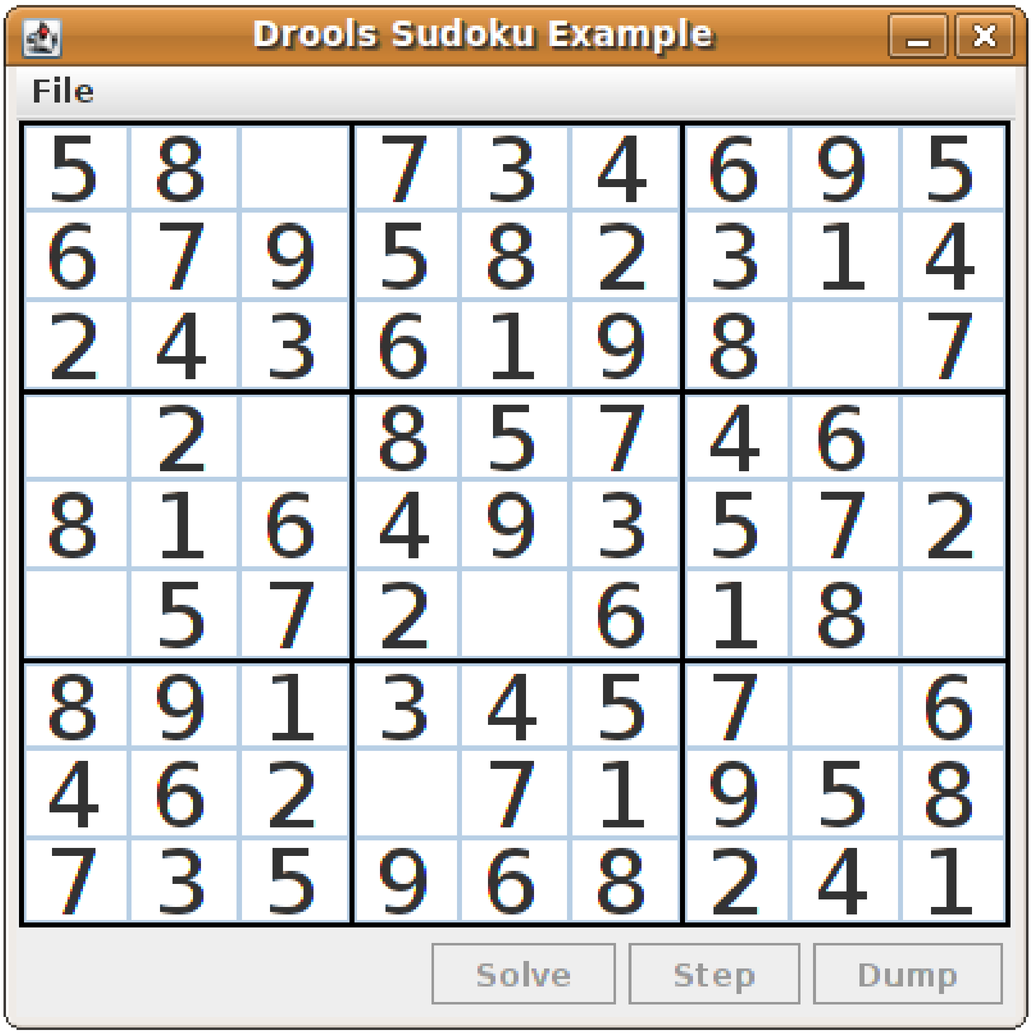
Click **Solve** to apply the solving rules to this invalid grid. The associated solving rules in the Sudoku example detect the issues in the sample and attempts to solve the puzzle as far as possible. This process does not complete and leaves some cells empty.

The solving rule activity is displayed in the IDE console window:

Detected issues in the broken sample

```
cell [0,8]: 5 has a duplicate in row 0
cell [0,0]: 5 has a duplicate in row 0
cell [6,0]: 8 has a duplicate in col 0
cell [4,0]: 8 has a duplicate in col 0
Validation complete.
```

Figure 7.23. Broken sample solution attempt



5	8		7	3	4	6	9	5
6	7	9	5	8	2	3	1	4
2	4	3	6	1	9	8		7
	2		8	5	7	4	6	
8	1	6	4	9	3	5	7	2
	5	7	2		6	1	8	
8	9	1	3	4	5	7		6
4	6	2		7	1	9	5	8
7	3	5	9	6	8	2	4	1

The sample Sudoku files labeled **Hard** are more complex and the solving rules might not be able to solve them. The unsuccessful solution attempt is displayed in the IDE console window:

Hard sample unresolved

```
Validation complete.
...
Sorry - can't solve this grid.
```

The rules that work to solve the broken sample implement standard solving techniques based on the sets of values that are still candidates for a cell. For example, if a set contains a single value, then this is the value for the cell. For a single occurrence of a value in one of the groups of nine cells, the rules insert a fact of type **Setting** with the solution value for some specific cell. This fact causes the elimination of this value from all other cells in any of the groups the cell belongs to and the value is retracted.

Other rules in the example reduce the permissible values for some cells. The rules **"naked pair"**, **"hidden pair in row"**, **"hidden pair in column"**, and **"hidden pair in square"** eliminate possibilities but do not establish solutions. The rules **"X-wings in rows"**, "``X-wings in columns"`, **"intersection removal**

row", and **"intersection removal column"** perform more sophisticated eliminations.

Sudoku example classes

The package **org.drools.examples.sudoku.swing** contains the following core set of classes that implement a framework for Sudoku puzzles:

- The **SudokuGridModel** class defines an interface that is implemented to store a Sudoku puzzle as a 9x9 grid of **Cell** objects.
- The **SudokuGridView** class is a Swing component that can visualize any implementation of the **SudokuGridModel** class.
- The **SudokuGridEvent** and **SudokuGridListener** classes communicate state changes between the model and the view. Events are fired when a cell value is resolved or changed.
- The **SudokuGridSamples** class provides partially filled Sudoku puzzles for demonstration purposes.

NOTE

This package does not have any dependencies on Red Hat Decision Manager libraries.

The package **org.drools.examples.sudoku** contains the following core set of classes that implement the elementary **Cell** object and its various aggregations:

- The **CellFile** class, with subtypes **CellRow**, **CellCol**, and **CellSqr**, all of which are subtypes of the **CellGroup** class.
- The **Cell** and **CellGroup** subclasses of **SetOfNine**, which provides a property **free** with the type **Set<Integer>**. For a **Cell** class, the set represents the individual candidate set. For a **CellGroup** class, the set is the union of all candidate sets of its cells (the set of digits that still need to be allocated).
  In the Sudoku example are 81 **Cell** and 27 **CellGroup** objects and a linkage provided by the **Cell** properties **cellRow**, **cellCol**, and **cellSqr**, and by the **CellGroup** property **cells** (a list of **Cell** objects). With these components, you can write rules that detect the specific situations that permit the allocation of a value to a cell or the elimination of a value from some candidate set.
- The **Setting** class is used to trigger the operations that accompany the allocation of a value. The presence of a **Setting** fact is used in all rules that detect a new situation in order to avoid reactions to inconsistent intermediary states.
- The **Stepping** class is used in a low priority rule to execute an emergency halt when a **"Step"** does not terminate regularly. This behavior indicates that the program cannot solve the puzzle.
- The main class **org.drools.examples.sudoku.SudokuExample** implements a Java application combining all of these components.

Sudoku validation rules (validate.drl)

The **validate.drl** file in the Sudoku example contains validation rules that detect duplicate numbers in cell groups. They are combined in a **"validate"** agenda group that enables the rules to be explicitly activated after a user loads the puzzle.

