JBoss Enterprise SOA Platform 5.0

JBoss Rules 5 Reference Guide

Your complete guide to using JBoss Rules 5 with the JBoss Enterprise SOA Platform.

Mark Proctor

Michael Neale

Edson Tirelli

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Edition 1.0

Author	Mark Proctor	
Author	Michael Neale	
Author	Edson Tirelli	
Editor	Darrin Mison	dmison@redhat.com

1801 Varsity Drive
Raleigh, NC 27606-2072 USA
Phone: +1 919 754 3700
Phone: 888 733 4281
Fax: +1 919 754 3701
PO Box 13588 Research Triangle Park, NC 27709 USA

This guide contains a complete overview and detailed reference for JBoss Rules 5 for use with the JBoss Enterprise SOA Platform.

Preface

1. Document Conventions

This manual uses several conventions to highlight certain words and phrases and draw attention to specific pieces of information.

In PDF and paper editions, this manual uses typefaces drawn from the *Liberation Fonts*[1] set. The Liberation Fonts set is also used in HTML editions if the set is installed on your system. If not, alternative but equivalent typefaces are displayed. Note: Red Hat Enterprise Linux 5 and later includes the Liberation Fonts set by default.

1.1. Typographic Conventions

Four typographic conventions are used to call attention to specific words and phrases. These conventions, and the circumstances they apply to, are as follows.

`Mono-spaced Bold`

Used to highlight system input, including shell commands, file names and paths. Also used to highlight key caps and key-combinations. For example:

> To see the contents of the file **`my_next_bestselling_novel`** in your current working directory, enter the **`cat my_next_bestselling_novel`** command at the shell prompt and press **`Enter`** to execute the command.

The above includes a file name, a shell command and a key cap, all presented in Mono-spaced Bold and all distinguishable thanks to context.

Key-combinations can be distinguished from key caps by the hyphen connecting each part of a key-combination. For example:

> Press **`Enter`** to execute the command.
>
> Press **`Ctrl`**-**`Alt`**-**`F1`** to switch to the first virtual terminal. Press **`Ctrl`**-**`Alt`**-**`F7`** to return to your X-Windows session.

The first sentence highlights the particular key cap to press. The second highlights two sets of three key caps, each set pressed simultaneously.

If source code is discussed, class names, methods, functions, variable names and returned values mentioned within a paragraph will be presented as above, in **`Mono-spaced Bold`**. For example:

> File-related classes include **`filesystem`** for file systems, **`file`** for files, and **`dir`** for directories. Each class has its own associated set of permissions.

Proportional Bold

This denotes words or phrases encountered on a system, including application names; dialogue box text; labelled buttons; check-box and radio button labels; menu titles and sub-menu titles. For example:

[1] https://fedorahosted.org/liberation-fonts/

> Choose **System > Preferences > Mouse** from the main menu bar to launch **Mouse Preferences**. In the **Buttons** tab, click the **Left-handed mouse** check box and click **Close** to switch the primary mouse button from the left to the right (making the mouse suitable for use in the left hand).
>
> To insert a special character into a **gedit** file, choose **Applications > Accessories > Character Map** from the main menu bar. Next, choose **Search > Find…** from the **Character Map** menu bar, type the name of the character in the **Search** field and click **Next**. The character you sought will be highlighted in the **Character Table**. Double-click this highlighted character to place it in the **Text to copy** field and then click the **Copy** button. Now switch back to your document and choose **Edit > Paste** from the **gedit** menu bar.

The above text includes application names; system-wide menu names and items; application-specific menu names; and buttons and text found within a GUI interface, all presented in Proportional Bold and all distinguishable by context.

Note the **>** shorthand used to indicate traversal through a menu and its sub-menus. This is to avoid the difficult-to-follow 'Select **Mouse** from the **Preferences** sub-menu in the **System** menu of the main menu bar' approach.

`Mono-spaced Bold Italic` or ***`Proportional Bold Italic`***

Whether Mono-spaced Bold or Proportional Bold, the addition of Italics indicates replaceable or variable text. Italics denotes text you do not input literally or displayed text that changes depending on circumstance. For example:

> To connect to a remote machine using ssh, type **`ssh`** ***`username@domain.name`*** at a shell prompt. If the remote machine is **`example.com`** and your username on that machine is john, type **`ssh john@example.com`**.
>
> The **`mount -o remount`** ***`file-system`*** command remounts the named file system. For example, to remount the **`/home`** file system, the command is **`mount -o remount /home`**.
>
> To see the version of a currently installed package, use the **`rpm -q`** ***`package`*** command. It will return a result as follows: ***`package-version-release`***.

Note the words in bold italics above — username, domain.name, file-system, package, version and release. Each word is a placeholder, either for text you enter when issuing a command or for text displayed by the system.

Aside from standard usage for presenting the title of a work, italics denotes the first use of a new and important term. For example:

> When the Apache HTTP Server accepts requests, it dispatches child processes or threads to handle them. This group of child processes or threads is known as a *server-pool*. Under Apache HTTP Server 2.0, the responsibility for creating and maintaining these server-pools has been abstracted to a group of modules called *Multi-Processing Modules* (*MPMs*). Unlike other modules, only one module from the MPM group can be loaded by the Apache HTTP Server.

1.2. Pull-quote Conventions

Two, commonly multi-line, data types are set off visually from the surrounding text.

Output sent to a terminal is set in `Mono-spaced Roman` and presented thus:

```
books         Desktop   documentation  drafts  mss    photos   stuff  svn
books_tests   Desktop1  downloads      images  notes  scripts  svgs
```

Source-code listings are also set in `Mono-spaced Roman` but are presented and highlighted as follows:

```
package org.jboss.book.jca.ex1;

import javax.naming.InitialContext;

public class ExClient
{
   public static void main(String args[])
       throws Exception
   {
      InitialContext iniCtx = new InitialContext();
      Object         ref    = iniCtx.lookup("EchoBean");
      EchoHome       home   = (EchoHome) ref;
      Echo           echo   = home.create();

      System.out.println("Created Echo");

      System.out.println("Echo.echo('Hello') = " + echo.echo("Hello"));
   }

}
```

1.3. Notes and Warnings

Finally, we use three visual styles to draw attention to information that might otherwise be overlooked.

Note

A Note is a tip or shortcut or alternative approach to the task at hand. Ignoring a note should have no negative consequences, but you might miss out on a trick that makes your life easier.

Important

Important boxes detail things that are easily missed: configuration changes that only apply to the current session, or services that need restarting before an update will apply. Ignoring Important boxes won't cause data loss but may cause irritation and frustration.

Warning

A Warning should not be ignored. Ignoring warnings will most likely cause data loss.

2. We Need Feedback!

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you! Please submit a report in Bugzilla: *http://bugzilla.redhat.com/bugzilla/* against the product **Documentation.**

When submitting a bug report, be sure to mention the manual's identifier: *JBoss_Rules_5_Reference_Guide*

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

Introduction

1.1. What is a Rule Engine?

Artificial Intelligence (A.I.) is a very broad research area that focuses on "Making computers think like people" and includes disciplines such as Neural Networks, Genetic Algorithms, Decision Trees, Frame Systems and Expert Systems. Knowledge representation is the area of A.I. concerned with how knowledge is represented and manipulated. Expert Systems use Knowledge representation to facilitate the codification of knowledge into a knowledge base which can be used for reasoning, i.e. we can process data with this knowledge base to infer conclusions. Expert Systems are also known as Knowledge-based Systems and Knowledge-based Expert Systems and are considered to be "applied artificial intelligence". The process of developing with an Expert System is Knowledge Engineering. EMYCIN was one of the first "shells" for an Expert System, which was created from the MYCIN medical diagnosis Expert System. Whereas early Expert Systems had their logic hard-coded, "shells" separated the logic from the system, providing an easy to use environment for user input. JBoss Rules is a Rule Engine that uses the rule-based approach to implement an Expert System and is more correctly classified as a Production Rule System.

The term "Production Rule" originates from formal grammars where it is described as "an abstract structure that describes a formal language precisely, i.e., a set of rules that mathematically delineates a (usually infinite) set of finite-length strings over a (usually finite) alphabet" (*http://en.wikipedia.org/wiki/Formal_grammar*).

Business Rule Management Systems build additional value on top of a general purpose Rule Engine by providing business user focused systems for rule creation, management, deployment, collaboration, analysis and end user tools. Further adding to this value is the fast evolving and popular methodology "Business Rules Approach", which is a helping to formalize the role of Rule Engines in the enterprise.

The term Rule Engine is quite ambiguous in that it can be any system that uses rules, in any form, that can be applied to data to produce outcomes. This includes simple systems like form validation and dynamic expression engines. The book "How to Build a Business Rules Engine (2004)" by Malcolm Chisholm exemplifies this ambiguity. The book is actually about how to build and alter a database schema to hold validation rules. The book then shows how to generate VB code from those validation rules to validate data entry. While a very valid and useful topic for some, this caused quite a surprise to this author, unaware at the time in the subtleties of Rules Engines' differences, who was hoping to find some hidden secrets to help improve the JBoss Rules engine. JBoss jBPM uses expressions and delegates in its Decision nodes which control the transitions in a Workflow. At each node it evaluates, there is a rule set that dictates the transition to undertake, and so this is also a Rule Engine. While a Production Rule System is a kind of Rule Engine and also an Expert System, the validation and expression evaluation Rule Engines mentioned previously are not Expert Systems.

A Production Rule System is Turing complete, with a focus on knowledge representation to express propositional and first order logic in a concise, non-ambiguous and declarative manner. The brain of a Production Rules System is an Inference Engine that is able to scale to a large number of rules and facts. The Inference Engine matches facts and data against Production Rules - also called Productions or Rules - to infer conclusions which result in actions. A Production Rule is a two-part structure using First Order Logic for reasoning over knowledge representation.

```
when
```

```
 <conditions>
then
 <actions>
```

The process of matching the new or existing facts against Production Rules is called Pattern Matching, which is performed by the Inference Engine. The most commonly used algorithms used for Pattern Matching are *Linear*, *Rete*, *Treat*, and *Leaps*.

JBoss Rules implements and extends the Rete algorithm. The Rete implementation used by JBoss Rules is called **`ReteOO`**, an enhanced and optimized implementation of the Rete algorithm for Object Oriented systems. The most common enhancements to Rete based systems are covered in "Production Matching for Large Learning Systems (Rete/UL)"(1995) by Robert B. Doorenbos.

The Rules are stored in the Production Memory and the facts that the Inference Engine matches against the Working Memory. Facts are asserted into the Working Memory where they may then be modified or retracted. A system with a large number of rules and facts may result in many rules being true for the same fact assertion, these rules are said to be in conflict. The Agenda manages the execution order of these conflicting rules using a Conflict Resolution strategy.

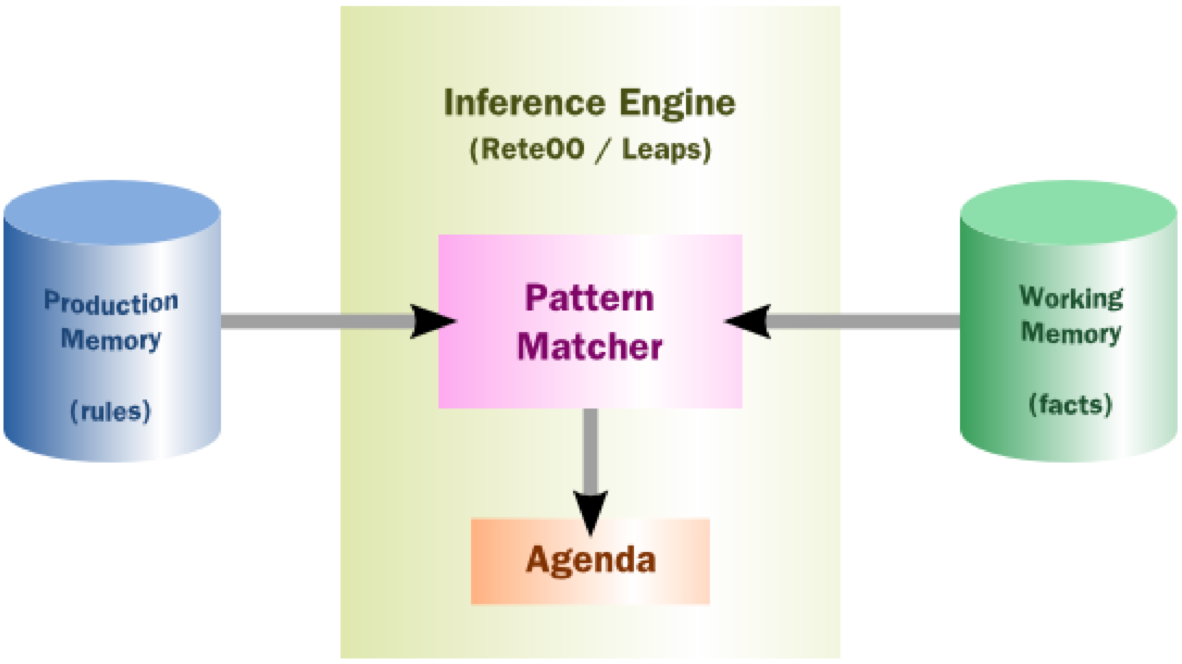


Figure 1.1. High-level View of a Rule Engine

There are two methods of execution for a Production Rule Systems, *Forward Chaining* and *Backward Chaining*. Systems that implement both methods are called *Hybrid Production Rule Systems*. Understanding these two modes of operation are key to understanding the differences between Production Rule Systems and how to optimize them.

Forward Chaining

Forward chaining is 'data-driven', it reacts to data presented to it. Facts are inserted into the working memory which results in one or more rules being true and scheduled for execution by the *Agenda*.

JBoss Rules is a Forward Chaining engine.

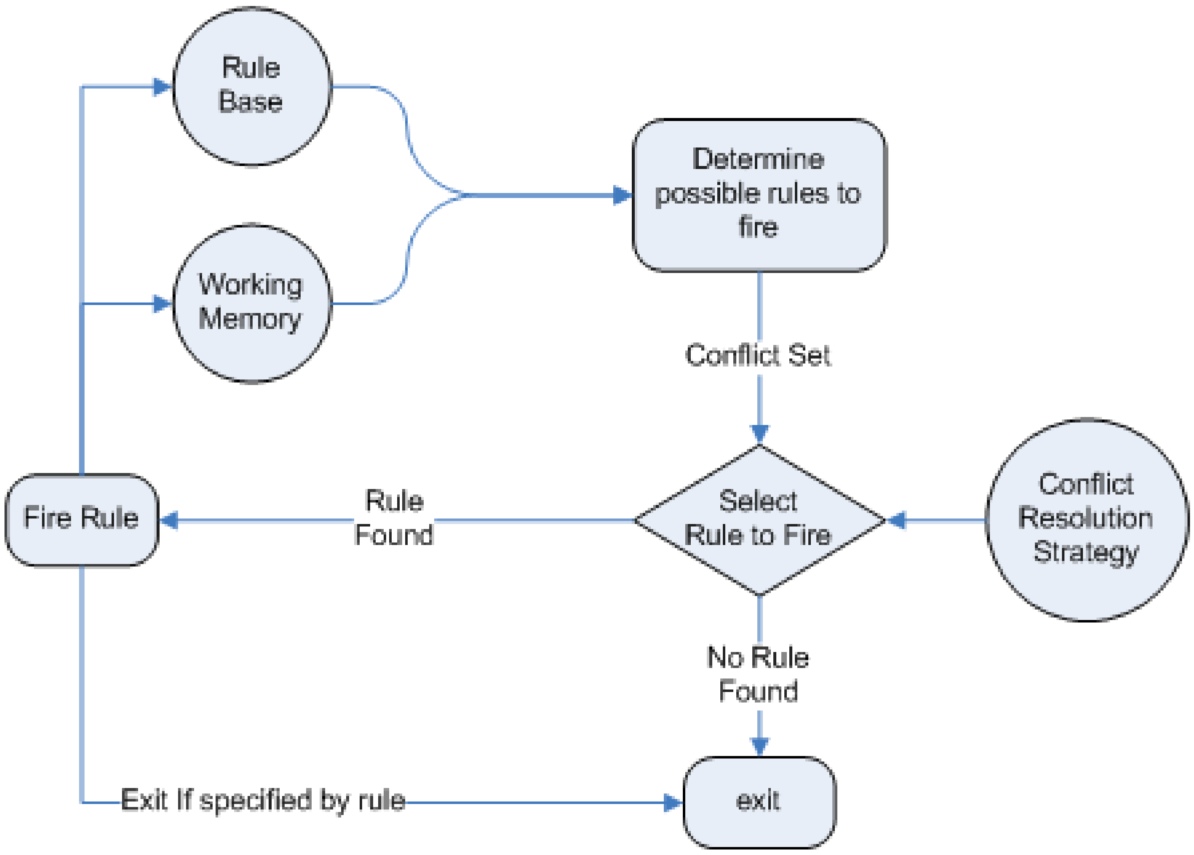


Figure 1.2. Forward Chaining

Backward Chaining

Backward chaining is 'goal-driven'. The system starts with a *conclusion* which the engine tries to satisfy. If this conclusion cannot be satisfied the engine searches for *sub goals*, conclusions that will help satisfy a part of the current goal. It continues this process until either the initial conclusion is satisfied or there are no more unsatisfied sub goals. Prolog is an example of a Backward Chaining engine.

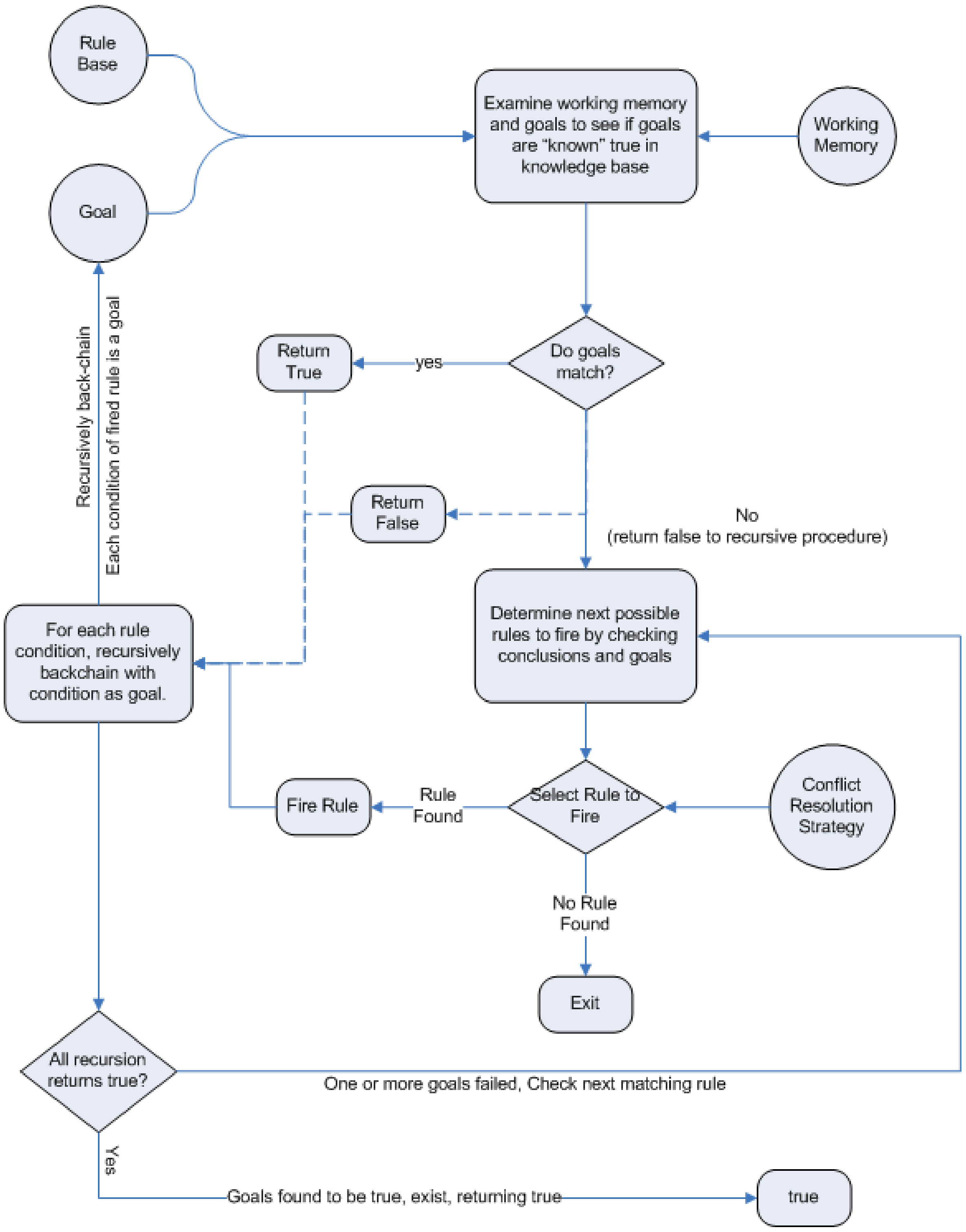

Rule Base
Goal
Examine working memory and goals to see if goals are "known" true in knowledge base
Working Memory
Do goals match?
yes
Return True
Return False
No (return false to recursive procedure)
Recursively back-chain
Each condition of fired rule is a goal
For each rule condition, recursively backchain with condition as goal.
Determine next possible rules to fire by checking conclusions and goals
Fire Rule
Rule Found
Select Rule to Fire
Conflict Resolution Strategy
No Rule Found
Exit
All recursion returns true?
One or more goals failed, Check next matching rule
Yes
Goals found to be true, exist, returning true
true

Figure 1.3. Backward Chaining

Support for Backward Chaining is planned for a future release of JBoss Rules.

1.2. Why use a Rule Engine?

The most frequently asked questions regarding Rules Engines are:

1. When should you use a rule engine?
2. What advantage does a rule engine have over hand coded "if...then" approaches?
3. Why should you use a rule engine instead of a scripting framework, like BeanShell?

We will attempt to address these questions below.

1.2.1. Advantages of a Rule Engine

- Declarative Programming

  Rule engines allow you to say "What to do", not "How to do it".

  Using rules can make it very easy to express solutions to difficult problems and consequently have those solutions verified. Declarative rules are much easier to read then imperative code.

  Rule systems are not only capable of solving very hard problems but also providing an explanation of how the solution was arrived at and why each decision along the way was made. This is not easy with other AI systems like neural networks.

- Logic and Data Separation

  Your data is in your domain objects, the logic is in the rules. This is a fundamental break from the object-orientated coupling of data and logic, which can be an advantage or a disadvantage depending on your point of view. The advantage is that the logic can be much easier to maintain when there are changes in the future, because it is all laid out in rules. This can be especially true if the logic is cross-domain or multi-domain logic. Instead of the logic being spread across many domain objects or controllers, it can all be organized in one or more very distinct rules files.

- Speed and Scalability

  The Rete algorithm,the Leaps algorithm, and their descendants such as JBoss Rules' ReteOO, provide very efficient ways of matching rule patterns to your domain object data. These are especially efficient when you have data sets that only change very slightly each time as the rule engine can remember past matches. These algorithms are battle proven.

- Centralization of Knowledge

  By using rules, you create a repository of knowledge (a knowledge base) which is executable. This means it's a single point of truth, for business policy for instance. Ideally rules are so readable that they can also serve as documentation.

- Tool Integration

  Tools such as Eclipse and Web based user interfaces such as the JBoss Enterprise BRMS Platform provide ways to edit and manage rules and get immediate feedback, validation and content assistance. Auditing and debugging tools are also available.

- Explanation Facility

  Rule systems can provide an "explanation facility" by logging the decisions made by the rule engine along with why the decisions were made.

- Understandable Rules

By creating object models and Domain Specific Languages that model your problem domain effectively you can write rules that look very close to natural language. These rules can be very understandable to non-technical domain experts.

1.2.2. When should you use a Rule Engine?

The shortest answer to this is "when there is no satisfactory traditional programming approach to solve the problem.". Given that short answer, some more explanation is required. The reason why there is no "traditional" approach is possibly one of the following:

- The problem is just too complex for traditional code.

  The problem may not be complex, but you can't see a robust way of building it.

- There are no obvious traditional solutions or the problem isn't fully understood.

- The logic changes often

  The logic itself may be simple but the rules change quite often. In many organizations software releases are rare and rules can help provide the "agility" that is needed and expected in a reasonably safe way.

- Domain experts and business analysts are readily available, but are nontechnical.

  Domain experts possess a wealth of knowledge about business rules and processes. They typically are nontechnical, but can be very logical. Rules can allow them to express the logic in their own terms. Of course, they still have to think critically and be capable of logical thinking. Many people in nontechnical positions do not have training in formal logic, so be careful and work with them, as by codifying business knowledge in rules, you will often expose problems with how the business rules and processes are currently understood.

If rules are a new technology for your project teams, the overhead in getting going must be factored in. It is not a trivial technology, but this document tries to make it easier to understand.

Typically you would use a rule engine to separate key parts of your business logic from your application. This is in opposition to the object-orientated (OO) concept of encapsulating all the logic inside your objects. This does not mean that you throw out OO practices away as business logic is only one part of your application. However you should consider a rule engine if your application code is becoming increasing complicated by conditionals (if, else, switch), excessive strategy patterns or other business logic that requires frequent change. If you are faced with tough problems of which there are no algorithms or patterns for, consider using rules.

Rules could be used embedded in your application or perhaps as a service. Often a rule engine works best as "stateful" component, being an integral part of an application. However, there have been successful cases of creating reusable rule services which are stateless.

For your organization it is important to decide about the process you will use for updating rules in systems that are in production. The options are many, but different organizations have different requirements. Often, rules maintenance is out of the control of the application vendors or project developers.

1.2.3. When not to use a Rule Engine

Rules engines are not designed to handle workflow or process executions. In the excitement of working with rules engines, that people sometimes forget that a rules engine is only one piece of a complex application or solution.

In some organizations rule engines are seen as a way of being able to update an application's behavior without the complications of having to formally re-deploy the application within their enterprise. In such circumstances it should be considered that rule engines work most effectively when the rules can be written in a declarative manner. If this cannot be done then you should consider alternative solutions such as data-driven designs, scripting engines or process engines.

Data-driven systems store meta-data that changes your applications behavior. These can work well when the control can remain relatively limited. However they often either grow to complex to maintain if extended too much or cause the application to stagnate as they are too inflexible.

Scripting engines separate your imperative business logic from your application. Your business logic is usually written in a simpler scripting language that does not need to be compiled. They are easy to implement and are a familiar environment for many imperative programmers. The downside of scripting engines is that you have created a tight coupling of your application to the scripts and such imperative scripts can easily grow in complexity and become difficult to maintain. When evaluating rule engines you may notice that some rule engines are really scripting engines.

Process and Workflow Engines such as jBPM allow you to graphically or programmatically describe steps in a process. Those steps can also involve decision points which can be considered simple rules. Process and rule engines complement each other very well, so they are not mutually exclusive.

1.2.4. Strong and Loose Coupling

No doubt you have heard terms like "tight coupling" and "loose coupling" in systems design. Generally people assert that "loose" or "weak" coupling is preferable in design terms, due to the added flexibility it affords. Similarly, you can have "strongly coupled" and "weakly coupled" rules. Strongly coupled in this sense means that one rule "firing" will clearly result in another rule firing, and so on; in other words, there is a clear (probably obvious) chain of logic. If your rules are all strongly coupled, the chances are that the will turn out to be inflexible, and, more significantly, that a rule engine is an overkill. A clear chain can be hard coded, or implemented using a Decision Tree. This is not to say that strong coupling is inherently bad, but it is a point to keep in mind when considering a rule engine and the way you capture the rules. "Loosely" coupled rules should result in a system that allows rules to be changed, removed and added without requiring changes to other, unrelated rules.

Quick Start

2.1. The Basics

For beginners, JBoss Rules™ can be overwhelming because there is so much functionality provided and the software can deal with many different use cases. The purpose of this chapter is to introduce the basics of this functionality with some very simple examples.

2.1.1. State-less Knowledge Session

A state-less (without inference) session, is the simplest use-case. A stateless session can be called like a function, passing it some data and then receiving some results back. Some common use cases for state-less sessions are, (but not limited to), the following:

- Validation: for example, "Is this person eligible for a mortgage?"
- Calculation: for example, "Compute a mortgage premium for me."
- Routing and filtering: for example "Filtering my incoming messages, such as e.-mails, into folders or sendg incoming messages to a destination."

You will start with a simple example, involving a driving license application. First of all you need your data, this being the *fact* that will be passed to your rule.

```
package com.company.license;

public class Applicant
{
    private String name;
    private int age;
    private boolean valid;

 public Applicant (String name, int age, boolean valid)
 {
  this.name = name;
  this.age = age;
  this.valid = valid;
 }

 //add getters & setters here

}
```

Now that you possess your data model, you can write your first rule. This rule will perform a simple validation to disqualify any applicant younger than eighteen years of age.

```
package com.company.license;

rule "Is of valid age"
when
    $a : Applicant( age < 18 )
```

```
then
    $a.setValid( false );
end
```

When the `Applicant` object is inserted into the rule engine, it is evaluated against the constraints of each rule to see which, if any, it matches. There is always an implied constraint of "object type" and, then, there can be any number of explicit field constraints. These constraints are referred to as a *pattern* and this process is often referred to as *pattern matching*. When an inserted object satisfies all the constraints of a rule it is said to be *matched*.

In the "`Is of valid age`" rule there are two constraints:

1. the fact being matched against must be of type Applicant, and

2. the value of age must be less than 18

The **`$a`** is a binding variable which allows the matched object to be referenced in the rule's consequence (where its properties can be updated.) The dollar character ('**`$`**') is optional but it helps to differentiate variable names from field names.

For the moment, one will assume that the rules are in the same folder as the classes. This is so that one can use the "classpath resource loader" to build your first *Knowledge Base*. "Knowledge Base" is the name given to a collection of rules, which have been compiled by the **`KnowledgeBuilder`**.

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
kbuilder.add( ResourceFactory.newClassPathResource(
 "licenseApplication.drl", getClass() ), ResourceType.DRL );
if ( kbuilder.hasErrors() ) {
    System.err.println( kbuilder.getErrors().toString() );
}
```

The piece of code quoted above searches the classpath for the **`licenseApplication.drl`** file, by using the method entitled `newClassPathResource()`. The **`ResourceType`** is written in the *JBoss Rules Rule Language* (DRL). Once the **`.drl`** file has been added, one can check the **`KnowledgeBuilder`** for any errors. If there are no errors, we are now ready to build our session and execute against some data.

One can then execute the data against the rules. Since the applicant is under the age of eighteen, the application is marked as "invalid."

```
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
kbase.addKnowledgePackages( kbuilder.getKnowledgePackages() );
StatelessKnowledgeSession ksession = kbase.newStatelessKnowledgeSession();
Applicant applicant = new Applicant( "Mr John Smith", 16, true );

assertTrue( applicant.isValid() );
ksession.execute( applicant );
assertFalse( applicant.isValid() );
```

So far the data has consisted of but a single object, yet what if one wanted to use more than this? You can execute against any object-implementing `Iterable`, such as a collection. In this next case, you will add another class called **`Application`**. This contains the application's date. You will also move the Boolean field entitled valid to the **`Application`** class, updating the constructors as appropriate.

```
public class Applicant {
    private String name;
    private int age;

    public Applicant (String name, int age)
 {
  this.name = name;
  this.age = age;
 }
    // getter and setter methods here
}

public class Application {
    private Date dateApplied;
    private boolean valid;

    public Application (boolean valid)
    {
        this.valid = valid;
    }
    // getter and setter methods here

}
```

One can also add another rule to validate that the application was made within a legitimate period of time.

```
package com.company.license

rule "Is of valid age"
when
    Applicant( age < 18 )
    $a : Application()
then
    $a.setValid( false );
end

rule "Application was made this year"
when
    $a : Application( dateApplied > "01-jan-2009" )
then
    $a.setValid( false );
end
```

Unfortunately, a Java array does not implement the `Iterable` interface, so one must use the JDK converter method, which commences with the line, `Arrays.asList(...)`. The code shown below executes against an iterable list, whereby all collection elements are inserted before any matched rules are fired.

```
StatelessKnowledgeSession ksession = kbase.newStatelessKnowledgeSession();
```

```
kbase.addKnowledgePackages( kbuilder.getKnowledgePackages() );
Applicant applicant = new Applicant( "Mr John Smith", 16 );
Application application = new Application(true);
assertTrue( application.isValid() );
ksession.execute( Arrays.asList( new Object[] {application, applicant} ));
assertFalse( application.isValid() );
```

The methods entitled `execute(Object object)` and `execute(Iterable objects)` are actually wrappers for a further method called `execute(Command command)` which is from the interface `BatchExecutor`.

A **`CommandFactory`** is used to create instructions, so that the following is equivalent to `execute( Iterable it )`:

```
ksession.execute(
   CommandFactory.newInsertElements(Arrays.asList(new Object[]
 {application,applicant}))
);
```

The `BatchExecutor` and **`CommandFactory`** are particularly useful when working with multiple commands and result output identifiers.

```
List<Command> cmds = new ArrayList<Command>();
cmds.add(
   CommandFactory.newInsertObject(new Person("Mr John Smith"), "mrSmith"));
cmds.add(
   CommandFactory.newInsertObject(new Person( "Mr John Doe" ), "mrDoe" ));

ExecutionResults results =
 ksession.execute( CommandFactory.newBatchExecution(cmds) );

assertEquals( new Person("Mr John Smith"), results.getValue("mrSmith") );
```

`CommandFactory` supports many other Commands that can be used in the `BatchExecutor` like `StartProcess`, `Query`, and `SetGlobal`.

2.1.2. State-ful Knowledge Session

State-ful sessions are live longer and allow iterative changes to be made to facts over time. Just some of the many common use-cases for state-ful sessions are as follows:

- Monitoring. An example would be stock market monitoring and analysis for semi-automatic buying.
- Diagnostics. Some examples would be fault-finding and medical diagnostics
- Logistic. Some examples would be parcel tracking and delivery provisioning
- Compliance. An example would be validation of legality for market trades.

In contrast to a state-less session, in this case the `dispose()` method must be called afterwards to ensure there are no memory leaks. This is due to the fact that the Knowledge Base contains references to state-ful knowledge sessions when they are created. `StatefulKnowledgeSession` also supports the `BatchExecutor` interface, like `StatelessKnowledgeSession`, the only difference being that the `FireAllRules` command is not automatically called at the end in this case.

We will illustrate the monitoring use case with an example of raising a fire alarm. Our model represents rooms in a house, each of which has one sprinkler. A fire can start in any of the rooms.

```
public class Room
{
 private String name
  // getter and setter methods here
}

public classs Sprinkler
{
 private Room room;
 private boolean on;
 // getter and setter methods here
}

public class Fire
{
 private Room room;
 // getter and setter methods here
}

public class Alarm
{
}
```

In the previous section on state-less sessions, you were introduced to the concepts of inserting and matching against data. Those examples used a single object and literal constraints. Now that you have more than one piece of data, the rules must express the relationships between those objects, (such as a sprinkler being in a certain room.) One can achieve this by using a binding variable as a constraint in a pattern. This results in what are called *cross products*, which are discussed more fully in *Section 2.2.2, “ Cross Products ”*.

An instance of the **`Fire`** class is created for that room when a conflagration occurs. The instance is then inserted into the session. The rule uses a binding on the room field of the **`Fire`** object to constrain matching to the currently-switched off **`Sprinkler`** for that room. When this rule fires and the consequence is executed, the sprinkler is turned on.

```
rule "When there is a fire turn on the sprinkler"
when
    Fire($room : room)
    $sprinkler : Sprinkler( room == $room, on == false )
then
    modify( $sprinkler ) { setOn( true ) };
    System.out.println("Turn on the sprinkler for room "+$room.getName());
end
```

Whereas the state-less session employs standard Java syntax to modify a field, in the above rule one uses the `modify` statement. (It acts much like a "with" statement.) It may contain a series of comma-separated Java expressions, which are, to all intents and purposes, calls to object **`setters`** that have been selected by the `modify` statement's control expression. They modify the data and make the engine aware of the changes so that it can "reason" over them once more. This process is termed *inference* and it is key to a state-ful session's operation. (By contrast, state-less sessions do not use inference, so the engine does not need to be aware of changes to data.) Inference can also be explicitly turned off via the *sequential mode*.

So far, you have seen rules that tell you when matching data exists but what happens when it does *not* exist? How does one determine that a fire has been extinguished, (or, to put it in programming terms, that there is not a `Fire` object any more?) Previously, the constraints have been sentences according to "*Propositional Logic*," whereby the engine is constraining against individual instances. JBoss Rules also has support for "*First Order Logic*," which allows you to look at sets of data. A pattern under the keyword "`not`" matches only when something does not exist.

The example rule given below turns the sprinkler off when the fire in which it resides room has been extinguished:

```
rule "When the fire is gone turn off the sprinkler"
when
    $room : Room( )
    $sprinkler : Sprinkler( room == $room, on == true )
    not Fire( room == $room )
then
    modify( $sprinkler ) { setOn( false ) };
    System.out.println("Turn off the sprinkler for room "+$room.getName());
end
```

In this example, whilst there is one sprinkler for each room, there is just a single alarm for the entire building. An `Alarm` object is created when a fire occurs, but only one `Alarm` is needed for the entire building, no matter how many fires there may be. Previously "`not`" was introduced to match the absence of a fact; now one can use its complement, "`exists`" which matches one or more instances of some category.

```
rule "Raise the alarm when we have one or more fires"
when
    exists Fire()
then
    insert( new Alarm() );
    System.out.println( "Raise the alarm" );
end
```

Likewise, when there are no fires you will want to remove the alarm, so the "`not`" keyword can be used again for this purpose.

```
rule "Cancel the alarm when all the fires have gone"
when
    not Fire()
    $alarm : Alarm()
then
    retract( $alarm );
    System.out.println( "Cancel the alarm" );
end
```

Finally, a general health status message is printed both when the application first starts and also after the **`alarm`** is removed and all **`sprinklers`** have been turned off.

```
rule "Status output when things are ok"
when
    not Alarm()
    not Sprinkler( on == true )
then
    System.out.println( "Everything is ok" );
end
```

The above rules should be stored in a file called **`fireAlarm.drl`**. Save this file in a subdirectory on the classpath, as you did in the "state-less session" example. You can then build a Knowledge Base, as you did before, using the new name **`fireAlarm.drl`**.

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
kbuilder.add( ResourceFactory.newClassPathResource( "fireAlarm.drl",
          getClass() ), ResourceType.DRL );

if ( kbuilder.hasErrors() )
 System.err.println( kbuilder.getErrors().toString() );

StatefulKnowledgeSession ksession = kbase.newStatefulKnowledgeSession();
```

Once the session has been created, one can work with it on an iteratve basis. In this example, four Room objects are created and inserted, along with one `Sprinkler` object for each room. At this point, the engine has concluded matching but no rules have yet been fired. Calling `ksession.fireAllRules()` allows the matched rules to execute but, without a `fire`, they will merely produce the health message.

```
String[] names = new String[]{"kitchen","bedroom","office","livingroom"};
Map<String,Room> name2room = new HashMap<String,Room>();

for( String name: names )
{
 Room room = new Room( name );
 name2room.put( name, room );
 ksession.insert( room );
 Sprinkler sprinkler = new Sprinkler( room );
 ksession.insert( sprinkler );
}

ksession.fireAllRules();
```

```
> Everything is Okay
```

One can now create and insert two `fires`; this time a reference is kept for the returned `FactHandle`. (A *Fact Handle* is an internal engine reference to the inserted instance. It allows instances to be retracted or modified at a later point in time.) With the `fires` now in the engine, once `fireAllRules()` is called the `alarm` is raised and the respective `sprinklers` are turned on.

```
Fire kitchenFire = new Fire( name2room.get( "kitchen" ) );
Fire officeFire = new Fire( name2room.get( "office" ) );

FactHandle kitchenFireHandle = ksession.insert( kitchenFire );
FactHandle officeFireHandle = ksession.insert( officeFire );

ksession.fireAllRules();
```

```
> Raise the alarm
> Turn on the sprinkler for room kitchen
> Turn on the sprinkler for room office
```

After a while, the fires will be extinguishged and the `fire` objects are, therefore, retracted. As a result of this, the `sprinklers` are turned off, the `alarm` is cancelled and he health message is printed once more.

```
ksession.retract( kitchenFireHandle );
ksession.retract( officeFireHandle );

ksession.fireAllRules();
```

```
> Turn off the sprinkler for room office
> Turn off the sprinkler for room kitchen
> Cancel the alarm
> Everything is ok
```

```
> Turn off the sprinkler for room office
> Turn off the sprinkler for room kitchen
> Cancel the alarm
> Everything is ok
```

In conclusion, this simple example has demonstrated some of the functionality and power of the declarative rule system.

2.2. A Little Theory

2.2.1. Methods versus Rules

New users often confuse methods and rules, and ask the question, "How do I call a rule?" The previous section should have clarified the matter but the differences are summarised again here:

```
public void helloWorld(Person person)
{
 if ( person.getName().equals( "Chuck" ) )
 {
     System.out.println( "Hello Chuck" );
 }
}
```

- Methods are called directly.
- Specific instances are passed.
- A single call results in a single execution.

```
rule "Hello World"
when
    Person( name == "Chuck" )
then
    System.out.println( "Hello Chuck" );
end
```

- Rules execute by matching against any data that has been inserted into the engine.
- Rules can never be called directly.
- Specific instances cannot be passed to a rule.
- Depending on the matches, a rule may fire once, several times or not at all.

2.2.2. Cross Products

A "*cross product*" is the result of combining two or more sets of data. Consider the following rule for the fire alarm example:

```
rule "show sprinklers in rooms"
when
    $room : Room()
    $sprinkler : Sprinkler()
then
    System.out.println( "room:" + $room.getName() +
        " sprinkler:" + $sprinkler.getRoom().getName() );
end
```

This is analogous with the Structured Query Language command to `select * from Room, Sprinkler`, in which case every row in the **`Room`** table would be joined with every row in the **`Sprinkler`** table, thereby resulting in the following output:

```
room:office sprinker:office
room:office sprinkler:kitchen
room:office sprinkler:livingroom
room:office sprinkler:bedroom
```

```
room:kitchen sprinkler:office
room:kitchen sprinkler:kitchen
room:kitchen sprinkler:livingroom
room:kitchen sprinkler:bedroom
room:livingroom sprinkler:office
room:livingroom sprinkler:kitchen
room:livingroom sprinkler:livingroom
room:livingroom sprinkler:bedroom
room:bedroom sprinkler:office
room:bedroom sprinkler:kitchen
room:bedroom sprinkler:livingroom
room:bedroom sprinkler:bedroom
```

Cross Products can become huge and, therefore, potentially cause performance problems. To prevent this, you can use variable constraints to eliminate nonsensical results:

```
rule "show sprinklers in rooms"
when
    $room : Room()
    $sprinkler : Sprinkler( room == $room )
then
    System.out.println( "room:" + $room.getName() +
                        " sprinkler:" + $sprinkler.getRoom().getName() );
end
```

This results in just four rows of data, with the correct **`Sprinkler`** assigned to each **`Room`**. In SQL (or HQL) the corresponding query would be `select * from Room, Sprinkler where Room == Sprinkler.room`

```
room:office sprinkler:office
room:kitchen sprinkler:kitchen
room:livingroom sprinkler:livingroom
room:bedroom sprinkler:bedroom
```

2.2.3. Activations, Agenda and Conflict Sets

So far, the data and the matching process have been simple and small. However, once you have many rules and facts being inserted over time, the rule engine needs a way to manage the execution of outcomes. JBoss Rules™ achieves this using *Activations*, *Agendas*, and a *conflict resolution strategy*.

This next example explores the handling of cashflow calculations over date periods. It is more complex than the previous examples. It is assumed that you are comfortable with the Java code for creating **`Knowledge Bases`** and populating a **`StatefulKnowledgeSession`** with facts, so that code will not be repeated here. Diagrams are used to illustrate the state of the rule engine at key stages.

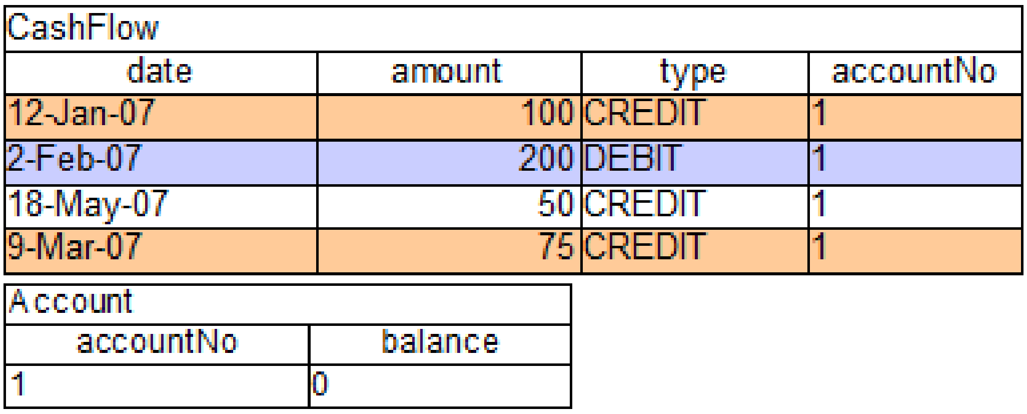
Three classes, **`Cashflow`**, **`Account`** and **`AccountPeriod`**, are used as the data model.

```
public class Cashflow
```

```
{
 private Date   date;
 private double amount;
 private int    type;
 long           accountNo;
 // getter and setter methods here
}

public class Account
{
 private long   accountNo;
 private double balance;
 // getter and setter methods here
}

public AccountPeriod
{
 private Date start;
 private Date end;
 // getter and setter methods here
}
```

By now, you already know how to create Knowledge Bases and how to instantiate facts to populate the `StatefulKnowledgeSession`. Therefore, tables will be used to show the state of the inserted data, as this makes things clearer for illustrative purposes. The tables below show that a single fact was inserted for the `Account`. A series of debits and credits extending over two quarters were also inserted into the account as `CashFlow` objects.

Figure 2.1, “Cash Flows and the Account” shows that a single Account fact was inserted along with four CashFlow facts.



CashFlow			
date	amount	type	accountNo
12-Jan-07	100	CREDIT	1
2-Feb-07	200	DEBIT	1
18-May-07	50	CREDIT	1
9-Mar-07	75	CREDIT	1

Account	
accountNo	balance
1	0

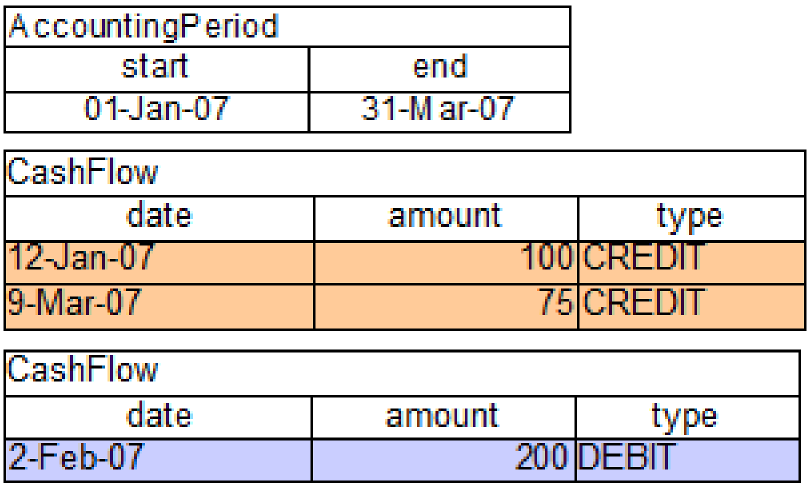
Figure 2.1. Cash Flows and the Account

The two rules which follow are used to, firstly, determine the debit and credit totals for the specified period and, secondly, update the account balance. (Notice the && operator that is used to avoid the need to repeat the field name.)

```
rule "increase balance for credits"
when
  ap : AccountPeriod()
  acc : Account( $accountNo : accountNo )
  CashFlow( type == CREDIT,
    accountNo == $accountNo,
    date >= ap.start && <= ap.end,
    $amount : amount )
then
  acc.setBalance(acc.getBalance() + $amount);
end
```

```
rule "decrease balance for debits"
when
    ap : AccountPeriod()
    acc : Account( $accountNo : accountNo )
    CashFlow( type == DEBIT,
        accountNo == $accountNo,
        date >= ap.start && <= ap.end,
        $amount : amount )
then
    acc.setBalance(acc.getBalance() - $amount);
end
```

As shown in *Figure 2.2, “Cash Flows and the Account”*, the account period starting date is set to the 1st of January and the end is set to the 31st of March. This constrains the data to two CashFlow objects for credit and one for debit, respectively.



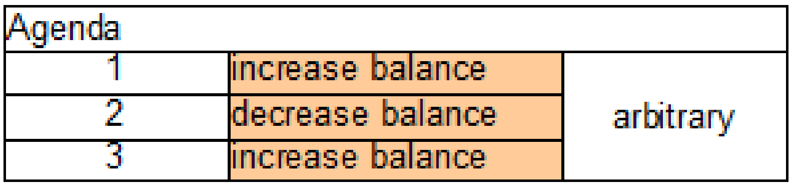
AccountingPeriod	
start	end
01-Jan-07	31-Mar-07

CashFlow		
date	amount	type
12-Jan-07	100	CREDIT
9-Mar-07	75	CREDIT

CashFlow		
date	amount	type
2-Feb-07	200	DEBIT

Figure 2.2. Cash Flows and the Account

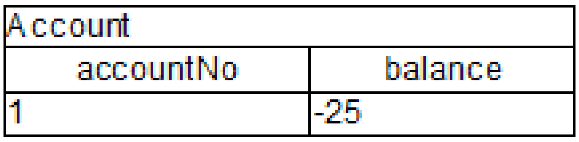
The data is matched during the insertion stage but, because this is a stateful session, the rules' consequences do not execute immediately. The matched rules and the corresponding data are referred to as *Activations*. Each Activation is added to a list called the *Agenda*. Each Activation on the Agenda is executed when `fireAllRules()` is called. Unless specified otherwise, the Activations are executed one after another in an arbitrary order.



Agenda		
1	increase balance	arbitrary
2	decrease balance	
3	increase balance	

Figure 2.3. Cash Flows and the Account

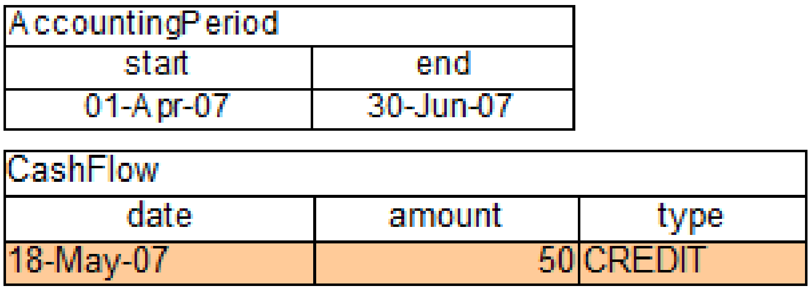
After all of the above activations are fired, the Account has a balance of minus twenty-five.



Account	
accountNo	balance
1	-25

Figure 2.4. Cash Flows and the Account

If the Account Period is updated to the second quarter, you will have just a single matched row of data and, thus, a mere single Activation on the Agenda.

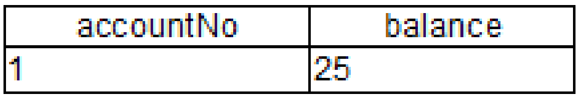


AccountingPeriod	
start	end
01-Apr-07	30-Jun-07

CashFlow		
date	amount	type
18-May-07	50	CREDIT

Figure 2.5. Cash Flows and the Account

The firing of that Activation results in a balance of twenty-five.



accountNo	balance
1	25

Figure 2.6. Cash Flows and the Account

When there are one or more Activations on the agenda, they are said to be "in conflict", and a conflict resolution strategy is used to determine the order of execution. At the simplest level, the default strategy uses *salience* to determine rule priority. Each rule has a default salience value of zero and the higher the value, the higher the priority shall be. The salience can also be a negative value. This lets you order the execution of rules relative to each other. The execution of rules with the same salience value is still arbitrary.

To illustrate this, we add a rule to print the Account balance. This rule is to be executed after all the debits and credits have been applied for all accounts. It has a negative salience value so it will execute after the rules with the default salience value of zero.

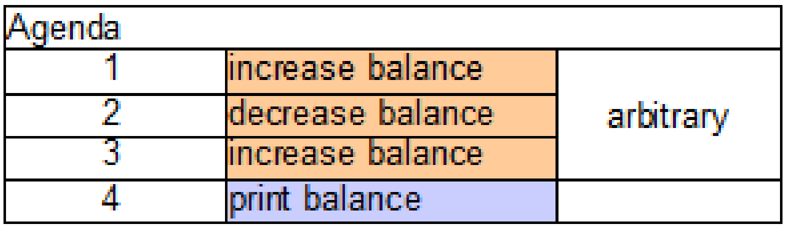
```
rule "Print balance for AccountPeriod"
    salience -50
when
    ap : AccountPeriod()
    acc : Account()
then
```

```
    System.out.println( acc.getAccountNo() + " : " + acc.getBalance() );
end
```

The table below depicts the resulting Agenda. The three debit and credit rules are shown to be in arbitrary order, while the print rule is ranked last, to execute afterwards.

Important

JBoss Rules includes "`ruleflow-group`" attributes. These allow you to declare work-flow diagrams in order to specify when rules can be fired. The screen shot below is taken from JBoss Developer Studio. It has two `ruleflow-group` nodes. These ensure that the calculation rules are executed before the reporting rules.



Agenda		
1	increase balance	arbitrary
2	decrease balance	
3	increase balance	
4	print balance	

Figure 2.7. CashFlows and Account

2.3. More on Building and Deploying

2.3.1. Using "Change Sets" to Add Rules

The examples so far have used the JBoss™ Rules API to build each *Knowledge Base*. They do so by manually adding each rule. JBoss™ Rules also provide a means to declare the resources to be added to a Knowledge Base in XML. This feature is called a *Change Set*.

The Change Set >XML file contains a list of rule resources that can be added to a Knowledge Base. This file may also point to another. At the current moment in time, Change Sets only support the <add> element. Future versions will add support for <remove> and <modify>.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set
    drools-change-set-5.0.xsd' >

    <add>
        <resource source='http://hostname/myrules.drl' type='DRL' />
    </add>

</change-set>
```

The source of each resource is specified by a URL. All the protocols provided by *java.net.URL* are supported. In addition, a protocol called "classpath" can be used. It refers to the "current processes" classpath for the resource. The "type" attribute must always be specified for a resource but it is not inferred from the file name extension.

Note

When use the above XML, note that the code is almost identical as before, with the exception that the ResourceType has been altered to **`CHANGE_SET`**.

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
kbuilder.add( ResourceFactory.newClasspathResource( "myChangeSet.xml",
 getClass() ), ResourceType.CHANGE_SET );

if ( kbuilder.hasErrors() ) {
 System.err.println( kbuilder.getErrors().toString() );
}
```

Change Sets can include any number of resources. They also support additional configuration information for decision tables. The example below loads rules from an HTTP uniform resource locator and an Excel™ decision table by using the classpath protocol.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd' >
  <add>
    <resource source='http://hostname/myrules.drl' type='DRL' />
    <resource source='classpath:data/IntegrationTest.xls' type="DTABLE">
        <decisiontable-conf input-type="XLS" worksheet-name="Tables_2" />
    </resource>
  </add>
</change-set>
```

If a directory name is specified for the resource source, all the files contained within it will be added. (Note that all the files must be of the specified type.)

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd' >
    <add>
        <resource source='file://rules/' type='DRL' />
    </add>
</change-set>
```

2.3.2. Knowledge Agent

The **`KnowledgeAgent`** provides automatic loading, re-loading and caching of rule resources. It is configured via a "properties" file. The **`KnowledgeAgent`** can update or rebuild a Knowledge Base when the resources it uses have changed. The strategy for this updating is determined by the configuration applied to the **`KnowledgeAgentFactory`**.

```
KnowledgeAgent kagent = KnowledgeAgentFactory.newKnowledgeAgent("MyAgent");
kagent.applyChangeSet( ResourceFactory.newUrlResource( url ) );
```

```
KnowledgeBase kbase = kagent.getKnowledgeBase();
```

The **`KnowledgeAgent`** will scan all the added resources, at a default polling interval of sixty seconds. If the last-modified date of the resource is changed, **`KnowledgeAgent`** will rebuild the Knowledge Base using the new resources. (If a directory is specified as one of the resources, then the entire contents of that directory will be scanned for changes.)

Note

The previous Knowledge Base reference will still exist after change, so you will have to call `getKnowledgeBase()` to access the newly built version.

User Guide

3.1. Building

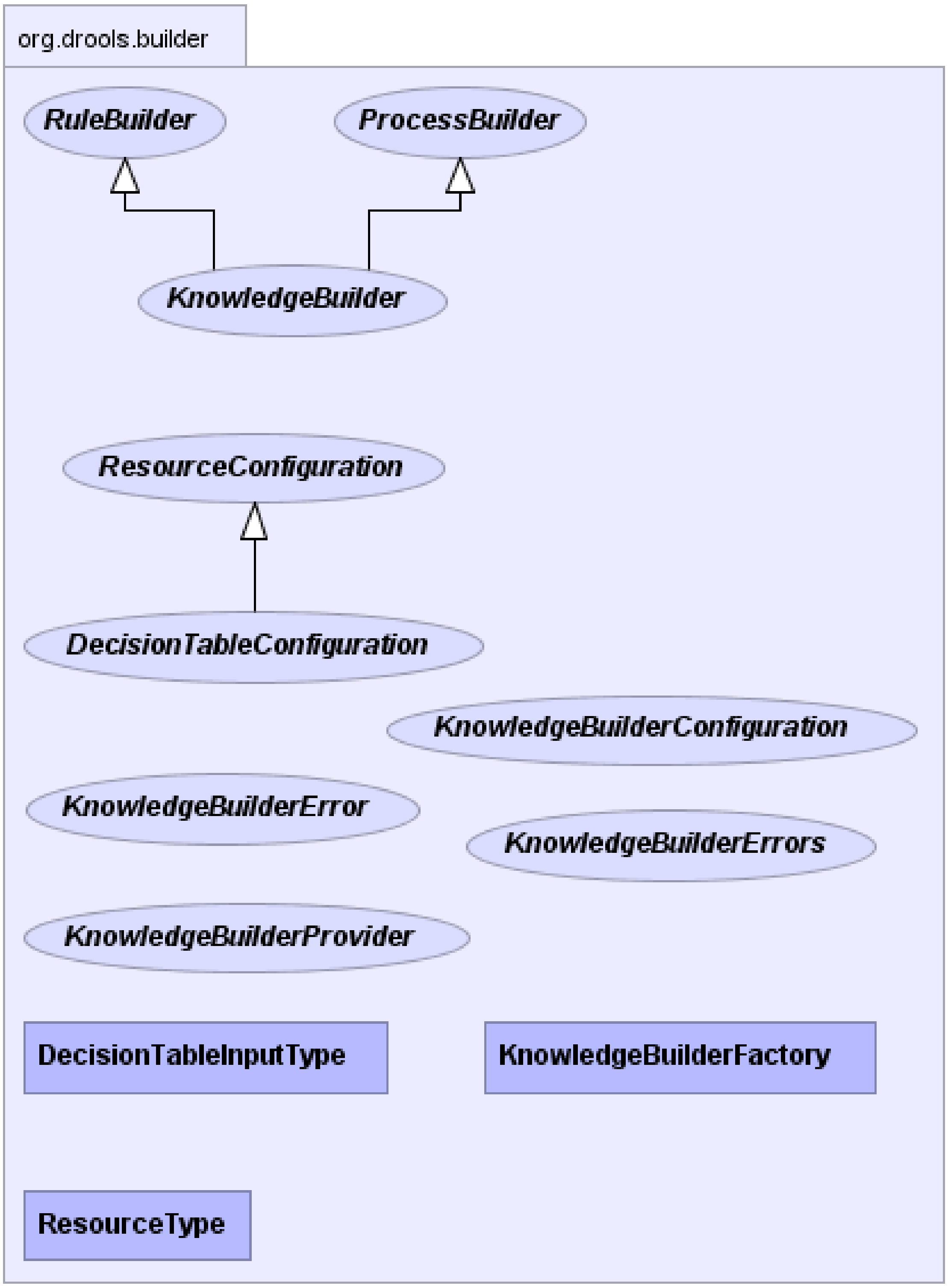


Figure 3.1. org.drools.builder

3.1.1. Building with Code

The **`Knowledge Builder`** is responsible for taking source data, (such as a **`.drl`** or Microsoft Excel™ file), and turning it into a **`Knowledge Package`**, that will contain rule and process definitions which a **`Knowledge Base`** can then consume. The object class **`ResourceType`** indicates, as its name implies, the type of resource being built.

The `ResourceFactory` provides the capability to load a resource from a number of sources, including a **`Reader`**, **`ClassPath`**, uniform resource locator, file or **`ByteArray`**.

Note

When one deals with binaries, such as decision tables (including Excel™ **`.xls`** files), one should not use a **`Reader`**-based resource handler, as they are only suitable for use with plain text.

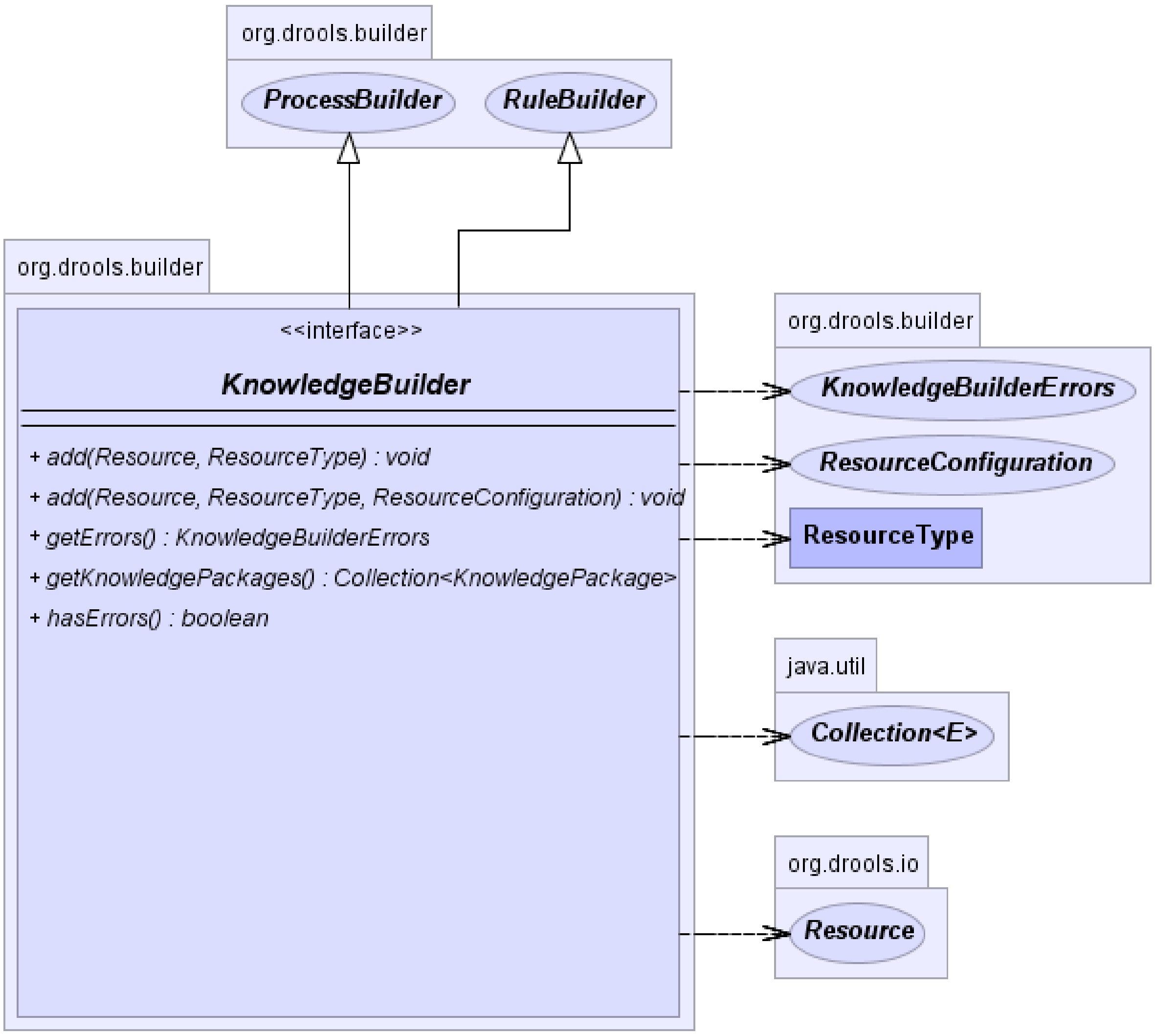


Figure 3.2. KnowledgeBuilder

The **`Knowledge Builder`** is created by the **`KnowledgeBuilderFactory`**.

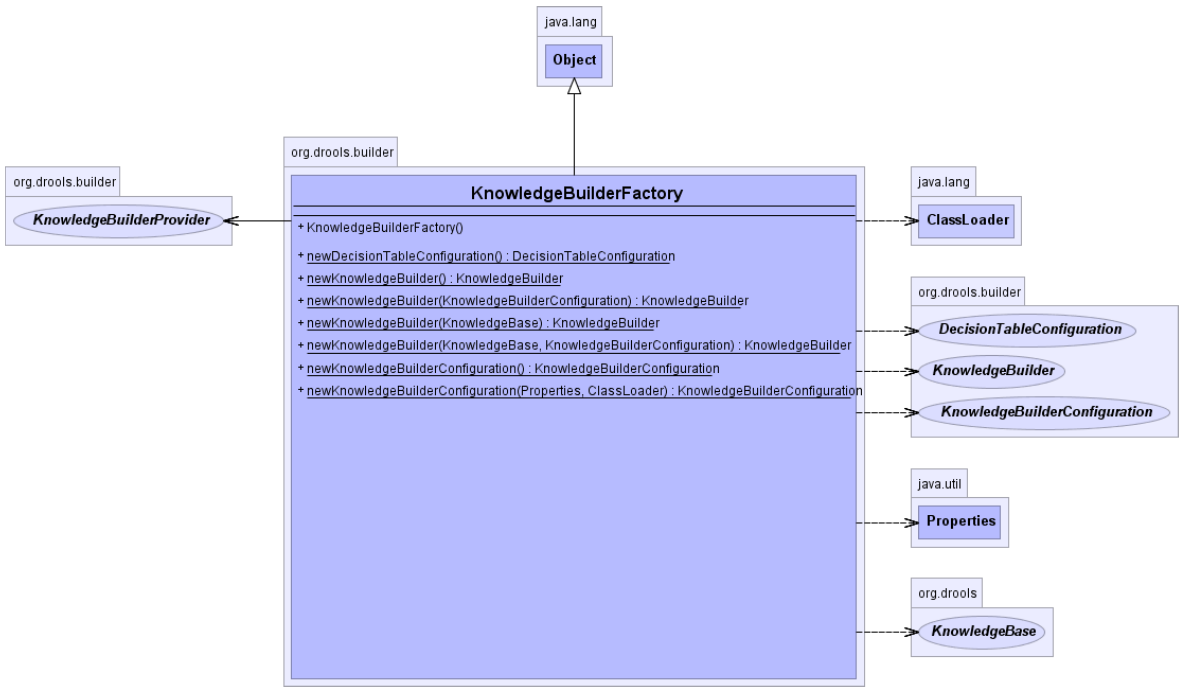

java.lang
Object
org.drools.builder
KnowledgeBuilderProvider
org.drools.builder
KnowledgeBuilderFactory
+ KnowledgeBuilderFactory()
+ newDecisionTableConfiguration() : DecisionTableConfiguration
+ newKnowledgeBuilder() : KnowledgeBuilder
+ newKnowledgeBuilder(KnowledgeBuilderConfiguration) : KnowledgeBuilder
+ newKnowledgeBuilder(KnowledgeBase) : KnowledgeBuilder
+ newKnowledgeBuilder(KnowledgeBase, KnowledgeBuilderConfiguration) : KnowledgeBuilder
+ newKnowledgeBuilderConfiguration() : KnowledgeBuilderConfiguration
+ newKnowledgeBuilderConfiguration(Properties, ClassLoader) : KnowledgeBuilderConfiguration
java.lang
ClassLoader
org.drools.builder
DecisionTableConfiguration
KnowledgeBuilder
KnowledgeBuilderConfiguration
java.util
Properties
org.drools
KnowledgeBase

Figure 3.3. KnowledgeBuilderFactory

A **`Knowledge Builder`** can be created by using the default configuration.

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
```

Example 3.1. Creating a new Knowledge Builder

One can create a configuration by using the `KnowledgeBuilderFactory`. This allows one to modify the behaviour of the **`Knowledge Builder`**. The most common usage is to provide a custom *class loader*, which performs the function of allowing the `KnowledgeBuilder` object to resolve classes that are not in the default path. The first parameter is for "**`properties`**" and it is optional and can, therefore, be left null, in which case the default options will be used. The "**`options`**" parameter can be used for such tasks as changing the dialect and registering new "**`accumulator`**" functions.

```
KnowledgeBuilderConfiguration kbuilderConf =
    KnowledgeBuilderFactory.newKnowledgeBuilderConfiguration(
        null, classLoader );

KnowledgeBuilder kbuilder =
 KnowledgeBuilderFactory.newKnowledgeBuilder(kbuilderConf);
```

Example 3.2. Creating a new Knowledge Builder with a custom Class Loader

Resources of any type can be added on an iterative basis. In the example below, a **`.drl`** file is added. The Knowledge Builder can now handle multiple name spaces, which was not the case with JBoss Rules 4.0 Package Builder. Therefore, you can just keep adding resources, regardless of name space.

```
kbuilder.add( ResourceFactory.newFileResource( "/project/myrules.drl" ),
    ResourceType.DRL);
```

Example 3.3. Adding DRL Resources

Note

It is best practice to always check the `hasErrors()` method after you make an addition. You should not add more resources or retrieve the **`KnowledgePackage`**s if there are errors. (You will find that `getKnowledgePackages()` returns an empty list if there are errors.)

```
if( kbuilder.hasErrors() )
{
 System.out.println( kbuilder.getErrors() );
 return;
}
```

Example 3.4. Validating

When all the resources have been added and there are no longer any errors, the collection of **`Knowledge Package`**s can be retrieved. It is termed a "**`Collection`**" because there is one **`Knowledge Package`** per package name space. These **`Knowledge Package`**s are serializable and are often used as a unit of deployment.

```
Collection<KnowledgePackage> kpkgs = kbuilder.getKnowledgePackages();
```

Example 3.5. Obtaining the Knowledge Packages

The final example combines all of these elements:

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
if( kbuilder.hasErrors() ) {
    System.out.println( kbuilder.getErrors() );
    return;
}

KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
kbuilder.add( ResourceFactory.newFileResource( "/project/myrules1.drl" ),
    ResourceType.DRL);
kbuilder.add( ResourceFactory.newFileResource( "/project/myrules2.drl" ),
    ResourceType.DRL);

if( kbuilder.hasErrors() )
{
    System.out.println( kbuilder.getErrors() );
    return;
}

Collection<KnowledgePackage> kpkgs = kbuilder.getKnowledgePackages();
```

Example 3.6. Combining All Elements

3.1.2. Building via Configurations and the `Change Set` XML

It is possible to create definitions via configurations, rather than programming them by adding resources. You do so via the `Change Set` XML. The simple XML file supports three elements: add, remove, and modify, each of which has a sequence of `resource` sub-elements that define a configuration entity. The following XML schema is *not* normative: it is intended for illustrative purposes only.

```
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
           xmlns="http://drools.org/drools-5.0/change-set"
           targetNamespace="http://drools.org/drools-5.0/change-set">

  <xs:element name="change-set" type="ChangeSet"/>

  <xs:complexType name="ChangeSet">
    <xs:choice maxOccurs="unbounded">
      <xs:element name="add"    type="Operation"/>
      <xs:element name="remove" type="Operation"/>
      <xs:element name="modify" type="Operation"/>
    </xs:choice>
  </xs:complexType>

  <xs:complexType name="Operation">
    <xs:sequence>
      <xs:element name="resource" type="Resource"
                  maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="Resource">
    <xs:sequence>
      <!-- To be used with <resource type="DTABLE"...&gt> -->
      <xs:element name="decisiontable-conf" type="DecTabConf"
                  minOccurs="0"/>
    </xs:sequence>
    <!-- java.net.URL, plus "classpath" protocol -->
    <xs:attribute name="source" type="xs:string"/>
    <xs:attribute name="type"   type="ResourceType"/>
  </xs:complexType>

  <xs:complexType name="DecTabConf">
    <xs:attribute name="input-type"     type="DecTabInpType"/>
    <xs:attribute name="worksheet-name" type="xs:string"
                  use="optional"/>
  </xs:complexType>

  <!-- according to org.drools.builder.ResourceType -->
  <xs:simpleType name="ResourceType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="DRL"/>
      <xs:enumeration value="XDRL"/>
      <xs:enumeration value="DSL"/>
      <xs:enumeration value="DSLR"/>
      <xs:enumeration value="DRF"/>
      <xs:enumeration value="DTABLE"/>
      <xs:enumeration value="PKG"/>
      <xs:enumeration value="BRL"/>
      <xs:enumeration value="CHANGE_SET"/>
    </xs:restriction>
```

Example 3.7. Schema for Change Set XML (Not "Normative")

```
  </xs:simpleType>

  <!-- according to org.drools.builder.DecisionTableInputType -->
  <xs:simpleType name="DecTabInpType">
    <xs:restriction base="xs:string">
      <xs:enumeration value="XLS"/>
      <xs:enumeration value="CSV"/>
```

Currently only the "add" element is supported. The others will soon be implemented to support iterative changes. The following example loads a single **.drl** file.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
            xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
            xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd'
 >
   <add>
      <resource source='file:/project/myrules.drl' type='DRL' />
   </add>
</change-set>
```

Example 3.8. Simple Change Set XML

Take note of the `file:` prefix, which signifies the protocol for the resource. The **Change Set** supports all the protocols provided by **java.net.URL**, such as "**file**" and "**http**", as well as an additional "**classpath**." Currently, the "**type**" attribute must always be specified for a resource, because it is not inferred from the filename extension.

Using the **ClassPath** resource loader in Java allows one to specify the **Class Loader** to be used to locate the resource; this is not possible from XML. Instead, the **Class Loader** to be used will, by default, be that which is employed by the Knowledge Builder unless the **Change Set** XML is loaded by the **ClassPath** resource. In the latter case, the Class Loader specified for that resource will be used instead.

Currently you still need to use the JBoss™ Rules API to load the `change set`. Support for containers such as **Spring** is planned for a future release. When this occurs, the process of creating a Knowledge Base shall be completely achievable solely by configuring the XML. Loading resources using an XML file is simple, as it is treatd as just another resource type.

```
kbuilder.add(ResourceFactory.newUrlResource(url),ResourceType.CHANGE_SET);
```

Example 3.9. Loading the Change Set XML

Any number of resources can be included in a `change set`. They even potentially support additional configuration information (this use is currently restricted to decision tables only.) *Example 3.10, "Change Set XML with Resource Configuration"* loads rules from both an HTTP uniform resource location and an Excel™ decision table found on the classpath.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd' >
    <add>
        <resource source='http:org/domain/myrules.drl' type='DRL' />
        <resource source='classpath:data/IntegrationExampleTest.xls'
          type="DTABLE">
          <decisiontable-conf input-type="XLS" worksheet-name="Tables_2" />
        </resource>
    </add>
</change-set>
```

Example 3.10. `Change Set` XML with Resource Configuration

One might find the `Change Set` is especially useful when working with a Knowledge Agent, as it facilitates "change notification" and automatic rebuilding of the Knowledge Base. These features are covered in more detail under the sub-heading "Deploying" in the section on the Knowledge Agent.

One can also specify a directory. This would be done to add all the resources found within it. Currently, the software expects that all of the resources in that folder will be of the same type. If one uses the Knowledge Agent, it will continuously scanning for added, modified or removed resources. It will also rebuild the cached Knowledge Base.

Note

Change Sets can also be used in conjunction with the **`KnowledgeAgent`**. Refer to *Section 3.2.6, “ KnowledgeAgent ”* for more information.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd' >
    <add>
        <resource source='file:/projects/myproject/myrules' type='DRL' />
    </add>
</change-set>
```

Example 3.11. `Change Set` XML Which Adds a Directory's Content.

3.2. Deploying

3.2.1. KnowledgePackage and Knowledge Definitions

A *KnowledgePackage* is a collection of *Knowledge Definitions*, which is simply another term for rules and processes. A **`KnowledgePackage`** is created by the **`KnowledgeBuilder`**, as described in *Section 3.1, “ Building ”*. **`KnowledgePackage`**s are self-contained and serializable. They form the current basic deployment unit.

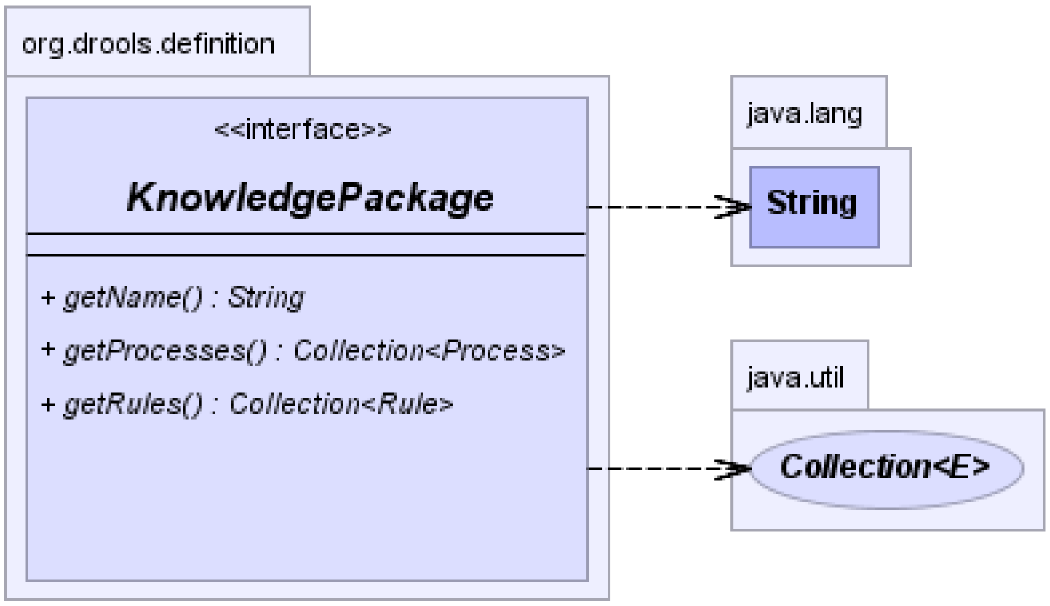


Figure 3.4. KnowledgePackage

Note

`KnowledgePackage`s are added to the **`Knowledge Base`**. However, it is important to know that a **`KnowledgePackage`** instance cannot be re-used once this has occurred. If you need to add it to another **`Knowledge Base`**, try "serializing" it first and using the "cloned" result. This limitation will be removed in a future version of JBoss Rules™ .

3.2.2. Knowledge Bases

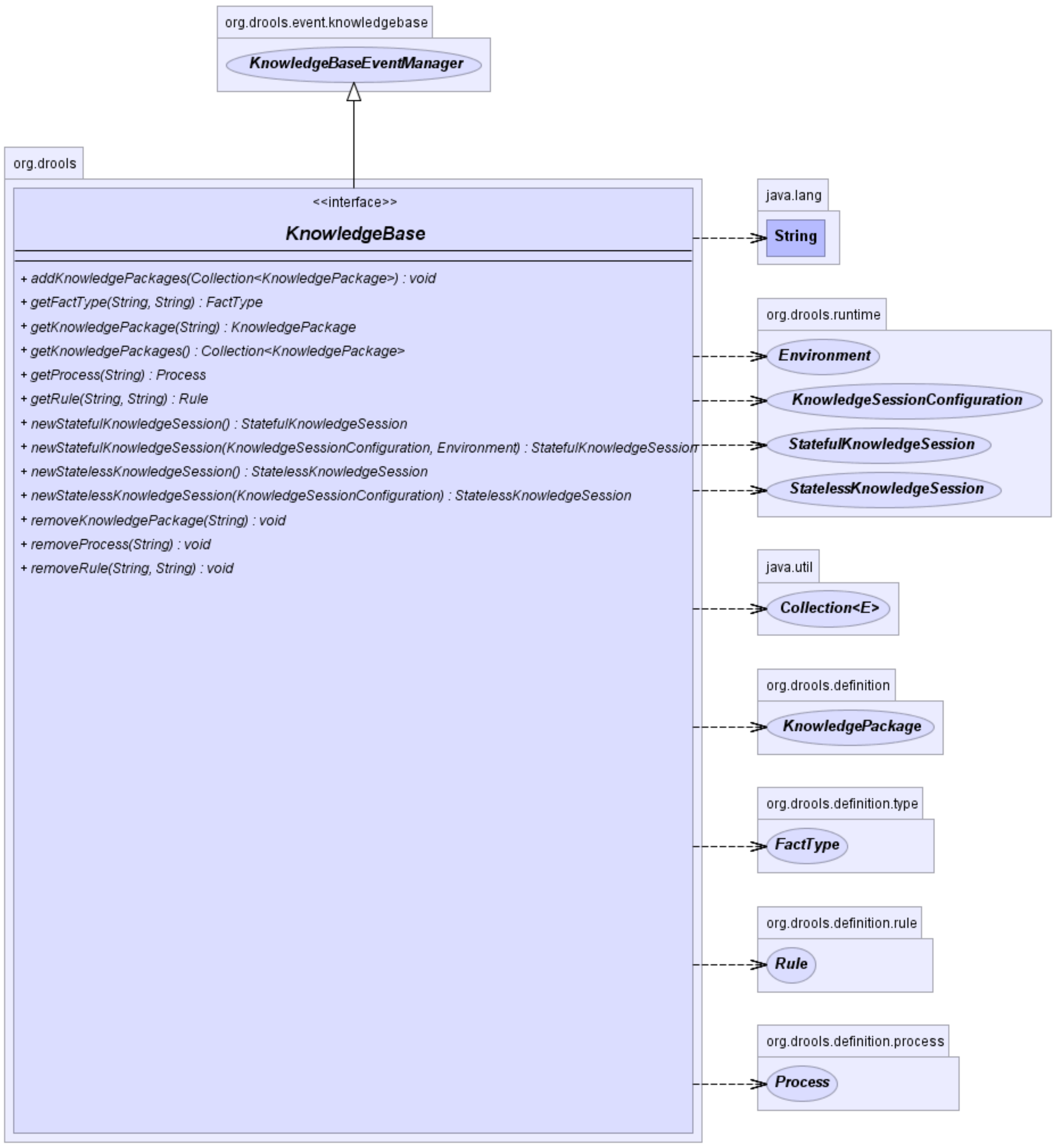

org.drools.event.knowledgebase
KnowledgeBaseEventManager
org.drools
<<interface>>
KnowledgeBase
+ addKnowledgePackages(Collection<KnowledgePackage>) : void
+ getFactType(String, String) : FactType
+ getKnowledgePackage(String) : KnowledgePackage
+ getKnowledgePackages() : Collection<KnowledgePackage>
+ getProcess(String) : Process
+ getRule(String, String) : Rule
+ newStatefulKnowledgeSession() : StatefulKnowledgeSession
+ newStatefulKnowledgeSession(KnowledgeSessionConfiguration, Environment) : StatefulKnowledgeSession
+ newStatelessKnowledgeSession() : StatelessKnowledgeSession
+ newStatelessKnowledgeSession(KnowledgeSessionConfiguration) : StatelessKnowledgeSession
+ removeKnowledgePackage(String) : void
+ removeProcess(String) : void
+ removeRule(String, String) : void
java.lang
String
org.drools.runtime
Environment
KnowledgeSessionConfiguration
StatefulKnowledgeSession
StatelessKnowledgeSession
java.util
Collection<E>
org.drools.definition
KnowledgePackage
org.drools.definition.type
FactType
org.drools.definition.rule
Rule
org.drools.definition.process
Process

Figure 3.5. A Knowledge Base

A **`Knowledge Base`** is a repository of all the application's knowledge definitions. It may contain rules, processes, functions and type models. The **`Knowledge Base`** itself does not contain "instance" data, (known as `facts`.) Instead, sessions are created from the **`Knowledge Base`** into which facts can be inserted and from which process instances can be commenced. Creation of a **`Knowledge Base`** is a rather intensive process, whereas session creation is not. Therefore, Red Hat™ recommend that **`Knowledge Base`**s be cached where possible to allow for repeated session creation.

A **`Knowledge Base`** object is also serializable and one may prefer to build and then store it. In this way, one can treat it, instead of the Knowledge Packages, as a unit of deployment.

A **`Knowledge Base`** is created by using the **`KnowledgeBaseFactory`**:

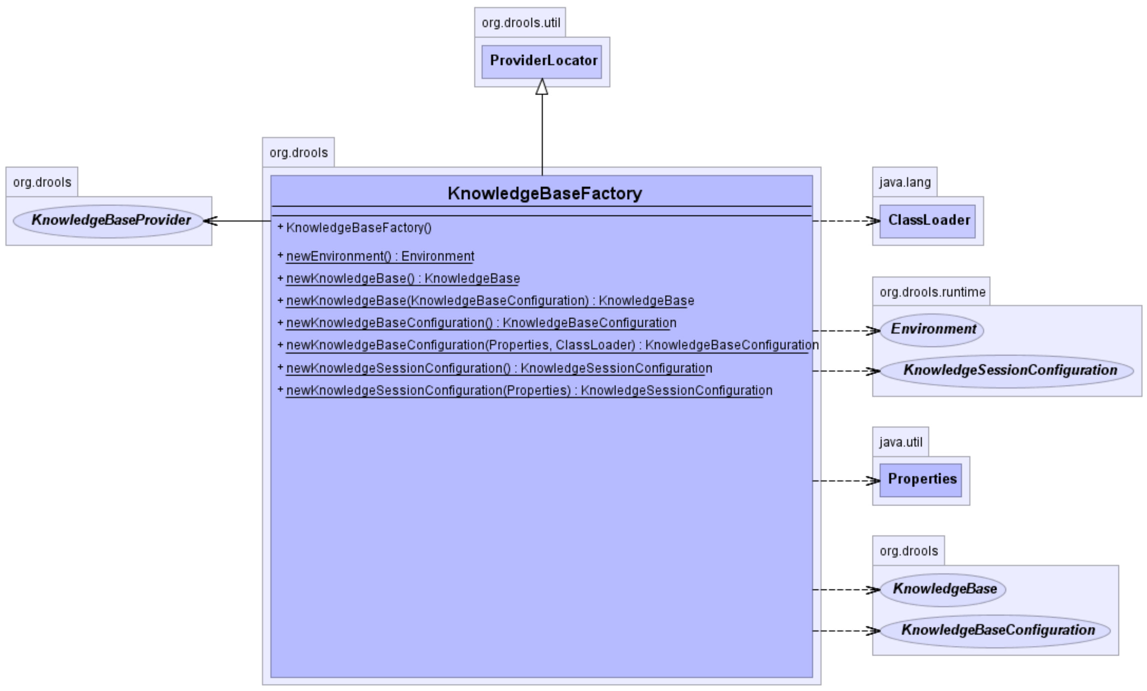

org.drools.util
ProviderLocator
org.drools
KnowledgeBaseProvider
org.drools
KnowledgeBaseFactory
+ KnowledgeBaseFactory()
+ newEnvironment() : Environment
+ newKnowledgeBase() : KnowledgeBase
+ newKnowledgeBase(KnowledgeBaseConfiguration) : KnowledgeBase
+ newKnowledgeBaseConfiguration() : KnowledgeBaseConfiguration
+ newKnowledgeBaseConfiguration(Properties, ClassLoader) : KnowledgeBaseConfiguration
+ newKnowledgeSessionConfiguration() : KnowledgeSessionConfiguration
+ newKnowledgeSessionConfiguration(Properties) : KnowledgeSessionConfiguration
java.lang
ClassLoader
org.drools.runtime
Environment
KnowledgeSessionConfiguration
java.util
Properties
org.drools
KnowledgeBase
KnowledgeBaseConfiguration

Figure 3.6. KnowledgeBaseFactory

A **`Knowledge Base`** can be created by employing the default configuration:

```
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
```

Example 3.12. Creating a New Knowledge Base

If one used a customised `class loader` in conjunction with the **`Knowledge Builder`** to resolve `types` that were not in the default `loader`, then it must also be set on the `Knowledge Base`. The technique for this is the same as that which applies to the `KnowledgeBuilder`.