The **when** conditions of the three rules **"duplicate in cell …"** all function in the following ways:

- The first condition in the rule locates a cell with an allocated value.

- The second condition in the rule pulls in any of the three cell groups to which the cell belongs.
- The final condition finds a cell (other than the first one) with the same value as the first cell and in the same row, column, or square, depending on the rule.

Rules "duplicate in cell ..."

```
rule "duplicate in cell row"
  when
    $c: Cell( $v: value != null )
    $cr: CellRow( cells contains $c )
    exists Cell( this != $c, value == $v, cellRow == $cr )
  then
    System.out.println( "cell " + $c.toString() + " has a duplicate in row " + $cr.getNumber() );
end

rule "duplicate in cell col"
  when
    $c: Cell( $v: value != null )
    $cc: CellCol( cells contains $c )
    exists Cell( this != $c, value == $v, cellCol == $cc )
  then
    System.out.println( "cell " + $c.toString() + " has a duplicate in col " + $cc.getNumber() );
end

rule "duplicate in cell sqr"
  when
    $c: Cell( $v: value != null )
    $cs: CellSqr( cells contains $c )
    exists Cell( this != $c, value == $v, cellSqr == $cs )
  then
    System.out.println( "cell " + $c.toString() + " has duplicate in its square of nine." );
end
```

The rule **"terminate group"** is the last to fire. This rule prints a message and stops the sequence.

Rule "terminate group"

```
rule "terminate group"
    salience -100
  when
  then
    System.out.println( "Validation complete." );
    drools.halt();
end
```

Sudoku solving rules (sudoku.drl)

The **sudoku.drl** file in the Sudoku example contains three types of rules: one group handles the allocation of a number to a cell, another group detects feasible allocations, and the third group eliminates values from candidate sets.

The rules **"set a value"**, **"eliminate a value from Cell"**, and **"retract setting"** depend on the presence of a **Setting** object. The first rule handles the assignment to the cell and the operations for removing the value from the **free** sets of the three groups of the cell. This group also reduces a counter that, when zero, returns control to the Java application that has called **fireUntilHalt()**.

The purpose of the rule **"eliminate a value from Cell"** is to reduce the candidate lists of all cells that are related to the newly assigned cell. Finally, when all eliminations have been made, the rule **"retract setting"** retracts the triggering **Setting** fact.

Rules "set a value", "eliminate a value from a Cell", and "retract setting"

```
// A Setting object is inserted to define the value of a Cell.
// Rule for updating the cell and all cell groups that contain it
rule "set a value"
  when
    // A Setting with row and column number, and a value
    $s: Setting( $rn: rowNo, $cn: colNo, $v: value )

    // A matching Cell, with no value set
    $c: Cell( rowNo == $rn, colNo == $cn, value == null,
              $cr: cellRow, $cc: cellCol, $cs: cellSqr )

    // Count down
    $ctr: Counter( $count: count )
  then
    // Modify the Cell by setting its value.
    modify( $c ){ setValue( $v ) }
    // System.out.println( "set cell " + $c.toString() );
    modify( $cr ){ blockValue( $v ) }
    modify( $cc ){ blockValue( $v ) }
    modify( $cs ){ blockValue( $v ) }
    modify( $ctr ){ setCount( $count - 1 ) }
end

// Rule for removing a value from all cells that are siblings
// in one of the three cell groups
rule "eliminate a value from Cell"
  when
    // A Setting with row and column number, and a value
    $s: Setting( $rn: rowNo, $cn: colNo, $v: value )

    // The matching Cell, with the value already set
    Cell( rowNo == $rn, colNo == $cn, value == $v, $exCells: exCells )

    // For all Cells that are associated with the updated cell
    $c: Cell( free contains $v ) from $exCells
  then
    // System.out.println( "clear " + $v + " from cell " + $c.posAsString()  );
    // Modify a related Cell by blocking the assigned value.
    modify( $c ){ blockValue( $v ) }
end

// Rule for eliminating the Setting fact
rule "retract setting"
  when
    // A Setting with row and column number, and a value
    $s: Setting( $rn: rowNo, $cn: colNo, $v: value )

    // The matching Cell, with the value already set
    $c: Cell( rowNo == $rn, colNo == $cn, value == $v )
    // This is the negation of the last pattern in the previous rule.
    // Now the Setting fact can be safely retracted.
    not( $x: Cell( free contains $v )
         and
         Cell( this == $c, exCells contains $x ) )
  then
    // System.out.println( "done setting cell " + $c.toString() );
    // Discard the Setter fact.
    delete( $s );
    // Sudoku.sudoku.consistencyCheck();
end
```

Two solving rules detect a situation where an allocation of a number to a cell is possible. The rule **"single"** fires for a **Cell** with a candidate set containing a single number. The rule **"hidden single"** fires when no cell exists with a single candidate, but when a cell exists containing a candidate, this candidate is absent from all other cells in one of the three groups to which the cell belongs. Both rules create and insert a **Setting** fact.

Rules "single" and "hidden single"

```
// Detect a set of candidate values with cardinality 1 for some Cell.
// This is the value to be set.
rule "single"
  when
    // Currently no setting underway
    not Setting()

    // One element in the "free" set
    $c: Cell( $rn: rowNo, $cn: colNo, freeCount == 1 )
  then
    Integer i = $c.getFreeValue();
    if (explain) System.out.println( "single " + i + " at " + $c.posAsString() );
    // Insert another Setter fact.
    insert( new Setting( $rn, $cn, i ) );
end

// Detect a set of candidate values with a value that is the only one
// in one of its groups. This is the value to be set.
rule "hidden single"
  when
    // Currently no setting underway
    not Setting()
    not Cell( freeCount == 1 )

    // Some integer
    $i: Integer()

    // The "free" set contains this number
    $c: Cell( $rn: rowNo, $cn: colNo, freeCount > 1, free contains $i )

    // A cell group contains this cell $c.
    $cg: CellGroup( cells contains $c )
    // No other cell from that group contains $i.
    not ( Cell( this != $c, free contains $i ) from $cg.getCells() )
  then
    if (explain) System.out.println( "hidden single " + $i + " at " + $c.posAsString() );
    // Insert another Setter fact.
    insert( new Setting( $rn, $cn, $i ) );
end
```

Rules from the largest group, either individually or in groups of two or three, implement various solving techniques used for solving Sudoku puzzles manually.

The rule **"naked pair"** detects identical candidate sets of size **2** in two cells of a group. These two values may be removed from all other candidate sets of that group.

Rule "naked pair"

```
// A "naked pair" is two cells in some cell group with their sets of
// permissible values being equal with cardinality 2. These two values
// can be removed from all other candidate lists in the group.
rule "naked pair"
  when
    // Currently no setting underway
    not Setting()
    not Cell( freeCount == 1 )

    // One cell with two candidates
    $c1: Cell( freeCount == 2, $f1: free, $r1: cellRow, $rn1: rowNo, $cn1: colNo, $b1: cellSqr )

    // The containing cell group
    $cg: CellGroup( freeCount > 2, cells contains $c1 )

    // Another cell with two candidates, not the one we already have
    $c2: Cell( this != $c1, free == $f1 /*** , rowNo >= $rn1, colNo >= $cn1 ***/ ) from $cg.cells

    // Get one of the "naked pair".
    Integer( $v: intValue ) from $c1.getFree()

    // Get some other cell with a candidate equal to one from the pair.
    $c3: Cell( this != $c1 && != $c2, freeCount > 1, free contains $v ) from $cg.cells
  then
    if (explain) System.out.println( "remove " + $v + " from " + $c3.posAsString() + " due to naked pair
at " + $c1.posAsString() + " and " + $c2.posAsString() );
    // Remove the value.
    modify( $c3 ){ blockValue( $v ) }
end
```

The three rules **"hidden pair in …"** functions similarly to the rule **"naked pair"**. These rules detect a subset of two numbers in exactly two cells of a group, with neither value occurring in any of the other cells of the group. This means that all other candidates can be eliminated from the two cells harboring the hidden pair.