```
KnowledgeBaseConfiguration kbaseConf =
    KnowledgeBaseFactory.newKnowledgeBaseConfiguration( null, cl );
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase( kbaseConf );
```

Example 3.13. Creating a New Knowledge Base with a Custom `Class Loader`

3.2.3. In-Process Building and Deployment

In-Process Building is the simplest form of deployment. It compiles the knowledge definitions and adds them to the **`Knowledge Base`** that resides in the same Java Virtual Machine. This approach requires the **`drools-core.jar`** and **`drools-compiler.jar`** files to be on the classpath.

```
Collection<KnowledgePackage> kpkgs = kbuilder.getKnowledgePackages();
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
kbase.addKnowledgePackages( kpkgs );
```

Example 3.14. Add **`KnowledgePackages`** to a **`Knowledge Base`**

Note

Understand that the `addKnowledgePackages(kpkgs)` method can be called on an iterative basis, in order to add additional knowledge.

3.2.4. Building and Deployment as Separate Processes

Both the **`Knowledge Base`** and the **`KnowledgePackage`** are units of deployment. They can, therefore, be serialized. This means you can assign one machine to undertake any necessary building that requires **`drools-compiler.jar`**, and have another machine reserved to deploy and execute everything, needing only **`drools-core.jar`** to do so.

Although "`serialization`" is standard Java, below is an example of how one machine might write out the deployment unit and how another machine might read in and use it.

```
ObjectOutputStream out =
 new ObjectOutputStream( new FileOutputStream( fileName ) );
out.writeObject( kpkgs );
out.close();
```

Example 3.15. Writing the **`KnowledgePackage`** to an `OutputStream`

```
ObjectInputStream in = new ObjectInputStream( new
 FileInputStream( fileName ) );
// The input stream might contain an individual
// package or a collection.
@SuppressWarnings( "unchecked" )
Collection<KnowledgePackage> kpkgs =
    ()in.readObject( Collection<KnowledgePackage> );
in.close();

KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
kbase.addKnowledgePackages( kpkgs );
```

Example 3.16. Reading the **`KnowledgePackage`** from an `InputStream`

The actual **`Knowledge Base`** is also serializable, so one may prefer to build and then store it itself, instead of the **`KnowledgePackage`**s.

Note

Red Hat™ 's server-side management system, Drools Guvnor™ , uses this deployment approach. After Guvnor™ has compiled and published serialized Knowledge Packages to a uniform resource locator, it has the capability to use the URL resource type to load them.

3.2.5. State-ful Knowledge Sessions and Knowledge Base Modifications

State-ful Knowledge Sessions are discussed in more detail in *Section 3.3.2, “StatefulKnowledgeSession”*. The **`Knowledge Base`** creates and returns State-ful Knowledge Sessions and it may, optionally, keep references to them. When **`Knowledge Base`** modifications occur, they are applied to the data in the sessions. This is a weak, optional reference, controlled by a Boolean flag.

3.2.6. KnowledgeAgent

The *KnowledgeAgent* is a class that provides automatic loading, caching and re-loading of resources. It is configured via a properties files. The **`KnowledgeAgent`** can update or rebuild the **`Knowledge Base`**, as the resources it uses are changed. The configuration given to the factory determines the strategy to be utilised, but it will typically be pull-based and use regular polling. (The capacity for push-based updates and rebuilds will be added in a future version.) The **`KnowledgeAgent`** will continuously scan all the added resources, using a default polling interval of sixty seconds. If the date of the last modification is updated, the cached **`Knowledge Base`** will be rebuilt using the new resources.

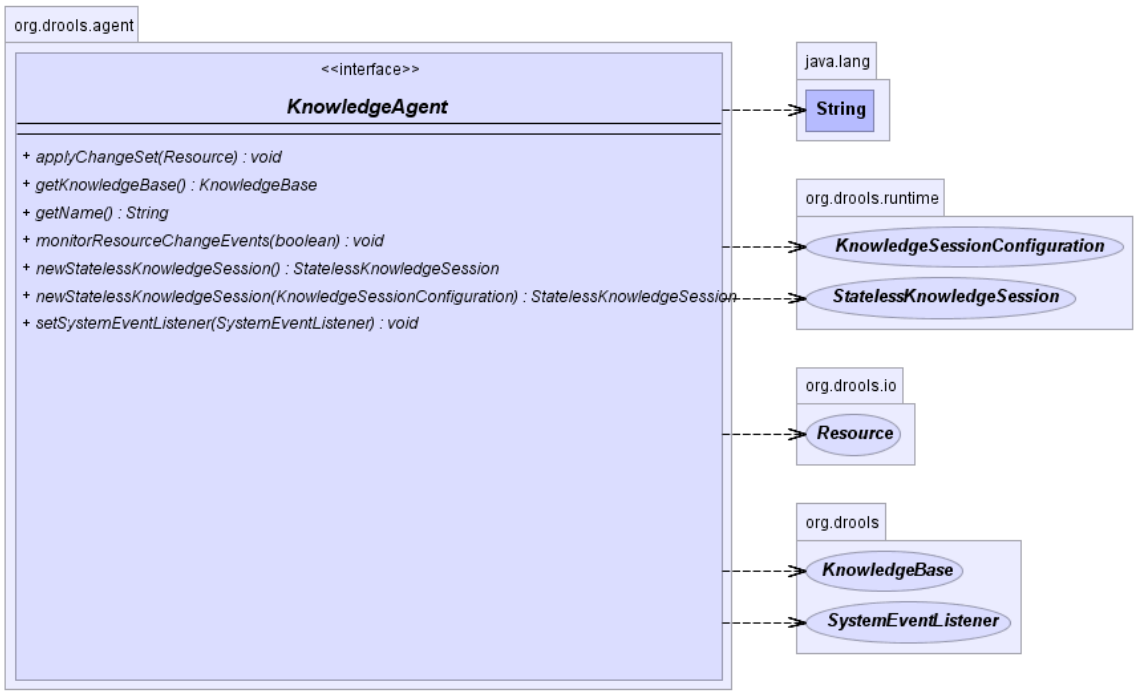

org.drools.agent
<<interface>>
KnowledgeAgent
+ applyChangeSet(Resource) : void
+ getKnowledgeBase() : KnowledgeBase
+ getName() : String
+ monitorResourceChangeEvents(boolean) : void
+ newStatelessKnowledgeSession() : StatelessKnowledgeSession
+ newStatelessKnowledgeSession(KnowledgeSessionConfiguration) : StatelessKnowledgeSession
+ setSystemEventListener(SystemEventListener) : void
java.lang
String
org.drools.runtime
KnowledgeSessionConfiguration
StatelessKnowledgeSession
org.drools.io
Resource
org.drools
KnowledgeBase
SystemEventListener

Figure 3.7. KnowledgeAgent

A `KnowledgeBuilderFactory` object is used to create the **`Knowledge Builder`**. The agent must specify a name because it is needed by the log files. This is so that the log entries can be associated against the correct agents.

```
KnowledgeAgent kagent = 
        KnowledgeAgentFactory.newKnowledgeAgent( "MyAgent" );
```

Example 3.17. Creating the **`KnowledgeAgent`**

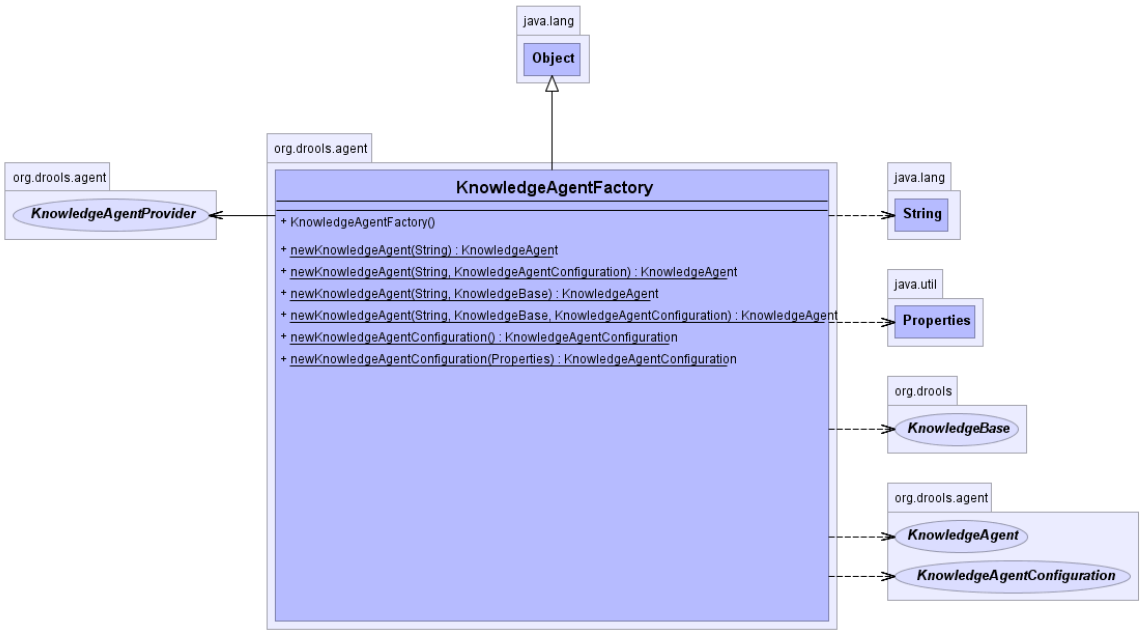

java.lang
Object
org.drools.agent
KnowledgeAgentFactory
+ KnowledgeAgentFactory()
+ newKnowledgeAgent(String) : KnowledgeAgent
+ newKnowledgeAgent(String, KnowledgeAgentConfiguration) : KnowledgeAgent
+ newKnowledgeAgent(String, KnowledgeBase) : KnowledgeAgent
+ newKnowledgeAgent(String, KnowledgeBase, KnowledgeAgentConfiguration) : KnowledgeAgent
+ newKnowledgeAgentConfiguration() : KnowledgeAgentConfiguration
+ newKnowledgeAgentConfiguration(Properties) : KnowledgeAgentConfiguration
org.drools.agent
KnowledgeAgentProvider
java.lang
String
java.util
Properties
org.drools
KnowledgeBase
org.drools.agent
KnowledgeAgent
KnowledgeAgentConfiguration

Figure 3.8. **`KnowledgeAgentFactory`**

The following example constructs an agent that will build a new **`Knowledge Base`** from the specified `change set`. Refer to *Section 3.1.2, “ Building via Configurations and the `Change Set` XML”* for additional details on `change sets`. Note that the method can be called on an iterative basis so that you can add new resources over time.

The **`KnowledgeAgent`** polls the resources added from the `change set` every sixty seconds, (the default interval), to see if they are updated. Whenever changes are found, it will construct a new **`Knowledge Base`**. In addition, if the `change set` specifies a resource that is a directory, its contents will be scanned for changes.

```
KnowledgeAgent kagent =
         KnowledgeAgentFactory.newKnowledgeAgent( "MyAgent" );
kagent.applyChangeSet( ResourceFactory.newUrlResource( url ) );
KnowledgeBase kbase = kagent.getKnowledgeBase();
```

Example 3.18. Writing the **`KnowledgePackage`** to an `OutputStream`

Resource scanning is switched off by default. It is a service, so it must be specifically started. The same thing is also true for notifications. Both of these can be activated via the **`ResourceFactory`**.

```
ResourceFactory.getResourceChangeNotifierService().start();
ResourceFactory.getResourceChangeScannerService().start();
```

Example 3.19. Starting the Scanning and Notification Services

The default resource scanning period may be changed via the **`ResourceChangeScannerService`** class. An updated **`ResourceChangeScannerConfiguration`** object is passed to the service's `configure()` method, thereby allowing for the service to be reconfigured on demand.

```
ResourceChangeScannerConfiguration sconf =
    ResourceFactory.getResourceChangeScannerService().
        newResourceChangeScannerConfiguration();
// Set the disk scanning interval to 30s, default is 60s.
sconf.setProperty( "drools.resource.scanner.interval", "30" );
ResourceFactory.getResourceChangeScannerService().configure( sconf );
```

Example 3.20. Changing the Scanning Intervals

A **`KnowledgeAgent`** can handle either an empty or a populated **`Knowledge Base`**. If a populated **`Knowledge Base`** is provided, the **`KnowledgeAgent`** will run an iterator from within it and subscribe to all the resources that are found. Whilst it is possible for the **`KnowledgeBuilder`** to build all of the resources found in a directory, that information is then lost by it. This means that those directories will not be continuously scanned. Only directories specified via the `applyChangeSet(Resource)` method are monitored.

You will find that one of the advantages of using **`Knowledge Base`** as the starting point is that you can provide it with a **`KnowledgeBaseConfiguration`** class. When resource changes are detected and a new **`Knowledge Base`** is instantiated, it will use the **`KnowledgeBaseConfiguration`** of the previous **`Knowledge Base`** object.

```
KnowledgeBaseConfiguration kbaseConf =
    KnowledgeBaseFactory.newKnowledgeBaseConfiguration( null, cl );
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase( kbaseConf );
// Populate kbase with resources here.

KnowledgeAgent kagent =
    KnowledgeAgentFactory.newKnowledgeAgent( "MyAgent", kbase );
KnowledgeBase kbase = kagent.getKnowledgeBase();
```

Example 3.21. Using an Existing Knowledge Base

In the example above, `getKnowledgeBase()` will return the same provided `kbase` instance until resource changes are detected and a new **`Knowledge Base`** is built. When the new **`Knowledge Base`** is built, it will be done with the **`KnowledgeBaseConfiguration`** that was provided to the previous **`Knowledge Base`**.

As mentioned previously, if a Change Set XML is used to specify a directory, all of its contents will be added. If this Change Set XML is used in conjunction with the `applyChangeSet()` method, any directories will also be added to the scanning process. When the directory scan detects an additional file it will be added to the **`Knowledge Base`**. Any removed file is removed from the **`Knowledge Base`** and modified files will, as usual, force the build of a new **`Knowledge Base`** using the latest version.

```
<change-set xmlns='http://drools.org/drools-5.0/change-set'
    xmlns:xs='http://www.w3.org/2001/XMLSchema-instance'
    xs:schemaLocation='http://drools.org/drools-5.0/change-set.xsd' >
   <add>
      <resource source='file:/projects/myproject/myrules' type='PKG' />
   </add>
</change-set>
```

Example 3.22. Change SetXML which adds the contents of a directory

Note

The **`drools-compiler`** dependency is not needed for the resource type entitled PKG, as the **`KnowledgeAgent`** is able to handle those with **`drools-core`** alone.

The **`KnowledgeAgentConfiguration`** can be used to modify a **`KnowledgeAgent`**'s default behavior. You could use this to load the resources from a directory, while inhibiting the continuous scan of that directory for changes.

```
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();

KnowledgeAgentConfiguration kaconf =
    KnowledgeAgentFactory.newKnowledgeAgentConfiguration();
// Do not scan directories, just files.
kaconf.setProperty( "drools.agent.scanDirectories", "false" );
KnowledgeAgent kagent =
    KnowledgeAgentFactory.newKnowledgeAgent( "test agent", kaconf );
```

Example 3.23. Change the Scanning Behaviour

Previously, one was taught how the JBoss™ Enterprise BRMS Platform can build and publish serialized **`Knowledge Package`**s through a URL and also how the Change Set XML can handle both URLs and Packages. Taken together, these form an important deployment scenario for the **`Knowledge Agent`**.

3.3. Running

3.3.1. KnowledgeBase

The **`KnowlegeBase`** is a repository of all the application's knowledge definitions. It may contain rules, processes, functions, and type models. The **`KnowledgeBase`** itself does not contain instance data, known as facts. Instead sessions are created from the **`KnowledgeBase`** into which data (facts) can be inserted and where process instances may be started. **`KnowlegeBase`** creation is a fairly intensive process, whereas session creation is not. It is recommended that **`KnowledgeBase`**s be cached where possible to allow for repeated session creation.

```
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
```

Example 3.24. Creating a new KnowledgeBase

3.3.2. StatefulKnowledgeSession

The **`StatefulKnowledgeSession`** stores and executes on the runtime data and is created from the **`KnowledgeBase`**.

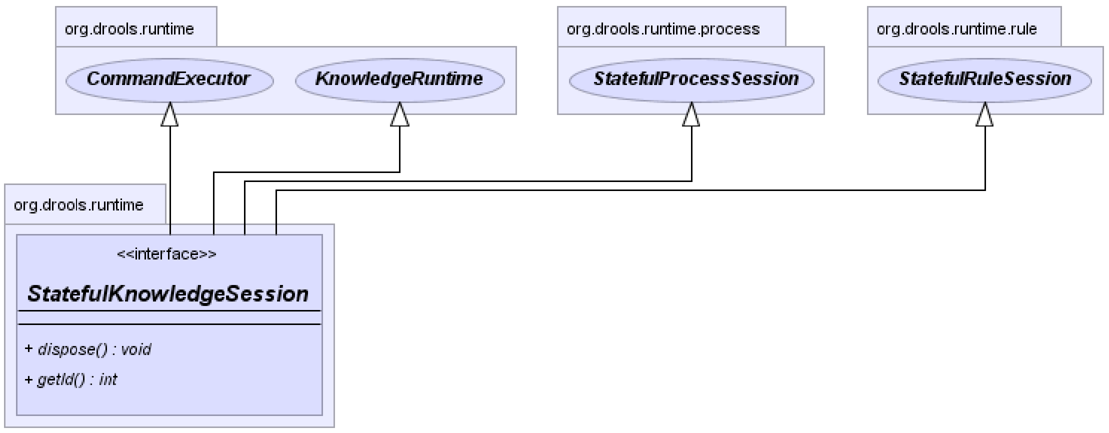


Figure 3.9. StatefulKnowledgeSession

```
StatefulKnowledgeSession ksession = kbase.newStatefulKnowledgeSession();
```

Example 3.25. Create a StatefulKnowledgeSession from a KnowledgeBase

3.3.3. KnowledgeRuntime

3.3.3.1. WorkingMemoryEntryPoint

The **`WorkingMemoryEntryPoint`** provides the methods for inserting, updating and retrieving facts. The term "entry point" is related to the fact that we have multiple partitions in a **`WorkingMemory`** and you can choose which one you are inserting into. However this use case is aimed at event processing and most rule based applications will only make use of the default entry point.

The **`KnowledgeRuntime`** interface provides the main interaction with the engine and is available in rule consequences and process actions. While the focus is on the methods and interfaces related to rules, you'll notice that the **`KnowledgeRuntime`** inherits methods from both the **`WorkingMemory`** and the **`ProcessRuntime`**. This provides a unified API to work with processes and rules. When working with rules three interfaces form the **`KnowledgeRuntime`**: **`WorkingMemoryEntryPoint`**, **`WorkingMemory`**, and the **`KnowledgeRuntime`** itself.

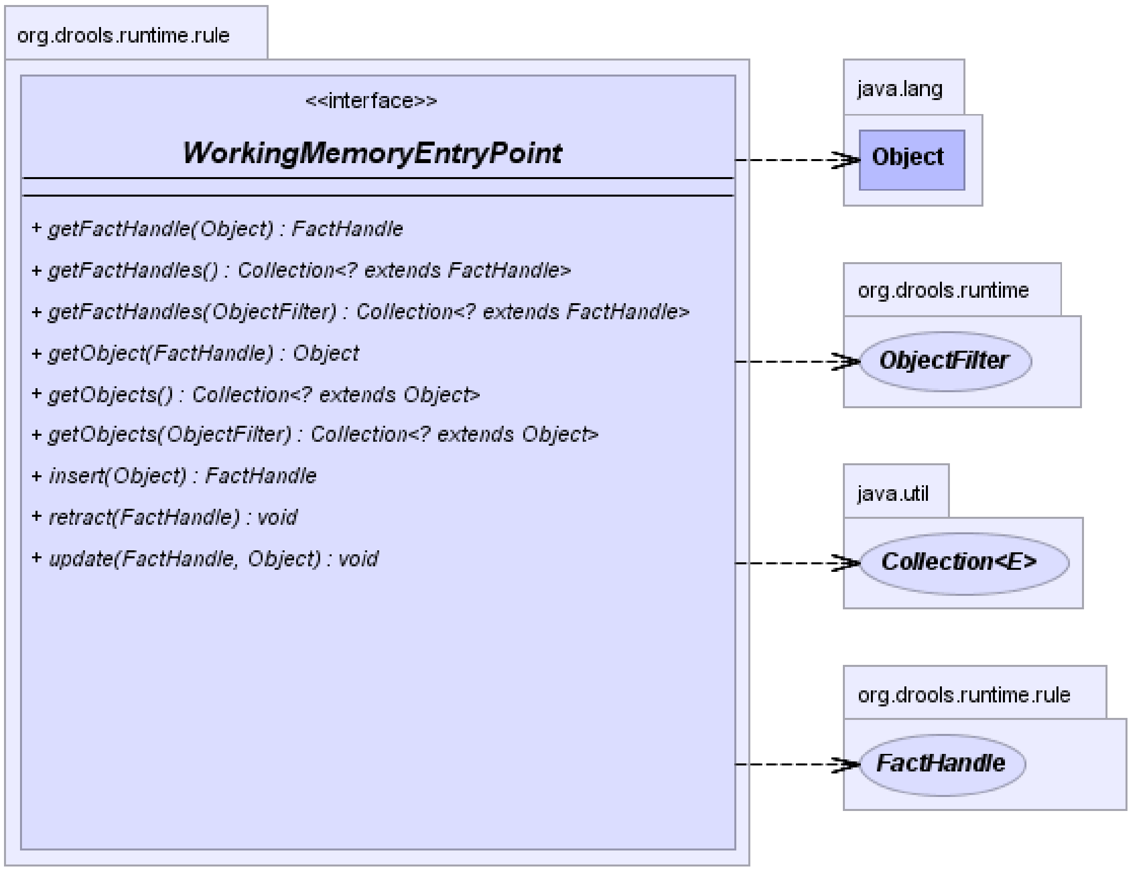

org.drools.runtime.rule
<<interface>>
WorkingMemoryEntryPoint
+ getFactHandle(Object) : FactHandle
+ getFactHandles() : Collection<? extends FactHandle>
+ getFactHandles(ObjectFilter) : Collection<? extends FactHandle>
+ getObject(FactHandle) : Object
+ getObjects() : Collection<? extends Object>
+ getObjects(ObjectFilter) : Collection<? extends Object>
+ insert(Object) : FactHandle
+ retract(FactHandle) : void
+ update(FactHandle, Object) : void
java.lang
Object
org.drools.runtime
ObjectFilter
java.util
Collection<E>
org.drools.runtime.rule
FactHandle

Figure 3.10. WorkingMemoryEntryPoint

3.3.3.1.1. Insertion

Insertion is the act of telling the **`WorkingMemory`** about a fact, e.g. `ksession.insert(yourObject)`. When you insert a fact, it is examined for matches against the rules. This means *all* of the work for deciding about firing or not firing a rule is done during insertion; no rule, however, is executed until you call `fireAllRules()`, which you call after you have finished inserting your facts. It is a common misunderstanding for people to think the condition evaluation happens when you call `fireAllRules()`.

Note

Expert systems typically use the term *assert* or *assertion* to refer to facts made available to the system. However, due to "assert" being a keyword in most languages, we have decided to use the `insert` keyword; so expect to hear the two used interchangeably.

When an object is inserted it returns a **`FactHandle`**. This **`FactHandle`** is the token used to represent your inserted object within the **`WorkingMemory`**. It is also used for interactions with the **`WorkingMemory`** when you wish to retract or modify an object.

```
Cheese stilton = new Cheese("stilton");
FactHandle stiltonHandle = ksession.insert( stilton );
```

A **`WorkingMemory`** may operate in one of two assertion modes: *equality* or *identity*. Identity is the default.

Identity means that the Working Memory uses an **`IdentityHashMap`** to store all asserted objects. New instance assertions always result in the return of a new **`FactHandle`**. Repeated insertions of the same instance will simply return the original fact handle.

Equality means that the Working Memory uses a **`HashMap`** to store all asserted objects. New instance assertions will only return a new **`FactHandle`** if no equal objects have been asserted.

3.3.3.1.2. Retraction

Retraction is the removal of a fact from the Working Memory. The fact will no longer be tracked or matched to rules, and any rules that are activated and dependent on that fact will be cancelled. Retraction is done using the **`FactHandle`** that was returned during the assert.

Note

It is possible to create rules (using the `not` and `exist` keywords) that will fire when certain facts don't exist. In that case retracting a fact may cause the rule to activate.

```
Cheese stilton = new Cheese("stilton");
FactHandle stiltonHandle = ksession.insert( stilton );

ksession.retract( stiltonHandle );
```

3.3.3.1.3. Update

The Rule Engine must be notified of modified facts, so that they can be reprocessed. A fact which is identified as updated is automatically retracted from the **`WorkingMemory`** and inserted again.

If an modified object is not able to notify the **`WorkingMemory`** itself you must use the `update` method to notify the **`WorkingMemory`**. The `update` method always takes the modified object as a second parameter, which allows you to specify new instances for immutable objects. The `update` method can only be used with objects that have shadow proxies turned on.

The `update` method is only for use from Java code. Within a rule the `modify` keyword is supported and provides calls to the setter methods of an object.

```
Cheese stilton = new Cheese("stilton");
FactHandle stiltonHandle = workingMemory.insert( stilton );
...
stilton.setPrice( 100 );
workingMemory.update( stiltonHandle, stilton );
```

3.3.3.2. WorkingMemory

The WorkingMemory provides access to the Agenda, permits query executions, and lets you access named Entry Points.

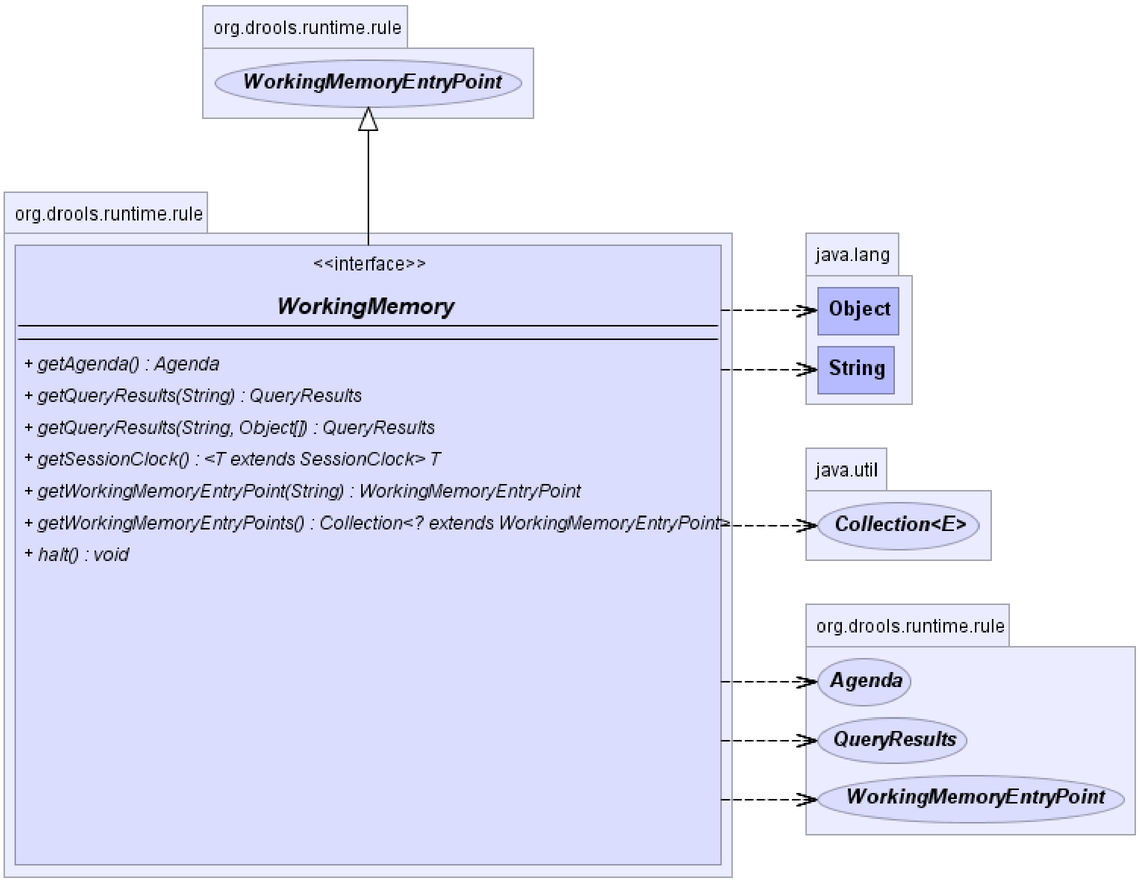

org.drools.runtime.rule
WorkingMemoryEntryPoint
org.drools.runtime.rule
<<interface>>
WorkingMemory
+ getAgenda() : Agenda
+ getQueryResults(String) : QueryResults
+ getQueryResults(String, Object[]) : QueryResults
+ getSessionClock() : <T extends SessionClock> T
+ getWorkingMemoryEntryPoint(String) : WorkingMemoryEntryPoint
+ getWorkingMemoryEntryPoints() : Collection<? extends WorkingMemoryEntryPoint>
+ halt() : void
java.lang
Object
String
java.util
Collection<E>
org.drools.runtime.rule
Agenda
QueryResults
WorkingMemoryEntryPoint

Figure 3.11. WorkingMemory

3.3.3.2.1. Query

Queries are used to retrieve fact sets based on patterns, as they are used in rules. Patterns may make use of optional parameters. Queries can be defined in the Knowlege Base, from where they are called up to return the matching results. While iterating over the result collection, any bound identifier in the query can be accessed using the get(String identifier) method and any FactHandle for that identifier can be retrieved using getFactHandle(String identifier).

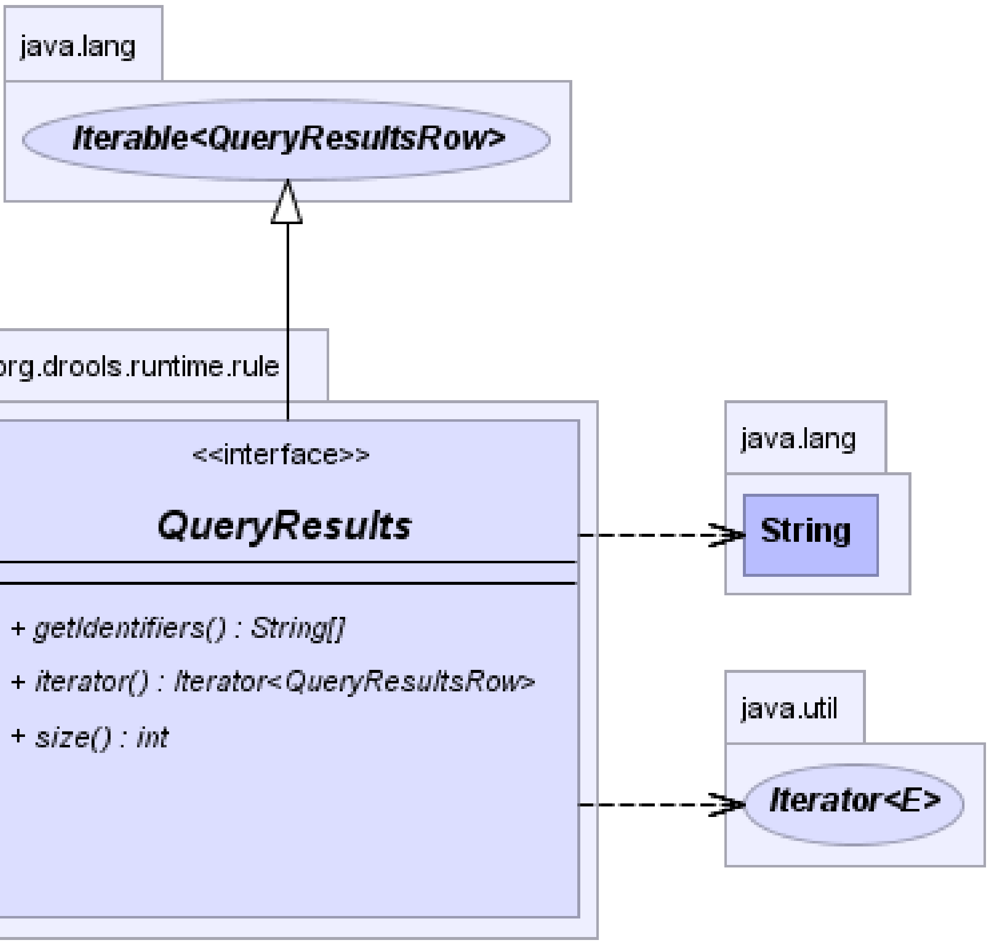


Figure 3.12. QueryResults

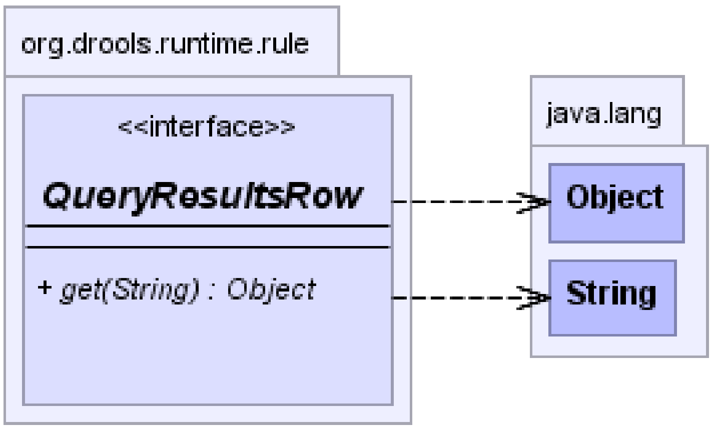


Figure 3.13. QueryResultsRow

```
QueryResults results =
    ksession.getQueryResults( "my query", new Object[] { "string" } );
for ( QueryResultsRow row : results ) {
    System.out.println( row.get( "varName" ) );
}
```

Example 3.26. Simple Query Example

3.3.3.3. KnowledgeRuntime

The **`KnowledgeRuntime`** provides further methods that are applicable to both rules and processes. Such as setting globals and registering **`ExitPoints`**.

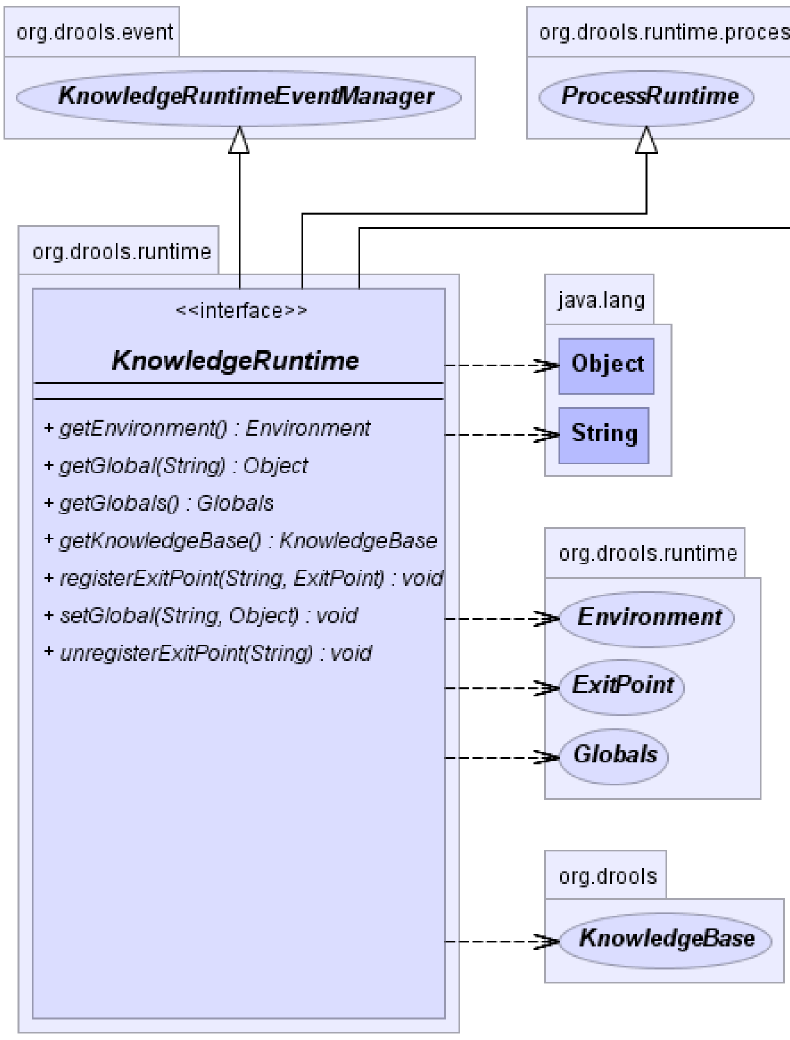

org.drools.event
KnowledgeRuntimeEventManager
org.drools.runtime.process
ProcessRuntime
org.drools.runtime.rule
WorkingMemory
org.drools.runtime
<<interface>>
KnowledgeRuntime
+ getEnvironment() : Environment
+ getGlobal(String) : Object
+ getGlobals() : Globals
+ getKnowledgeBase() : KnowledgeBase
+ registerExitPoint(String, ExitPoint) : void
+ setGlobal(String, Object) : void
+ unregisterExitPoint(String) : void
java.lang
Object
String
org.drools.runtime
Environment
ExitPoint
Globals
org.drools
KnowledgeBase

Figure 3.14. KnowledgeRuntime

3.3.3.3.1. Globals

Globals are named objects that can be passed to the rule engine, without needing to insert them. Most often these are used for static information, or for services that are used in the RHS of a rule, or perhaps as a means to return objects from the rule engine. If you use a global on the LHS of a rule, make sure it is immutable. A global must first be declared in a rules file before it can be set on the session.

```
global java.util.List list
```

With the **`KnowledgeBase`** now aware of the global identifier and its type, it is now possible to call `ksession.setGlobal` for any session. Failure to declare the global type and identifier first will result in an exception being thrown. To set the global on the session use `ksession.setGlobal(identifier, value)`.

```
List list = new ArrayList();
ksession.setGlobal("list", list);
```

If a rule evaluates on a global before you set it then a `NullPointerException` exception will be thrown.

3.3.3.4. StatefulRuleSession

The **`StatefulRuleSession`** is inherited by the **`StatefulKnowledgeSession`** and provides the rule related methods that are relevant from outside of the engine.

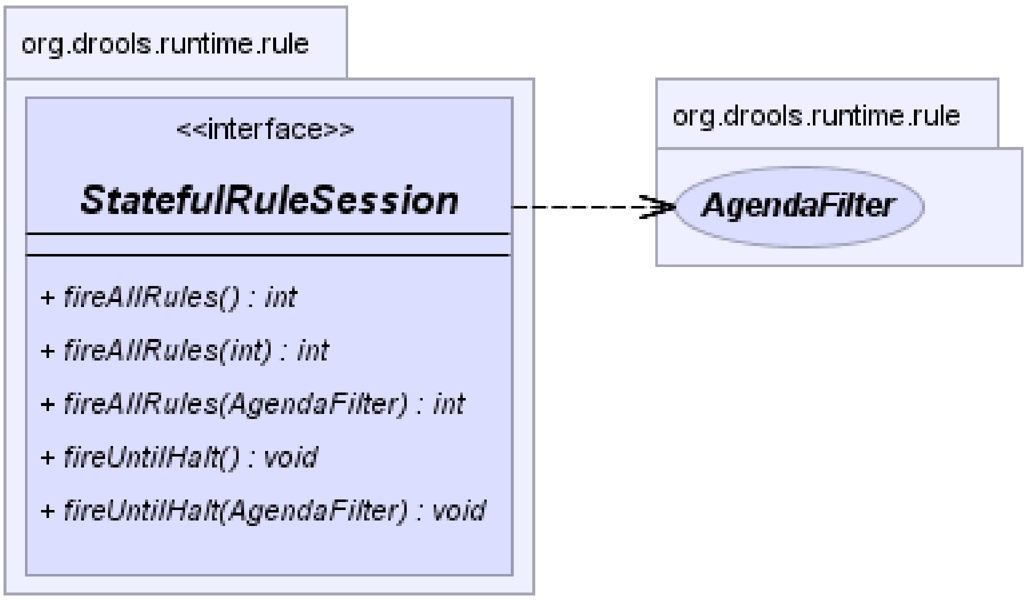


Figure 3.15. StatefulRuleSession

3.3.3.4.1. Agenda Filters

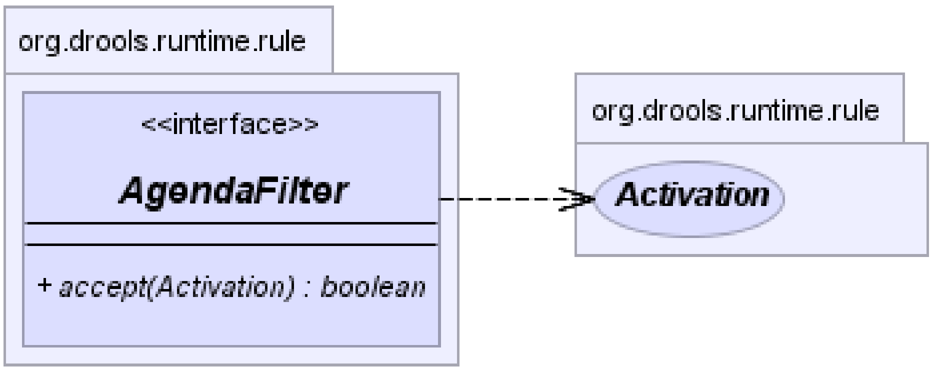


Figure 3.16. AgendaFilters

Agenda filters are optional implementations of the `filter` interface which are used to allow or deny the firing of an activation. What you filter on is entirely up to the implementation.

Note

Earlier versions of JBoss Rules supplied several filters which are not provided in version 5.0. They are simple to implement and the JBoss Rules 4 code base can be referred to.

To use a filter specify it when calling `fireAllRules()`. The following example permits only rules ending in the string *Test*. All others will be filtered out.