Rules "hidden pair in ..."

```
// If two cells within the same cell group contain candidate sets with more than
// two values, with two values being in both of them but in none of the other
// cells, then we have a "hidden pair". We can remove all other candidates from
// these two cells.
rule "hidden pair in row"
  when
```

```
    // Currently no setting underway
    not Setting()
    not Cell( freeCount == 1 )

    // Establish a pair of Integer facts.
    $i1: Integer()
    $i2: Integer( this > $i1 )

    // Look for a Cell with these two among its candidates. (The upper bound on
    // the number of candidates avoids a lot of useless work during startup.)
    $c1: Cell( $rn1: rowNo, $cn1: colNo, freeCount > 2 && < 9, free contains $i1 && contains $i2,
$cellRow: cellRow )

    // Get another one from the same row, with the same pair among its candidates.
    $c2: Cell( this != $c1, cellRow == $cellRow, freeCount > 2, free contains $i1 && contains $i2 )

    // Ascertain that no other cell in the group has one of these two values.
    not( Cell( this != $c1 && != $c2, free contains $i1 || contains $i2 ) from $cellRow.getCells() )
  then
    if( explain) System.out.println( "hidden pair in row at " + $c1.posAsString() + " and " +
$c2.posAsString() );
    // Set the candidate lists of these two Cells to the "hidden pair".
    modify( $c1 ){ blockExcept( $i1, $i2 ) }
    modify( $c2 ){ blockExcept( $i1, $i2 ) }
end

rule "hidden pair in column"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i1: Integer()
    $i2: Integer( this > $i1 )
    $c1: Cell( $rn1: rowNo, $cn1: colNo, freeCount > 2 && < 9, free contains $i1 && contains $i2,
$cellCol: cellCol )
    $c2: Cell( this != $c1, cellCol == $cellCol, freeCount > 2, free contains $i1 && contains $i2 )
    not( Cell( this != $c1 && != $c2, free contains $i1 || contains $i2 ) from $cellCol.getCells() )
  then
    if (explain) System.out.println( "hidden pair in column at " + $c1.posAsString() + " and " +
$c2.posAsString() );
    modify( $c1 ){ blockExcept( $i1, $i2 ) }
    modify( $c2 ){ blockExcept( $i1, $i2 ) }
end

rule "hidden pair in square"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i1: Integer()
    $i2: Integer( this > $i1 )
    $c1: Cell( $rn1: rowNo, $cn1: colNo, freeCount > 2 && < 9, free contains $i1 && contains $i2,
               $cellSqr: cellSqr )
    $c2: Cell( this != $c1, cellSqr == $cellSqr, freeCount > 2, free contains $i1 && contains $i2 )
    not( Cell( this != $c1 && != $c2, free contains $i1 || contains $i2 ) from $cellSqr.getCells() )
  then
```

```
    if (explain) System.out.println( "hidden pair in square " + $c1.posAsString() + " and " +
$c2.posAsString() );
    modify( $c1 ){ blockExcept( $i1, $i2 ) }
    modify( $c2 ){ blockExcept( $i1, $i2 ) }
end
```

Two rules deal with **"X-wings"** in rows and columns. When only two possible cells for a value exist in each of two different rows (or columns) and these candidates lie also in the same columns (or rows), then all other candidates for this value in the columns (or rows) can be eliminated. When you follow the pattern sequence in one of these rules, notice how the conditions that are conveniently expressed by words such as **same** or **only** result in patterns with suitable constraints or that are prefixed with **not**.

Rules "X-wings in ..."

```
rule "X-wings in rows"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i: Integer()
    $ca1: Cell( freeCount > 1, free contains $i,
                $ra: cellRow, $rano: rowNo,         $c1: cellCol,        $c1no: colNo )
    $cb1: Cell( freeCount > 1, free contains $i,
                $rb: cellRow, $rbno: rowNo > $rano,      cellCol == $c1 )
    not( Cell( this != $ca1 && != $cb1, free contains $i ) from $c1.getCells() )

    $ca2: Cell( freeCount > 1, free contains $i,
                cellRow == $ra, $c2: cellCol,       $c2no: colNo > $c1no )
    $cb2: Cell( freeCount > 1, free contains $i,
                cellRow == $rb,      cellCol == $c2 )
    not( Cell( this != $ca2 && != $cb2, free contains $i ) from $c2.getCells() )

    $cx: Cell( rowNo == $rano || == $rbno, colNo != $c1no && != $c2no,
               freeCount > 1, free contains $i )
  then
    if (explain) {
        System.out.println( "X-wing with " + $i + " in rows " +
            $ca1.posAsString() + " - " + $cb1.posAsString() +
            $ca2.posAsString() + " - " + $cb2.posAsString() + ", remove from " + $cx.posAsString() );
    }
    modify( $cx ){ blockValue( $i ) }
end

rule "X-wings in columns"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i: Integer()
    $ca1: Cell( freeCount > 1, free contains $i,
                $c1: cellCol, $c1no: colNo,         $ra: cellRow,        $rano: rowNo )
    $ca2: Cell( freeCount > 1, free contains $i,
                $c2: cellCol, $c2no: colNo > $c1no,      cellRow == $ra )
    not( Cell( this != $ca1 && != $ca2, free contains $i ) from $ra.getCells() )

    $cb1: Cell( freeCount > 1, free contains $i,
            cellCol == $c1, $rb: cellRow,  $rbno: rowNo > $rano )
    $cb2: Cell( freeCount > 1, free contains $i,
            cellCol == $c2,      cellRow == $rb )
    not( Cell( this != $cb1 && != $cb2, free contains $i ) from $rb.getCells() )

    $cx: Cell( colNo == $c1no || == $c2no, rowNo != $rano && != $rbno,
           freeCount > 1, free contains $i )
  then
    if (explain) {
        System.out.println( "X-wing with " + $i + " in columns " +
            $ca1.posAsString() + " - " + $ca2.posAsString() +
            $cb1.posAsString() + " - " + $cb2.posAsString() + ", remove from " + $cx.posAsString()  );
    }
    modify( $cx ){ blockValue( $i ) }
end
```

The two rules **"intersection removal ..."** are based on the restricted occurrence of some number within one square, either in a single row or in a single column. This means that this number must be in one of those two or three cells of the row or column and can be removed from the candidate sets of all other cells of the group. The pattern establishes the restricted occurrence and then fires for each cell outside of the square and within the same cell file.