```
ksession.fireAllRules( new RuleNameEndsWithAgendaFilter( "Test" ) );
```

3.3.4. Agenda

The *Agenda* is a *Rete* feature. During actions on the **`WorkingMemory`**, rules may become fully matched and eligible for execution. A single Working Memory Action can result in multiple eligible rules. When a rule is fully matched an Activation is created, referencing the rule and the matched facts, and placed onto the Agenda. The Agenda controls the execution order of these Activations using a Conflict Resolution strategy.

The engine cycles repeatedly through two phases:

1. Working Memory Actions. This is where most of the work takes place, either in the *Consequence* (the RHS itself) or the main Java application process. Once the Consequence has finished or the main Java application process calls `fireAllRules()` the engine switches to the Agenda Evaluation phase.

2. Agenda Evaluation. This attempts to select a rule to fire. If no rule is found it exits, otherwise it fires the found rule, switching the phase back to Working Memory Actions.

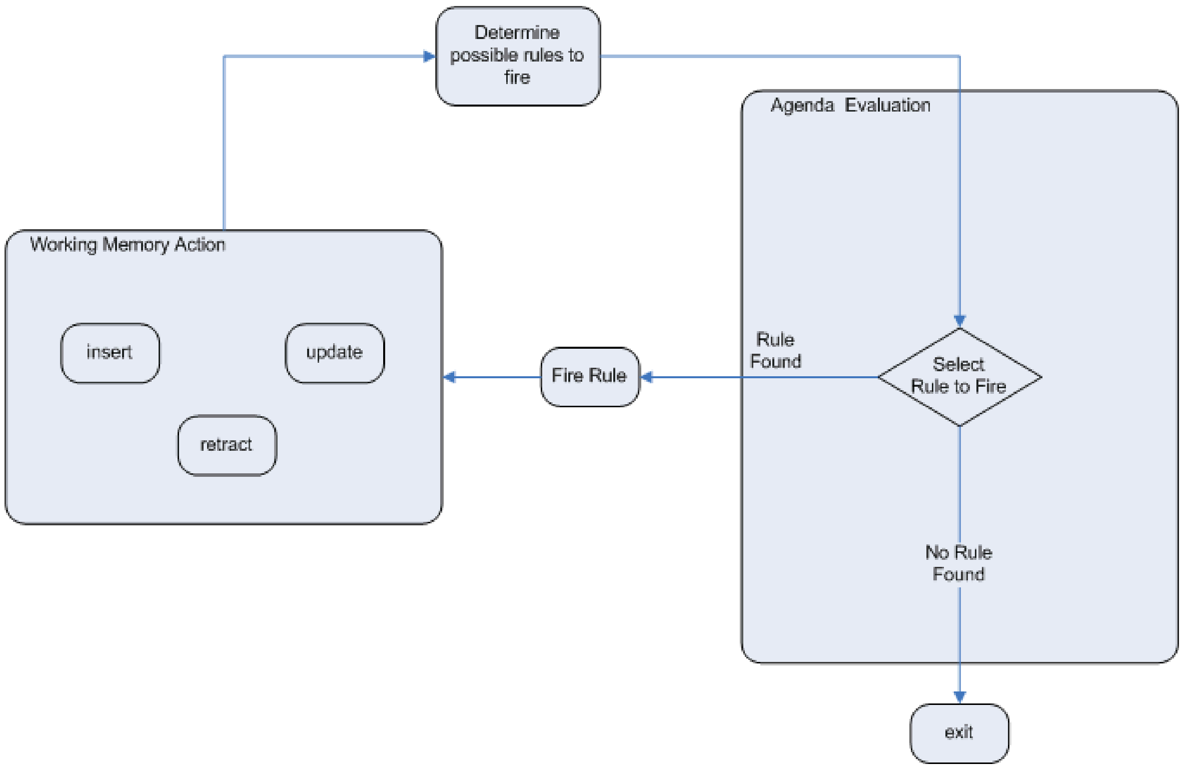


Figure 3.17. Two Phase Execution

The process repeats until the agenda is clear, in which case control returns to the calling application. When Working Memory Actions are taking place, no rules are being fired.

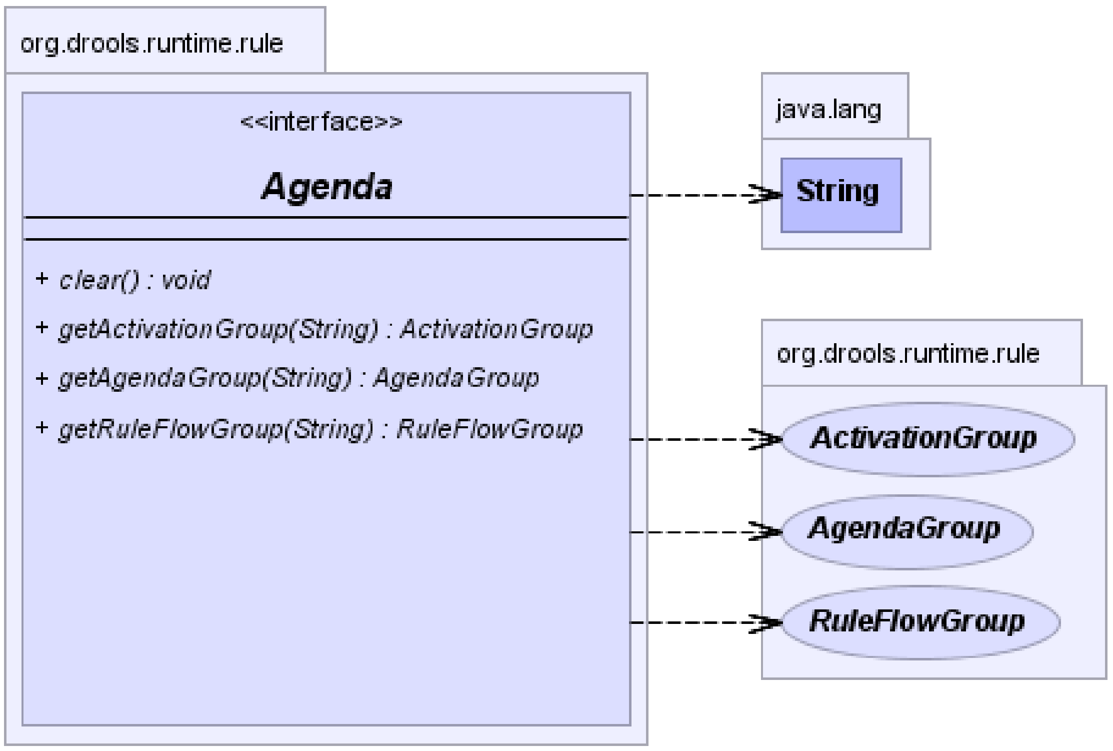


Figure 3.18. Agenda

3.3.4.1. Conflict Resolution

Conflict resolution is required when there are multiple rules on the agenda, the basics to this are covered in *Chapter 2, Quick Start*. As firing a rule may have side effects on the working memory, the rule engine needs to know in what order the rules should fire. For example, firing **`ruleA`** may cause **`ruleB`** to be removed from the agenda.

The default conflict resolution strategies employed by JBoss Rules are: Salience and LIFO (last in, first out).

The most visible one is "salience" or priority, in which a user can specify that a certain rule has a higher priority (by giving it a higher number) than other rules. In that case, the rule with higher salience will be preferred.

LIFO priorities are based on the assigned Working Memory Action counter value, with all rules created during the same action receiving the same value. The execution order of a set of firings with the same priority value is arbitrary.

As a general rule, it is a good idea not to count on the rules firing in any particular order. Remember that you should not be authoring rules as though they are steps in a imperative process.

Note

Previous versions of JBoss Rules supported custom conflict resolution strategies. This capability still exists in version 5 but the API is not currently exposed.

3.3.4.2. AgendaGroup

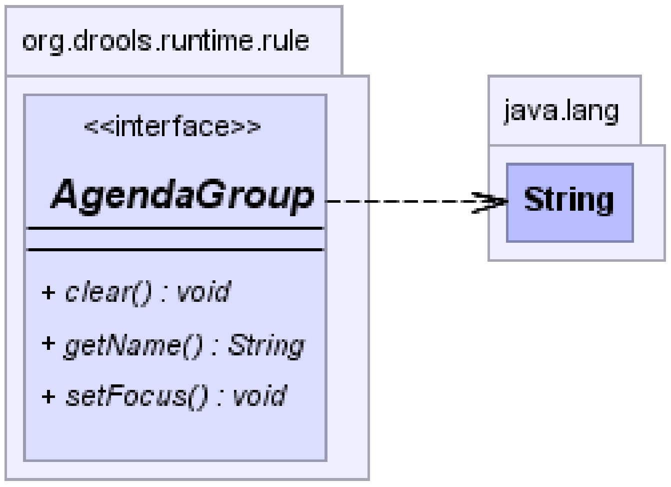


Figure 3.19. AgendaGroup

Agenda Groups, known as "modules" in CLIPS terminology, are a way to partition Activations on the Agenda. At any time only one group can have "focus", and only the Activations belonging to that group will take effect.

Focus can be set from within a rule or by using the JBoss Rules API. Rules can also be set with "auto focus", so its Agenda Group will become focused when it becomes matched.

Agenda Groups are most commonly used to define phases of processing.

Each time `setFocus()` is called it pushes that Agenda Group onto a stack. When the focus group is empty it is popped from the stack and the focus group that is now on top evaluates. An Agenda Group can appear in multiple locations on the stack.

```
ksession.getAgenda().getAgendaGroup( "Group A" ).setFocus();
```

The default Agenda Group is "MAIN". It it the first group on the stack and has the initial focus. Any rule without a Agenda Group is automatically placed in this group.

3.3.4.3. ActivationGroup

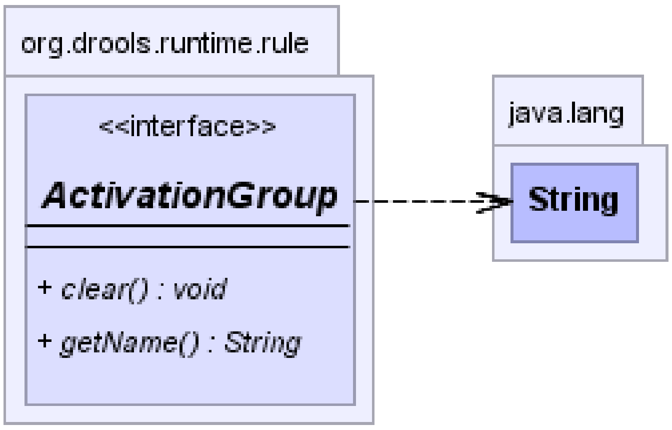


Figure 3.20. ActivationGroup

An activation group is set of rules bound together by the activation-group rule attribute. In this group only one rule can fire. After that rule has fired all the other rules are cancelled. The `clear()` method can be called at any time, which cancels all of the activations before one has a chance to fire.

```
ksession.getAgenda().getActivationGroup( "Group B" ).clear();
```

3.3.5. Event Model

The event package provides means to be notified of rule engine events, including rules firing, objects being asserted, etc. This allows you, for instance, to separate logging and auditing activities from the main part of your application and the rules.

The `KnowlegeRuntimeEventManager` interface is implemented by the **`KnowledgeRuntime`** which provides two interfaces, `WorkingMemoryEventManager` and `ProcessEventManager`. We will only cover the `WorkingMemoryEventManager` here.

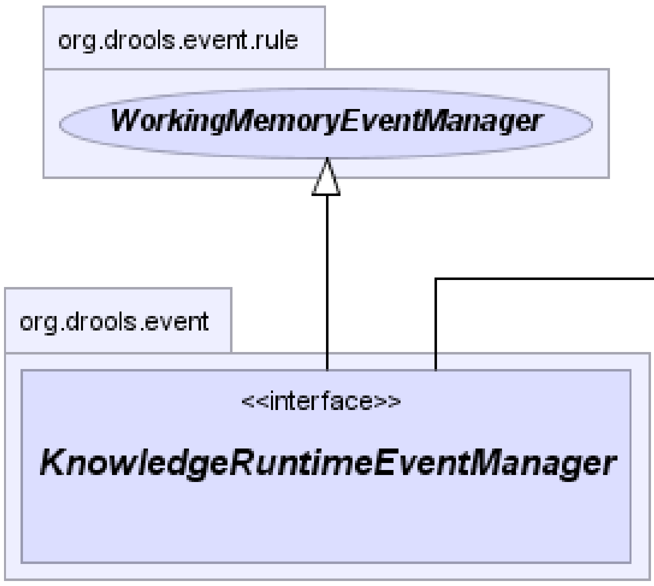


Figure 3.21. KnowledgeRuntimeEventManager

The `WorkingMemoryEventManager` allows for listeners to be added and removed, so that events for the working memory and the agenda can be listened to.

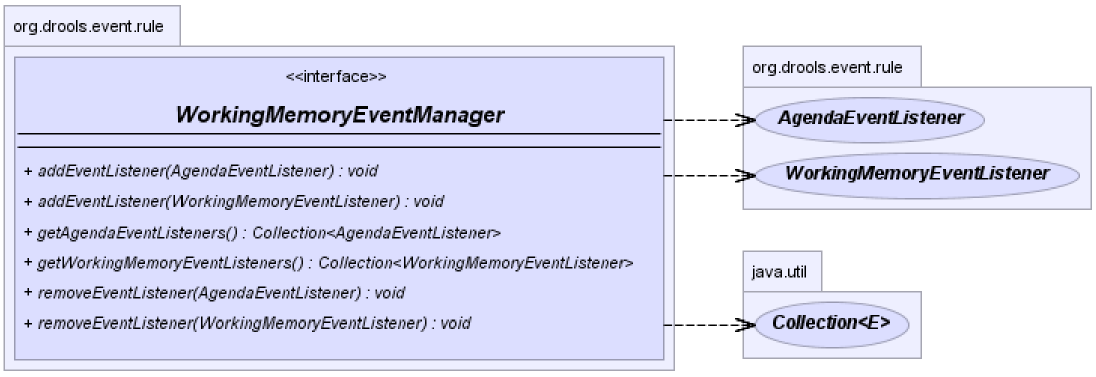

org.drools.event.rule
<<interface>>
WorkingMemoryEventManager
+ addEventListener(AgendaEventListener) : void
+ addEventListener(WorkingMemoryEventListener) : void
+ getAgendaEventListeners() : Collection<AgendaEventListener>
+ getWorkingMemoryEventListeners() : Collection<WorkingMemoryEventListener>
+ removeEventListener(AgendaEventListener) : void
+ removeEventListener(WorkingMemoryEventListener) : void
org.drools.event.rule
AgendaEventListener
WorkingMemoryEventListener
java.util
Collection<E>

Figure 3.22. WorkingMemoryEventManager

The following code shows how a simple agenda listener is declared and attached to a session. It will print activations after they have fired.

```
ksession.addEventListener( new DefaultAgendaEventListener() {
    public void afterActivationFired(AfterActivationFiredEvent event) {
        super.afterActivationFired( event );
        System.out.println( event );
    }
});
```

Example 3.27. Adding an AgendaEventListener

JBoss Rules also provides **`DebugWorkingMemoryEventListener`**, **`DebugAgendaEventListener`** which implement each method with a debug print statement. To print all Working Memory events, you can add one of these listeners.

```
ksession.addEventListener( new DebugWorkingMemoryEventListener() );
```

Example 3.28. Creating a new KnowledgeBuilder

All emitted events implement the `KnowlegeRuntimeEvent` interface which can be used to retrieve the **`KnowlegeRuntime`**, the event originated from.

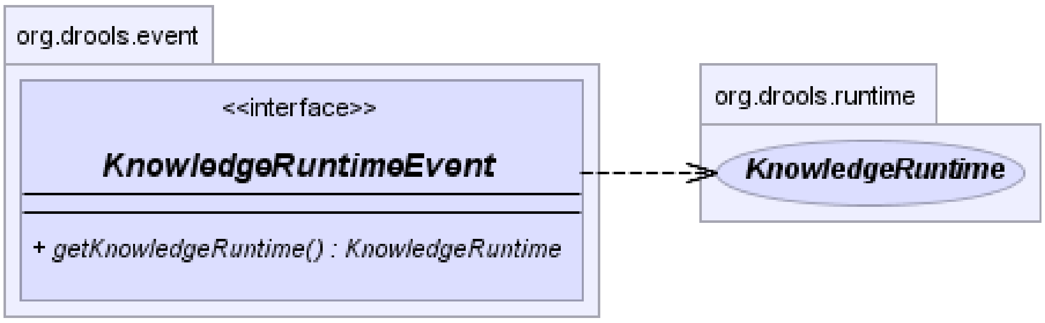


Figure 3.23. KnowlegeRuntimeEvent

The events currently supported are:

ActivationCreatedEvent	ActivationCancelledEvent
BeforeActivationFiredEvent	AfterActivationFiredEvent
AgendaGroupPushedEvent	AgendaGroupPoppedEvent
ObjectInsertEvent	ObjectRetractedEvent
ObjectUpdatedEvent	ProcessCompletedEvent
ProcessNodeLeftEvent	ProcessNodeTriggeredEvent
ProcessStartEvent	

3.3.6. KnowledgeRuntimeLogger

The **`KnowledgeRuntimeLogger`** uses the comprehensive event system in JBoss Rules to create an audit log of the execution of an application for later inspection. This log can be inspected in tools such as the Eclipse audit viewer.

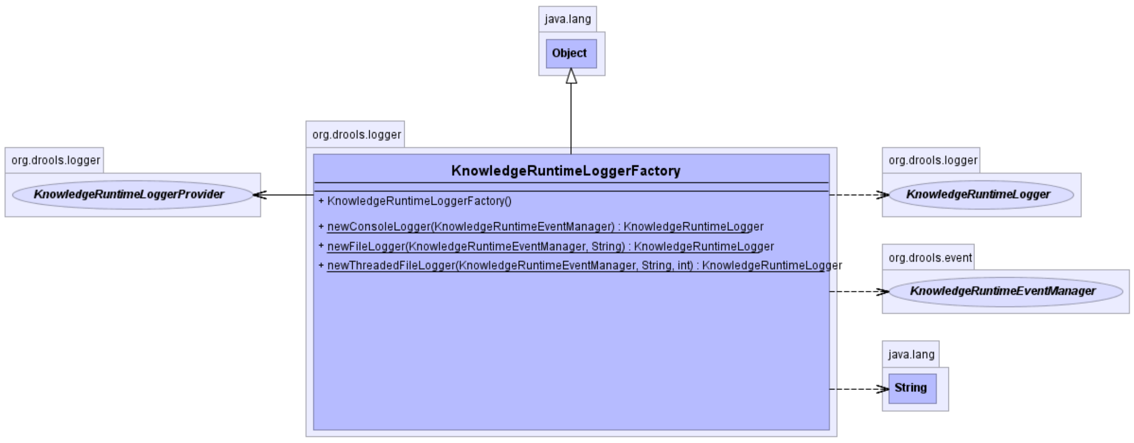

java.lang
Object
org.drools.logger
KnowledgeRuntimeLoggerFactory
+ KnowledgeRuntimeLoggerFactory()
+ newConsoleLogger(KnowledgeRuntimeEventManager) : KnowledgeRuntimeLogger
+ newFileLogger(KnowledgeRuntimeEventManager, String) : KnowledgeRuntimeLogger
+ newThreadedFileLogger(KnowledgeRuntimeEventManager, String, int) : KnowledgeRuntimeLogger
org.drools.logger
KnowledgeRuntimeLoggerProvider
org.drools.logger
KnowledgeRuntimeLogger
org.drools.event
KnowledgeRuntimeEventManager
java.lang
String

Figure 3.24. KnowledgeRuntimeLoggerFactory

```
KnowledgeRuntimeLogger logger =
    KnowledgeRuntimeLoggerFactory.newFileLogger(ksession, "logdir/
mylogfile");
...
logger.close();
```

Example 3.29. FileLogger

The `newFileLogger()` method automatically appends the file extension of **`.log`** to the filename that you specify.

3.3.7. StatelessKnowledgeSession

The **`StatelessKnowledgeSession`** wraps the **`StatefulKnowledgeSession`**. Its main focus is on decision service type scenarios. It removes the need to call `dispose()`.

Stateless sessions do not support iterative insertions or calling the method `fireAllRules()` from java code. The `execute()` internally instantiates a **`StatefullKnowledgeSession`**, adds all the user data and execute user commands, calls `fireAllRules()`, and then calls `dispose()`.

The usual way to work with this class is via the `BatchExecution` command as supported by the `CommandExecutor` interface. However two convenience methods are provided for when simple object insertion is all that is required. The `CommandExecutor` and `BatchExecution` are discussed in detail in their own section.

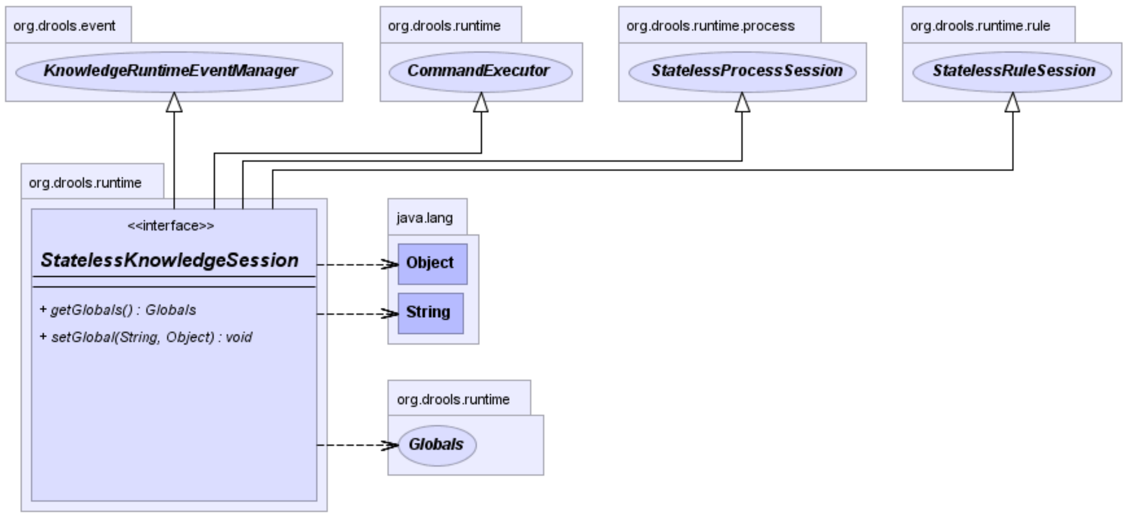


Figure 3.25. StatelessKnowledgeSession

A simple example shows a stateless session executing for a given collection of java objects using the convenience API. It iterates the collection, inserting each element in turn.

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();
kbuilder.add( ResourceFactory.newFileResource( fileName ),
 ResourceType.DRL );
if (kbuilder.hasErrors() ) {
    System.out.println( kbuilder.getErrors() );
} else {
    KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
    kbase.addKnowledgePackages( kbuilder.getKnowledgePackages() );
    StatelessKnowledgeSession ksession =
 kbase.newStatelessKnowledgeSession();
    ksession.execute( collection );
}
```

Example 3.30. Simple StatelessKnowledgeSession execution with a Collection

If this was done as a single Command it would be as follows:

```
ksession.execute( CommandFactory.newInsertElements( collection ) );
```

Example 3.31. Simple StatelessKnowledgeSession execution with InsertElements Command

Note if you wanted to insert the collection itself, and not the iterate and insert the elements, then you can use `CommandFactory.newInsert(collection)`.

The **`CommandFactory`** details the supported commands, all of which can marshalled using **`XStream`** and the **`BatchExecutionHelper`**. **`BatchExecutionHelper`** provides details on the XML format as well as how to use JBoss Rules Pipeline to automate the marshalling of **`BatchExecution`** and **`ExecutionResults`**.

`StatelessKnowledgeSession` supports globals, scoped in a number of ways. I'll cover the non-command way first, as commands are scoped to a specific execution call. Globals can be resolved in three ways.

- The Stateless Knowledge Session method `getGlobals()` returns a Globals instance which provides access to the session's globals. These are shared for *all* execution calls. Exercise caution regarding mutable globals because execution calls can be executing simultaneously in different threads.

  ```
  StatelessKnowledgeSession ksession =
   kbase.newStatelessKnowledgeSession();
  // sets a global hibernate session, that can be used
  // for DB interactions in the rules.
  ksession.setGlobal( "hbnSession", hibernateSession );
  // Execute while being able to resolve the "hbnSession" identifier.
  ksession.execute( collection );
  ```

  Example 3.32. Session scoped global

- Using a delegate is another way of global resolution. Assigning a value to a global (with `setGlobal(String, Object)`) results in the value being stored in an internal collection mapping identifiers to values. Identifiers in this internal collection will have priority over any supplied delegate.

Only if an identifier cannot be found in this internal collection, the delegate global (if any) will be used.

- The third way of resolving globals is to have execution scoped globals. Here, a `Command` to set a global is passed to the `CommandExecutor`.

The `CommandExecutor` interface also offers the ability to export data via "out" parameters. Inserted facts, globals and query results can all be returned.

```
// Set up a list of commands
List cmds = new ArrayList();
cmds.add( CommandFactory.newSetGlobal( "list1", new ArrayList(), true ) );
cmds.add( CommandFactory.newInsert( new Person( "jon", 102 ), "person" ) );
cmds.add( CommandFactory.newQuery( "Get People" "getPeople" );

// Execute the list
ExecutionResults results =
    ksession.execute( CommandFactory.newBatchExecution( cmds ) );

// Retrieve the ArrayList
results.getValue( "list1" );
// Retrieve the inserted Person fact
results.getValue( "person" );
// Retrieve the query as a QueryResults instance.
results.getValue( "Get People" );
```

Example 3.33. Out identifiers

3.3.7.1. Sequential Mode

With Rete you have a stateful session where objects can be asserted and modified over time, and where rules can also be added and removed. Now what happens if we assume a stateless session, where after the initial data set no more data can be asserted or modified and rules cannot be added or removed? Certainly it won't be necessary to re-evaluate rules, and the engine will be able to operate in a simplified way.

1. Order the Rules by salience and position in the ruleset (by setting a sequence attribute on the rule terminal node).

2. Create an array, one element for each possible rule activation; element position indicates firing order.

3. Turn off all node memories, except the right-input Object memory.

4. Disconnect the Left Input Adapter Node propagation, and let the Object plus the Node be referenced in a Command object, which is added to a list on the Working Memory for later execution.

5. Assert all objects, and, when all assertions are finished and thus right-input node memories are populated, check the Command list and execute each in turn.

6. All resulting Activations should be placed in the array, based upon the determined sequence number of the Rule. Record the first and last populated elements, to reduce the iteration range.

7. Iterate the array of Activations, executing populated element in turn.
8. If we have a maximum number of allowed rule executions, we can exit our network evaluations early to fire all the rules in the array.

The `LeftInputAdapterNode` no longer creates a Tuple, adding the Object, and then propagate the Tuple – instead a Command object is created and added to a list in the Working Memory. This Command object holds a reference to the `LeftInputAdapterNode` and the propagated object. This stops any left-input propagations at insertion time, so that we know that a right-input propagation will never need to attempt a join with the left-inputs (removing the need for left-input memory). All nodes have their memory turned off, including the left-input Tuple memory but excluding the right-input object memory, which means that the only node remembering an insertion propagation is the right-input object memory. Once all the assertions are finished and all right-input memories populated, we can then iterate the list of `LeftInputAdatperNode` Command objects calling each in turn. They will propagate down the network attempting to join with the right-input objects, but they won't be remembered in the left input as we know there will be no further object assertions and thus propagations into the right-input memory.

There is no longer an Agenda, with a priority queue to schedule the Tuples; instead, there is simply an array for the number of rules. The sequence number of the `RuleTerminalNode` indicates the element within the array where to place the Activation. Once all Command objects have finished we can iterate our array, checking each element in turn, and firing the Activations if they exist. To improve performance, we remember the first and the last populated cell in the array. The network is constructed, with each `RuleTerminalNode` being given a sequence number based on a salience number and its order of being added to the network.

Typically the right-input node memories are Hash Maps, for fast object retraction; here, as we know there will be no object retractions, we can use a list when the values of the object are not indexed. For larger numbers of objects indexed Hash Maps provide a performance increase; if we know an object type has only a few instances, indexing is probably not advantageous, and a list can be used.

Sequential mode can only be used with a Stateless Session and is off by default. To turn it on, either call `RuleBaseConfiguration.setSequential(true)`, or set the rulebase configuration property `drools.sequential` to true. Sequential mode can fall back to a dynamic agenda by calling `setSequentialAgenda` with `SequentialAgenda.DYNAMIC`. You may also set the "drools.sequential.agenda" property to "sequential" or "dynamic".

3.3.8. Pipeline

The `PipelineFactory` and associated classes are there to help with the automation of getting information into and out of JBoss Rules, especially when using services such as Java Message Service (JMS), and other data sources that aren't Java objects. Transformers for Smooks, JAXB, XStream and jXLS are povided. Smooks is an ETL (extract, transform, load) tool and can work with a variety of data sources. JAXB is a Java standard for XML binding capable of working with XML schemas. XStream is a simple and fast XML serialisation framework. jXLS finally allows for loading of Java objects from an Excel spreadsheet. Minimal information on these technologies will be provided here; beyond this, you should consult the relevant user guide for each of these tools.

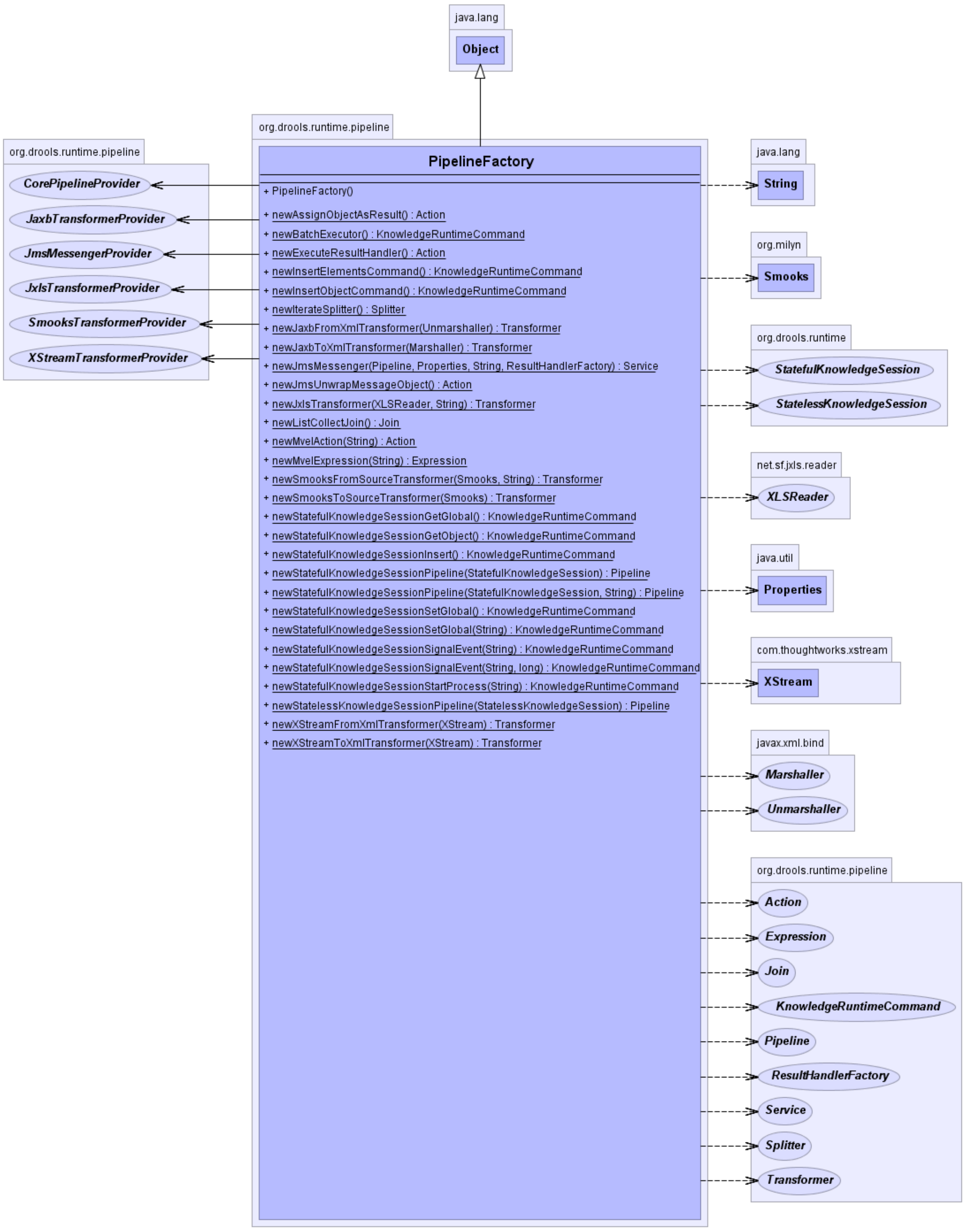

java.lang
Object
org.drools.runtime.pipeline
PipelineFactory
+ PipelineFactory()
+ newAssignObjectAsResult() : Action
+ newBatchExecutor() : KnowledgeRuntimeCommand
+ newExecuteResultHandler() : Action
+ newInsertElementsCommand() : KnowledgeRuntimeCommand
+ newInsertObjectCommand() : KnowledgeRuntimeCommand
+ newIterateSplitter() : Splitter
+ newJaxbFromXmlTransformer(Unmarshaller) : Transformer
+ newJaxbToXmlTransformer(Marshaller) : Transformer
+ newJmsMessenger(Pipeline, Properties, String, ResultHandlerFactory) : Service
+ newJmsUnwrapMessageObject() : Action
+ newJxlsTransformer(XLSReader, String) : Transformer
+ newListCollectJoin() : Join
+ newMvelAction(String) : Action
+ newMvelExpression(String) : Expression
+ newSmooksFromSourceTransformer(Smooks, String) : Transformer
+ newSmooksToSourceTransformer(Smooks) : Transformer
+ newStatefulKnowledgeSessionGetGlobal() : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionGetObject() : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionInsert() : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionPipeline(StatefulKnowledgeSession) : Pipeline
+ newStatefulKnowledgeSessionPipeline(StatefulKnowledgeSession, String) : Pipeline
+ newStatefulKnowledgeSessionSetGlobal() : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionSetGlobal(String) : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionSignalEvent(String) : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionSignalEvent(String, long) : KnowledgeRuntimeCommand
+ newStatefulKnowledgeSessionStartProcess(String) : KnowledgeRuntimeCommand
+ newStatelessKnowledgeSessionPipeline(StatelessKnowledgeSession) : Pipeline
+ newXStreamFromXmlTransformer(XStream) : Transformer
+ newXStreamToXmlTransformer(XStream) : Transformer
org.drools.runtime.pipeline
CorePipelineProvider
JaxbTransformerProvider
JmsMessengerProvider
JxlsTransformerProvider
SmooksTransformerProvider
XStreamTransformerProvider
java.lang
String
org.milyn
Smooks
org.drools.runtime
StatefulKnowledgeSession
StatelessKnowledgeSession
net.sf.jxls.reader
XLSReader
java.util
Properties
com.thoughtworks.xstream
XStream
javax.xml.bind
Marshaller
Unmarshaller
org.drools.runtime.pipeline
Action
Expression
Join
KnowledgeRuntimeCommand
Pipeline
ResultHandlerFactory
Service
Splitter
Transformer

Figure 3.26. PipelineFactory

Pipeline is not meant as a replacement for products like the more powerful Apache Camel. It is a simple framework aimed at the specific JBoss Rules use cases.

In JBoss Rules, a pipeline is a series of stages that operate on and propagate a given payload. Typically this starts with a `Pipeline` instance which is responsible for taking the payload, creating a `PipelineContext` for it and propagating that to the first receiver stage.

Two subtypes of `Pipeline` are provided, both requiring a different `PipelineContext`: `StatefulKnowledgeSessionPipeline` and `StatelessKnowledgeSessionPipeline`. `PipelineFactory` provides methods to create both of the two `Pipeline` subtypes. Notice that both factory methods take the relevant session as an argument. The construction of a `StatefulKnowledgeSessionPipeline` is shown below, where also its receiver is set.

```
Pipeline pipeline =
    PipelineFactory.newStatefulKnowledgeSessionPipeline( ksession );
pipeline.setReceiver( receiver );
```

Example 3.34. StatefulKnowledgeSessionPipeline

A pipeline is then made up of a chain of `Stages` that implement both the `Emitter` and the `Receiver` interfaces. The `Emitter` interface enables the `Stage` to propagate a payload, and the `Receiver` interface lets it receive a payload. This is why the `Pipeline` interface only implements `Emitter` and `Stage` and not `Receiver`, as it is the first instance in the chain. The `Stage` interface allows a custom exception handler to be set on the `Stage` object.

```
Transformer transformer =
 PipelineFactory.newXStreamFromXmlTransformer( xstream );
transformer.setStageExceptionHandler( new StageExceptionHandler()
 { .... } );
```

Example 3.35. StageExceptionHandler

The `Transformer` interface extends `Stage`, `Emitter` and `Receiver`, providing those interface methods as a single type. Its other purpose is that of a marker interface indicating this particulare role of the implementing class. (We have several other marker interfaces such as `Expression` and `Action`, both of which also extend `Stage`, `Emitter` and `Receiver`.) One of the stages should be responsible for setting a result value on the `PipelineContext`. It's the responsibility of the `ResultHandler` interface, to be implemented by the user, to process on these results. It may do so by inserting them into some suitable object, whence the user's code may retrieve them.

```
ResultHandler resultHandler = new ResultHandlerImpl();
pipeline.insert( factHandle, resultHandler );
System.out.println( resultHandler );
...
public class ResultHandlerImpl implements ResultHandler {
    Object result;

    public void handleResult(Object result) {
        this.result = result;
    }

    public Object getResult() {
        return this.result;
    }
}
```

Example 3.36. StageExceptionHandler

While the above example shows a simple handler that merely assigns the result to a field that the user can access, it could do more complex work like sending the object as a message.

Pipeline provides an adapter to insert the payload and to create the correct Pipeline Context internally.

In general it is easier to construct the pipelines in reverse. In the following example XML data is loaded from disk, transformed with XStream and finally inserted into the session.

```
// Make the results (here: FactHandles) available to the user
Action executeResultHandler = PipelineFactory.newExecuteResultHandler();

// Insert the transformed object into the session
// associated with the PipelineContext
KnowledgeRuntimeCommand insertStage =
    PipelineFactory.newStatefulKnowledgeSessionInsert();
insertStage.setReceiver( executeResultHandler );

// Create the transformer instance and the Transformer Stage,
// to transform from Xml to a Java object.
XStream xstream = new XStream();
Transformer transformer =
 PipelineFactory.newXStreamFromXmlTransformer( xstream );
transformer.setReceiver( insertStage );

// Create the start adapter Pipeline for StatefulKnowledgeSessions
Pipeline pipeline =
 PipelineFactory.newStatefulKnowledgeSessionPipeline( ksession );
pipeline.setReceiver( transformer );

// Instantiate a simple result handler and load and insert the XML
ResultHandlerImpl resultHandler = new ResultHandlerImpl();
pipeline.insert( ResourceFactory.newClassPathResource( "path/facts.xml",
 getClass() ),
                 resultHandler );
```

Example 3.37. Constructing a pipeline

While the above example is for loading a resource from disk, it is also possible to work from a running messaging service. JBoss Rules currently provides a single service for JMS, called `JmsMessenger`. Support for other services will be added later. The code below shows part of a unit test which illustrates part of the `JmsMessenger` in action:

```
// As this is a service, it's more likely that
 // the results will be logged or sent as a return message
Action resultHandlerStage = PipelineFactory.newExecuteResultHandler();

// Insert the transformed object into the session associated with the
 PipelineContext
KnowledgeRuntimeCommand insertStage =
 PipelineFactory.newStatefulKnowledgeSessionInsert();
insertStage.setReceiver( resultHandlerStage );

// Create the transformer instance and create the Transformer stage where
 we are
// going from XML to Pojo. JAXB needs an array of the available classes.
JAXBContext jaxbCtx = KnowledgeBuilderHelper.newJAXBContext( classNames,
                                                              kbase );
Unmarshaller unmarshaller = jaxbCtx.createUnmarshaller();
Transformer transformer =
 PipelineFactory.newJaxbFromXmlTransformer( unmarshaller );
transformer.setReceiver( insertStage );

// Payloads for JMS arrive in a Message wrapper: we need to unwrap this
 object.
Action unwrapObjectStage = PipelineFactory.newJmsUnwrapMessageObject();
unwrapObjectStage.setReceiver( transformer );

// Create the start adapter Pipeline for StatefulKnowledgeSessions
Pipeline pipeline =
 PipelineFactory.newStatefulKnowledgeSessionPipeline( ksession );
pipeline.setReceiver( unwrapObjectStage );

// Services, like JmsMessenger take a ResultHandlerFactory implementation.
// This is because a result handler must be created for each incoming
 message.
ResultHandlerFactory factory = new ResultHandlerFactoryImpl();
Service messenger = PipelineFactory.newJmsMessenger( pipeline,
                                                     props,
                                                     destinationName,
                                                     factory );
messenger.start();
```

Example 3.38. Using JMS with Pipeline

3.3.8.1. Xstream Transformer

```
XStream xstream = new XStream();
Transformer transformer =
    PipelineFactory.newXStreamFromXmlTransformer( xstream );
transformer.setReceiver( nextStage );
```

Example 3.39. XStream FromXML transformer stage

```
XStream xstream = new XStream();
Transformer transformer =
 PipelineFactory.newXStreamToXmlTransformer( xstream );
transformer.setReceiver( receiver );
```

Example 3.40. XStream ToXML transformer stage

3.3.8.2. JAXB Transformer

The Transformer objects are `JaxbFromXmlTransformer` and `JaxbToXmlTransformer`. The former uses an `javax.xml.bind.Unmarshaller` for converting an XML document into a content tree; the latter serializes a content tree to XML by passing it to a `javax.xml.bind.Marshaller`. Both of these objects can be obtained from a `JAXBContext` object.

A JAXBContext maintains the set of Java classes that are bound to XML elements. Such classes may be generated from an XML schema, by compiling it with JAXB's schema compiler **`xjc`**. Alternatively, handwritten classes can be augmented with annotations from `jaxb.xml.bind.annotation`.