Rules "intersection removal ..."

```
rule "intersection removal column"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i: Integer()
    // Occurs in a Cell
    $c: Cell( free contains $i, $cs: cellSqr, $cc: cellCol )
    // Does not occur in another cell of the same square and a different column
    not Cell( this != $c, free contains $i, cellSqr == $cs, cellCol != $cc )

    // A cell exists in the same column and another square containing this value.
    $cx: Cell( freeCount > 1, free contains $i, cellCol == $cc, cellSqr != $cs )
  then
    // Remove the value from that other cell.
    if (explain) {
        System.out.println( "column elimination due to " + $c.posAsString() +
                            ": remove " + $i + " from " + $cx.posAsString() );
    }
    modify( $cx ){ blockValue( $i ) }
end

rule "intersection removal row"
  when
    not Setting()
    not Cell( freeCount == 1 )

    $i: Integer()
    // Occurs in a Cell
    $c: Cell( free contains $i, $cs: cellSqr, $cr: cellRow )
    // Does not occur in another cell of the same square and a different row.
    not Cell( this != $c, free contains $i, cellSqr == $cs, cellRow != $cr )
    // A cell exists in the same row and another square containing this value.
    $cx: Cell( freeCount > 1, free contains $i, cellRow == $cr, cellSqr != $cs )
  then
    // Remove the value from that other cell.
    if (explain) {
        System.out.println( "row elimination due to " + $c.posAsString() +
                            ": remove " + $i + " from " + $cx.posAsString() );
    }
    modify( $cx ){ blockValue( $i ) }
end
```

These rules are sufficient for many but not all Sudoku puzzles. To solve very difficult grids, the rule set requires more complex rules. (Ultimately, some puzzles can be solved only by trial and error.)

7.9. CONWAY'S GAME OF LIFE EXAMPLE DECISIONS (RULEFLOW GROUPS AND GUI INTEGRATION)

The Conway's Game of Life example decision set, based on the famous cellular automaton by John Conway, demonstrates how to use ruleflow groups in rules to control rule execution. The example also demonstrates how to integrate Red Hat Decision Manager rules with a graphical user interface (GUI), in this case a Swing-based implementation of Conway's Game of Life.

The following is an overview of the Conway's Game of Life (Conway) example:

- Name: **conway**
- Main classes: **org.drools.examples.conway.ConwayRuleFlowGroupRun**, **org.drools.examples.conway.ConwayAgendaGroupRun** (in **src/main/java**)
- Module: **droolsjbpm-integration-examples**
- **Type**: Java application
- Rule files: **org.drools.examples.conway.*.drl** (in **src/main/resources**)
- **Objective**: Demonstrates ruleflow groups and GUI integration

NOTE

The Conway's Game of Life example is separate from most of the other example decision sets in Red Hat Decision Manager and is located in **~/rhdm-7.3.0-sources/src/droolsjbpm-integration-$VERSION/droolsjbpm-integration-examples** of the **Red Hat Decision Manager 7.3.0 Source Distribution**from the Red Hat Customer Portal.

In Conway's Game of Life, a user interacts with the game by creating an initial configuration or an advanced pattern with defined properties and then observing how the initial state evolves. The objective of the game is to show the development of a population, generation by generation. Each generation results from the preceding one, based on the simultaneous evaluation of all cells.

The following basic rules govern what the next generation looks like:

- If a live cell has fewer than two live neighbors, it dies of loneliness.

- If a live cell has more than three live neighbors, it dies from overcrowding.
- If a dead cell has exactly three live neighbors, it comes to life.

Any cell that does not meet any of those criteria is left as is for the next generation.

The Conway's Game of Life example uses Red Hat Decision Manager rules with **ruleflow-group** attributes to define the pattern implemented in the game. The example also contains a version of the decision set that achieves the same behavior using agenda groups. Agenda groups enable you to partition the decision engine agenda to provide execution control over groups of rules. By default, all rules are in the agenda group **MAIN**. You can use the **agenda-group** attribute to specify a different agenda group for the rule.

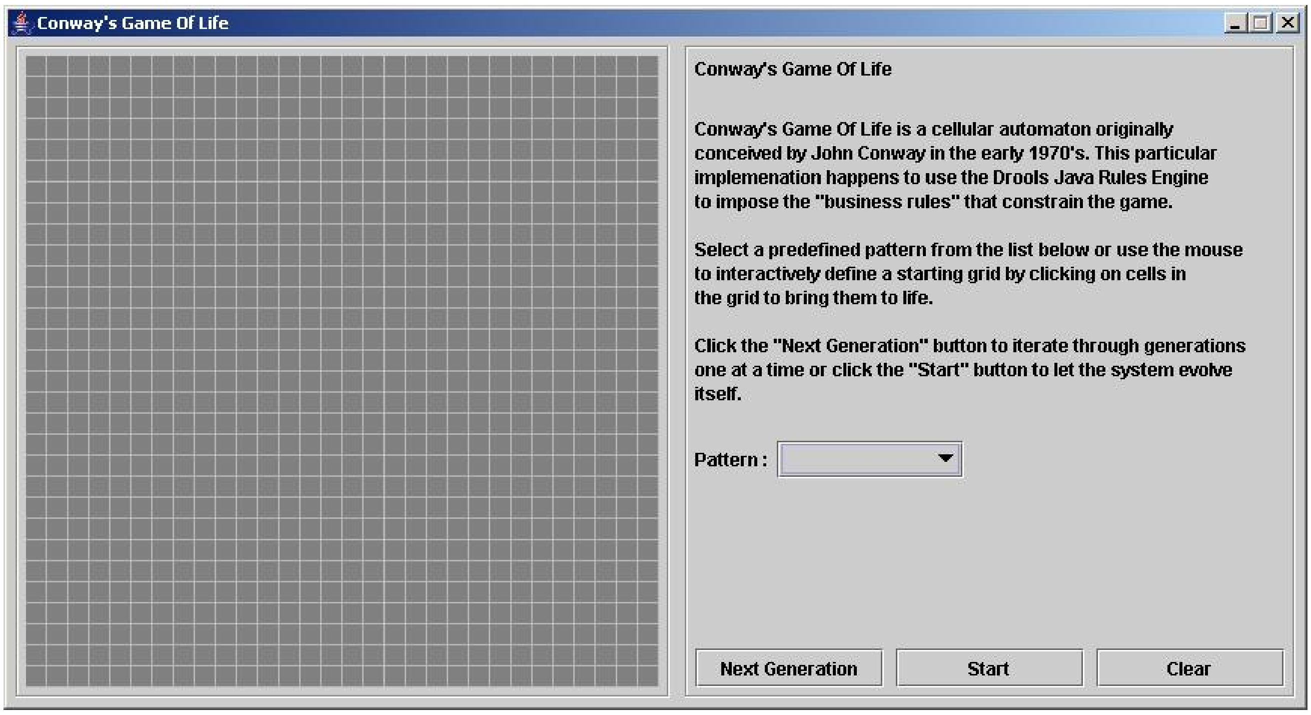
This overview does not explore the version of the Conway example using agenda groups. For more information about agenda groups, see the Red Hat Decision Manager example decision sets that specifically address agenda groups.

Conway example execution and interaction

Similar to other Red Hat Decision Manager decision examples, you execute the Conway ruleflow example by running the **org.drools.examples.conway.ConwayRuleFlowGroupRun** class as a Java application in your IDE.

When you execute the Conway example, the **Conway's Game of Life** GUI window appears. This window contains an empty grid, or "arena" where the life simulation takes place. Initially the grid is empty because no live cells are in the system yet.