Unmarshalling an XML document results in an object tree. Inserting objects from this tree as facts into a session can be done by walking the tree and inserting nodes as appropriate. This could be done in the context of a pipeline by a custom Transformer that emits the nodes one by one to its receiver.

```
Options xjcOpts = new Options();
xjcOpts.setSchemaLanguage( Language.XMLSCHEMA );
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();

String[] classNames =
  KnowledgeBuilderHelper.addXsdModel(
    ResourceFactory.newClassPathResource( "order.xsd", getClass() ),
    kbuilder,
    xjcOpts,
    "xsd" );
```

Example 3.41. JAXB XSD Generation into the KnowlegeBuilder

```
JAXBContext jaxbCtx =
    KnowledgeBuilderHelper.newJAXBContext( classNames, kbase );
Unmarshaller unmarshaller = jaxbCtx.createUnmarshaller();
Transformer transformer =
 PipelineFactory.newJaxbFromXmlTransformer( unmarshaller );
transformer.setReceiver( receiver );
```

Example 3.42. JAXB From XML transformer stage

```
Marshaller marshaller = jaxbCtx.createMarshaller();
Transformer transformer =
 PipelineFactory.newJaxbToXmlTransformer( marshaller );
transformer.setReceiver( receiver );
```

Example 3.43. JAXB to XML transformer stage

3.3.8.3. Smooks Transformer

```
Smooks smooks = new Smooks( getClass().getResourceAsStream( "smooks-
config.xml" ) );
Transformer transformer =
  PipelineFactory.newSmooksFromSourceTransformer( smooks, "orderItem" );
transformer.setReceiver( receiver );
```

Example 3.44. Smooks FromSource transformer stage

```
Smooks smooks = new Smooks( getClass().getResourceAsStream( "smooks-
config.xml" ) );

Transformer transformer =
 PipelineFactory.newSmooksToSourceTransformer( smooks );
transformer.setReceiver( receiver );
```

Example 3.45. Smooks ToSource transformer stage

3.3.8.4. jXLS (Excel/Calc/CSV) Transformer

This transformer transforms from an Excel spreadsheet to a map of Java objects, using jXLS, and the resulting map is set as the propagating object. You may need to use splitters and MVEL expressions to split up the transformation to insert individual Java objects. Note that you must provde an XLSReader, which references the mapping file and also an MVEL string which will instantiate the map. The MVEL expression is pre-compiled but executed on each usage of the transformation.

```
XLSReader mainReader =

 ReaderBuilder.buildFromXML( ResourceFactory.newClassPathResource( "departments.xml",
 getClass() ).getInputStream() );
String expr = "[ 'departments' : new java.util.ArrayList()," +
              "  'company' : new
 org.drools.runtime.pipeline.impl.Company() ]";
Transformer transformer = PipelineFactory.newJxlsTransformer(mainReader,
 expr );
```

Example 3.46. JXLS transformer stage

3.3.8.5. JMS Messenger

This transformer creates a new `JmsMessenger` which runs as a service in its own thread. It expects an existing JNDI entry for "ConnectionFactory", used to create the MessageConsumer which will feed into the specified pipeline.

```
// As this is a service, it's more likely the results
// will be logged or sent as a return message
Action resultHandlerStage = PipelineFactory.newExecuteResultHandler();

// Insert the transformed object into the session associated with the
 PipelineContext
KnowledgeRuntimeCommand insertStage =
 PipelineFactory.newStatefulKnowledgeSessionInsert();
insertStage.setReceiver( resultHandlerStage );

// Create the transformer instance and create the Transformer stage,
// where we are going from XML to Java object.
// JAXB needs an array of the available classes
JAXBContext jaxbCtx = KnowledgeBuilderHelper.newJAXBContext( classNames,
 kbase );
Unmarshaller unmarshaller = jaxbCtx.createUnmarshaller();
Transformer transformer =
 PipelineFactory.newJaxbFromXmlTransformer( unmarshaller );
transformer.setReceiver( insertStage );

// Payloads for JMS arrive in a Message wrapper, we need to unwrap this
 object.
Action unwrapObjectStage = PipelineFactory.newJmsUnwrapMessageObject();
unwrapObjectStage.setReceiver( transformer );

// Create the start adapter Pipeline for StatefulKnowledgeSessions
Pipeline pipeline =
    PipelineFactory.newStatefulKnowledgeSessionPipeline( ksession );
pipeline.setReceiver( unwrapObjectStage );

// Services like JmsMessenger take a ResultHandlerFactory implementation.
// This is so because a result handler must be created for each incoming
 message.
ResultHandleFactoryImpl factory = new ResultHandleFactoryImpl();
Service messenger = PipelineFactory.newJmsMessenger( pipeline,
                                                     props,
                                                     destinationName,
                                                     factory );
```

Example 3.47. JMS Messenger stage

3.3.9. Commands and the CommandExecutor

JBoss Rules has the concept of stateful or stateless sessions. We've already covered stateful sessions, which use the standard working memory that can be worked with iteratively over time. Stateless is a one-off execution of a working memory with a provided data set. It may return some results, with the session being disposed at the end, prohibiting further iterative interactions. You can think of stateless as treating a rule engine like a function call with optional return results.

In previous versions we supported these two paradigms but the way the user interacted with them was different. StatelessSession used an execute(...) method which would insert a collection of objects as facts. StatefulSession didn't have this method, and insert used the more traditional `insert(...)` method. The other issue was that the StatelessSession did not return any results, so that users themselves had to map globals to get results, and it wasn't possible to do anything besides inserting objects; users could not start processes or execute queries.

JBoss Rules 5.0 addresses all of these issues and more. The foundation for this is the `CommandExecutor` interface, which both the stateful and stateless interfaces extend, creating consistency and `ExecutionResults`:

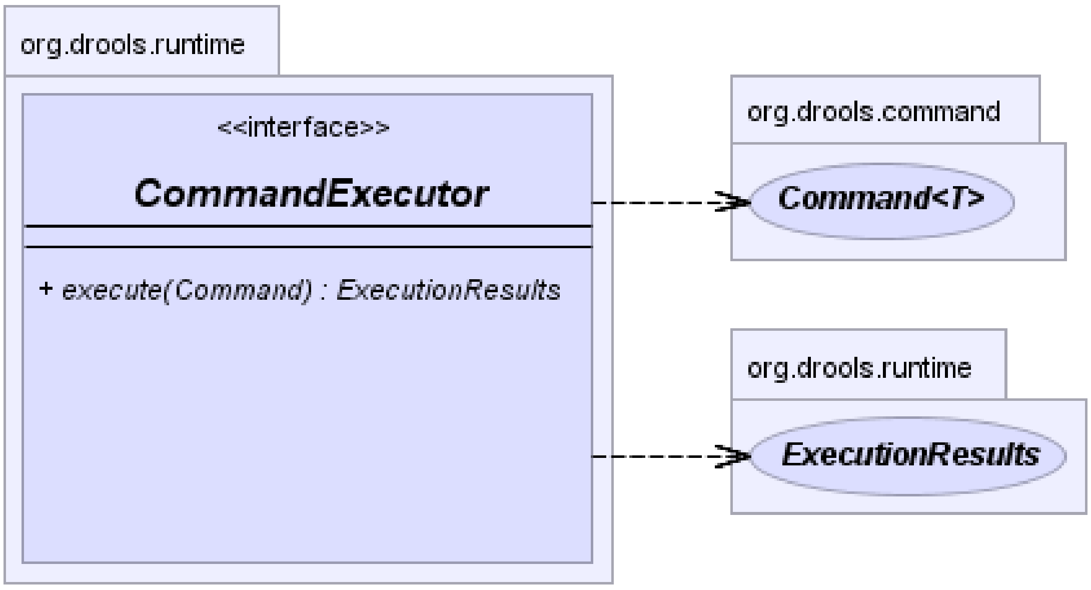


Figure 3.27. CommandExecutor

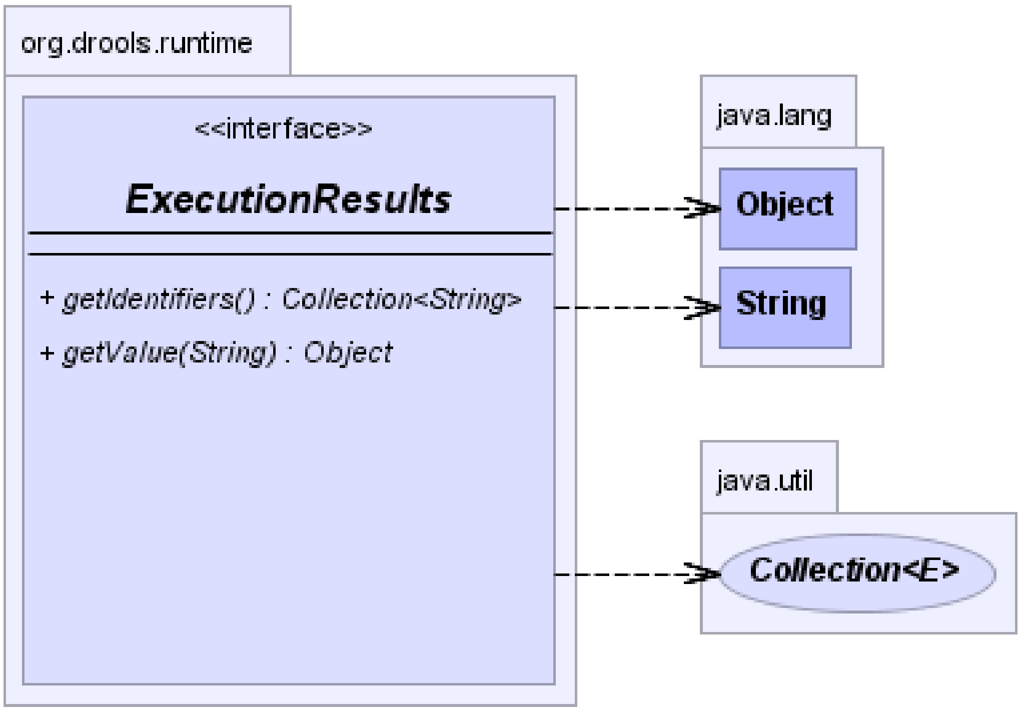


Figure 3.28. ExecutionResults

The `CommandFactory` allows for commands to be executed on those sessions, the only difference being that the Stateless Knowledge Session executes `fireAllRules()` at the end before disposing the session. The currently supported commands are:

The current supported commands are:

FireAllRules	GetGlobal
SetGlobal	InsertObject
InsertElements	Query
StartProcess	BatchExecution

`InsertObject` will insert a single object, with an optional "out" identifier. `InsertElements` will iterate an Iterable, inserting each of the elements. What this means is that a Stateless Knowledge Session is no longer limited to just inserting objects, it can now start processes or execute queries, and do this in any order.

```
StatelessKnowledgeSession ksession = kbase.newStatelessKnowledgeSession();
ExecutionResults bresults =
  ksession.execute( CommandFactory.newInsert( new Cheese( "stilton"
 ), "stilton_id" ) );
Stilton stilton = bresults.getValue( "stilton_id" );
```

Example 3.48. Insert Command

The execute method always returns an `ExecutionResults` instance, which allows access to any command results if they specify an out identifier such as the "stilton_id" above.

```
StatelessKnowledgeSession ksession = kbase.newStatelessKnowledgeSession();
Command cmd = CommandFactory.newInsertElements(
    Arrays.asList(new Object[] {
        new Cheese("stilton"), new Cheese("brie"), new Cheese("cheddar")}
));

ExecutionResults bresults = ksession.execute( cmd );
```

Example 3.49. InsertElements Command

However this method only allows for a single command. BatchExecution is a composite command that takes a list of commands and will iterate and execute each command in turn. This means you can insert some objects, start a process, call fireAllRules and execute a query all in a single execute(...) call - much more powerful.

As mentioned previosly, the Stateless Knowledge Session will execute `fireAllRules()` automatically at the end. However the keen-eyed reader probably has already noticed the `FireAllRules` command and wondered how that works with a StatelessKnowledgeSession. The `FireAllRules` command is allowed, and using it will disable the automatic execution at the end; think of using it as a sort of manual override function.

Commands support out identifiers. Any command that has an out identifier set on it will add its results to the returned ExecutionResults instance. Let's look at a simple example to see how this works.

```
StatelessKnowledgeSession ksession = kbase.newStatelessKnowledgeSession();
List cmds = new ArrayList();
cmds.add( CommandFactory.newInsertObject( new
 Cheese( "stilton", 1), "stilton") );
cmds.add( CommandFactory.newStartProcess( "process cheeses" ) );
cmds.add( CommandFactory.newQuery( "cheeses" ) );
ExecutionResults bresults =
 ksession.execute( CommandFactory.newBatchExecution( cmds ) );
Cheese stilton = ( Cheese ) bresults.getValue( "stilton" );
QueryResults qresults = ( QueryResults ) bresults.getValue( "cheeses" );
```

Example 3.50. BatchExecution Command

In the above example multiple commands are executed, two of which populate the `ExecutionResults`. The query command defaults to use the same identifier as the query name, but it can also be mapped to a different identifier.

A custom XStream marshaller can be used with the JBoss Rules Pipeline to achieve XML scripting, which is perfect for services. Here are two simple XML samples, one for the BatchExecution and one for the `ExecutionResults`.

```
<batch-execution>
   <insert out-identifier='outStilton'>
      <org.drools.Cheese>
         <type>stilton</type>
         <price>25</price>
         <oldPrice>0</oldPrice>
      </org.drools.Cheese>
   </insert>
</batch-execution>
```

Example 3.51. Simple BatchExecution XML

```
<execution-results>
   <result identifier='outStilton'>
      <org.drools.Cheese>
         <type>stilton</type>
         <oldPrice>25</oldPrice>
         <price>30</price>
      </org.drools.Cheese>
   </result>
</execution-results>
```

Example 3.52. Simple ExecutionResults XML

The previously mentioned pipeline allows for a series of Stage objects, combined to help with getting data into and out of sessions. There is a Stage implementing the `CommandExecutor` interface that allows the pipeline to script either a stateful or stateless session. The pipeline setup is trivial:

```
Action executeResultHandler = PipelineFactory.newExecuteResultHandler();

Action assignResult = PipelineFactory.newAssignObjectAsResult();

assignResult.setReceiver( executeResultHandler );

Transformer outTransformer =
  PipelineFactory.newXStreamToXmlTransformer(
    BatchExecutionHelper.newXStreamMarshaller() );
outTransformer.setReceiver( assignResult );

KnowledgeRuntimeCommand cmdExecution =
    PipelineFactory.newCommandExecutor();
batchExecution.setReceiver( cmdExecution );

Transformer inTransformer =
  PipelineFactory.newXStreamFromXmlTransformer(
    BatchExecutionHelper.newXStreamMarshaller() );
inTransformer.setReceiver( batchExecution );

Pipeline pipeline =
    PipelineFactory.newStatelessKnowledgeSessionPipeline( ksession );
pipeline.setReceiver( inTransformer );
```

Example 3.53. Pipeline for CommandExecutor

The key thing here to note is the use of the `BatchExecutionHelper` to provide a specially configured XStream with custom converters for our Command objects and the new `BatchExecutor` stage.

Using the pipeline is very simple. You must provide your own implementation of the `ResultHandler` which is called when the pipeline executes the `ExecuteResultHandler` stage.

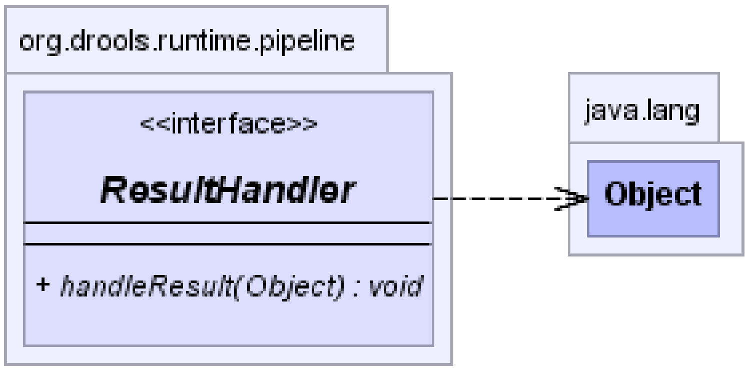


Figure 3.29. Pipeline ResultHandler

```
public static class ResultHandlerImpl implements ResultHandler {
    Object object;

    public void handleResult(Object object) {
       this.object = object;
    }

    public Object getObject() {
        return this.object;
    }
}
```

Example 3.54. Simple Pipeline ResultHandler

```

ResultHandler resultHandler = new ResultHandlerImpl();
pipeline.insert( inXml, resultHandler );
```

Example 3.55. Using a Pipeline

Earlier a `BatchExecution` was created with Java to insert some objects and execute a query. The XML representation to be used with the pipeline for that example is shown below, with parameters added to the query.

```

<batch-execution>
  <insert out-identifier="stilton">
    <org.drools.Cheese>
      <type>stilton</type>
      <price>1</price>
      <oldPrice>0</oldPrice>
    </org.drools.Cheese>
  </insert>
  <query out-identifier='cheeses2' name='cheesesWithParams'>
    <string>stilton</string>
    <string>cheddar</string>
  </query>
</batch-execution>
```

Example 3.56. BatchExecution Marshalled to XML

The `CommandExecutor` returns an `ExecutionResults`, and this is handled by the pipeline code snippet as well. A similar output for the <batch-execution> XML sample above would be:

```
<execution-results>
  <result identifier="stilton">
    <org.drools.Cheese>
      <type>stilton</type>
      <price>2</price>
    </org.drools.Cheese>
  </result>
  <result identifier='cheeses2'>
    <query-results>
      <identifiers>
        <identifier>cheese</identifier>
      </identifiers>
      <row>
        <org.drools.Cheese>
          <type>cheddar</type>
          <price>2</price>
          <oldPrice>0</oldPrice>
        </org.drools.Cheese>
      </row>
      <row>
        <org.drools.Cheese>
          <type>cheddar</type>
          <price>1</price>
          <oldPrice>0</oldPrice>
        </org.drools.Cheese>
      </row>
    </query-results>
  </result>
</execution-results>
```

Example 3.57. ExecutionResults Marshalled to XML

The `BatchExecutionHelper` provides a configured XStream instance to support the marshalling of Batch Executions, where the resulting XML can be used as a message format, as shown above. Configured converters only exist for the commands supported via the Command Factory. The user may add other converters for their user objects. This is very useful for scripting stateless or stateful knowledge sessions, especially when services are involved.

There is currently no XML schema to support schema validation. The basic format is outlined here, and the drools-transformer-xstream module has an illustrative unit test in the `XStreamBatchExecutionTest` unit test. The root element is <batch-execution> and it can contain zero or more commands elements.

```
<batch-execution>
...
</batch-execution>
```

Example 3.58. Root XML element

This contains a list of elements that represent commands, the supported commands is limited to those Commands provided by the Command Factory. The most basic of these is the <insert> element, which inserts objects. The contents of the insert element is the user object, as dictated by XStream.

```
<batch-execution>
   <insert>
      ...<!-- any user object -->
   </insert>
</batch-execution>
```

Example 3.59. Insert

The insert element features an "out-identifier" attribute, demanding that the inserted object will also be returned as part of the result payload.

```
<batch-execution>
   <insert out-identifier='userVar'>
      ...
   </insert>
</batch-execution>
```

Example 3.60. Insert with Out Identifier Command

It's also possible to insert a collection of objects using the <insert-elements> element. This command does not support an out-identifier. The `org.domain.UserClass` is just an illustrative user object that XStream would serialize.

```
<batch-execution>
   <insert-elements>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
   </insert-elements>
</batch-execution>
```

Example 3.61. Insert Elements command

Next, there is the `<set-global>` element, which sets a global for the session.

```
<batch-execution>
   <set-global identifier='userVar'>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
   </set-global>
</batch-execution>
```

Example 3.62. Insert Elements command

<set-global> also supports two other optional attributes, out and out-identifier. A true value for the boolean out will add the global to the <batch-execution-results> payload, using the name from the identifier attribute. out-identifier works like out but additionally allows you to override the identifier used in the <batch-execution-results> payload.

```
<batch-execution>
   <set-global identifier='userVar1' out='true'>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
   </set-global>
   <set-global identifier='userVar2' out-identifier='alternativeUserVar2'>
      <org.domain.UserClass>
         ...
      </org.domain.UserClass>
   </set-global>
</batch-execution>
```

Example 3.63. Set Global Command

There is also a <get-global> element, without contents, with just an out-identifier attribute. (There is no need for an out attribute because retrieving the value is the sole purpose of a <get-global> element.

```
<batch-execution>
   <get-global identifier='userVar1' />
   <get-global identifier='userVar2' out-identifier='alternativeUserVar2'/>
</batch-execution>
```

Example 3.64. Get Global Command

While the out attribute is useful in returning specific instances as a result payload, we often wish to run actual queries. Both parameter and parameterless queries are supported. The name attribute is the name of the query to be called, and the out-identifier is the identifier to be used for the query results in the <execution-results> payload.

```
<batch-execution>
   <query out-identifier='cheeses' name='cheeses'/>
   <query out-identifier='cheeses2' name='cheesesWithParams'>
      <string>stilton</string>
      <string>cheddar</string>
   </query>
</batch-execution>
```

Example 3.65. Query Command

The <start-process> command accepts optional parameters. Other process related methods will be added later, like interacting with work items.

```
<batch-execution>
   <startProcess processId='org.drools.actions'>
      <parameter identifier='person'>
         <org.drools.TestVariable>
            <name>John Doe</name>
          </org.drools.TestVariable>
       </parameter>
   </startProcess>
</batch-execution
```

Example 3.66. Start Process Command

```

<signal-event process-instance-id='1' event-type='MyEvent'>
   <string>MyValue</string>
</signal-event>
```

Example 3.67. Signal Event Command

```

<complete-work-item id='" + workItem.getId() + "' >
   <result identifier='Result'>
      <string>SomeOtherString</string>
   </result>
</complete-work-item>
```

Example 3.68. Complete Work Item Command

```

<abort-work-item id='21' />
```

Example 3.69. Abort Work Item Command

Support for more commands will be added over time.

3.3.10. Marshalling

The `MarshallerFactory` is used to marshal and unmarshal Stateful Knowledge Sessions.

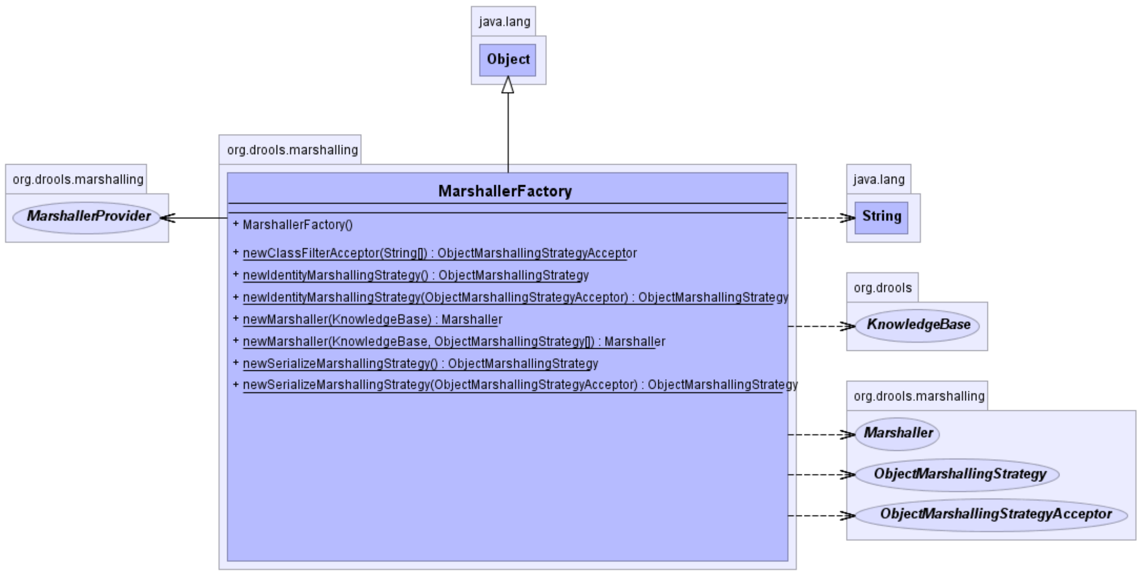

java.lang
Object
org.drools.marshalling
MarshallerFactory
+ MarshallerFactory()
+ newClassFilterAcceptor(String[]) : ObjectMarshallingStrategyAcceptor
+ newIdentityMarshallingStrategy() : ObjectMarshallingStrategy
+ newIdentityMarshallingStrategy(ObjectMarshallingStrategyAcceptor) : ObjectMarshallingStrategy
+ newMarshaller(KnowledgeBase) : Marshaller
+ newMarshaller(KnowledgeBase, ObjectMarshallingStrategy[]) : Marshaller
+ newSerializeMarshallingStrategy() : ObjectMarshallingStrategy
+ newSerializeMarshallingStrategy(ObjectMarshallingStrategyAcceptor) : ObjectMarshallingStrategy
org.drools.marshalling
MarshallerProvider
java.lang
String
org.drools
KnowledgeBase
org.drools.marshalling
Marshaller
ObjectMarshallingStrategy
ObjectMarshallingStrategyAcceptor

Figure 3.30. MarshallerFactory

At the simplest the MarshallerFactory can be used as follows:

```
// ksession is the StatefulKnowledgeSession
// kbase is the KnowledgeBase
ByteArrayOutputStream baos = new ByteArrayOutputStream();
Marshaller marshaller = MarshallerFactory.newMarshaller( kbase );
marshaller.marshall( baos, ksession );
baos.close();
```

Example 3.70. Simple Marshaller Example

However, with marshalling you need more flexibility when dealing with referenced user data. To achieve this we have the `ObjectMarshallingStrategy` interface. Two implementations are provided, but users can implement their own. The two supplied strategies are `IdentityMarshallingStrategy` and `SerializeMarshallingStrategy`. `SerializeMarshallingStrategy` is the default, as used in the example above, and it just calls the `Serializable` or `Externalizable` methods on a user instance. `IdentityMarshallingStrategy` instead creates an integer id for each user object and stores them in a Map, while the id is written to the stream. When unmarshalling it accesses the `IdentityMarshallingStrategy` map to retrieve the instance. This means that if you use the `IdentityMarshallingStrategy`, it is stateful for the life of the Marshaller instance and will create ids and keep references to all objects that it attempts to marshal. Below is he code to use an Identity Marshalling Strategy.

```
ByteArrayOutputStream baos = new ByteArrayOutputStream();
ObjectMarshallingStrategy oms =
 MarshallerFactory.newIdentityMarshallingStrategy()
Marshaller marshaller =
  MarshallerFactory.newMarshaller( kbase, new ObjectMarshallingStrategy[]
{ oms } );
marshaller.marshall( baos, ksession );
baos.close();
```

Example 3.71. IdentityMarshallingStrategy

For added flexability we can't assume that a single strategy is suitable. Therefore we have added the `ObjectMarshallingStrategyAcceptor` interface that each Object Marshalling Strategy contains. The Marshaller has a chain of strategies, and when it attempts to read or write a user object it iterates the strategies asking if they accept responsability for marshalling the user object. One of the provided implementations is `ClassFilterAcceptor`. This allows strings and wild cards to be used to match class names. The default is "*.*", so in the above example the Identity Marshalling Strategy is used which has a default "*.*" acceptor.

Assuming that we want to serialize all classes except for one given package, where we will use identity lookup, we could do the following:

```
ByteArrayOutputStream baos = new ByteArrayOutputStream();
ObjectMarshallingStrategyAcceptor identityAcceptor =
  MarshallerFactory.newClassFilterAcceptor( new String[]
 { "org.domain.pkg1.*" } );
ObjectMarshallingStrategy identityStrategy =
  MarshallerFactory.newIdentityMarshallingStrategy( identityAcceptor );
ObjectMarshallingStrategy sms =
 MarshallerFactory.newSerializeMarshallingStrategy();
Marshaller marshaller =
    MarshallerFactory.newMarshaller( kbase,
                                    new ObjectMarshallingStrategy[]
{ identityStrategy, sms } );
marshaller.marshall( baos, ksession );
baos.close();
```

Example 3.72. IdentityMarshallingStrategy with Acceptor

Note that the acceptance checking order is in the natural order of the supplied array.

3.3.11. Persistence and Transactions

Longterm out of the box persistence with Java Persistence API (JPA) is possible with JBoss Rules. You will need to have some implementation of the Java Transaction API (JTA) installed. For development purposes we recommend the Bitronix Transaction Manager, as it's simple to set up and works embedded, but for production use JBoss Transactions is recommended.

```
Environment env = KnowledgeBaseFactory.newEnvironment();

env.set( EnvironmentName.ENTITY_MANAGER_FACTORY,
    Persistence.createEntityManagerFactory( "emf-name" ) );
env.set( EnvironmentName.TRANSACTION_MANAGER,
    TransactionManagerServices.getTransactionManager() );

// KnowledgeSessionConfiguration may be null, and a default will be used

StatefulKnowledgeSession ksession =
    JPAKnowledgeService.newStatefulKnowledgeSession( kbase, null, env );
int sessionId = ksession.getId();

UserTransaction ut =
  (UserTransaction) new InitialContext().lookup( "java:comp/
UserTransaction" );
ut.begin();
ksession.insert( data1 );
ksession.insert( data2 );
ksession.startProcess( "process1" );
ut.commit();
```

Example 3.73. Simple example using transactions

To use a JPA, the Environment must be set with both the `EntityManagerFactory` and the `TransactionManager`. If rollback occurs the ksession state is also rolled back, so you can continue to use it after a rollback. To load a previously persisted Stateful Knowledge Session you'll need the id, as shown below:

```
StatefulKnowledgeSession ksession =
  JPAKnowledgeService.loadStatefulKnowledgeSession( sessionId, kbase, null,
 env );
```

Example 3.74. Loading a StatefulKnowledgeSession

To enable persistence several classes must be added to your persistence.xml, as in the example below:

```
<persistence-unit name="org.drools.persistence.jpa" transaction-type="JTA">
    <provider>org.hibernate.ejb.HibernatePersistence</provider>
    <jta-data-source>jdbc/BitronixJTADataSource</jta-data-source>
    <class>org.drools.persistence.session.SessionInfo</class>
   <class>org.drools.persistence.processinstance.ProcessInstanceInfo</
class>
   <class>org.drools.persistence.processinstance.ProcessInstanceEventInfo</
class>
    <class>org.drools.persistence.processinstance.WorkItemInfo</class>
    <properties>

  <property name="hibernate.dialect" value="org.hibernate.dialect.H2Dialect"/
>
        <property name="hibernate.max_fetch_depth" value="3"/>
        <property name="hibernate.hbm2ddl.auto" value="update" />
        <property name="hibernate.show_sql" value="true" />
        <property name="hibernate.transaction.manager_lookup_class"
           value="org.hibernate.transaction.BTMTransactionManagerLookup" />
    </properties>
</persistence-unit>
```

Example 3.75. Configuring JPA

The jdbc JTA data source would have to be configured first. Bitronix provides a number of ways of doing this, and its documentation should be contsulted for details. For a quick start, here is the programmatic approach:

```
PoolingDataSource ds = new PoolingDataSource();
ds.setUniqueName( "jdbc/BitronixJTADataSource" );
ds.setClassName( "org.h2.jdbcx.JdbcDataSource" );
ds.setMaxPoolSize( 3 );
ds.setAllowLocalTransactions( true );
ds.getDriverProperties().put( "user", "sa" );
ds.getDriverProperties().put( "password", "sasa" );
ds.getDriverProperties().put( "URL", "jdbc:h2:mem:mydb" );
ds.init();
```

Example 3.76. Configuring JTA DataSource

Bitronix also provides a simple embedded JNDI service, ideal for testing, to use it add a **`jndi.properties`** file to your **`META-INF`** and add the following line to it:

```
java.naming.factory.initial=bitronix.tm.jndi.BitronixInitialContextFactory
```

Example 3.77. JNDI properties

The Rule Language

4.1. Overview

Jboss Rules has a "native" rule language. This format is very light in terms of punctuation, and supports natural and domain specific languages via "expanders" that allow the language to adapt to your problem domain. This chapter is mostly concerted with this native rule format.

The diagrams used to present the syntax are known as *railroad* diagrams, and are like flow charts for the language terms. Interested readers can also refer to Antlr3 grammar for the rule language which is in **`DRL.g`** but this is not required. If you use the Rule Workbench, a lot of the rule structure is done for you with content assistance, for example, type "ru" and press ctrl+space, and it will build the rule structure for you.

4.1.1. A rule file

A rule file is typically a file with a **`.drl`** extension. In a DRL file you can have multiple rules, queries and functions, as well as some resource declarations like imports, globals and attributes that are assigned and used by your rules and queries. However, you are also able to spread your rules across multiple rule files and in that case, the extension **`.rule`** is suggested but not required. Spreading rules across files can help with managing large numbers of rules. A DRL file is simply a text file.

The overall structure of a rule file is:

```
package package-name

imports

globals

functions

queries

rules
```

Example 4.1. Rules file

The order in which the elements are declared is not important, except for the package name that, if declared, must be the first element in the rules file. All elements are optional, so you will use only those you need. We will discuss each of them in the following sections.

4.1.2. What makes a rule

A rule has the following rough structure:

```
rule "name"
    attributes
when
    LHS
```

```
then
    RHS
end
```

It's really that simple. Mostly punctuation is not needed, even the double quotes for "name" are optional, as are newlines. Attributes are simple (always optional) hints to how the rule should behave. LHS is the conditional parts of the rule, which follows a certain syntax which is covered below. RHS is basically a block that allows dialect specific semantic code to be executed.

It is important to note that white space is not important, *except* in the case of domain specific languages. When using a domain specific language each line is processed before the following line and spaces may be significant to the domain language.

4.2. Keywords

JBoss Rules 5 introduces the concept of Hard and Soft keywords.

Hard keywords are reserved, you cannot use any hard keyword when naming your domain objects, properties, methods, functions and other elements that are used in the rule text.

Here is the list of hard keywords that must be avoided as identifiers when writing rules:

true	false	accumulate
collect	from	null
over	then	when

Soft keywords are just recognized in their context, enabling you to use these words in any other place you wish. Here is a list of the soft keywords:

lock-on-active	date-effective	date-expires
no-loop	auto-focus	activation-group
agenda-group	ruleflow-group	entry-point
duration	package	import
dialect	salience	enabled
attributes	rule	extend
template	query	declare
function	global	eval
not	in	or
and	exists	forall
action	reverse	result
end	init	

You can use both hard and soft keywords as part of a method name in camel case, like `notSomething()` or `accumulateSomething()`.

Another improvement of the DRL language is the ability to escape hard keywords on rule text. This feature enables you to use your existing domain objects without worrying about keyword collision. To escape a word, simply enclose it in grave accents, like this:

```
Holiday( `when` == "july" )
```

The escape should be used everywhere in rule text, except within code expressions in the LHS or RHS code block. Here are examples of proper usage:

```
rule "validate holiday by eval"
dialect "mvel"
when
    h1 : Holiday( )
    eval( h1.when == "july" )
then
    System.out.println(h1.name + ":" + h1.when);
end
```

```
rule "validate holiday"
dialect "mvel"
when
    h1 : Holiday( `when` == "july" )
then
    System.out.println(h1.name + ":" + h1.when);
end
```

4.3. Comments

Comments are sections of text that are ignored by the rule engine. They are stripped out when they are encountered, except inside semantic code blocks, like the RHS of a rule.

4.3.1. Single line comment

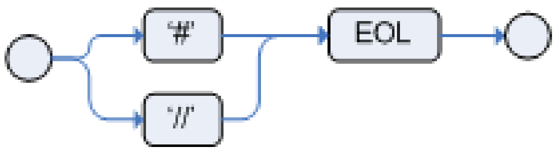


Figure 4.1. Single line comment

To create single line comments, you can use either '#' or '//'. The parser will ignore anything in the line after the comment symbol. Example:

```
rule "Testing Comments"
when
    # this is a single line comment
    // this is also a single line comment
    eval( true ) # this is a comment in the same line of a pattern
then
    // this is a comment inside a semantic code block
    # this is another comment in a semantic code block
end
```

4.3.2. Multi-line comment

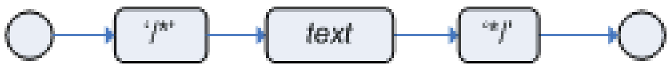


Figure 4.2. Multi-line comment

Multi-line comments are used to comment blocks of text, both in and outside semantic code blocks. Example:

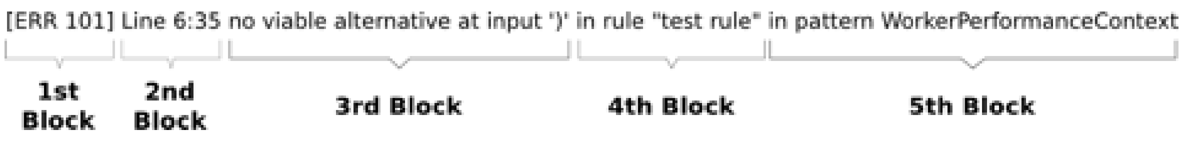
```
rule "Test Multi-line Comments"
when
    /* this is a multi-line comment
       in the left hand side of a rule */
    eval( true )
then
    /* and this is a multi-line comment
       in the right hand side of a rule */
end
```

4.4. Error Messages

JBoss Rules 5 introduces standardized error messages. This standardization aims to help users to find and resolve problems in a easier and faster way. In this section you will learn how to identify and interpret those error messages, and you will also receive some tips on how to solve the problems associated with them.

4.4.1. Message format

The standardization includes the error message format and to better explain this format, let's use the following example:



```
[ERR 101] Line 6:35 no viable alternative at input ')' in rule "test rule" in pattern WorkerPerformanceContext
```

Figure 4.3. Error Message Format

1st Block
: This area identifies the error code.

2nd Block
: Line and column information.

3rd Block
: Some text describing the problem.

4th Block
: This is the first context. Usually indicates the rule, function, template or query where the error occurred. This block is not mandatory.

5th Block
: Identifies the pattern where the error occurred. This block is not mandatory.

4.4.2. Error Messages Description

4.4.2.1. 101: No viable alternative

Indicates the most common errors, where the parser came to a decision point but couldn't identify an alternative. Here are some examples:

```
rule one
when
    exists Foo()
    exits Bar()
then
end
```

The above example generates this message:

```
[ERR 101] Line 4:4 no viable alternative at input 'exits' in rule one
```

At first glance this seems to be valid syntax, but it is not (exits != exists). Let's take a look at next example:

```
package org.drools;
rule
when
    Object()
then
    System.out.println("A RHS");
end
```

Now the above code generates this message:

```
[ERR 101] Line 3:2 no viable alternative at input 'WHEN'
```

This message means that the parser encountered the token WHEN, actually a hard keyword, but it's in the wrong place since the the rule name is missing.

The error "no viable alternative" also occurs when you make a simple lexical mistake. Here is a sample of a lexical problem:

```
rule simple_rule
when
    Student( name == "Andy )
then
end
```

The above code misses to close the quotes and because of this the parser generates this error message:

```
[ERR 101] Line 0:-1 no viable alternative at input
```

```
'<eof>' in rule simple_rule in pattern Student
```

Note

Usually the Line and Column information are accurate, but in some cases (like unclosed quotes), the parser generates a 0:-1 position. In this case you should check whether you didn't forget to close quotes, apostrophes or parentheses.

4.4.2.2. 102: Mismatched input

This error indicates that the parser was looking for a particular symbol that it didn't find at the current input position. Here are some samples:

```
rule simple_rule
when
    foo3 : Bar(
```

The above example generates this message:

```
[ERR 102] Line 0:-1 mismatched input '<eof>' expecting
')' in rule simple_rule in pattern Bar
```

To fix this problem, it is necessary to complete the rule statement.

Note

Usually when you get a 0:-1 position, it means that parser reached the end of source.

The following code generates more than one error message:

```
package org.drools;

rule "Avoid NPE on wrong syntax"
when
    not(Cheese((type=="stilton",price==10)||(type=="brie",price==15))
        from $cheeseList)
then
    System.out.println("OK");
end
```

These are the errors associated with this source:

```
[ERR 102] Line 5:36 mismatched input ',' expecting ')' in rule
"Avoid NPE on wrong syntax" in pattern Cheese

[ERR 101] Line 5:57 no viable alternative at input 'type' in
rule "Avoid NPE on wrong syntax"
```

```
[ERR 102] Line 5:106 mismatched input ')' expecting 'then' in
          rule "Avoid NPE on wrong syntax"
```

Note that the second problem is related to the first. To fix it, just replace the commas (',') by AND operator ('&&').

Note

In some situations you can get more than one error message. Try to fix one by one, starting at the first one. Some error messages are generated merely as consequences of other errors.

4.4.2.3. 103: Failed predicate

A validating semantic predicate evaluated to false. Usually these semantic predicates are used to identify soft keywords. This sample shows exactly this situation:

```
package nesting;
dialect "mvel"

import org.drools.Person
import org.drools.Address

fdsfdsfds

rule "test something"
when
    p: Person( name=="Michael" )
then
    p.name = "other";
    System.out.println(p.name);
end
```

With this sample, we get this error message:

```
[ERR 103] Line 7:0 rule 'rule_key' failed predicate:
{(validateIdentifierKey(DroolsSoftKeywords.RULE))}? in rule
```

The 'fdsfdsfds' text is invalid and the parser couldn't identify it as the soft keyword rule.

Note

This error is very similar to 102: Mismatched input, but usually involves soft keywords.

4.4.2.4. 104: Trailing semi-colon not allowed

This error is associated with the eval clause, where its expression may not be terminated with a semi-colon. Check this example:

```
rule simple_rule
when
    eval(abc();)
then
end
```

Due to the trailing semi-colon within eval, we get this error message:

```
[ERR 104] Line 3:4 trailing semi-colon not allowed in rule
simple_rule
```

This problem is simple to fix: just remove the semi-colon.

4.4.2.5. 105: Early Exit

The recognizer came to a subrule in the grammar that must match an alternative at least once, but the subrule did not match anything. Simply put: the parser has entered a branch from where there is no way out. This example illustrates it:

```
template test_error
    aa s  11;
end
```

This is the message associated to the above sample:

```
[ERR 105] Line 2:2 required (...)+ loop did not match anything
at input 'aa' in template test_error
```

To fix this problem it is necessary to remove the numeric value as it is neither a valid data type which might begin a new template slot nor a possible start for any other rule file construct.

4.5. Package

A package is a collection of rules and other related constructs, such as imports and globals. The package members are typically related to each other - perhaps HR rules, for instance. A package represents a namespace, which ideally is kept unique for a given grouping of rules. The package name itself is the namespace, and is not related to files or folders in any way.

It is possible to assemble rules from multiple rule sources, and have one top level package configuration that all the rules are kept under (when the rules are assembled). Although, it is not possible to merge into the same package resources declared under different names. A single Rulebase, can contain multiple packages built on it. It is common practice to have all the rules for a package in the same file as the package declaration so that is it entirely self contained.

The following railroad diagram shows all the components that may make up a package. Note that a package *must* have a namespace and be declared using standard Java conventions for package names; i.e., no spaces, unlike rule names which allow spaces. In terms of the order of elements, they can appear in any order in the rule file, with the exception of the package statement which must be at the top of the file. In all cases, the semicolons are optional.

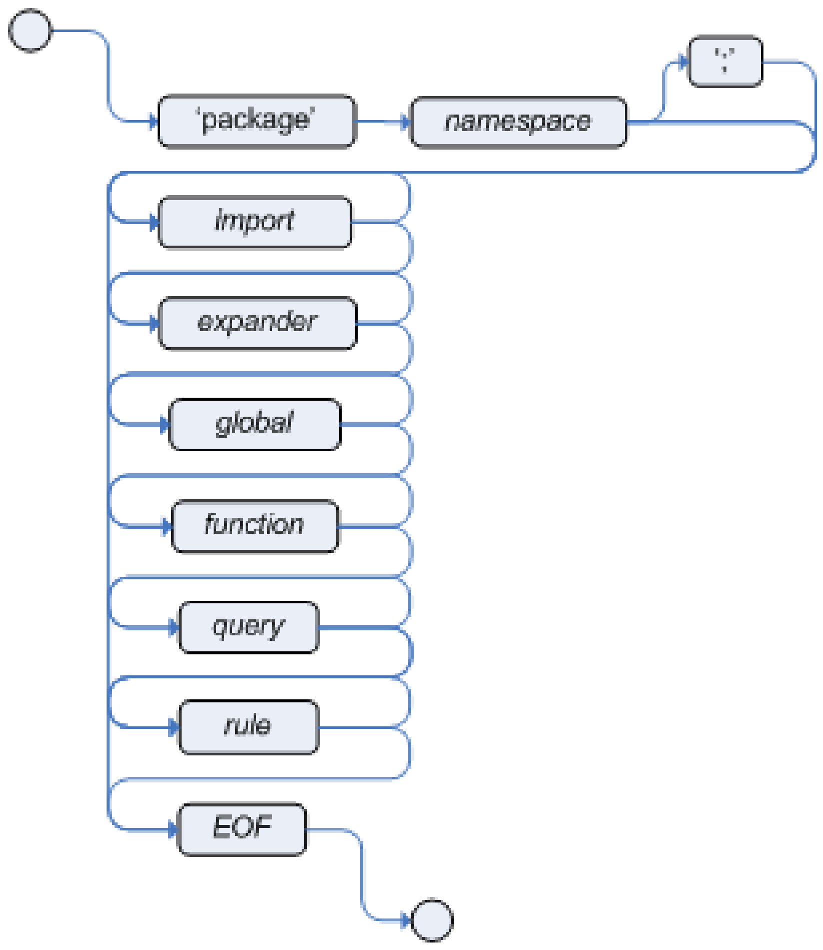


Figure 4.4. package

Note

Notice that any rule atttribute (as described the section Rule Attributes) may also be written at package level, superseding the attribute's default value. The modified default may still be replaced by an attribute setting within a rule.