Figure 7.24. Conway example GUI after launch



Conway's Game Of Life

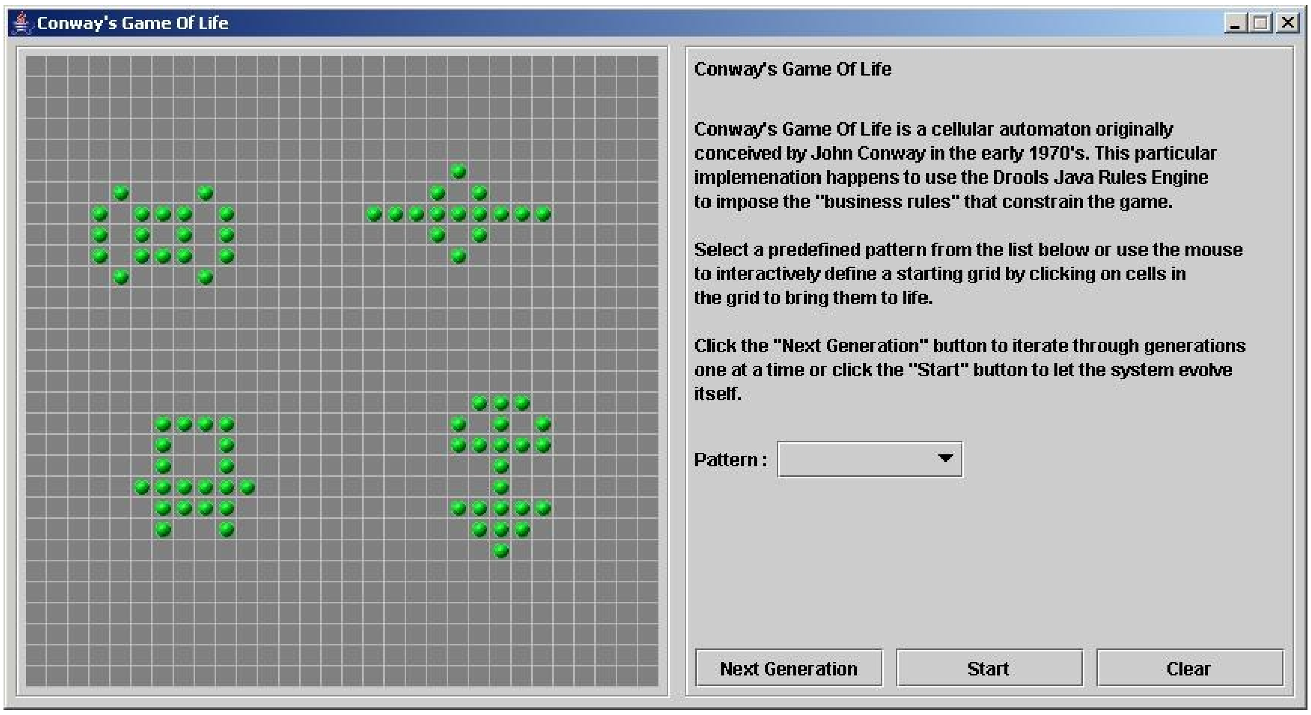
Conway's Game Of Life is a cellular automaton originally conceived by John Conway in the early 1970's. This particular implemenation happens to use the Drools Java Rules Engine to impose the "business rules" that constrain the game.

Select a predefined pattern from the list below or use the mouse to interactively define a starting grid by clicking on cells in the grid to bring them to life.

Click the "Next Generation" button to iterate through generations one at a time or click the "Start" button to let the system evolve itself.

Select a predefined pattern from the **Pattern** drop-down menu and click **Next Generation** to click through each population generation. Each cell is either alive or dead, where live cells contain a green ball. As the population evolves from the initial pattern, cells live or die relative to neighboring cells, according to the rules of the game.

Figure 7.25. Generation evolution in Conway example



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Select a predefined pattern from the list below or use the mouse to interactively define a starting grid by clicking on cells in the grid to bring them to life.

Click the "Next Generation" button to iterate through generations one at a time or click the "Start" button to let the system evolve itself.

Neighbors include not only cells to the left, right, top, and bottom but also cells that are connected diagonally, so that each cell has a total of eight neighbors. Exceptions are the corner cells, which have only three neighbors, and the cells along the four borders, with five neighbors each.

You can manually intervene to create or kill cells by clicking the cell.

To run through an evolution automatically from the initial pattern, click **Start**.

Conway example rules with ruleflow groups

The rules in the **ConwayRuleFlowGroupRun** example use ruleflow groups to control rule execution. A ruleflow group is a group of rules associated by the **ruleflow-group** rule attribute. These rules can only fire when the group is activated. The group itself can only become active when the elaboration of the ruleflow diagram reaches the node representing the group.

The Conway example uses the following ruleflow groups for rules:

- **"register neighbor"**
- **"evaluate"**
- **"calculate"**
- **"reset calculate"**
- **"birth"**
- **"kill"**
- **"kill all"**

All of the **Cell** objects are inserted into the KIE session and the **"register ..."** rules in the ruleflow group **"register neighbor"** are allowed to execute by the ruleflow process. This group of four rules creates **Neighbor** relations between some cell and its northeastern, northern, northwestern, and western neighbors.

This relation is bidirectional and handles the other four directions. Border cells do not require any special treatment. These cells are not paired with neighboring cells where there is not any.

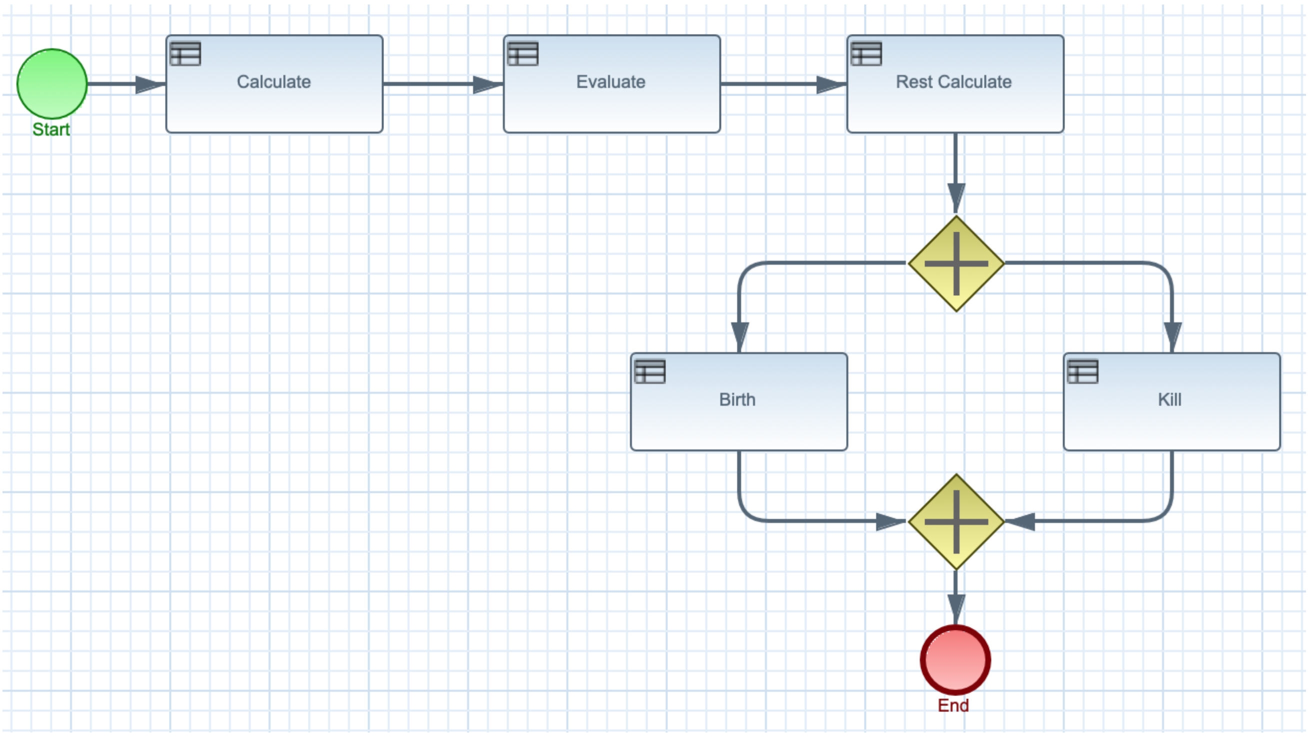
By the time all activations have fired for these rules, all cells are related to all their neighboring cells.