4.5.1. import

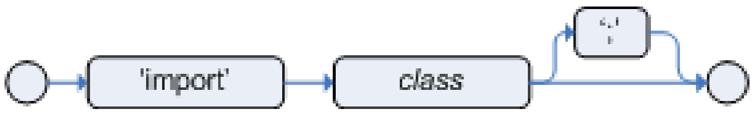


Figure 4.5. import

Import statements work like import statements in Java. You need to specify the fully qualified paths and type names for any objects you want to use in the rules. JBoss Rules automatically imports classes from the Java package of the same name, and also from the package `java.lang`.

4.5.2. global

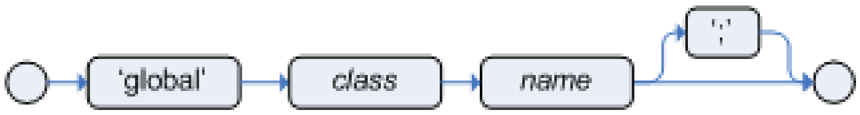


Figure 4.6. global

With global you define global variables. They are used to make application objects available to the rules. Typically, they are used to provide data or services that the rules use, especially application services used in rule consequences, and to return data from the rules, like logs or values added in rule consequences, or for the rules to interact with the application, doing callbacks. Globals are not inserted into the Working Memory, and therefore a global should never be used to establish conditions in rules except when it has a constant immutable value. The engine cannot be notified about value changes of globals and does not track their changes. Incorrect use of globals in constraints may yield surprising results - surprising in a bad way.

If multiple packages declare globals with the same identifier they must be of the same type and all of them will reference the same global value.

In order to use globals you must:

1. Declare your global variable in your rules file and use it in rules. Example:

```
global java.util.List myGlobalList;

rule "Using a global"
when
    eval( true )
then
    myGlobalList.add( "Hello World" );
end
```

2. Set the global value on your working memory. It is a best practice to set all global values before asserting any fact to the working memory. Example:

```
List list = new ArrayList();
WorkingMemory wm = rulebase.newStatefulSession();
wm.setGlobal( "myGlobalList", list );
```

Note that these are just named instances of objects that you pass in from your application to the working memory. This means you can pass in any object you want: you could pass in a service locator, or perhaps a service itself. With the new from element it is now common to pass a Hibernate session as a global, to allow from to pull data from a named Hibernate query.

One example may be an instance of a Email service. In your integration code that is calling the rule engine, you obtain your emailService object, and then set it in the working memory. In the DRL, you declare that you have a global of type EmailService, and give it the name "email". Then in your rule consequences, you can use things like email.sendSMS(number, message).

Globals are not designed to share data between rules and they should never be used for that purpose. Rules always reason and react to the working memory state, so if you want to pass data from rule to rule, assert the data as facts into the working memory.

It is strongly discouraged to set or change a global value from inside your rules. We recommend to you always set the value from your application using the working memory interface.

4.6. Function

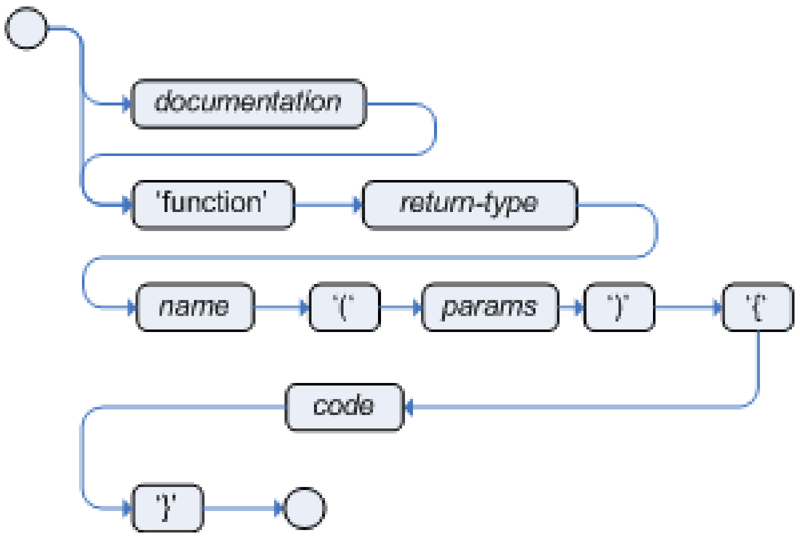


Figure 4.7. function

Functions are a way to put semantic code in your rule source file, as opposed to in normal Java classes. They can't do anything more then what you can do with helper classes (in fact, the compiler generates the helper class for you behind the scenes). The main advantage of using functions in a rule is that you can keep the logic all in one place, and you can change the functions as needed (this can be a good and bad thing). Functions are most useful for invoking actions on the consequence ("then") part of a rule, especially if that particular action is used over and over (perhaps with only differing parameters for each rule - for example the contents of an email message).

A typical function declaration looks like:

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

Note that the "function" keyword is used, even though its not really part of Java. Parameters to the function are just like a normal method (and you don't have to have parameters if they are not needed). Return type is just like a normal method.

An alternative to the use of a function, could be to use a static method in a helper class: Foo.hello(). JBoss Rules supports the use of function imports, so all you would need to do is:

```
import function my.package.Foo.hello
```

In both cases above, to use the function, just call it by its name in the consequence or inside a semantic code block. Example:

```
rule "using a static function"
```

```
when
    eval( true )
then
    System.out.println( hello( "Bob" ) );
end
```

4.7. Type Declaration

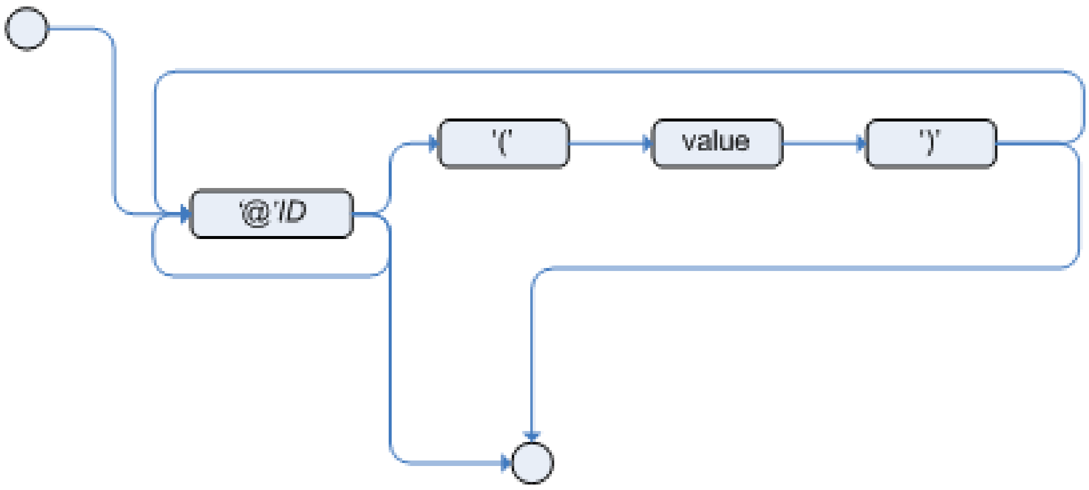


Figure 4.8. meta_data

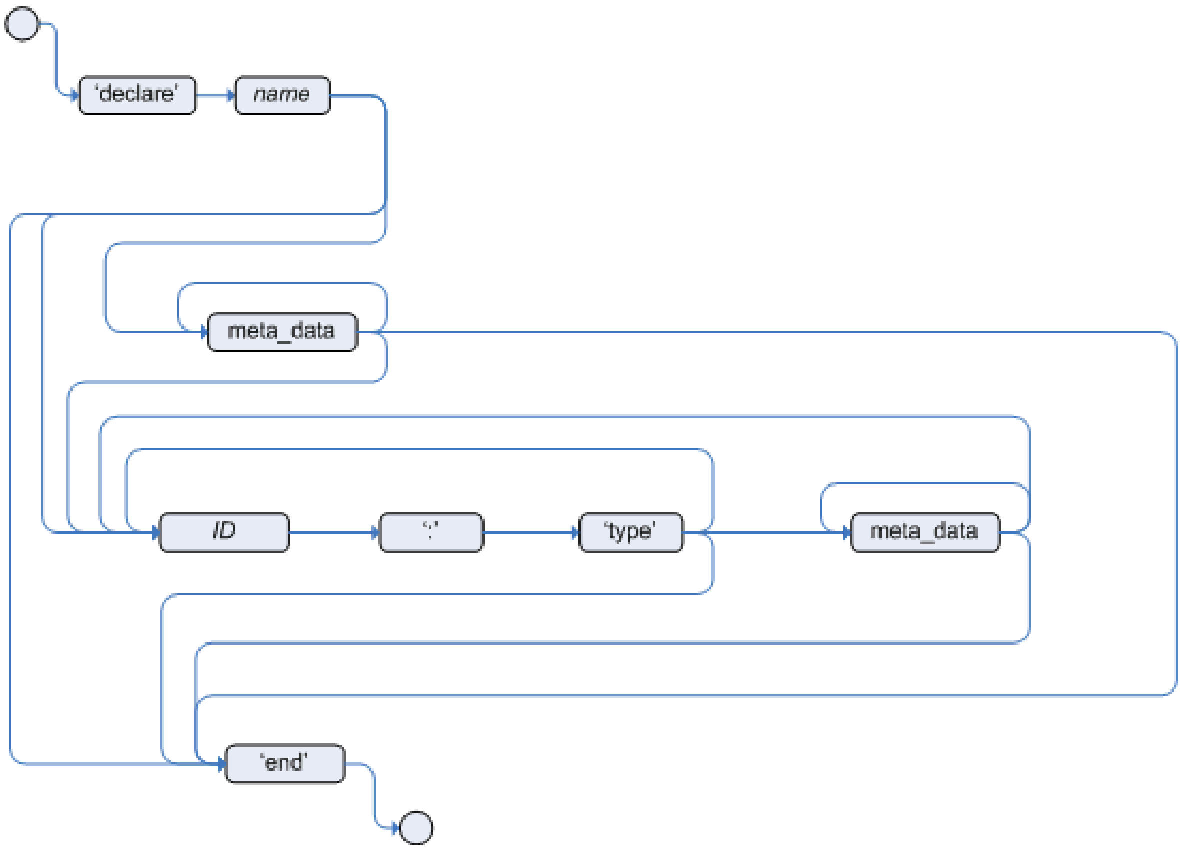


Figure 4.9. type_declaration

Type declarations have two main goals in the rules engine: to allow the declaration of new types, and to allow the declaration of metadata for types.

- **Declaring new types:** JBoss Rules works out of the box with plain POJOs as facts. Although, sometimes the users may want to define the model directly to the rules engine, without worrying to create their models in a lower level language like Java. At other times, there is a domain model already built, but eventually the user wants or needs to complement this model with additional entities that are used mainly during the reasoning process.
- **Declaring metadata:** facts may have meta information associated to them. Examples of meta information include any kind of data that is not represented by the fact attributes and are consistent among all instances of that fact type. This meta information may be queried at runtime by the engine and used in the reasoning process.

4.7.1. Declaring New Types

To declare a new type, all you need to do is use the keyword **declare**, followed by the list of fields and the keyword **end**.

```
declare Address
   number : int
   streetName : String
   city : String
end
```

Example 4.2. declaring a new fact type: Address

The previous example declares a new fact type called *Address*. This fact type will have 3 attributes: *number*, *streetName* and *city*. Each attribute has a type that can be any valid Java type, including any other class created by the user or even other fact types previously declared.

For instance, we may want to declare another fact type *Person*:

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

Example 4.3. declaring a new fact type: Person

As we can see on the previous example, *dateOfBirth* is of type `java.util.Date`, from the Java API, while *address* is of the previously defined fact type Address.

You may avoid having to write the fully qualified name of a class every time you write it by using the **import** clause, previously discussed.

```
import java.util.Date

declare Person
    name : String
    dateOfBirth : Date
    address : Address
end
```

Example 4.4. avoiding the need to use fully qualified class names by using import

When you declare a new fact type, JBoss Rules will, at compile time, generate bytecode implementing a POJO that represents the fact type. The generated Java class will be a one-to-one Java Bean mapping of the type definition. So, for the previous example, the generated Java class would be:

```
public class Person implements Serializable {
    private String name;
    private java.util.Date dateOfBirth;
    private Address address;

    // getters and setters
    // equals/hashCode
    // toString
}
```

Example 4.5. generated Java class for the previous Person fact type declaration

Since it is a simple POJO, the generated class can be used transparently in the rules, like any other fact.

```
rule "Using a declared Type"
when
    $p : Person( name == "Bob" )
then
    System.out.println( "The name of the person is "+ )
    // lets insert Mark, that is Bob's mate
    Person mark = new Person();
    mark.setName("Mark");
    insert( mark );
end
```

Example 4.6. using the declared types in rules

4.7.2. Declaring Metadata

Metadata may be assigned to several different constructions in JBoss Rules, like fact types, fact attributes and rules. JBoss Rules uses the @ symbol to introduce metadata, and it always uses the form:

```
@matadata_key( metadata_value )
```

The parenthesis and the metadata_value are optional.

For instance, if you want to declare a metadata attribute like *author*, whose value is *Bob*, you could simply write:

```
@author( Bob )
```

Example 4.7. declaring an arbitrary metadata attribute

JBoss Rules allows the declaration of any arbitrary metadata attribute, but some will have special meaning to the engine, while others are simply available for querying at runtime. JBoss Rules allows the declaration of metadata both for fact types and for fact attributes. Any metadata that is declared before the fields of a fact type are assigned to the fact type, while metadata declared after an attribute are assigned to the attribute in particular.

```
import java.util.Date

declare Person
    @author( Bob )
    @dateOfCreation( 01-Feb-2009 )

    name : String @key @maxLength( 30 )
    dateOfBirth : Date
    address : Address
end
```

Example 4.8. declaring metadata attributes for fact types and attributes

In the previous example, there are two metadata declared for the fact type (*@author* and *@dateOfCreation*), and two more defined for the name attribute (*@key* and *@maxLength*). Please note that the *@key* metadata has no value, and so the parenthesis and the value were omitted.

4.7.3. Declaring Metadata for Existing Types

JBoss Rules allows the declaration of metadata attributes for existing types in the same way as when declaring metadata attributes for new fact types. The only difference is that there are no fields in that declaration.

For instance, if there is a class org.drools.examples.Person, and one wants to declare metadata for it, just write the following code:

```
import org.drools.examples.Person

declare Person
    @author( Bob )
    @dateOfCreation( 01-Feb-2009 )
end
```

Example 4.9. declaring metadata for an existing type

Instead of using the import, it is also possible to reference the class by its fully qualified name, but since the class will also be referenced in the rules, usually it is shorter to add the import and use the short class name everywhere.

```
declare org.drools.examples.Person
    @author( Bob )
    @dateOfCreation( 01-Feb-2009 )
end
```

Example 4.10. declaring metadata using the fully qualified class name

4.7.4. Accessing Declared Types from the Application Code

Declared types are usually used inside rules files, while Java models are used when sharing the model between rules and applications. Although, sometimes, the application may need to access and handle facts from the declared types, specially when the application is wrapping the rules engine and providing higher level, domain specific, user interfaces for rules management.

In such cases, the generated classes can be handled as usual with the Java Reflection APIs, but as we know, that usually requires a lot of work for small results. This way, JBoss Rules provides a simplified API for the most common fact handling the application may want to do.

The first important thing to realize is that a declared fact will belong to the package where it was declared. So, for instance, in the example below, *Person* will belong to the *org.drools.examples* package, and so the generated class fully qualified name will be: *org.drools.examples.Person*.

```
package org.drools.examples

import java.util.Date

declare Person
    name : String
    dateOfBirth : Date
    address : Address
end
```

Example 4.11. declaring a type in the org.drools.examples package

Declared types, as discussed previously, are generated at knowledge base compilation time, i.e., the application will only have access to them at application run time. As so, these classes are not available for direct reference from the application.

JBoss Rules then provides an interface through which the users can handle declared types from the application code: org.drools.definition.type.FactType. Through this interface, the user can instantiate, read and write fields in the declared fact types.

```
// get a reference to a knowledge base with a declared type:
KnowledgeBase kbase = ...

// get the declared FactType
FactType personType = kbase.getFactType( "org.drools.examples",
                                         "Person" );

// handle the type as necessary:
// create instances:
Object bob = personType.newInstance();

// set attributes values
personType.set( bob,
                "name",
                "Bob" );
personType.set( bob,
                "age",
                42 );

// insert fact into a session
StatefulKnowledgeSession ksession = ...
ksession.insert( bob );
ksession.fireAllRules();

// read attributes
String name = personType.get( bob, "name" );
int age = personType.get( bob, "age" );
```

Example 4.12. handling declared fact types through the API

The API also includes other helpful methods, like setting all the attributes at once, reading values from a Map, or read all attributes at once, populating a Map.

Although the API is similar to Java reflection it does not use reflection. It instead relies on much faster bytecode generated accessors.

4.8. Rule

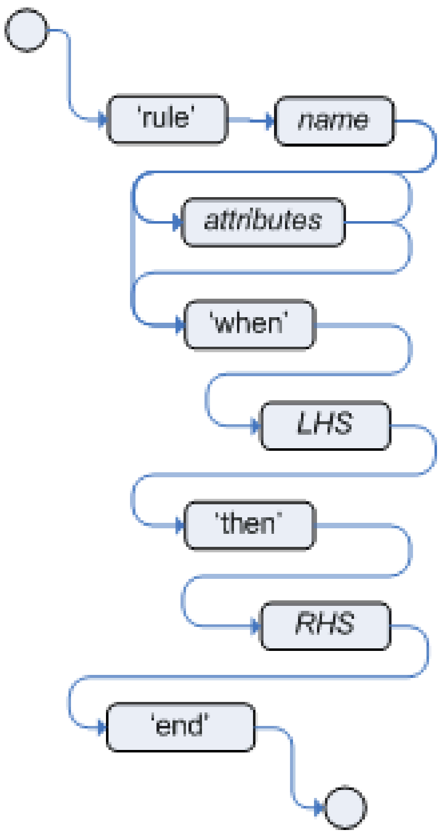


Figure 4.10. rule

A rule specifies that *when* a particular set of conditions occur, specified in the Left Hand Side (LHS), *then* do what is specified as a list of actions in the Right Hand Side (RHS). A common question from users is "Why use when instead of if?" "When" was chosen over "if" because "if" is normally part of a procedural execution flow, where, at a specific point in time, a condition is to be checked. In contrast, "when" indicates that the condition evaluation is not tied to a specific evaluation sequence or point in time, but that it happens continually, at any time during the life time of the engine; whenever the condition is met, the actions are executed.

A rule must have a name, unique within its rule package. If you define a rule twice in the same DRL it produces an error while loading. If you add a DRL that includes a rule name already in the package, it replaces the previous rule. If a rule name is to have spaces, then it will need to be enclosd in double quotes (it is best to always use double quotes).

Attributes are optional. They are best written one per line.

The LHS of the rule follows the when keyword (ideally on a new line), similarly the RHS follows the then keyword (again, ideally on a newline). The rule is terminated by the keyword end. Rules cannot be nested.

```
rule "<name>"
    <attribute>*
when
    <conditional element>*
then
    <action>*
end
```

Example 4.13. Rule Syntax Overview

```

rule "Approve if not rejected"
    salience -100
    agenda-group "approval"
when
    not Rejection()
    p : Policy(approved == false, policyState:status)
    exists Driver(age > 25)
    Process(status == policyState)
then
    log("APPROVED: due to no objections.");
    p.setApproved(true);
end
```

Example 4.14. A simple rule

4.8.1. Rule Attributes

Rule attributes provide a declarative way to influence the behavior of the rule. Some are quite simple, while others are part of complex subsystems such as Ruleflow. To get the most from JBoss Rules you should make sure you have a proper understanding of each attribute.

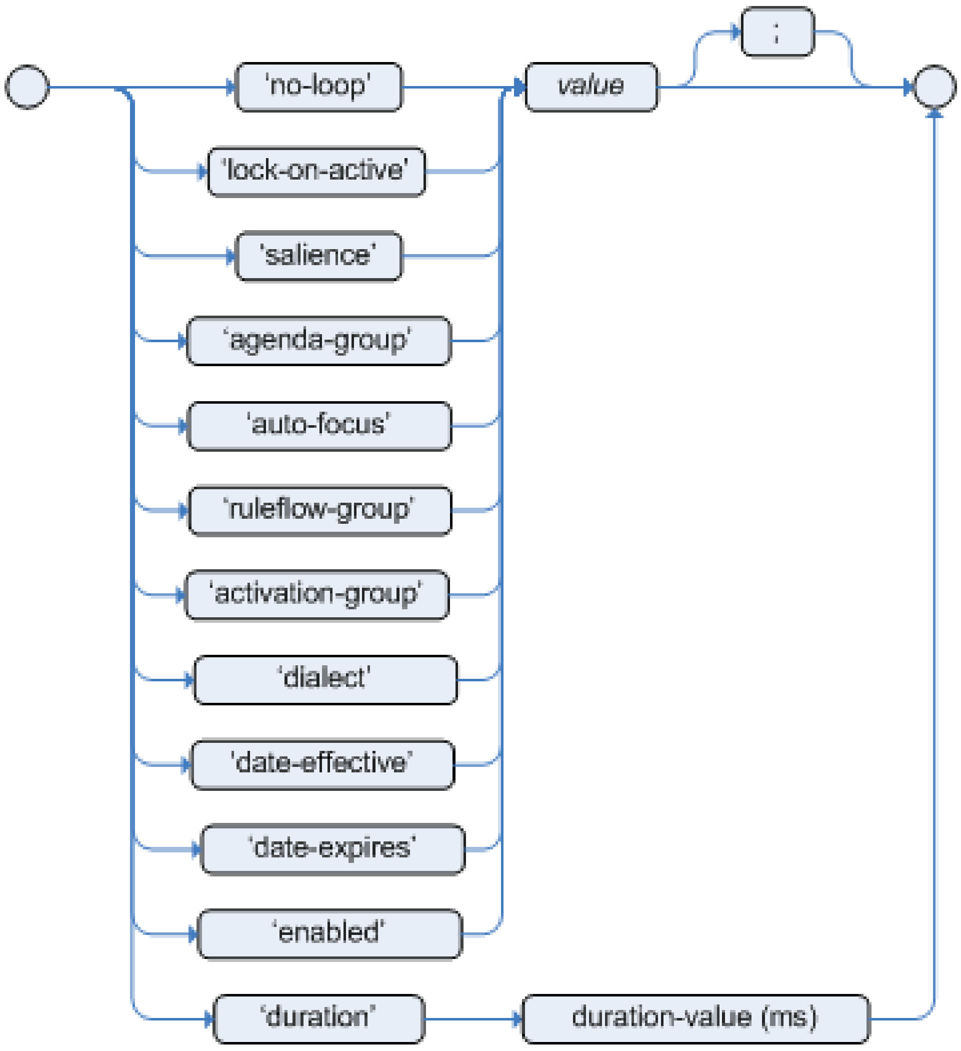


Figure 4.11. rule attributes

no-loop

default value: false

type: Boolean

When the rule's consequence modifies a fact it may cause the Rule to activate again, causing recursion. Setting no-loop to true means the attempt to create the Activation for the current set of data will be ignored.

ruleflow-group

default value: N/A

type: String

Ruleflow is a JBoss Rules feature that lets you exercise control over the firing of rules. Rules that are assembled by the same ruleflow-group identifier fire only when their group is active.

lock-on-active

default value: false

type: Boolean

Whenever a ruleflow-group becomes active or an agenda-group receives the focus, any rule within that group that has lock-on-active set to true will not be activated any more; irrespective of the origin of the update, the activation of a matching rule is discarded. This is a stronger version of no-loop, because the change could now be caused not only by the rule itself. It's ideal for calculation rules where you have a number of rules that modify a fact and you don't want any rule re-matching and firing again. Only when the ruleflow-group is no longer active or the agenda-group loses the focus those rules with lock-on-active set to true become eligible again for their activations to be placed onto the agenda.

salience

default value : 0

type : integer

Each rule has a salience attribute that can be assigned an integer number, which defaults to zero and can be negative or positive. Salience is a form of priority where rules with higher salience values are given higher priority when ordered in the Activation queue.

agenda-group

default value: MAIN

type: String

Agenda groups allow the user to partition the Agenda providing more execution control. Only rules in the agenda group that has acquired the focus are allowed to fire.

auto-focus

default value: false

type: Boolean

When a rule is activated where the `auto-focus` value is true and the rule's agenda group does not have focus yet, then it is given focus, allowing the rule to potentially fire.

activation-group

default value: N/A

type: String

Rules that belong to the same activation-group, identified by this attribute's string value, will only fire exclusively. In other words, the first rule in an activation-group to fire will cancel the other rules' activations, i.e., stop them from firing.

Note

This used to be called Xor group, but technically it's not quite an Xor. You may still hear people mention Xor group; just swap that term in your mind with activation-group.

dialect

default value : as specified by the package

type : String

possible values: "java" or "mvel"

The dialect species the language to be used for any code expressions in the LHS or the RHS code block. Currently two dialects are available, Java and MVEL. While the dialect can be specified at the package level, this attribute allows the package definition to be overridden for a rule.

date-effective
: default value: N/A

  type: String, containing a date and time definition

  A rule can only activate if the current date and time is after date-effective attribute.

date-expires
: default value: N/A

  type: String, containing a date and time definition

  A rule cannot activate if the current date and time is after the date-expires attribute.

duration
: default value: no default value

  type: long

  The duration dictates that the rule will fire after a specified duration, if it is still true.

```
rule "my rule"
salience 42
agenda-group "number 1"
when ...
```

Example 4.15. Some attribute examples

4.8.2. Left Hand Side (when) Conditional Elements

The Left Hand Side (LHS) is a common name for the conditional part of the rule. It consists of zero or more Conditional Elements. If the LHS is left empty, it is re-written as `eval(true)`, which means that the rule's condition is always true. It will be activated, once, when a new Working Memory session is created.

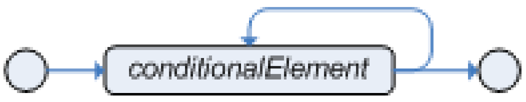


Figure 4.12. Left Hand Side

```
rule "no CEs"
when
then
        <action>*
end
```

Is internally re-written as:

```
rule "no CEs"
when
    eval( true )
then
    <action>*
end
```

Example 4.16. Rule without a Conditional Element

Conditional elements work on one or more *patterns* (which are described below). The most common one is `and`, which is implicit when you have multiple patterns in the LHS of a rule that are not connected in any way. Note that an `and` cannot have a leading declaration binding like `or`. This is obvious, since a declaration can only reference a single fact, and when the `and` is satisfied it matches more than one fact - so which fact would the declaration bind to?

4.8.2.1. Pattern

The pattern element is the most important Conditional Element. The entity relationship diagram below provides an overview of the various parts that make up the pattern's constraints and how they work together; each is then covered in more detail with railroad diagrams and examples.

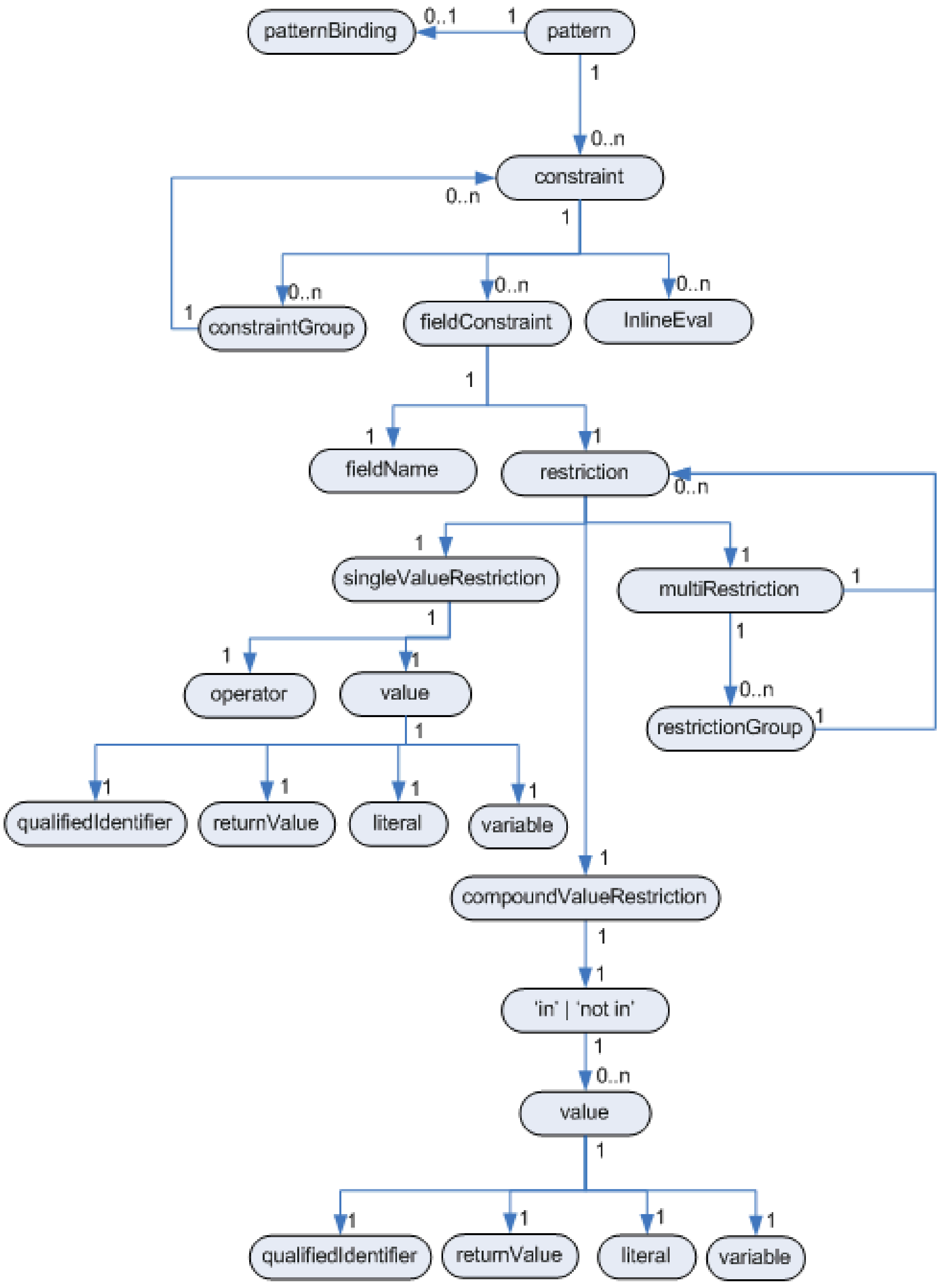


Figure 4.13. Pattern Entity Relationship Diagram

At the top of the ER diagram you can see that the pattern consists of zero or more constraints and has an optional pattern binding. The railroad diagram below shows the syntax for this.

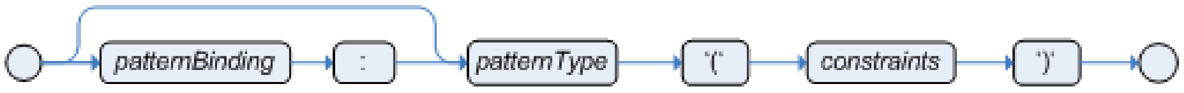


Figure 4.14. Pattern

In its simplest form with no constraints, a pattern matches against a fact of the given type. In the following case the type is `Cheese`, which means that the pattern will match against all `Cheese` objects in the Working Memory.

Notice that the type need not be the actual class of some fact object. Patterns may refer to superclasses or even interfaces, thereby potentially matching facts from many different classes.

```
Cheese( )
```

Example 4.17. Simple Pattern

For referring to the matched object, use a pattern binding variable such as `$c`. The prefixed dollar symbol ('$') is optional and can be useful in complex rules where it helps to more easily differentiate between variables and fields.

```
$c : Cheese( )
```

Example 4.18. Pattern with a binding variable

Inside of the pattern parenthesis is where all the action happens. A constraint can be either a Field Constraint, Inline Eval, or a Constraint Group. Constraints can be separated by the following symbols: ',', '&&' or '||'.

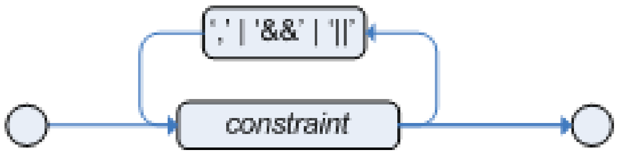


Figure 4.15. Constraints

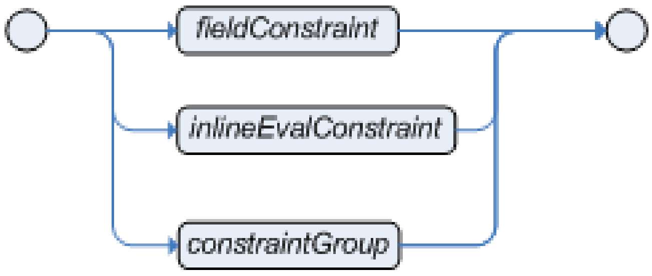


Figure 4.16. Constraint

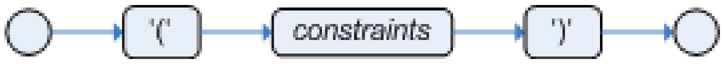


Figure 4.17. constraintGroup

The comma character (',') is used to separate constraint groups. It has implicit and connective semantics.

```
# Cheese type is stilton and price < 10 and age is mature.
Cheese( type == "stilton", price < 10, age == "mature" )
```

Example 4.19. Constraint Group connective ','

The above example has three constraint groups, each with a single constraint:

1. The type is stilton, `type == "stilton"`
2. The price is less than 10, `price < 10`
3. The age is mature, `age == "mature"`

The '&&' (and) and '||' (or) constraint connectives allow constraint groups to have multiple constraints. Example:

```
// Cheese type is "stilton" and price < 10, and age is mature
Cheese( type == "stilton" && price < 10, age == "mature" )
// Cheese type is "stilton" or price < 10, and age is mature
Cheese( type == "stilton" || price < 10, age == "mature" )
```

Example 4.20. && and || Constraint Connectives

The above example has two constraint groups. The first has two constraints and the second has one constraint.

The connectives are evaluated in the following order, from first to last:

1. &&
2. ||
3. ,

It is possible to change the evaluation priority by using parenthesis, as in any logic or mathematical expression. Example:

```
# Cheese type is stilton and ( price is less than 20 or age is mature ).
Cheese( type == "stilton" && ( price < 20 || age == "mature" ) )
```

Example 4.21. Using parenthesis to change evaluation priority

In the above example, the use of parenthesis makes the || connective be evaluated before the && connective.

Also, it is important to note that besides having the same semantics, the connectives '&&' and ',' are resolved with different priorities, and ',' cannot be embedded in a composite constraint expression.

```
// invalid as ',' cannot be embedded in an expression:
Cheese( ( type == "stilton", price < 10 ) || age == "mature" )
// valid as '&&' can be embedded in an expression:
Cheese( ( type == "stilton" && price < 10 ) || age == "mature")
```

Example 4.22. Not Equivalent connectives

4.8.2.1.1. Field Constraints

A Field constraint specifies a restriction to be used on a named field; the field name can have an optional variable binding.

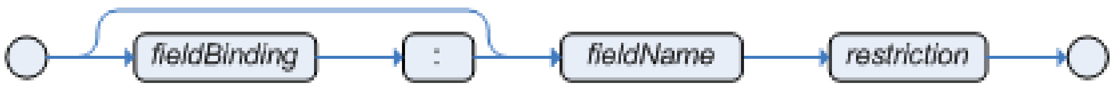


Figure 4.18. fieldConstraint

There are three types of restrictions: Single Value Restriction, Compound Value Restriction, and Multi Restriction.

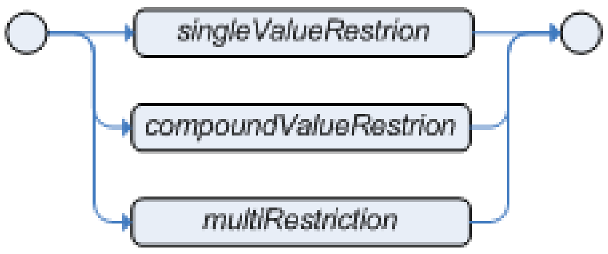


Figure 4.19. restriction

4.8.2.1.2. JavaBeans as facts

A field is derived from an accessible method of the object. If your model objects follow the Java Bean pattern, then fields are exposed using "getXXX" or "isXXX" methods, where these methods take no arguments, and return something. Within patterns, fields can be accessed using the bean naming convention, so that "getType" would be accessed as "type". JBoss Rules uses the standard JDK Introspector class to do this mapping.

For example, referring to our Cheese class, the pattern `Cheese(type == "brie")` applies the getType() method to a Cheese instance. If a field name cannot be found, the compiler will resort to using the name as a method without arguments. Thus, the method `toString()` is called due to a constraint `Cheese(toString == "cheddar")`. In this case, you use the full name of the method with correct capitalization, but still without parentheses. Do please make sure that you are accessing methods that take no parameters, and that are in fact *accessors* which don't change the state of the object in a way that may effect the rules. Remember that the rule engine effectively caches the results of its matching in between invocations to make it faster.

4.8.2.1.3. Values

The field constraints can take a number of values; including literal, qualifiedIdentifier (enum), variable and returnValue.

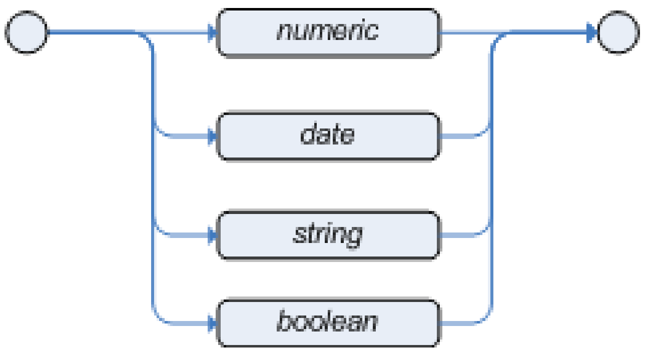


Figure 4.20. literal

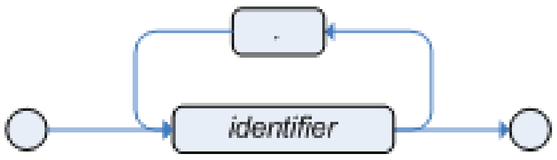


Figure 4.21. qualifiedIdentifier

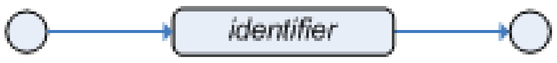


Figure 4.22. variable

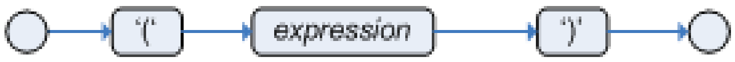


Figure 4.23. returnValue

You can do checks against fields that are or may be null, using '==' and '!=' as you would expect, and the literal `null` keyword, as in `Cheese(type != null)`, where the evaluator will not throw an exception and return true if the value is null. Type coercion is always attempted if the field and the value are of different types; exceptions will be thrown if a bad coercion is attempted. For instance, if "ten" is provided as a string in a numeric evaluator, an exception is thrown, whereas "10" would coerce to a numeric 10. Coercion is always in favor of the field type and not the value type.

4.8.2.1.4. Single Value Restriction

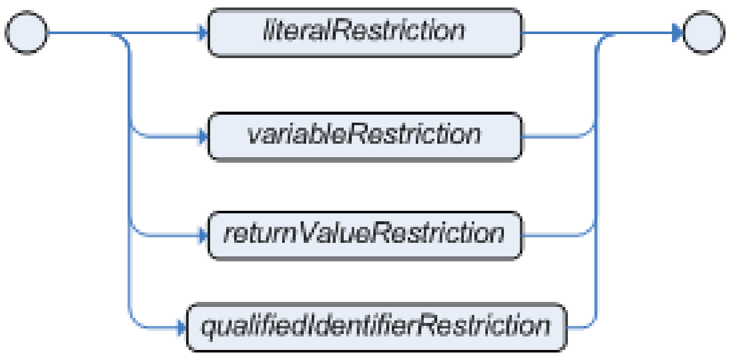


Figure 4.24. singleValueRestriction

4.8.2.1.5. Operators

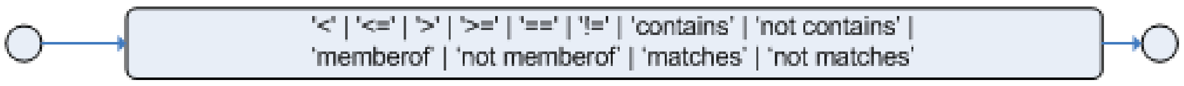

'<' | '<=' | '>' | '>=' | '==' | '!=' | 'contains' | 'not contains' |
'memberof' | 'not memberof' | 'matches' | 'not matches'

Figure 4.25. Operators

The operators '==' and '!=' are valid for all types. Other relational operatory may be used whenever the type values are ordered; for date fields, '<' means "before". The pair `matches` and `not matches` is only applicable to string fields, `contains` and `not contains` require the field to be of some Collection type. Coercion to the correct value for the evaluator and the field will be attempted, as mentioned in the "Values" section.

The Operator `matches`

Matches a field against any valid Java Regular Expression. Typically that regexp is a string literal, but variables that resolve to a valid regexp are also allowed. It is important to note that, *different from Java*, within regular expressions written as string literals *you don't need to escape* '\'.

```
Cheese( type matches "(Buffalo)?\S*Mozarella" )
```

Example 4.23. Regular Expression Constraint

The Operator `not matches`

The operator returns true if the string does not match the regular expression. The same rules apply as for the `matches` operator. Example:

```
Cheese( type not matches "(Buffulo)?\S*Mozerella" )
```

Example 4.24. Regular Expression Constraint

The Operator `contains`

The operator `contains` is used to check whether a field that is a Collection or array contains the specified value.

```
CheeseCounter( cheeses contains "stilton" ) // contains with a String
 literal
CheeseCounter( cheeses contains $var ) // contains with a variable
```

Example 4.25. Contains with Collections

The Operator `not contains`

The operator `not contains` is used to check whether a field that is a Collection or array does *not* contain the specified value.

```
CheeseCounter( cheeses not contains "cheddar" ) // not contains with a
 String literal
CheeseCounter( cheeses not contains $var ) // not contains with a
 variable
```

Example 4.26. Literal Constraint with Collections

Note

For backward compatibility, the `excludes` operator is supported as a synonym for `not contains`.

The Operator `memberOf`

The operator `memberOf` is used to check whether a field is a member of a collection or array; that collection must be a variable.

```
CheeseCounter( cheese memberOf $matureCheeses )
```

Example 4.27. Literal Constraint with Collections

The Operator `not memberOf`

The operator `not memberOf` is used to check whether a field is not a member of a collection or array; that collection must be a variable.

```
CheeseCounter( cheese not memberOf $matureCheeses )
```

Example 4.28. Literal Constraint with Collections

The Operator `soundslike`

This operator is similar to `matches`, but it checks whether a word has almost the same sound (using English pronounciation) as the given value. This is based on the Soundex algorithm described at *http://en.wikipedia.org/wiki/Soundex*.

```
// match cheese "fubar" or "foobar"
Cheese( name soundslike 'foobar' )
```

Example 4.29. Test with soundslike

4.8.2.1.6. Literal Restrictions

Literal restrictions are the simplest form of restrictions and evaluate a field against a specified literal, which may be numeric or a date, a string or a boolean.

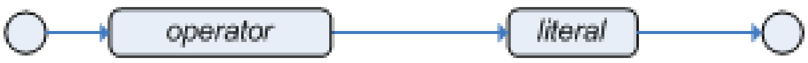


Figure 4.26. literalRestriction

Literal Restrictions using the operator '==' provide for faster execution as we can index using hashing to improve performance.

Numeric

All standard Java numeric primitives are supported.

```
Cheese( quantity == 5 )
```

Example 4.30. Numeric Literal Restriction

Date
: The date format "dd-mmm-yyyy" is supported by default. You can customize this by providing an alternative date format mask as the System property named `drools.dateformat`. If more control is required, use the inline-eval constraint.

```
Cheese( bestBefore < "27-Oct-2007" )
```

Example 4.31. Date Literal Restriction

String
: Any valid Java String is allowed.

```
Cheese( type == "stilton" )
```

Example 4.32. String Literal Restriction

Boolean
: Only `true` or `false` can be used; 0 and 1 are not acceptable. A boolean field alone (as in `Cheese( smelly )` is not permitted; you must compare this to a boolean literal.

```
Cheese( smelly == true )
```

Example 4.33. Boolean Literal Restriction

Qualified Identifier
: Enums can be used as well, both JDK 1.4 and 5 style enums are supported. For the latter you must be executing on a JDK 5 environment.

```
Cheese( smelly == SomeClass.TRUE )
```

Example 4.34. Boolean Literal Restriction

4.8.2.1.7. Bound Variable Restriction

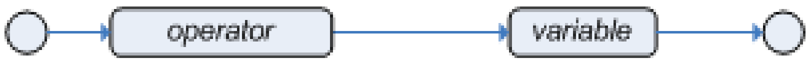


Figure 4.27. variableRestriction

Variables can be bound to facts and their fields and then used in subsequent Field Constraints. A bound variable is called a Declaration. Valid operators are determined by the type of the field being constrained; coercion will be attempted where possible. Bound Variable Restrictions using the operator '==' provide for very fast execution as we can use hashing to improve performance.

```
Person( likes : favouriteCheese )
Cheese( type == likes )
```

Example 4.35. Bound Field using the operator '=='

Here, `likes` is the variable that is bound in its declaration to the field `favouriteCheese` of any matching Person instance. It is then used to constrain the type of Cheese in the following pattern. Any valid Java variable name can be used, and it may be prefixed with a '$', which you will often see used to help differentiate declarations from fields. The example below shows a declaration for `$stilton`, bound to the object matching the first pattern and used with a `contains` operator. - Note the optional use of '$'.

```
$stilton : Cheese( type == "stilton" )
Cheesery( cheeses contains $stilton )
```

Example 4.36. Bound Fact using 'contains' operator

4.8.2.1.8. Return Value Restriction

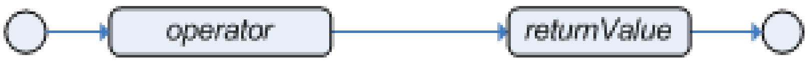


Figure 4.28. returnValueRestriction

A Return Value restriction is a parenthesized expression composed from literals, any valid Java primitive or object, previously bound variables, function calls, and operators. Functions used in a Return Value must return results that do not depend on time.

```
Person( girlAge : age, sex == "F" )
Person( age == ( girlAge + 2) ), sex == 'M' )
```

Example 4.37. Return Value Restriction

4.8.2.1.9. Compound Value Restriction

The compound value restriction is used where there is more than one possible value to match. Currently only the `in` and `not in` evaluators support this. The second operand of this operator must be a comma-separated list of values, enclosed in parentheses. Values may be given as variables, literals, return values or qualified identifiers. Both evaluators are actually "syntactic sugar", internally rewritten as a list of multiple restrictions using the operators '!=' and '=='.

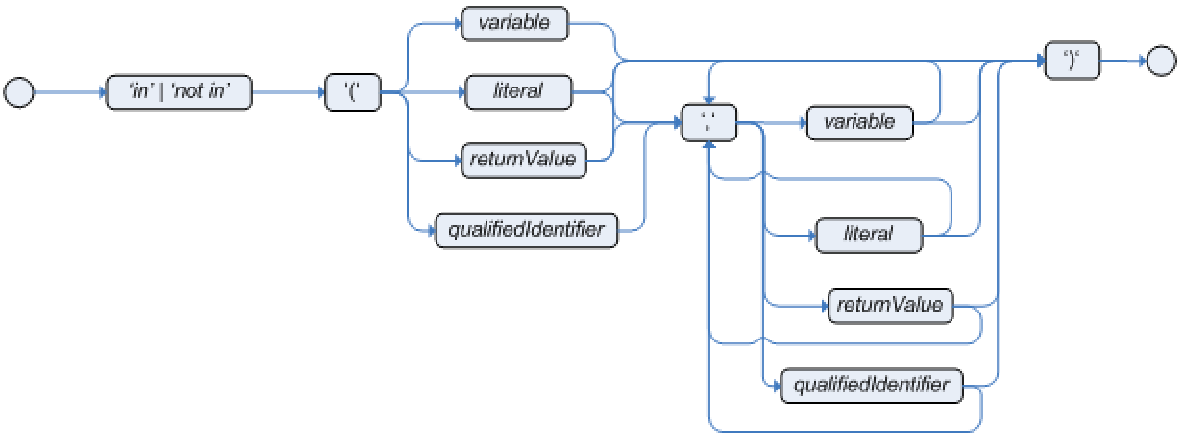


Figure 4.29. compoundValueRestriction

```
Person( $cheese : favouriteCheese )
Cheese( type in ( "stilton", "cheddar", $cheese )
```

Example 4.38. Compound Restriction using "in"

4.8.2.1.10. Multi Restriction

Multi restriction allows you to place more than one restriction on a field using the restriction connectives '&&' or '||'. Grouping via parentheses is permitted, resulting in a recursive syntax pattern.

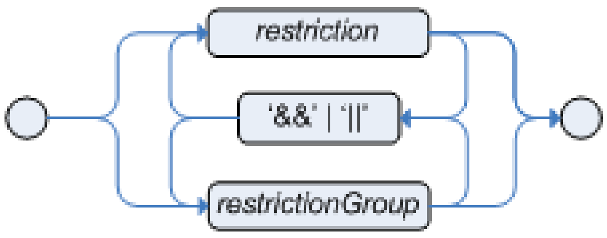


Figure 4.30. multiRestriction

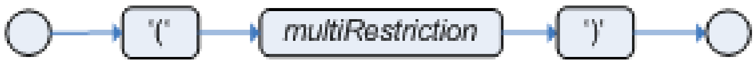


Figure 4.31. restrictionGroup

```
// Simple multi restriction using a single &&
Person( age > 30 && < 40 )
// Complex multi restriction using groupings of multi restrictions
Person( age ( (> 30 && < 40) ||
              (> 20 && < 25) ) )
// Mixing muti restrictions with constraint connectives
Person( age > 30 && < 40 || location == "london" )
```

Example 4.39. Multi Restriction

4.8.2.1.11. Inline Eval Constraints

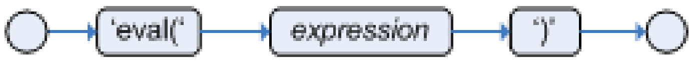


Figure 4.32. Inline Eval Expression

An inline eval constraint can use any valid dialect expression as long as it results to a primitive boolean. The expression must be constant over time. Any previously bound variable, from the current or previous pattern, can be used; auto-vivification is also used to auto-create field binding variables. When an identifier is found that is not a current variable, the builder looks to see if the identifier is a field on the current object type, if it is, the field binding is auto-created as a variable of the same name. This is called auto-vivification of field variables inside of inline evals.

This example will find all male-female pairs where the male is 2 years older than the female; the variable `age` is auto-created in the second pattern by the auto-vivification process.

```
Person( girlAge : age, sex = "F" )
Person( eval( age == girlAge + 2 ), sex = 'M' )
```

Example 4.40. Return Value operator

4.8.2.1.12. Nested Accessors

JBoss Rules permits *nested accessors* in in the field constraints using the MVEL accessor graph notation. Field constraints involving nested accessors are actually re-written as an MVEL dialect inline-eval. Care should be taken when using nested accessors as the Working Memory is not aware of any of the nested values, and does not know when they change; they should be considered immutable while any of their parent references are inserted into the Working Memory. If you wish to modify a nested value you should remove the parent objects first and re-assert afterwards. If you only have a single parent at the root of the graph, when in the MVEL dialect, you can use the `modify` construct and its block setters to write the nested accessor assignments while retracting and inserting the the root parent object as required. Nested accessors can be used on either side of the operator symbol.

```
// Find a pet older than its owners first-born child
$p : Person( )
Pet( owner == $p, age > $p.children[0].age )
```

This is internally rewriten as an MVEL inline eval:

```
// Find a pet older than its owners first-born child
$p : Person( )
Pet( owner == $p, eval( age > $p.children[0].age ) )
```

Example 4.41. Nested Accessors

Note

Nested accessors have a much greater performance cost than direct field accesses, so use them carefully.

4.8.2.2. Conditional Element and

The Conditional Element `and` is used to group other Conditional Elements into a logical conjunction. The root element of the LHS is an implicit prefix `and` and doesn't need to be specified. JBoss Rules supports both prefix `and` and infix `and`, but prefix is the preferred option as its implicit grouping avoids confusion.

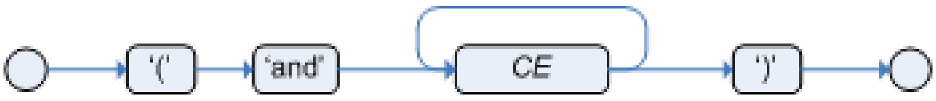


Figure 4.33. prefixAnd

```
(and Cheese( cheeseType : type )
Person( favouriteCheese == cheeseType ) )
```

Example 4.42. prefixAnd

```
when
Cheese( cheeseType : type )
Person( favouriteCheese == cheeseType )
```

Example 4.43. implicit root prefixAnd

Infix `and` is supported along with explicit grouping with parentheses, should it be needed. The symbol '&&', as an alternative to `and`, is deprecated although it is still supported in the syntax for legacy support reasons.

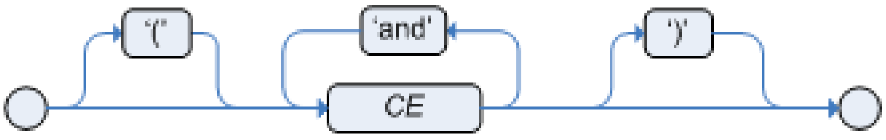


Figure 4.34. infixAnd

```
//infixAnd
Cheese( cheeseType : type ) and Person( favouriteCheese == cheeseType )
//infixAnd with grouping
( Cheese( cheeseType : type ) and
( Person( favouriteCheese == cheeseType ) or
Person( favouriteCheese == cheeseType ) )
```

Example 4.44. infixAnd

4.8.2.3. Conditional Element or

The Conditional Element `or` is used to group other Conditional Elements into a logical disjunction. JBoss Rules supports both prefix `or` and infix `or`, but prefix is the preferred option as its implicit grouping avoids confusion. The behavior of the Conditional Element `or` is different from the connective '||' for constraints and restrictions in field constraints. The engine actually has no understanding of the Conditional Element `or`; instead, via a number of different logic transformations, a rule with `or` is rewritten as a number of subrules. This process ultimately results in a rule that has a single `or` as the root node and one subrule for each of its CEs. Each subrule can activate and fire like any normal rule; there is no special behavior or interaction between these subrules. - This can be most confusing to new rule authors.

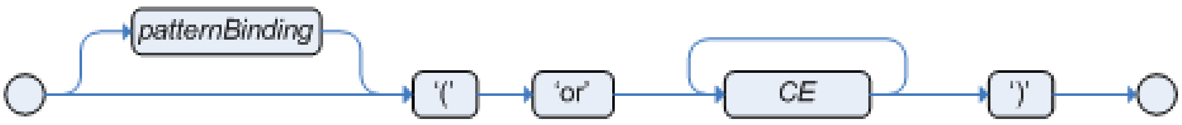


Figure 4.35. prefixOr

```
(or Person( sex == "f", age > 60 )
Person( sex == "m", age > 65 )
```

Example 4.45. prefixOr

Infix `or` is supported along with explicit grouping with parentheses, should it be needed. The symbol '||', as an alternative to `or`, is deprecated although it is still supported in the syntax for legacy support reasons.

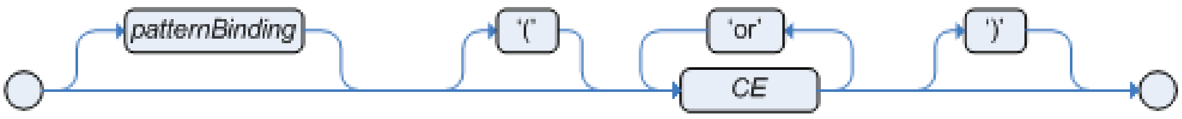


Figure 4.36. infixOr

```
//infixOr
Cheese( cheeseType : type ) or Person( favouriteCheese == cheeseType )
//infixOr with grouping
( Cheese( cheeseType : type ) or
( Person( favouriteCheese == cheeseType ) and
Person( favouriteCheese == cheeseType ) )
```

Example 4.46. infixOr

The Conditional Element `or` also allows for optional pattern binding. This means that each resulting subrule will bind its pattern to the pattern binding. Each pattern must be bound separately, using eponymous variables:

```
(or pensioner : Person( sex == "f", age > 60 )
pensioner : Person( sex == "m", age > 65 ) )
```

Example 4.47. or with binding

Since the conditional element `or` results in multiple subrule generation, one for each possible logically outcome, the example above would result in the internal generation of two rules. These two rules work independently within the Working Memory, which means both can match, activate and fire - there is no shortcutting.

The best way to think of the conditional element `or` is as a shortcut for generating two or more similar rules. When you think of it that way, it's clear that for a single rule there could be multiple activations if two or more terms of the disjunction are true.

4.8.2.4. Conditional Element `eval`

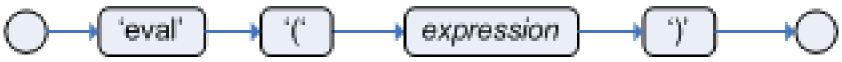


Figure 4.37. eval

The CE `eval` is essentially a catch-all which allows any semantic code (that returns a primitive boolean) to be executed. This code can refer to variables that were bound in the LHS of the rule, and functions in the rule package. Overuse of eval reduces the declarativeness of your rules and can result in a poorly performing engine. While `eval` can be used anywhere in the patterns, the best practice is to add it as the last conditional element in the LHS of a rule.

Evals cannot be indexed and thus are not as efficient as Field Constraints. However this makes them ideal for being used when functions return values that change over time, which is not allowed within Field Constraints.

```
p1 : Parameter()
p2 : Parameter()
eval( p1.getList().containsKey(p2.getItem()) )
// call function isValid in the LHS
eval( isValid(p1, p2) )
```

Example 4.48. eval

4.8.2.5. Conditional Element `not`

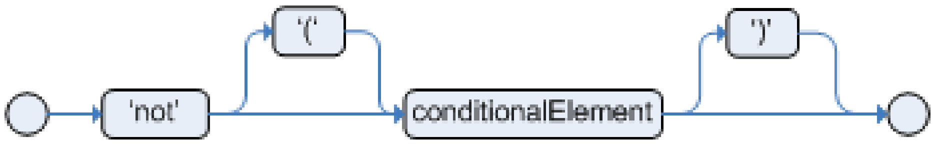


Figure 4.38. not

The CE `not` is first order logic's non-existential quantifier and checks for the non-existence of something in the Working Memory. Think of "not" as meaning "there must be none of".

The keyword `not` be followed by parentheses around the CEs that it applies to. In the simplest case of a single pattern (like below) you may optionally omit the parentheses.

```
not Bus()
```

Example 4.49. No Busses

```
// Brackets are optional:
not Bus(color == "red")

// Brackets are optional:
not ( Bus(color == "red", number == 42) )

// "not" with nested infix and - two patterns,
// brackets are requires:
not ( Bus(color == "red") and Bus(color == "blue") )
```

Example 4.50. No red Busses

4.8.2.6. Conditional Element `exists`

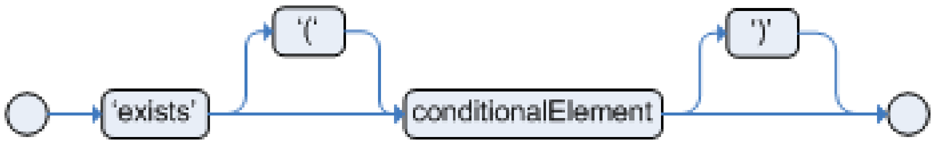


Figure 4.39. exists

The CE `exists` is first order logic's existential quantifier and checks for the existence of something in the Working Memory. Think of "exists" as meaning "there is at least one". It is different from just having the pattern on its own, which is more like saying "for each one of". If you use `exists` with a pattern, the rule will only activate at most once, regardless of how much data there is in working memory that matches the condition inside of the `exists` pattern. Since only the existence matters, no bindings will be established.

The keyword `exists` must be followed by parentheses around the CEs that it applies to. In the simplest case of a single pattern, like below, you may optionally omit the parentheses.

```
exists Bus()
```

Example 4.51. At least one Bus

```
exists Bus(color == "red")
// brackets are optional:
exists ( Bus(color == "red", number == 42) )
// "exists" with nested infix and,
// brackets are required:
exists ( Bus(color == "red") and
Bus(color == "blue") )
```

Example 4.52. At least one red Bus

4.8.2.7. Conditional Element `forall`

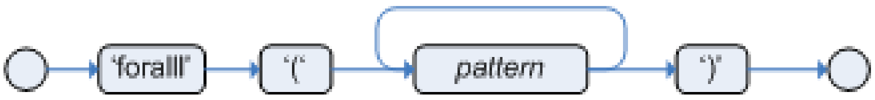


Figure 4.40. forall

The Conditional Element `forall` completes the First Order Logic support in JBoss Rules. The Conditional Element `forall` evaluates to true when all facts that match the first pattern match all the remaining patterns. Example:

```
rule "All English buses are red"
when
    forall( $bus : Bus( type == 'english')
    Bus( this == $bus, color = 'red' ) )
then
    # all english buses are red
end
```

In the above rule, we "select" all Bus objects whose type is "english". Then, for each fact that matches this pattern we evaluate the following patterns and if they match, the forall CE will evaluate to true.

To state that all facts of a given type in the working memory must match a set of constraints, `forall` can be written with a single pattern for simplicity.

```
rule "All Buses are Red"
when
    forall( Bus( color == 'red' ) )
then
    # all asserted Bus facts are red
end
```

Example 4.53. Single Pattern Forall

Another example shows multiple patterns inside the `forall`.

```
rule "all employees have health and dental care programs"
when
    forall( $emp : Employee()
        HealthCare( employee == $emp )
        DentalCare( employee == $emp )
    )
then
    # all employees have health and dental care
end
```

Example 4.54. Multi-Pattern Forall

Forall can be nested inside other CEs for complete expressiveness. For instance, `forall` can be used inside a `not` CE. Note that only single patterns have optional parentheses, so that with a nested forall parentheses must be used.

```
rule "not all employees have health and dental care"
when
    not ( forall( $emp : Employee()
        HealthCare( employee == $emp )
        DentalCare( employee == $emp ) )
    )
then
    # not all employees have health and dental care
end
```

Example 4.55. Combining Forall with Not CE

As a side note, `not( forall( p1 p2 p3...))` is equivalent to writing:

```
not(p1 and not(and p2 p3...))
```

Also, it is important to note that `forall` is a *scope delimiter*. Therefore, it can use any previously bound variable, but no variable bound inside it will be available for use outside of it.

4.8.2.8. Conditional Element `from`

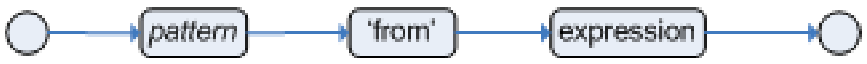


Figure 4.41. from

The Conditional Element `from` enables users to specify an arbitrary source for data to be matched by LHS patterns. This allows the engine to reason over data not in the Working Memory. The data source could be a sub-field on a bound variable or the results of a method call. It is a powerful construction that allows out of the box integration with other application components and frameworks. One common example is the integration with data retrieved on-demand from databases using hibernate named queries.

The expression used to define the object source is any expression that follows regular MVEL syntax. Therefore, it allows you to easily use object property navigation, execute method calls and access maps and collections elements.

Here is a simple example of reasoning and binding on another pattern sub-field.

```
rule "validate zipcode"
when
    Person( $personAddress : address )
    Address( zipcode == "23920W") from $personAddress
then
    # zip code is ok
end
```

With all the flexibility from the new expressiveness in the JBoss Rules engine you can slice and dice this problem many ways. This is the same but shows how you can use a graph notation with the 'from'.

```
rule "validate zipcode"
when
    $p : Person( )
    $a : Address( zipcode == "23920W") from $p.address
then
    # zip code is ok
end
```

Previous examples were evaluations using a single pattern. The CE `from` also supports object sources that return a collection of objects. In that case, `from` will iterate over all objects in the collection and try to match each of them individually. For instance, if we want a rule that applies 10% discount to each item in an order, we could do:

```
rule "apply 10% discount to all items over US$ 100,00 in an order"
when
    $order : Order()
    $item  : OrderItem( value > 100 ) from $order.items
then
    # apply discount to $item
end
```

The above example will cause the rule to fire once for each item whose value is greater than 100 for each given order.

You must take caution, however, when using `from`, especially in conjunction with the `lock-on-active` rule attribute as it may produce unexpected results. Consider the example provided earlier, but now slightly modified as follows:

```
rule "Assign people in North Carolina (NC) to sales region 1"
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person( )
    $a : Address( state == "NC") from $p.address
then
    modify ($p) {} #Assign person to sales region 1 in a modify block
end
```

```
rule "Apply a discount to people in the city of Raleigh"
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person( )
    $a : Address( city == "Raleigh") from $p.address
then
    modify ($p) {} #Apply discount to person in a modify block
end
```

In the above example, persons in Raleigh, NC should be assigned to sales region 1 and receive a discount; i.e., you would expect both rules to activate and fire. Instead you will find that only the second rule fires.

If you were to turn on the audit log, you would also see that when the second rule fires, it deactivates the first rule. Since the rule attribute `lock-on-active` prevents a rule from creating new activations when a set of facts change, the first rule fails to reactivate. Though the set of facts have not changed, the use of `from` returns a new fact for all intents and purposes each time it is evaluated.

First, it's important to review why you would use the above pattern. You may have many rules across different rule-flow groups. When rules modify working memory and other rules downstream of your RuleFlow (in different rule-flow groups) need to be reevaluated, the use of `modify` is critical. You don't, however, want other rules in the same rule-flow group to place activations on one another recursively. In this case, the `no-loop` attribute is ineffective, as it would only prevent a rule from activating itself recursively. Hence, you resort to `lock-on-active`.

There are several ways to address this issue.

- Avoid the use of `from` when you can assert all facts into working memory or use nested object references in your constraint expressions (shown below).
- Place the variable assigned used in the modify block as the last sentence in your condition (LHS).
- Avoid the use of `lock-on-active` when you can explicitly manage how rules within the same rule-flow group place activations on one another as explained below.

The preferred solution is to minimize use of `from` when you can assert all your facts into working memory directly. In the example above, both the Person and Address instance can be asserted into working memory. In this case, because the graph is fairly simple, an even easier solution is to modify your rules as follows:

```
rule "Assign people in North Carolina (NC) to sales region 1"
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person(address.state == "NC" )
then
    modify ($p) {} #Assign person to sales region 1 in a modify block
end

rule "Apply a discount to people in the city of Raleigh"
```

```
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person(address.city == "Raleigh" )
then
    modify ($p) {} #Apply discount to person in a modify block
end
```

Now, you will find that both rules fire as expected. However, it is not always possible to access nested facts as above. Consider an example where a Person holds one or more Addresses and you wish to use an existential quantifier to match people with at least one address that meets certain conditions. In this case, you would have to resort to the use of `from` to reason over the collection.

There are several ways to use `from` to achieve this and not all of them exhibit an issue with the use of `lock-on-active`. For example, the following use of `from` causes both rules to fire as expected:

```
rule "Assign people in North Carolina (NC) to sales region 1"
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person($addresses : addresses)
    exists (Address(state == "NC") from $addresses)
then
    modify ($p) {} #Assign person to sales region 1 in a modify block
end

rule "Apply a discount to people in the city of Raleigh"
    ruleflow-group "test"
    lock-on-active true
when
    $p : Person($addresses : addresses)
    exists (Address(city == "Raleigh") from $addresses)
then
    modify ($p) {} #Apply discount to person in a modify block
end
```

However, the following slightly different approach does exhibit the problem.

```
rule "Assign people in North Carolina (NC) to sales region 1"
    ruleflow-group "test"
    lock-on-active true
when
    $assessment : Assessment()
    $p : Person()
    $addresses : List() from $p.addresses
    exists (Address( state == "NC") from $addresses)
then
    modify ($assessment) {} #Modify assessment in a modify block
end

rule "Apply a discount to people in the city of Raleigh"
```

```
    ruleflow-group "test"
    lock-on-active true
when
    $assessment : Assessment()
    $p : Person()
    $addresses : List() from $p.addresses
    exists (Address( city == "Raleigh") from $addresses)
then
    modify ($assessment) {} #Modify assessment in a modify block
end
```

In the above example, the $addresses variable is returned from the use of `from`. The example also introduces a new object, assessment, to highlight one possible solution in this case. If the $assessment variable assigned in the condition (LHS) is moved to the last condition in each rule, both rules fire as expected.

Though the above examples demonstrate how to combine the use of `from` with `lock-on-active` where no loss of rule activations occurs, they carry the drawback of placing a dependency on the order of conditions on the LHS. In addition, the solutions present greater complexity for the rule author in terms of keeping track of which conditions may create issues.

A better alternative is to assert more facts into working memory. In this case, a person's addresses may be asserted into working memory and the use of `from` would not be necessary.

There are cases, however, where asserting all data into working memory is not practical and we need to find other solutions. Another option is to reevaluate the need for `lock-on-active`. An alternative to `lock-on-active` is to directly manage how rules within the same rule-flow group activate one another by including conditions in each rule that prevent rules from activating each other recursively when working memory is modified. For example, in the case above where a discount is applied to citizens of Raleigh, a condition may be added to the rule that checks whether the discount has already been applied. If so, the rule does not activate.

4.8.2.9. Conditional Element collect

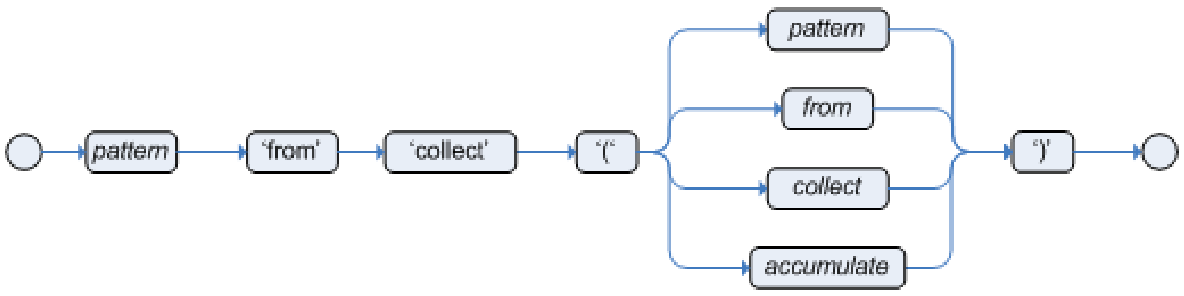


Figure 4.42. collect

The Conditional Element `collect` allows rules to reason over a collection of objects obtained from the given source or from the working memory. In First Order Logic terms this is the cardinality quantifier.

```
import java.util.ArrayList
rule "Raise priority if system has more than 3 pending alarms"
```

```
when
    $system : System()
    $alarms : ArrayList( size >= 3 )
    from collect( Alarm( system == $system, status == 'pending' ) )
then
    # Raise priority, because system $system has
    # 3 or more alarms pending. The pending alarms
    # are $alarms.
end
```

In the above example, the rule will look for all pending alarms in the working memory for each given system and group them in **`ArrayLists`**. If 3 or more alarms are found for a given system, the rule will fire.

The result pattern of `collect` can be any concrete class that implements the `java.util.Collection` interface and provides a default public constructor with no arguments. This means that you can use Java collections like **`ArrayList`**, **`LinkedList`**, **`HashSet`**, or your own class, as long as it implements the `java.util.Collection` interface and provide a default public constructor with no arguments.

Both source and result patterns can be constrained as any other pattern.

Variables bound before the `collect` CE are in the scope of both source and result patterns and therefore you can use them to constrain both your source and result patterns. But note that `collect` is a scope delimiter for bindings, so that any binding made inside of it is not available for use outside of it.

Collect accepts nested `from` CEs. The following example is a valid use of "collect":

```
import java.util.LinkedList;
rule "Send a message to all mothers"
when
    $town : Town( name == 'Paris' )
    $mothers : LinkedList()
    from collect(
        Person( gender == 'F', children > 0 )
        from $town.getPeople()
        )
then
    # send a message to all mothers
end
```

4.8.2.10. Conditional Element `accumulate`

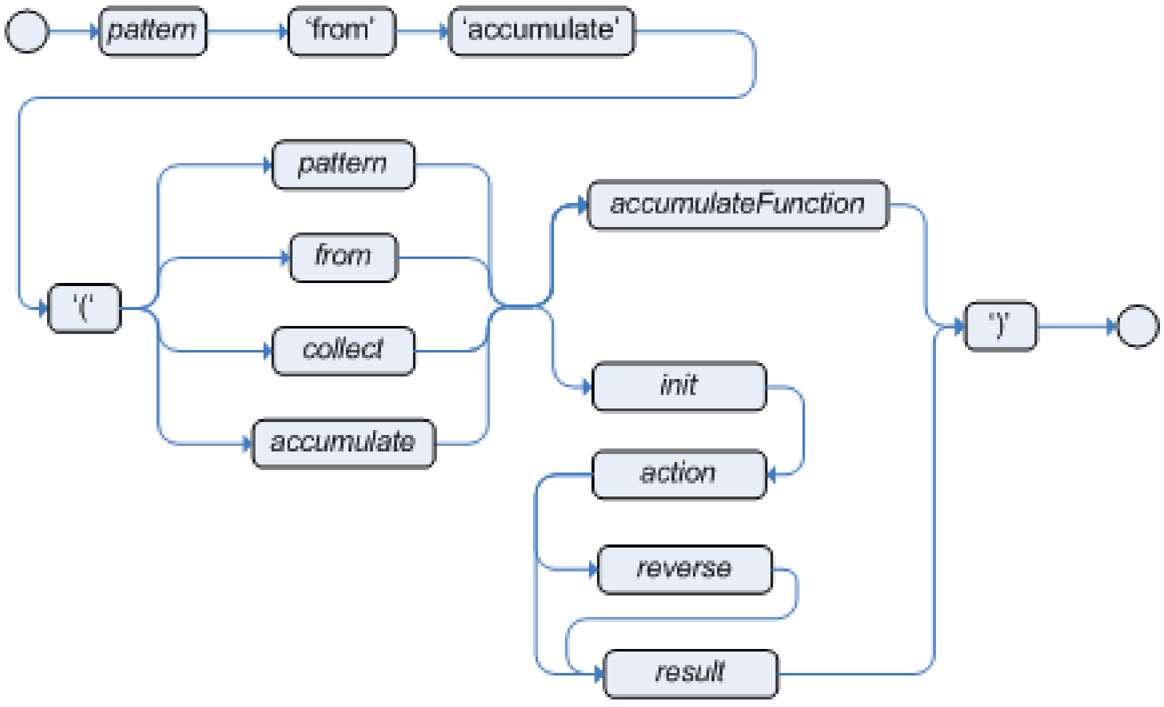


Figure 4.43. accumulate

The Conditional Element `accumulate` is a more flexible and powerful form of `collect`, the sense that it can be used to do what `collect` does and also achieve things that the CE `collect` is not capable of doing. Basically, what it does is that it allows a rule to iterate over a collection of objects, executing custom actions for each of the elements, and at the end it returns a result object.

The general syntax of the `accumulate` CE is:

```
<result pattern> from accumulate(<source pattern>,
    init( <init code> ),
    action( <action code> ),
    reverse( <reverse code> ),
    result( <result expression> ) )
```

The meaning of each of the elements is the following:

- *<source pattern>*: the source pattern is a regular pattern that the engine will try to match against each of the source objects.
- *<init code>*: this is a semantic block of code in the selected dialect that will be executed once for each tuple, before iterating over the source objects.
- *<action code>*: this is a semantic block of code in the selected dialect that will be executed for each of the source objects.
- *<reverse code>*: this is an optional semantic block of code in the selected dialect that if present will be executed for each source object that no longer matches the source pattern. The objective of this code block is to undo any calculation done in the *<action code>* block, so that the engine

can do decremental calculation when a source object is modified or retracted, hugely improving performance of these operations.

- *<result expression>*: this is a semantic expression in the selected dialect that is executed after all source objects are iterated.
- *<result pattern>*: this is a regular pattern that the engine tries to match against the object returned from the *<result expression>*. If it matches, the `accumulate` conditional element evaluates to *true* and the engine proceeds with the evaluation of the next CE in the rule. If it does not matches, the `accumulate` CE evaluates to *false* and the engine stops evaluating CEs for that rule.

It is easier to understand if we look at an example:

```
rule "Apply 10% discount to orders over US$ 100,00"
when
    $order : Order()
    $total : Number( doubleValue > 100 )
    from accumulate( OrderItem( order == $order, $value : value ),
        init( double total = 0; ),
        action( total += $value; ),
        reverse( total -= $value; ),
        result( total ) )
then
    # apply discount to $order
end
```

In the above example, for each `Order` in the Working Memory, the engine will execute the *init code* initializing the total variable to zero. Then it will iterate over all `OrderItem` objects for that order, executing the *action* for each one (in the example, it will sum the value of all items into the total variable). After iterating over all `OrderItem` objects, it will return the value corresponding to the *result expression* (in the above example, the value of variable `total`). Finally, the engine will try to match the result with the `Number` pattern, and if the double value is greater than 100, the rule will fire.

The example used Java as the semantic dialect, and as such, note that the usage of the semicolon as statement delimiter is mandatory in the init, action and reverse code blocks. The result is an expression and, as such, it does not admit ';'. If the user uses any other dialect, he must comply to that dialect's specific syntax.

As mentioned before, the *reverse code* is optional, but it is strongly recommended that the user writes it in order to benefit from the *improved performance on update and retract*.

The `accumulate` CE can be used to execute any action on source objects. The following example instantiates and populates a custom object:

```
rule "Accumulate using custom objects"
when
$person   : Person( $likes : likes )
$cheesery : Cheesery( totalAmount > 100 )
from accumulate( $cheese : Cheese( type == $likes ),
init( Cheesery cheesery = new Cheesery(); ),
action( cheesery.addCheese( $cheese ); ),
reverse( cheesery.removeCheese( $cheese ); ),
result( cheesery ) );
then
// do something
end
```

4.8.2.10.1. Accumulate Functions

The accumulate CE is a very powerful CE, but it gets real declarative and easy to use when using predefined functions that are known as Accumulate Functions. They work exactly like accumulate, but instead of explicitly writing custom code in every accumulate CE, the user can use predefined code for common operations.

For instance, the rule to apply discount on orders written in the previous section, could be written in the following way, using Accumulate Functions:

```
rule "Apply 10% discount to orders over US$ 100,00"
when
$order : Order()
$total : Number( doubleValue > 100 )
from accumulate( OrderItem( order == $order, $value : value ),
sum( $value ) )
then
# apply discount to $order
end
```

In the above example, sum is an Accumulate Function and will sum the $value of all OrderItems and return the result.

JBoss Rules ships with the following built-in accumulate functions: `average`, `min` , `max`, `count`, and `sum`.

These common functions accept any expression as input. For instance, if someone wants to calculate the average profit on all items of an order, a rule could be written using the average function:

```
rule "Average profit"
when
    $order : Order()
    $profit : Number()
    from accumulate( OrderItem( order == $order, $cost : cost, $price :
 price )
        average( 1 - $cost / $price ) )
then
    # average profit for $order is $profit
end
```

Accumulate Functions are all pluggable. That means that if needed, custom, domain specific functions can easily be added to the engine and rules can start to use them without any restrictions. To implement a new Accumulate Functions all one needs to do is to create a Java class that implements the `org.drools.base.acumulators.AccumulateFunction` interface and add a line to the configuration file or set a system property to let the engine know about the new function. As an example of an Accumulate Function implementation, the following is the implementation of the "average" function:

```
/*
* Copyright 2007 JBoss Inc
*
* Licensed under the Apache License, Version 2.0 (the "License");
* you may not use this file except in compliance with the License.
* You may obtain a copy of the License at
*
*      http://www.apache.org/licenses/LICENSE-2.0
*
* Unless required by applicable law or agreed to in writing, software
* distributed under the License is distributed on an "AS IS" BASIS,
* WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
* See the License for the specific language governing permissions and
* limitations under the License.
*
* Created on Jun 21, 2007
*/
package org.drools.base.accumulators;


/**
* An implementation of an accumulator capable of calculating average values
*
* @author etirelli
*
*/
public class AverageAccumulateFunction implements AccumulateFunction {

protected static class AverageData {
public int    count = 0;
public double total = 0;
}

/* (non-Javadoc)
* @see org.drools.base.accumulators.AccumulateFunction#createContext()
*/
public Object createContext() {
return new AverageData();
}

/* (non-Javadoc)
* @see
 org.drools.base.accumulators.AccumulateFunction#init(java.lang.Object)
*/
public void init(Object context) throws Exception {
AverageData data = (AverageData) context;
data.count = 0;
data.total = 0;
}

/* (non-Javadoc)
* @see
 org.drools.base.accumulators.AccumulateFunction#accumulate(java.lang.Object,
* java.lang.Object)
*/
public void accumulate(Object context,
               Object value) {
AverageData data = (AverageData) context;
data.count++;
data.total += ((Number) value).doubleValue();
}

/* (non-Javadoc)
* @see
 org.drools.base.accumulators.AccumulateFunction#reverse(java.lang.Object,
* java.lang.Object)
*/
public void reverse(Object context,
            Object value) throws Exception {
AverageData data = (AverageData) context;
data.count--;
data.total -= ((Number) value).doubleValue();
}

/* (non-Javadoc)
* @see
 org.drools.base.accumulators.AccumulateFunction#getResult(java.lang.Object)
*/
public Object getResult(Object context) throws Exception {
AverageData data = (AverageData) context;
return new Double( data.count == 0 ? 0 : data.total / data.count );
}

/* (non-Javadoc)
* @see org.drools.base.accumulators.AccumulateFunction#supportsReverse()
*/
public boolean supportsReverse() {
return true;
}

}
```

The code for the function is very simple, as we could expect, as all the "dirty" integration work is done by the engine. Finally, to plug the function into the engine, we added it to the configuration file:

```
drools.accumulate.function.average =
    org.drools.base.accumulators.AverageAccumulateFunction
```

Here, `drools.accumulate.function.` is a prefix that must always be used, "average" is how the function will be used in the rule file, and "org.drools.base.accumulators.AverageAccumulateFunction" is the fully qualified name of the class that implements the function behavior.

4.8.3. The Right Hand Side (then)

4.8.3.1. Usage

The Right Hand Side (RHS) is a common name for the consequence or action part of the rule; this part should contain a list of actions to be executed. It is bad practice to use imperative or conditional code in the RHS of a rule; as a rule should be atomic in nature - "when this, then do this", not "when this, maybe do this". The RHS part of a rule should also be kept small, thus keeping it declarative and readable. If you find you need imperative and/or conditional code in the RHS, then maybe you should be breaking that rule down into multiple rules. The main purpose of the RHS is to insert, retractor modify working memory data. To assist with that there are a few convenience methods you can use to modify working memory; without having to first reference a working memory instance.

`update(object, handle)` will tell the engine that an object has changed (one that has been bound to something on the LHS) and rules may need to be reconsidered.

`update(object)` can also be used; here the Knowledge Helper will look up the facthandle for you, using an identity check, for the passed object. If you provide Property Change Listeners to your Java beans, you are inserting into the engine, and you do not need to call `update()` when the object changes.

`insert(new Something ())` will place a new object of your creation into the Working Memory.

`insertLogical(new Something())` is similar to insert, but the object will be automatically retracted when there are no more facts to support the truth of the currently firing rule.

`retract(handle)` removes an object from Working Memory.

These convenience methods are basically macros that provide short cuts to the `KnowledgeHelper` instance that lets you access your Working Memory from rules files. The predefined variable `drools` of type `KnowledgeHelper` lets you call several other useful methods. (Refer to the `KnowledgeHelper` interface documentation for more advanced operations).

- The call `drools.halt()` terminates rule execution immediately. This is required for returning control to the point whence the current session was put to work with `fireUntilHalt()`.
- Methods `insert(Object o)`, `update(Object o)` and `retract(Object o)` can be called on `drools` as well, but due to their frequent use they can be called without the object reference.
- `drools.getWorkingMemory()` returns the `WorkingMemory` object.
- `drools.setFocus( String s)` sets the focus to the specified agenda group.
- `drools.getRule().getName()`, called from a rule's RHS, returns the name of the rule.
- `drools.getTuple()` returns the Tuple that matches the currently executing rule, and `drools.getActivation()` delivers the corresponding Activation. (These calls are useful for logging and debugging purposes.)

The full Knowlege Runtime API is exposed through another predefined variable, `kcontext`, of type `KnowledgeContext`. Its method `getKnowledgeRuntime()` delivers an object of type

`KnowledgeRuntime`, which, in turn, provides access to a wealth of methods, many of which are quite useful for coding RHS logic.

- The call `kcontext.getKnowledgeRuntime().halt()` terminates rule execution immediately.
- The accessor `getAgenda()` returns a reference to this session's `Agenda`, which in turn provides access to the various rule groups: activation groups, agenda groups, and rule flow groups. A fairly common paradigm is the activation of some agenda group, which could be done with the lengthy call:

  ```
  // give focus to the agenda group CleanUp
  kcontext.getKnowledgeRuntime().getAgenda().getAgendaGroup( "CleanUp" ).setFocus();
  ```

  You can also achieve the same using `drools.setFocus( "CleanUp" )`.
- To run a query, you call `getQueryResults(String query)`, whereupon you may process the results, as explained in section *Section 4.9, “Query”*.
- A set of methods dealing with event management lets you, among other things, add and remove event listeners for the Working Memory and the Agenda.
- Method`getKnowledgeBase()` returns the `KnowledgeBase` object, the backbone of all the Knowledge in your system, and the originator of the current session.
- You can manage globals with `setGlobal(...)`, `getGlobal(...)` and `getGlobals()`.
- Method `getEnvironment()` returns the runtime's `Environment` which works much like what you know as your operating system's environment.