Rules "register ..."

```
rule "register north east"
    ruleflow-group "register neighbor"
  when
    $cell: Cell( $row : row, $col : col )
    $northEast : Cell( row  == ($row - 1), col == ( $col + 1 ) )
  then
    insert( new Neighbor( $cell, $northEast ) );
    insert( new Neighbor( $northEast, $cell ) );
end

rule "register north"
    ruleflow-group "register neighbor"
  when
    $cell: Cell( $row : row, $col : col )
    $north : Cell( row  == ($row - 1), col == $col )
  then
    insert( new Neighbor( $cell, $north ) );
    insert( new Neighbor( $north, $cell ) );
end

rule "register north west"
    ruleflow-group "register neighbor"
  when
    $cell: Cell( $row : row, $col : col )
    $northWest : Cell( row  == ($row - 1), col == ( $col - 1 ) )
  then
    insert( new Neighbor( $cell, $northWest ) );
    insert( new Neighbor( $northWest, $cell ) );
end

rule "register west"
    ruleflow-group "register neighbor"
  when
    $cell: Cell( $row : row, $col : col )
    $west : Cell( row  == $row, col == ( $col - 1 ) )
  then
    insert( new Neighbor( $cell, $west ) );
    insert( new Neighbor( $west, $cell ) );
end
```

After all the cells are inserted, some Java code applies the pattern to the grid, setting certain cells to **Live**. Then, when the user clicks **Start** or **Next Generation**, the example executes the **Generation** ruleflow. This ruleflow manages all changes of cells in each generation cycle.

Figure 7.26. Generation ruleflow



The ruleflow process enters the **"evaluate"** ruleflow group and any active rules in the group can fire. The rules **"Kill the ..."** and **"Give Birth"** in this group apply the game rules to birth or kill cells. The example uses the **phase** attribute to drive the reasoning of the **Cell** object by specific groups of rules. Typically, the phase is tied to a ruleflow group in the ruleflow process definition.

Notice that the example does not change the state of any **Cell** objects at this point because it must complete the full evaluation before those changes can be applied. The example sets the cell to a **phase** that is either **Phase.KILL** or **Phase.BIRTH**, which is used later to control actions applied to the **Cell** object.

Rules "Kill the ..." and "Give Birth"

```
rule "Kill The Lonely"
    ruleflow-group "evaluate"
    no-loop
  when
    // A live cell has fewer than 2 live neighbors.
    theCell: Cell( liveNeighbors < 2, cellState == CellState.LIVE,
                   phase == Phase.EVALUATE )
  then
    modify( theCell ){
        setPhase( Phase.KILL );
    }
end

rule "Kill The Overcrowded"
    ruleflow-group "evaluate"
    no-loop
  when
    // A live cell has more than 3 live neighbors.
    theCell: Cell( liveNeighbors > 3, cellState == CellState.LIVE,
                   phase == Phase.EVALUATE )
  then
```

```
    modify( theCell ){
      setPhase( Phase.KILL );
    }
end

rule "Give Birth"
    ruleflow-group "evaluate"
    no-loop
  when
    // A dead cell has 3 live neighbors.
    theCell: Cell( liveNeighbors == 3, cellState == CellState.DEAD,
                   phase == Phase.EVALUATE )
  then
    modify( theCell ){
      theCell.setPhase( Phase.BIRTH );
    }
end
```

After all **Cell** objects in the grid have been evaluated, the example uses the **"reset calculate"** rule to clear any activations in the **"calculate"** ruleflow group. The example then enters a split in the ruleflow that enables the rules **"kill"** and **"birth"** to fire, if the ruleflow group is activated. These rules apply the state change.

Rules "reset calculate", "kill", and "birth"

```
rule "reset calculate"
    ruleflow-group "reset calculate"
  when
  then
    WorkingMemory wm = drools.getWorkingMemory();
    wm.clearRuleFlowGroup( "calculate" );
end

rule "kill"
    ruleflow-group "kill"
    no-loop
  when
    theCell: Cell( phase == Phase.KILL )
  then
    modify( theCell ){
      setCellState( CellState.DEAD ),
      setPhase( Phase.DONE );
    }
end

rule "birth"
    ruleflow-group "birth"
    no-loop
  when
    theCell: Cell( phase == Phase.BIRTH )
  then
    modify( theCell ){
      setCellState( CellState.LIVE ),
      setPhase( Phase.DONE );
    }
end
```

At this stage, several **Cell** objects have been modified with the state changed to either **LIVE** or **DEAD**. When a cell becomes live or dead, the example uses the **Neighbor** relation in the rules **"Calculate ..."** to iterate over all surrounding cells, increasing or decreasing the **liveNeighbor** count. Any cell that has its count changed is also set to to the **EVALUATE** phase to make sure it is included in the reasoning during the evaluation stage of the ruleflow process.

After the live count has been determined and set for all cells, the ruleflow process ends. If the user initially clicked **Start**, the decision engine restarts the ruleflow at that point. If the user initially clicked **Next Generation**, the user can request another generation.

Rules "Calculate ..."

```
rule "Calculate Live"
    ruleflow-group "calculate"
    lock-on-active
  when
    theCell: Cell( cellState == CellState.LIVE )
    Neighbor( cell == theCell, $neighbor : neighbor )
  then
    modify( $neighbor ){
        setLiveNeighbors( $neighbor.getLiveNeighbors() + 1 ),
        setPhase( Phase.EVALUATE );
    }
end

rule "Calculate Dead"
    ruleflow-group "calculate"
    lock-on-active
  when
    theCell: Cell( cellState == CellState.DEAD )
    Neighbor( cell == theCell, $neighbor : neighbor )
  then
    modify( $neighbor ){
        setLiveNeighbors( $neighbor.getLiveNeighbors() - 1 ),
        setPhase( Phase.EVALUATE );
    }
end
```

7.10. HOUSE OF DOOM EXAMPLE DECISIONS (BACKWARD CHAINING AND RECURSION)

The House of Doom example decision set demonstrates how the decision engine uses backward chaining and recursion to reach defined goals or subgoals in a hierarchical system.

The following is an overview of the House of Doom example:

- Name: **backwardchaining**
- Main class: **org.drools.examples.backwardchaining.HouseOfDoomMain** (in **src/main/java**)
- Module: **drools-examples**
- **Type**: Java application

- Rule file: **org.drools.examples.backwardchaining.BC-Example.drl** (in **src/main/resources**)
- **Objective**: Demonstrates backward chaining and recursion

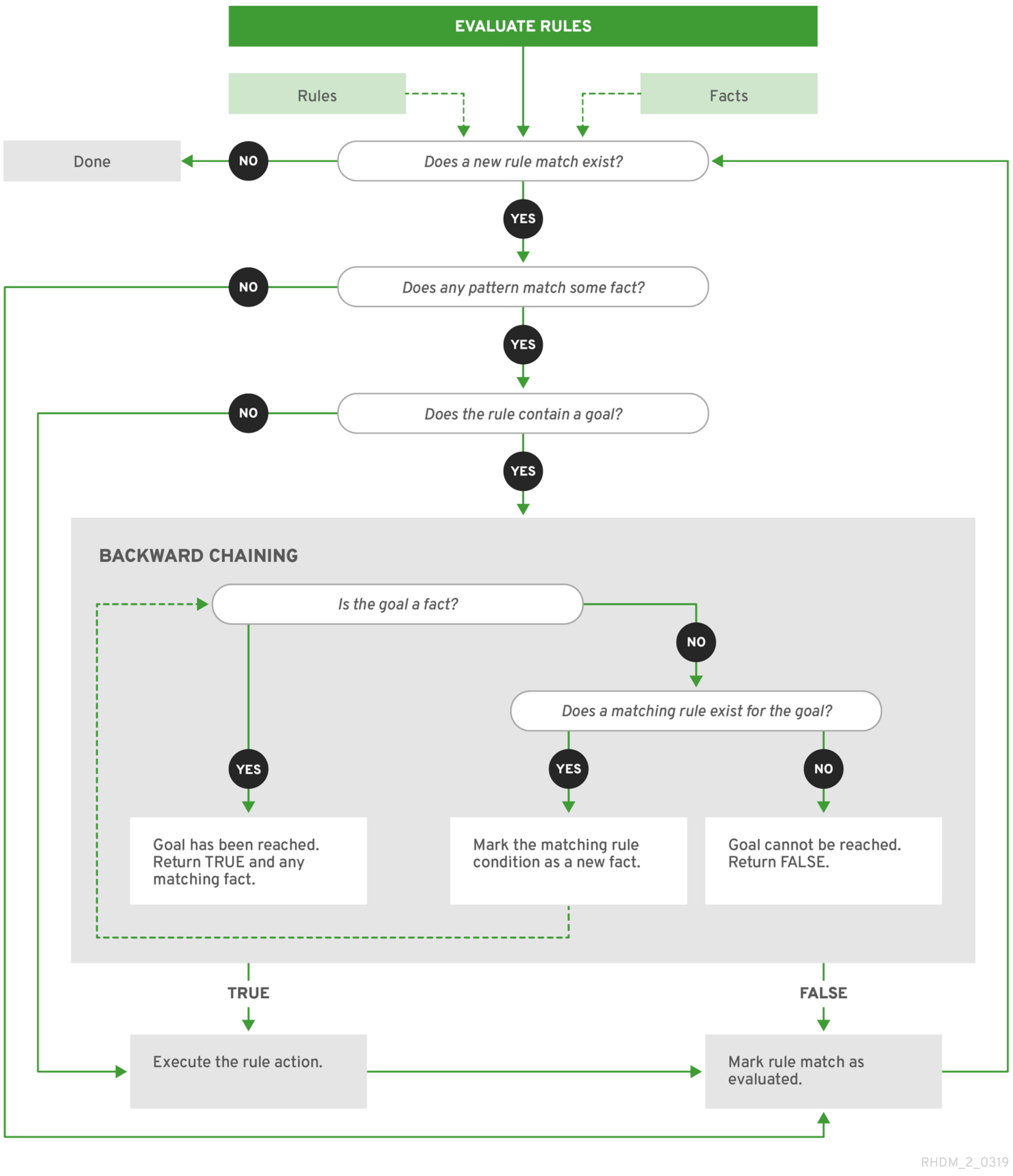
A backward-chaining rule system is a goal-driven system that starts with a conclusion that the decision engine attempts to satisfy, often using recursion. If the system cannot reach the conclusion or goal, it searches for subgoals, which are conclusions that complete part of the current goal. The system continues this process until either the initial conclusion is satisfied or all subgoals are satisfied.

In contrast, a forward-chaining rule system is a data-driven system that starts with a fact in the working memory of the decision engine and reacts to changes to that fact. When objects are inserted into working memory, any rule conditions that become true as a result of the change are scheduled for execution by the agenda.

The decision engine in Red Hat Decision Manager uses both forward and backward chaining to evaluate rules.

The following diagram illustrates how the decision engine evaluates rules using forward chaining overall with a backward-chaining segment in the logic flow:

Figure 7.27. Rule evaluation logic using forward and backward chaining


EVALUATE RULES
Rules
Facts
Done
NO
Does a new rule match exist?
YES
NO
Does any pattern match some fact?
YES
NO
Does the rule contain a goal?
YES
BACKWARD CHAINING
Is the goal a fact?
NO
Does a matching rule exist for the goal?
YES
YES
NO
Goal has been reached. Return TRUE and any matching fact.
Mark the matching rule condition as a new fact.
Goal cannot be reached. Return FALSE.
TRUE
FALSE
Execute the rule action.
Mark rule match as evaluated.
RHDM_2_0319

The House of Doom example uses rules with various types of queries to find the location of rooms and items within the house. The sample class **Location.java** contains the **item** and **location** elements used in the example. The sample class **HouseOfDoomMain.java** inserts the items or rooms in their respective locations in the house and executes the rules.

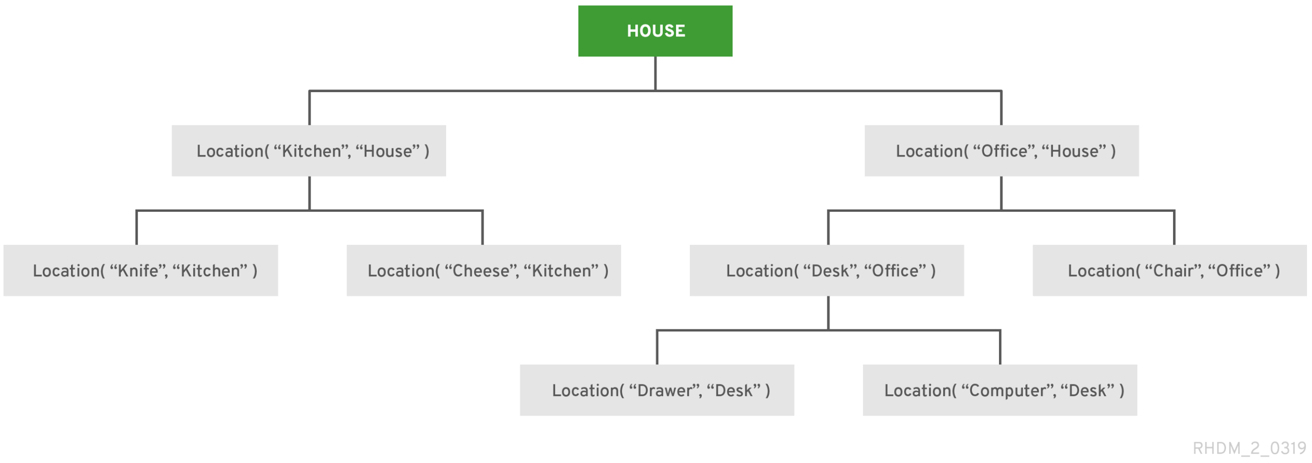
Items and locations in HouseOfDoomMain.java class

```
ksession.insert( new Location("Office", "House") );
ksession.insert( new Location("Kitchen", "House") );
ksession.insert( new Location("Knife", "Kitchen") );
ksession.insert( new Location("Cheese", "Kitchen") );
ksession.insert( new Location("Desk", "Office") );
ksession.insert( new Location("Chair", "Office") );
ksession.insert( new Location("Computer", "Desk") );
ksession.insert( new Location("Drawer", "Desk") );
```

The example rules rely on backward chaining and recursion to determine the location of all items and rooms in the house structure.

The following diagram illustrates the structure of the House of Doom and the items and rooms within it:

Figure 7.28. House of Doom structure


HOUSE
Location(“Kitchen”, “House”)
Location(“Office”, “House”)
Location(“Knife”, “Kitchen”)
Location(“Cheese”, “Kitchen”)
Location(“Desk”, “Office”)
Location(“Chair”, “Office”)
Location(“Drawer”, “Desk”)
Location(“Computer”, “Desk”)
RHDM_2_0319

To execute the example, run the **org.drools.examples.backwardchaining.HouseOfDoomMain** class as a Java application in your IDE.

After the execution, the following output appears in the IDE console window:

Execution output in the IDE console

```
go1
Office is in the House
---
go2
Drawer is in the House
---
go3
---
Key is in the Office
---
go4
Chair is in the Office
Desk is in the Office
Key is in the Office
Computer is in the Office
Drawer is in the Office
---
go5
Chair is in Office
Desk is in Office
```

```
Drawer is in Desk
Key is in Drawer
Kitchen is in House
Cheese is in Kitchen
Knife is in Kitchen
Computer is in Desk
Office is in House
Key is in Office
Drawer is in House
Computer is in House
Key is in House
Desk is in House
Chair is in House
Knife is in House
Cheese is in House
Computer is in Office
Drawer is in Office
Key is in Desk
```

All rules in the example have fired to detect the location of all items in the house and to print the location of each in the output.

Recursive query and related rules

A recursive query repeatedly searches through the hierarchy of a data structure for relationships between elements.

In the House of Doom example, the **BC-Example.drl** file contains an **isContainedIn** query that most of the rules in the example use to recursively evaluate the house data structure for data inserted into the decision engine:

Recursive query in BC-Example.drl

```
query isContainedIn( String x, String y )
  Location( x, y; )
  or
  ( Location( z, y; ) and isContainedIn( x, z; ) )
end
```

The rule **"go"** prints every string inserted into the system to determine how items are implemented, and the rule **"go1"** calls the query **isContainedIn**:

Rules "go" and "go1"

```
rule "go" salience 10
  when
    $s : String( )
  then
    System.out.println( $s );
end

rule "go1"
  when
    String( this == "go1" )
    isContainedIn("Office", "House"; )
  then
    System.out.println( "Office is in the House" );
end
```

The example inserts the **"go1"** string into the decision engine and activates the **"go1"** rule to detect that item **Office** is in the location **House**:

Insert string and fire rules

```
ksession.insert( "go1" );
ksession.fireAllRules();
```

Rule "go1" output in the IDE console

```
go1
Office is in the House
```

Transitive closure rule

Transitive closure is a relationship between an element contained in a parent element that is multiple levels higher in a hierarchical structure.

The rule **"go2"** identifies the transitive closure relationship of the **Drawer** and the **House**: The **Drawer** is in the **Desk** in the **Office** in the **House**.

```
rule "go2"
  when
    String( this == "go2" )
    isContainedIn("Drawer", "House"; )
  then
    System.out.println( "Drawer is in the House" );
end
```

The example inserts the **"go2"** string into the decision engine and activates the **"go2"** rule to detect that item **Drawer** is ultimately within the location **House**:

Insert string and fire rules

```
ksession.insert( "go2" );
ksession.fireAllRules();
```

Rule "go2" output in the IDE console

```
go2
Drawer is in the House
```

The decision engine determines this outcome based on the following logic:

1. The query recursively searches through several levels in the house to detect the transitive closure between **Drawer** and **House**.

2. Instead of using **Location(x, y;)**, the query uses the value of **(z, y;)** because **Drawer** is not directly in **House**.

3. The **z** argument is currently unbound, which means it has no value and returns everything that is in the argument.
4. The **y** argument is currently bound to **House**, so **z** returns **Office** and **Kitchen**.
5. The query gathers information from the **Office** and checks recursively if the **Drawer** is in the **Office**. The query line **isContainedIn(x, z;)** is called for these parameters.
6. No instance of **Drawer** exists directly in **Office**, so no match is found.
7. With **z** unbound, the query returns data within the **Office** and determines that **z == Desk**.

   ```
   isContainedIn(x==drawer, z==desk)
   ```

8. The **isContainedIn** query recursively searches three times, and on the third time, the query detects an instance of **Drawer** in **Desk**.

   ```
   Location(x==drawer, y==desk)
   ```

9. After this match on the first location, the query recursively searches back up the structure to determine that the **Drawer** is in the **Desk**, the **Desk** is in the **Office**, and the **Office** is in the **House**. Therefore, the **Drawer** is in the **House** and the rule is satisfied.

Reactive query rule

A reactive query searches through the hierarchy of a data structure for relationships between elements and is dynamically updated when elements in the structure are modified.

The rule **"go3"** functions as a reactive query that detects if a new item **Key** ever becomes present in the **Office** by transitive closure: A **Key** in the **Drawer** in the **Office**.

Rule "go3"

```
rule "go3"
  when
    String( this == "go3" )
    isContainedIn("Key", "Office"; )
  then
    System.out.println( "Key is in the Office" );
end
```

The example inserts the **"go3"** string into the decision engine and activates the **"go3"** rule. Initially, this rule is not satisfied because no item **Key** exists in the house structure, so the rule produces no output.

Insert string and fire rules

```
ksession.insert( "go3" );
ksession.fireAllRules();
```

Rule "go3" output in the IDE console (unsatisfied)

```
go3
```

The example then inserts a new item **Key** in the location **Drawer**, which is in **Office**. This change satisfies the transitive closure in the **"go3"** rule and the output is populated accordingly.

Insert new item location and fire rules

```
ksession.insert( new Location("Key", "Drawer") );
ksession.fireAllRules();
```

Rule "go3" output in the IDE console (satisfied)

```
Key is in the Office
```

This change also adds another level in the structure that the query includes in subsequent recursive searches.

Queries with unbound arguments in rules

A query with one or more unbound arguments returns all undefined (unbound) items within a defined (bound) argument of the query. If all arguments in a query are unbound, then the query returns all items within the scope of the query.

The rule **"go4"** uses an unbound argument **thing** to search for all items within the bound argument **Office**, instead of using a bound argument to search for a specific item in the **Office**:

Rule "go4"

```
rule "go4"
  when
    String( this == "go4" )
    isContainedIn(thing, "Office"; )
  then
    System.out.println( thing + "is in the Office" );
end
```

The example inserts the **"go4"** string into the decision engine and activates the **"go4"** rule to return all items in the **Office**:

Insert string and fire rules

```
ksession.insert( "go4" );
ksession.fireAllRules();
```

Rule "go4" output in the IDE console

```
go4
Chair is in the Office
Desk is in the Office
Key is in the Office
Computer is in the Office
Drawer is in the Office
```

The rule **"go5"** uses both unbound arguments **thing** and **location** to search for all items and their locations in the entire **House** data structure:

Rule "go5"

```
rule "go5"
```

```
  when
    String( this == "go5" )
    isContainedIn(thing, location; )
  then
    System.out.println(thing + " is in " + location );
end
```

The example inserts the **"go5"** string into the decision engine and activates the **"go5"** rule to return all items and their locations in the **House** data structure:

Insert string and fire rules

```
ksession.insert( "go5" );
ksession.fireAllRules();
```

Rule "go5" output in the IDE console

```
go5
Chair is in Office
Desk is in Office
Drawer is in Desk
Key is in Drawer
Kitchen is in House
Cheese is in Kitchen
Knife is in Kitchen
Computer is in Desk
Office is in House
Key is in Office
Drawer is in House
Computer is in House
Key is in House
Desk is in House
Chair is in House
Knife is in House
Cheese is in House
Computer is in Office
Drawer is in Office
Key is in Desk
```

CHAPTER 8. NEXT STEPS

- *Testing a decision service using test scenarios*
- *Packaging and deploying a Red Hat Decision Manager project*

APPENDIX A. VERSIONING INFORMATION

Documentation last updated on Wednesday, June 10, 2020.