4.8.3.2. The modify Statement

This language extension provides a structured approach to fact updates. It combines the update operation with a number of setter calls to change the object's fields. This is the syntax schema for the modify statement:

```
modify ( <fact-expression> ) {
    <expression> [ , <expression> ]*
}
```

The parenthesized <*fact-expression*> must yield a fact object reference. The expression list in the block should consist of setter calls for the given object, to be written without the usual object reference, which is automatically prepended by the compiler.

The example illustrates a simple fact modification.

```
rule "modify stilton"
when
    $stilton : Cheese(type == "stilton")
then
    modify( $stilton ){
        setPrice( 20 ),
        setAge( "overripe" )
    }
end
```

Example 4.56. A modify statement

4.8.4. A Note on Auto-boxing and Primitive Types

JBoss Rules attempts to preserve numbers in their primitive or object wrapper form, so a variable bound to an int primitive when used in a code block or expression will no longer need manual unboxing; unlike JBoss Rules 3.0 where all primitives were autoboxed, requiring manual unboxing. A variable bound to an object wrapper will remain as an object; the existing JDK 1.5 and JDK 5 rules to handle auto-boxing and unboxing apply in this case. When evaluating field constraints, the system attempts to coerce one of the values into a comparable format; so a primitive is comparable to an object wrapper.

4.9. Query

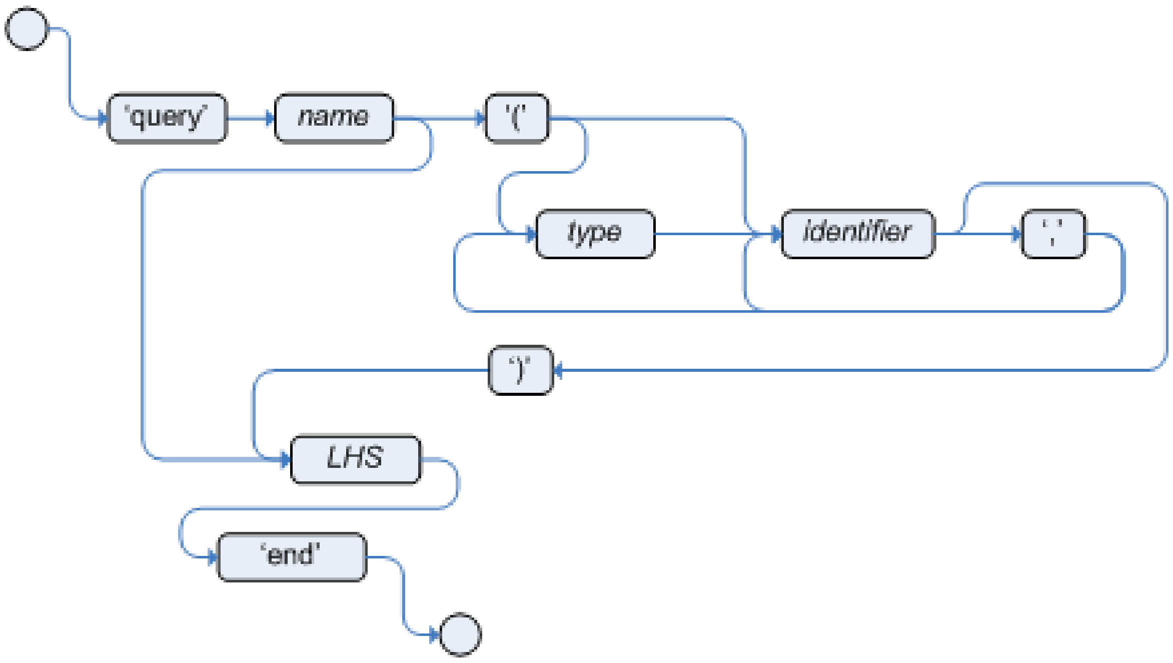


Figure 4.44. query

A query is a simple way to search the working memory for facts that match the stated conditions. Therefore, it contains only the structure of the LHS of a rule, so that you specify neither "when" nor "then". A query has an optional set of parameters, each of which can also be optionally typed. If the type is not given then the type Object is assumed. The engine will attempt to coerce the values as needed. Query names are global to the **`KnowledgeBase`**, so do not add queries of the same name to different packages for the same **`RuleBase`**.

To return the results use `ksession.getQueryResults("name")`, where "name" is the query's name. This returns a list of query results, which allow you to retrieve the objects that matched the query.

The first example is a simple query for all the people over the age of 30. The second one, using parameters, combines the age limit with a location.

```
query "people over the age of 30"
    person : Person( age > 30 )
end
```

Example 4.57. Query People over the age of 30

```
query "people over the age of x"  (int x, String y)
    person : Person( age > x, location == y )
end
```

Example 4.58. Query People over the age of x, and who live in y

We iterate over the returned QueryResults using a standard for loop. Each element is a **`QueryResultsRow`** which we can use to access each of the columns in the tuple. These columns can be accessed by bound declaration name or index position.

```
QueryResults results = ksession.getQueryResults( "people over the age of
 30" );
System.out.println( "we have " + results.size() + " people over the age  of
 30" );

System.out.println( "These people are are over 30:" );

for ( QueryResultsRow row : results ) {
    Person person = ( Person ) row.get( "person" );
    System.out.println( person.getName() + "\n" );
}
```

Example 4.59. Query People over the age of 30

4.10. Domain Specific Languages

Domain Specific Languages (or DSLs) are a way of extending the rule language to your problem domain. They are wired in to the rule language for you, and can make use of all the underlying rule language and engine features.

DSLs are used both in the IDE, as well as the web based BRMS UI. Of course as rules are text, you can use them even without this tooling.

4.10.1. When to use a DSL

DSLs can serve as a layer of separation between rule authoring (and rule authors) and the domain objects that the engine operates on. DSLs can also act as "templates" of conditions or actions that are used over and over in your rules, perhaps only with parameters changing each time. If your rules need to be read and validated by less technical folk, (such as Business Analysts) the DSLs are definitely for you. If the conditions or consequences of your rules follow similar patterns which you can express in a template. You wish to hide away your implementation details, and focus on the business rule. You want to provide a controlled means of editing rules based on pre-defined templates.

DSLs have no impact on the rules at runtime, they are just a parse/compile time feature.

4.10.2. Editing and managing a DSL

A DSL's configuration like most things is stored in plain text. If you use the IDE, you get a nice graphical editor (with some validation), but the format of the file is quite simple, and is basically a properties file.

Note that since JBoss Rules 4.0, DSLs have become more powerful in allowing you to customize almost any part of the language, including keywords. Regular expressions can also be used to match words/sentences if needed (this is provided for enhanced localization). However, not all features are supported by all the tools (although you can use them, the content assistance just may not be 100% accurate in certain cases).

```
[when]This is {something}=Something(something=={something})
```

Example 4.60. Example DSL mapping

Referring to the above example, the [when] refers to the scope of the expression: i.e. does it belong on the LHS or the RHS of a rule. The part after the [scope] is the expression that you use in the rule (typically a natural language expression, but it doesn't have to be). The part on the right of the "=" is the mapping into the rule language (of course the form of this depends on if you are talking about the RHS or the LHS - if its the LHS, then its the normal LHS syntax, if its the RHS then its fragments of Java code for instance).

The parser will take the expression you specify, and extract the values that match where the {something} (named Tokens) appear in the input. The values that match the tokens are then interpolated with the corresponding {something} (named Tokens) on the right hand side of the mapping (the target expression that the rule engine actually uses).

Note also that the "sentences" above can be regular expressions. This means the parser will match the sentence fragments that match the expressions. This means you can use (for instance) the '?' to indicate the character before it is optional (think of each sentence as a regular expression pattern - this means if you want to use regular expression characters - you will need to escape them with a '\' of course.

It is important to note that the DSL expressions are processed one line at a time. This means that in the above example, all the text after "This is " to the end of the line will be included as the value for "{something}" when it is interpolated into the target string. This may not be exactly what you want, as you may want to "chain" together different DSL expressions to generate a target expression. The best way around this is to make sure that the {tokens} are enclosed with characters or words. This means that the parser will scan along the sentence, and pluck out the value BETWEEN the characters (in the example below they are double-quotes). Note that the characters that surround the token are not included in when interpolating, just the contents between them (rather then all the way to the end of the line, as would otherwise be the case).

As a rule of thumb, use quotes for textual data that a rule editor may want to enter. You can also wrap words around the {tokens} to make sure you enclose the data you want to capture (see other example).

```
[when]This is "{something}" and
 "{another}"=Something(something=="{something}", another=="{another}")
[when]This is {also} valid=Another(something=="{also}")
```

Example 4.61. Example with quotes

It is a good idea to try and avoid punctuation in your DSL expressions where possible, other then quotes and the like - keep it simple and things will be easier. Using a DSL can make debugging slightly harder when you are first building rules, but it can make the maintenance easier (and of course the readability of the rules).

The "{" and "}" characters should only be used on the left hand side of the mapping (the expression) to mark tokens. On the right hand side you can use "{" and "}" on their own if needed - such as

```
if (foo) \{ doSomething();\ }
```

as well as with the token names as shown above.

Important

If you want curly braces to appear literally as curly braces, then escape them with a backslash (\). Otherwise it may think it is a token to be replaced.

Don't forget that if you are capturing strings from users, you will also need the quotes on the right hand side of the mapping, just like a normal rule, as the result of the mapping must be a valid expression in the rule language.

```
#This is a comment to be ignored.
[when]There is a Person with name of "{name}"=Person(name=="{name}")
[when]Person is at least {age} years old and lives in
 "{location}"=Person(age > {age}, location=="{location}")
[then]Log "{message}"=System.out.println("{message}");
[when]And = and
```

Example 4.62. Some more examples

Referring to the above examples, this would render the following input as shown below:

```
There is a Person with name of "kitty" ---> Person(name="kitty")
Person is at least 42 years old and lives in "atlanta" ---> Person(age >
 42, location="atlanta")
Log "boo" ---> System.out.println("boo");
There is a Person with name of "bob" and Person is at least 30 years old
 and lives in "atlanta"
         ---> Person(name="kitty") and Person(age > 30,
 location="atlanta")
```

Example 4.63. Some examples as processed

4.10.3. Using a DSL in your rules

A good way to get started if you are new to Rules (and DSLs) is just write the rules as you normally would against your object model. You can unit test as you go (like a good agile citizen!). Once you feel comfortable, you can look at extracting a domain language to express what you are doing in the rules. Note that once you have started using the "expander" keyword, you will get errors if the parser does not recognize expressions you have in there - you need to move everything to the DSL. As a way around this, you can prefix each line with ">" and it will tell the parser to take that line literally, and not try and expand it (this is handy also if you are debugging why something isn't working).

Also, it is better to rename the extension of your rules file from ".drl" to ".dslr" when you start using DSLs, as that will allow the IDE to correctly recognize and work with your rules file.

As you work through building up your DSL, you will find that the DSL configuration stabilizes pretty quickly, and that as you add new rules and edit rules you are reusing the same DSL expressions over and over. The aim is to make things as fluent as possible.

To use the DSL when you want to compile and run the rules, you will need to pass the DSL configuration source along with the rule source.

```
// source is a reader for the rule source,
// dsl is a reader for the DSL configuration
PackageBuilder builder = new PackageBuilder();
builder.addPackageFromDrl( source, dsl );
```

You will also need to specify the expander by name in the rule source file:

```
expander your-expander.dsl
```

Typically you keep the DSL in the same directory as the rule, but this is not required if you are using the above API (you only need to pass a reader). Otherwise everything is just the same.

You can chain DSL expressions together on one line, as long as it is clear to the parser what the {tokens} are (otherwise you risk reading in too much text until the end of the line). The DSL expressions are processed according to the mapping file, top to bottom in order. You can also have the resulting rule expressions span lines - this means that you can do things like:

```

There is a person called Bob who is happy
  Or
There is a person called Mike who is sad

```

Example 4.64. Chaining DSL Expressions

Of course this assumes that "Or" is mapped to the "or" conditional element (which is a sensible thing to do).

4.10.4. Adding constraints to facts

A common requirement when writing rule conditions is to be able to add many constraints to fact declarations. A fact may have many (dozens) of fields, all of which could be used or not used at various times. To come up with every combination as separate DSL statements would in many cases not be feasible.

The DSL facility allows you to achieve this however, with a simple convention. If your DSL expression starts with a "-", then it will be assumed to be a field constraint, which will be added to the declaration that is above it (one per line).

This is easier to explain with an example. Lets take look at Cheese class, with the following fields: type, price, age, country. We can express some LHS condition in normal DRL like the following

```
Cheese(age < 5, price == 20, type=="stilton", country=="ch")
```

If you know ahead of time that you will use all the fields, all the time, it is easy to do a mapping using the above techniques. However, chances are that you will have many fields, and many combinations. If this is the case, you can setup your mappings like so:

```
[when]There is a Cheese with=Cheese()
[when]- age is less than {age}=age<{age}
[when]- type is '{type}'=type=='{type}'
[when]- country equal to '{country}'=country=='{country}'
```

Important

It is *NOT* possible to use the "-" feature after an *accumulate* statement to add constraints to the accumulate pattern. This limitation will be removed in a future version.

You can then write rules with conditions like the following:

```
There is a Cheese with
        - age is less than 42
        - type is 'stilton'
```

The parser will pick up the "-" lines (they have to be on their own line) and add them as constraints to the declaration above. So in this specific case, using the above mappings, is the equivalent to doing (in DRL):

```
Cheese(age<42, type=='stilton')
```

The parser will do all the work for you, meaning you just define mappings for individual constraints, and can combine them how you like (if you are using context assistant, if you press "-" followed by CTRL+space it will conveniently provide you with a filtered list of field constraints to choose from.

To take this further, after alter the DSL to have [when][org.drools.Cheese]- age is less than {age} ... (and similar to all the items in the example above).

The extra [org.drools.Cheese] indicates that the sentence only applies for the main constraint sentence above it (in this case "There is a Cheese with"). For example, if you have a class called "Cheese" - then if you are adding constraints to the rule (by typing "-" and waiting for content assistance) then it will know that only items marked as having an object-scope of "com.yourcompany.Something" are valid, and suggest only them. This is entirely optional (you can leave out that section if needed - OR it can be left blank).

4.10.5. How it works

DSLs kick in when the rule is parsed. The DSL configuration is read and supplied to the parser, so the parser can "expand" the DSL expressions into the real rule language expressions.

When the parser is processing the rules, it will check if an "expander" representing a DSL is enabled, if it is, it will try to expand the expression based on the context of where it is the rule. If an expression can not be expanded, then an error will be added to the results, and the line number recorded (this insures against typos when editing the rules with a DSL). At present, the DSL expander is fairly space sensitive, but this will be made more tolerant in future releases (including tolerance for a wide range of punctuation).

The expansion itself works by trying to match a line against the expression in the DSL configuration. The values that correspond to the token place holders are stored in a map based on the name of the token, and then interpolated to the target mapping. The values that match the token placeholders are extracted by either searching until the end of the line, or until a character or word after the token place holder is matched. The "{" and "}" are not included in the values that are extracted, they are only used to demarcate the tokens - you should not use these characters in the DSL expression (but you can in the target).

4.10.6. Creating a DSL from scratch

Rules engines require an object or a data model to operate on - in many cases you may know this up front. In other cases the model will be discovered with the rules. In any case, rules generally work better with simpler flatter object models. In some cases, this may mean having a rule object model which is a subset of the main applications model (perhaps mapped from it). Object models can often have complex relationships and hierarchies in them - for rules you will want to simplify and flatten the model where possible, and let the rule engine infer relationships (as it provides future flexibility). As stated previously, DSLs can have an advantage of providing some insulation between the object model and the rule language.

Coming up with a DSL is a collaborative approach for both technical and domain experts. Historically there was a role called "knowledge engineer" which is someone skilled in both the rule technology, and in capturing rules. Over a short period of time, your DSL should stabilize, which means that changes to rules are done entirely using the DSL. A suggested approach if you are starting from scratch is the following workflow:

- Capture rules as loose "if then" statements - this is really to get an idea of size and complexity (possibly in a text document).
- Look for recurring statements in the rules captured. Also look for the rule objects/fields (and match them up with what may already be known of the object model).
- Create a new DSL, and start adding statements from the above steps. Provide the "holes" for data to be edited (as many statements will be similar, with only some data changing).
- Use the above DSL, and try to write the rules just like that appear in the "if then" statements from the first and second steps. Iterate this process until patterns appear and things stabilize. At this stage, you are not so worried about the rule language underneath, just the DSL.
- At this stage you will need to look at the Objects, and the Fields that are needed for the rules, reconcile this with the datamodel so far.
- Map the DSL statements to the rule language, based on the object model. Then repeat the process. Obviously this is best done in small steps, to make sure that things are on the right track.

4.10.7. Scope and keywords

If you are editing the DSL with the GUI, or as text, you will notice there is a [scope] item at the start of each mapping line. This indicates if the sentence/word applies to the LHS, RHS or is a keyword. Valid values for this are [condition], [consequence] and [keyword] (with [when] and [then] being the same as [condition] and [consequence] respectively). When [keyword] is used, it means you can map any keyword of the language like "rule" or "end" to something else. Generally this is only used when you want to have a non English rule language (and you would ideally map it to a single word).

4.10.8. DSLs in the BRMS and IDE

You can use DSLs in the BRMS in both guided editor rules, and textual rules that use a DSL. (In fact, the same applies to the IDE).

In the guided editor - the DSLs generally have to be simpler - what you are doing is defining little "forms" to capture data from users in text fields (i.e. as you pick a DSL expression - it will add an item to the GUI which only allows you enter data in the {token} parts of a DSL expression). You can not use sophisticated regular expressions to match text. However, in textual rules (which have a .dslr extension in the IDE) you are free to use the full power as needed.

In the BRMS - when you build a package the DSLs are already included and all the work is done for you. In the IDE (or in any IDE) - you will either need to use the drools-ant task, or otherwise use the code shown in sections above.

4.11. XML Rule Language

As an option, JBoss Rules also supports a "native" XML rule language as an alternative to DRL. This allows you to capture and manage your rules as XML data. Just like the non-XML DRL format, the XML format is parsed into the internal "AST" representation - as fast as possible (using a SAX parser). There is no external transformation step required. All the features are available with XML that are available to DRL.

4.11.1. When to use XML

There are several scenarios that XML is desirable. However, we recommend that it is not a default choice, as XML is not readily human readable (unless you like headaches) and can create visually bloated rules.

Other scenarios where you may want to use the XML format are if you have a tool that generates rules from some input (programmatically generated rules), or perhaps interchange from another rule language, or from another tool that emits XML (using XSLT you can easily transform between XML formats). Note you can always generate normal DRL as well.

Alternatively you may be embedding JBoss Rules in a product that already uses XML for configuration, so you would like the rules to be in an XML format. You may be creating your own rule language on XML - note that you can always use the AST objects directly to create your own rule language as well (the options are many, due to the open architecture).

4.11.2. The XML format

A full W3C standards (XML Schema) compliant XSD is provided that describes the XML language, which will not be repeated here verbatim. A summary of the language follows.

```
<?xml version="1.0" encoding="UTF-8"?>
```

```
<package name="com.sample"
  xmlns="http://drools.org/drools-4.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
  xs:schemaLocation="http://drools.org/drools-4.0 drools-4.0.xsd">

  <import name="java.util.HashMap" />
  <import name="org.drools.*" />

  <global identifier="x" type="com.sample.X" />
  <global identifier="yada" type="com.sample.Yada" />

  <function return-type="void" name="myFunc">
    <parameter identifier="foo" type="Bar" />
    <parameter identifier="bada" type="Bing" />
    <body>System.out.println("hello world");</body>
  </function>

  <rule name="simple_rule">
    <rule-attribute name="salience" value="10" />
    <rule-attribute name="no-loop" value="true" />
    <rule-attribute name="agenda-group" value="agenda-group" />
    <rule-attribute name="activation-group" value="activation-group" />

    <lhs>
      <pattern identifier="foo2" object-type="Bar" >
        <or-constraint-connective>
          <and-constraint-connective>
            <field-constraint field-name="a">
              <or-restriction-connective>
                <and-restriction-connective>
                  <literal-restriction evaluator=">" value="60" />
                  <literal-restriction evaluator="<" value="70" />
                </and-restriction-connective>
                <and-restriction-connective>
                  <literal-restriction evaluator="<" value="50" />
                  <literal-restriction evaluator=">" value="55" />
                </and-restriction-connective>
              </or-restriction-connective>
            </field-constraint>

            <field-constraint field-name="a3">
              <literal-restriction evaluator="==" value="black" />
            </field-constraint>
          </and-constraint-connective>

          <and-constraint-connective>
            <field-constraint field-name="a">
              <literal-restriction evaluator="==" value="40" />
            </field-constraint>
            <field-constraint field-name="a3">
              <literal-restriction evaluator="==" value="pink" />
            </field-constraint>
          </and-constraint-connective>

          <and-constraint-connective>
            <field-constraint field-name="a">
              <literal-restriction evaluator="==" value="12"/>
            </field-constraint>

            <field-constraint field-name="a3">
              <or-restriction-connective>
                <literal-restriction evaluator="==" value="yellow"/>
                <literal-restriction evaluator="==" value="blue" />
              </or-restriction-connective>
            </field-constraint>
          </and-constraint-connective>
        </or-constraint-connective>
      </pattern>

      <not>
        <pattern object-type="Person">
          <field-constraint field-name="likes">
            <variable-restriction evaluator="==" identifier="type"/>
          </field-constraint>
        </pattern>

        <exists>
          <pattern object-type="Person">
            <field-constraint field-name="likes">
              <variable-restriction evaluator="==" identifier="type"/>
            </field-constraint>
          </pattern>
        </exists>
      </not>

      <or-conditional-element>
        <pattern identifier="foo3" object-type="Bar" >
          <field-constraint field-name="a">
            <or-restriction-connective>
              <literal-restriction evaluator="==" value="3" />
              <literal-restriction evaluator="==" value="4" />
            </or-restriction-connective>
          </field-constraint>
          <field-constraint field-name="a3">
            <literal-restriction evaluator="==" value="hello" />
          </field-constraint>
          <field-constraint field-name="a4">
            <literal-restriction evaluator="==" value="null" />
          </field-constraint>
        </pattern>
```

```
        <pattern identifier="foo4" object-type="Bar" >
          <field-binding field-name="a" identifier="a4" />
          <field-constraint field-name="a">
            <literal-restriction evaluator="!=" value="4" />
            <literal-restriction evaluator="!=" value="5" />
          </field-constraint>
        </pattern>
      </or-conditional-element>

      <pattern identifier="foo5" object-type="Bar" >
        <field-constraint field-name="b">
          <or-restriction-connective>
            <return-value-restriction evaluator="==" >
              a4 + 1
            </return-value-restriction>
            <variable-restriction evaluator=">" identifier="a4" />
            <qualified-identifier-restriction evaluator="==">
              org.drools.Bar.BAR_ENUM_VALUE
            </qualified-identifier-restriction>
          </or-restriction-connective>
        </field-constraint>
      </pattern>

      <pattern identifier="foo6" object-type="Bar" >
        <field-binding field-name="a" identifier="a4" />
        <field-constraint field-name="b">
          <literal-restriction evaluator="==" value="6" />
        </field-constraint>
      </pattern>
    </lhs>
    <rhs>
      if ( a == b ) {
      assert( foo3 );
      } else {
      retract( foo4 );
      }
      System.out.println( a4 );
    </rhs>
  </rule>

</package>
```

In the preceding XML text you will see the typical XML element, the package declaration, imports, globals, functions, and the rule itself. Most of the elements are self explanatory if you have some understanding of the JBoss Rules features.

The `import` elements import the types you wish to use in the rule.

The `global` elements define global objects that can be referred to in the rules.

The `function` contains a function declaration, for a function to be used in the rules. You have to specify a return type, a unique name and parameters, in the body goes a snippet of code.

The rule is discussed below.

```
<rule name="simple_rule">
<rule-attribute name="salience" value="10" />
<rule-attribute name="no-loop" value="true" />
<rule-attribute name="agenda-group" value="agenda-group" />
<rule-attribute name="activation-group" value="activation-group" />

<lhs>
    <pattern identifier="cheese" object-type="Cheese">
        <from>
            <accumulate>
                <pattern object-type="Person"></pattern>
                <init>
                    int total = 0;
                </init>
                <action>
                    total += $cheese.getPrice();
                </action>
                <result>
                    new Integer( total ) );
                </result>
            </accumulate>
        </from>
    </pattern>

    <pattern identifier="max" object-type="Number">
        <from>
            <accumulate>
               <pattern identifier="cheese" object-type="Cheese"></pattern>
               <external-function evaluator="max" expression="$price"/>
            </accumulate>
        </from>
    </pattern>
</lhs>
<rhs>
    list1.add( $cheese );
</rhs>
</rule>
```

Example 4.65. Detail of rule element

In the above detail of the rule we see that the rule has LHS and RHS (conditions and consequence) sections. The RHS is simple, it is just a block of semantic code that will be executed when the rule is activated. The LHS is slightly more complicated as it contains nested elements for conditional elements, constraints and restrictions.

A key element of the LHS is the Pattern element. This allows you to specify a type (class) and perhaps bind a variable to an instance of that class. Nested under the pattern object are constraints and restrictions that have to be met. The Predicate and Return Value constraints allow Java expressions to be embedded.

That leaves the conditional elements, not, exists, and, or etc. They work like their DRL counterparts. Elements that are nested under and an "and" element are logically "anded" together. Likewise with "or" (and you can nest things further). "Exists" and "Not" work around patterns, to check for the existence or nonexistence of a fact meeting the pattern's constraints.

The Eval element allows the execution of a valid snippet of Java code - as long as it evaluates to a boolean (do not end it with a semi-colon, as it is just a fragment) - this can include calling a function. The Eval is less efficient than the columns, as the rule engine has to evaluate it each time, but it is a "catch all" feature for when you can express what you need to do with Column constraints.

4.11.3. Automatic transforming between formats (XML and DRL)

JBoss Rules comes with some utility classes to transform between formats. This works by parsing the rules from the source format into the AST, and then "dumping" out to the appropriate target format. This allows you, for example, to write rules in DRL, and when needed, export to XML if necessary at some point in the future.

The classes to look at if you need to do this are:

```
XmlDumper - for exporting XML.
DrlDumper - for exporting DRL.
DrlParser - reading DRL.
XmlPackageReader - reading XML.
```

Using combinations of the above, you can convert between any format (including round trip). Note that DSLs will not be preserved (from DRLs that are using a DSL) - but they will be able to be converted.

Feel free to make use of XSLT to provide all sorts of possibilities for XML, XSLT and its ilk are what make XML powerful.

Authoring

5.1. Decision tables in spreadsheets

Decision tables are a "precise yet compact" way of representing conditional logic, and are well suited to *business* level rules.

JBoss Rules supports managing rules in a Spreadsheet format. Formats supported are Excel, and CSV. Meaning that a variety of spreadsheet programs (such as Microsoft Excel, OpenOffice.org Calc amongst others) can be utalized. It is expected that web based decision table editors will be included in a near future release.

Decision tables are an old concept (in software terms) but have proven useful over the years. Very briefly speaking, in JBoss Rules decision tables are a way to generate rules driven from the data entered into a spreadsheet. All the usual features of a spreadsheet for data capture and manipulation can be taken advantage of.

5.1.1. When to use Decision tables

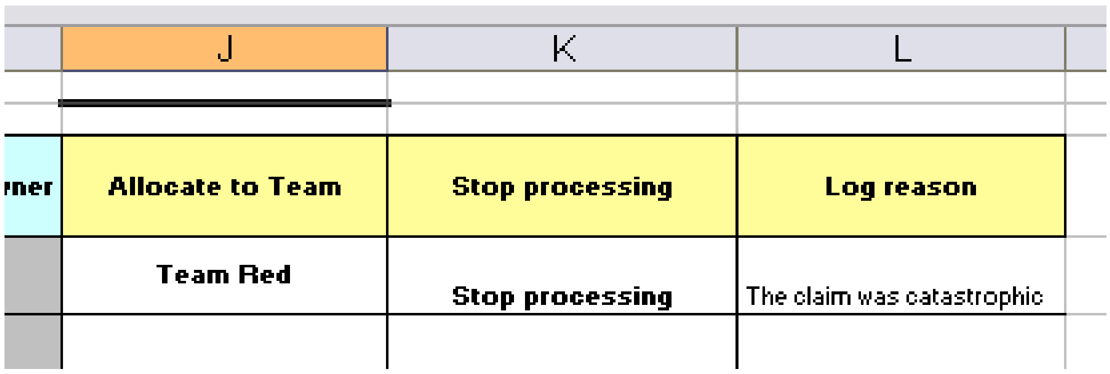
Decision tables my want to be considered as a course of action if rules exist that can be expressed as rule templates + data. In each row of a decision table, data is collected that is combined with the templates to generate a rule.

Many businesses already use spreadsheets for managing data, calculations etc. If you are happy to continue this way, you can also manage your business rules this way. This also assumes you are happy to manage packages of rules in .xls or .csv files. Decision tables are not recommenced for rules that do not follow a set of templates, or where there are a small number of rules (or if there is a dislike towards software like excel or open office). They are ideal in the sense that there can be control over what *parameters* of rules can be edited, without exposing the rules directly.

Decision tables also provide a degree of insulation from the underlying object model.

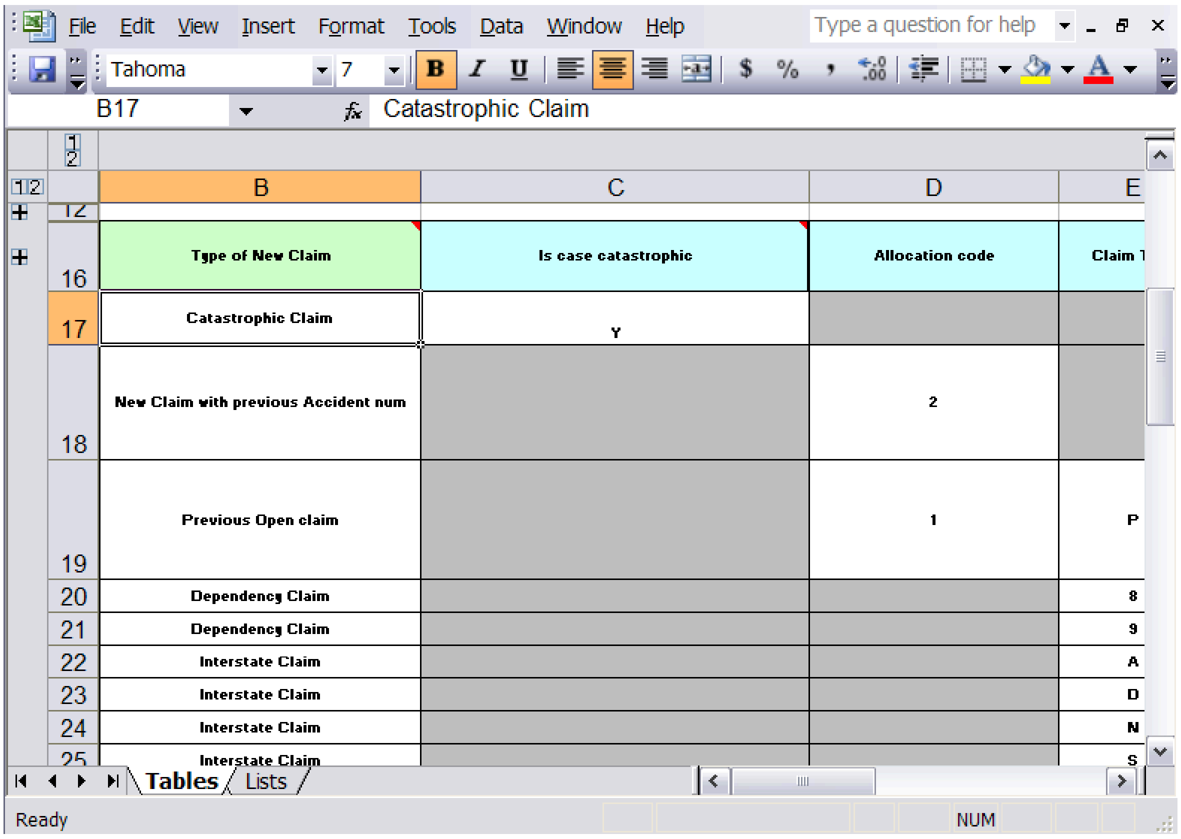
5.1.2. Overview

Here are some examples of real world decision tables.



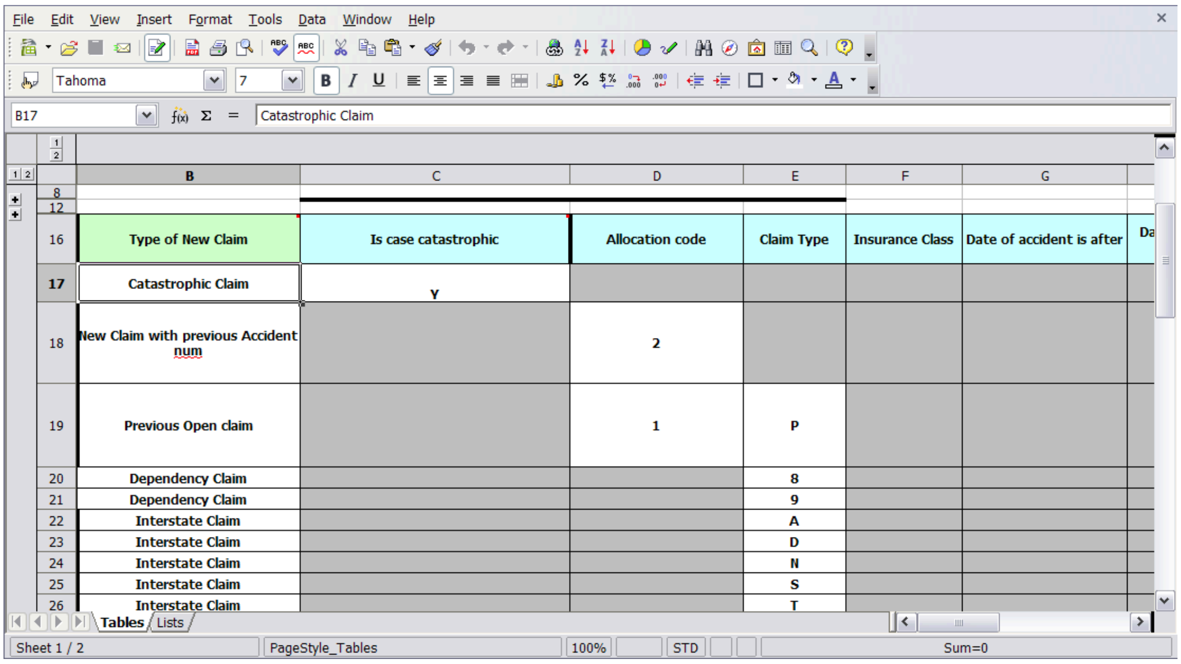
	J	K	L
ner	Allocate to Team	Stop processing	Log reason
	Team Red	Stop processing	The claim was catastrophic

Figure 5.1. Can have multiple actions for a rule row



	B	C	D	E
12				
16	Type of New Claim	Is case catastrophic	Allocation code	Claim T
17	Catastrophic Claim	Y		
18	New Claim with previous Accident num		2	
19	Previous Open claim		1	P
20	Dependency Claim			8
21	Dependency Claim			9
22	Interstate Claim			A
23	Interstate Claim			D
24	Interstate Claim			N
25	Interstate Claim			S

Figure 5.2. Using excel to edit a decision table



	B	C	D	E	F	G	
8							
12							
16	Type of New Claim	Is case catastrophic	Allocation code	Claim Type	Insurance Class	Date of accident is after	Da
17	Catastrophic Claim	Y					
18	New Claim with previous Accident num		2				
19	Previous Open claim		1	P			
20	Dependency Claim			8			
21	Dependency Claim			9			
22	Interstate Claim			A			
23	Interstate Claim			D			
24	Interstate Claim			N			
25	Interstate Claim			S			
26	Interstate Claim			T			

Figure 5.3. Using OpenOffice

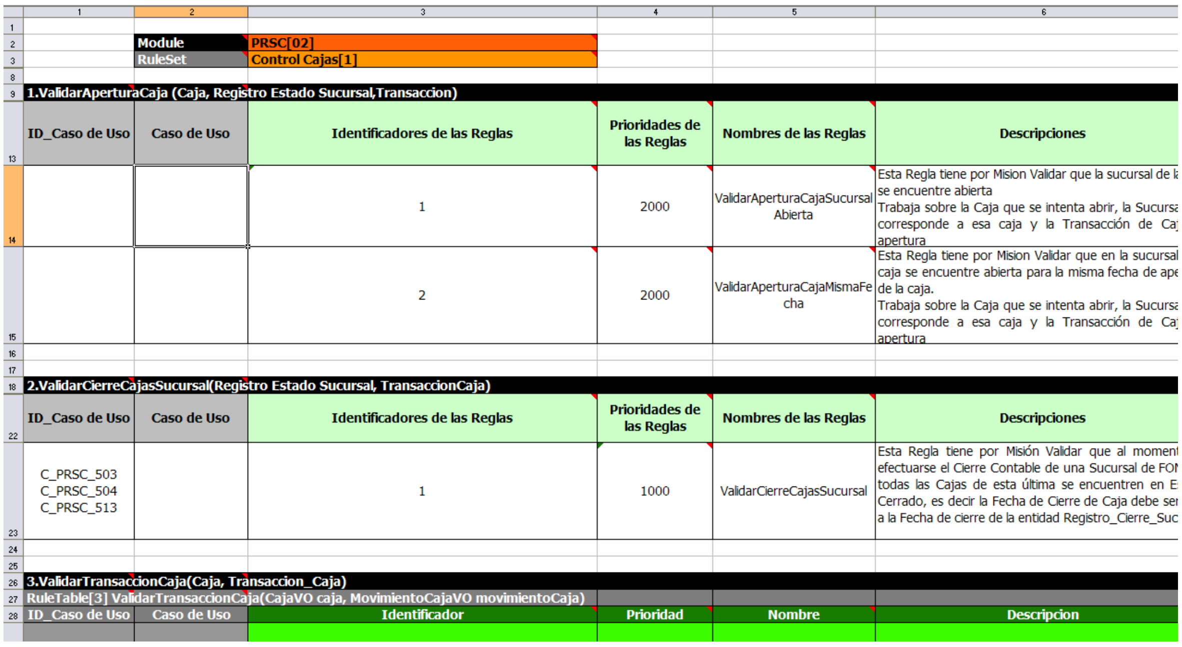
In the above examples, the technical aspects of the decision table have been collapsed away (standard spreadsheet feature).

The rules start from row 17 (each row results in a rule). The conditions are in column C, D, E etc.. (off screen are the actions). The value in the cells are quite simple, and have meaning when looking at the headers in Row 16. Column B is just a description. It is conventional to use color to make it obvious what the different areas of the table mean.

Note

Note that although the decision tables look like they process top down, this is not necessarily the case. Ideally, if the rules are able to be authored in such a way as order does not matter (simply as it makes maintenance easier, as rows will not need to be shifted around all the time).

As each row is a rule, the same principles apply. As the rule engine processes the facts, any rules that match may fire (some people are confused by this. It is possible to clear the agenda when a rule fires and simulate a very simple decision table where the first match exists). Also note that you can have multiple tables on the one spreadsheet (so rules can be grouped where they share common templates, yet at the end of the day they are all combined into a one rule package). Decision tables are essentially a tool to generate DRL rules automatically.

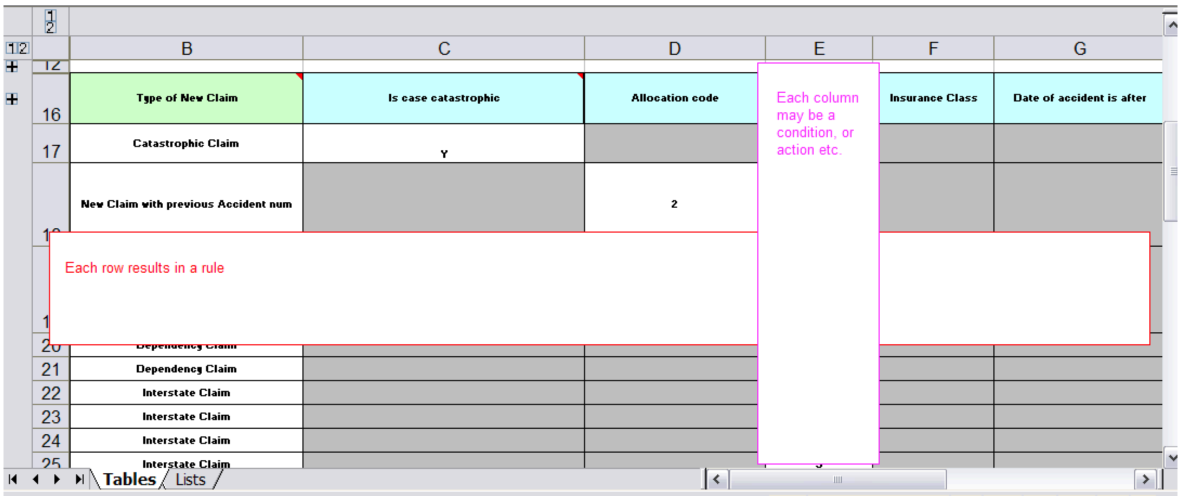


	1	2	3	4	5	6
1						
2		Module	PRSC[02]			
3		RuleSet	Control Cajas[1]			
8						
9	1.ValidarAperturaCaja (Caja, Registro Estado Sucursal,Transaccion)					
13	ID_Caso de Uso	Caso de Uso	Identificadores de las Reglas	Prioridades de las Reglas	Nombres de las Reglas	Descripciones
14			1	2000	ValidarAperturaCajaSucursalAbierta	Esta Regla tiene por Mision Validar que la sucursal de l se encuentre abierta Trabaja sobre la Caja que se intenta abrir, la Sucursa corresponde a esa caja y la Transacción de Ca apertura
15			2	2000	ValidarAperturaCajaMismaFecha	Esta Regla tiene por Mision Validar que en la sucursal caja se encuentre abierta para la misma fecha de ape de la caja. Trabaja sobre la Caja que se intenta abrir, la Sucursa corresponde a esa caja y la Transacción de Ca apertura
16						
17						
18	2.ValidarCierreCajasSucursal(Registro Estado Sucursal, TransaccionCaja)					
22	ID_Caso de Uso	Caso de Uso	Identificadores de las Reglas	Prioridades de las Reglas	Nombres de las Reglas	Descripciones
23	C_PRSC_503 C_PRSC_504 C_PRSC_513		1	1000	ValidarCierreCajasSucursal	Esta Regla tiene por Misión Validar que al moment efectuarse el Cierre Contable de una Sucursal de FO todas las Cajas de esta última se encuentren en E Cerrado, es decir la Fecha de Cierre de Caja debe se a la Fecha de cierre de la entidad Registro_Cierre_Suc
24						
25						
26	3.ValidarTransaccionCaja(Caja, Transaccion_Caja)					
27	RuleTable[3] ValidarTransaccionCaja(CajaVO caja, MovimientoCajaVO movimientoCaja)					
28	ID_Caso de Uso	Caso de Uso	Identificador	Prioridad	Nombre	Descripcion

Figure 5.4. Using multiple tables for grouping similar rules

5.1.3. How decision tables work

The key point to keep in mind is that in a decision table, each row is a rule, and each column in that row is either a condition or action for that rule.



	B	C	D	E	F	G
16	Type of New Claim	Is case catastrophic	Allocation code		Insurance Class	Date of accident is after
17	Catastrophic Claim	Y				
	New Claim with previous Accident num		2			
21	Dependency Claim					
22	Interstate Claim					
23	Interstate Claim					
24	Interstate Claim					
25	Interstate Claim					

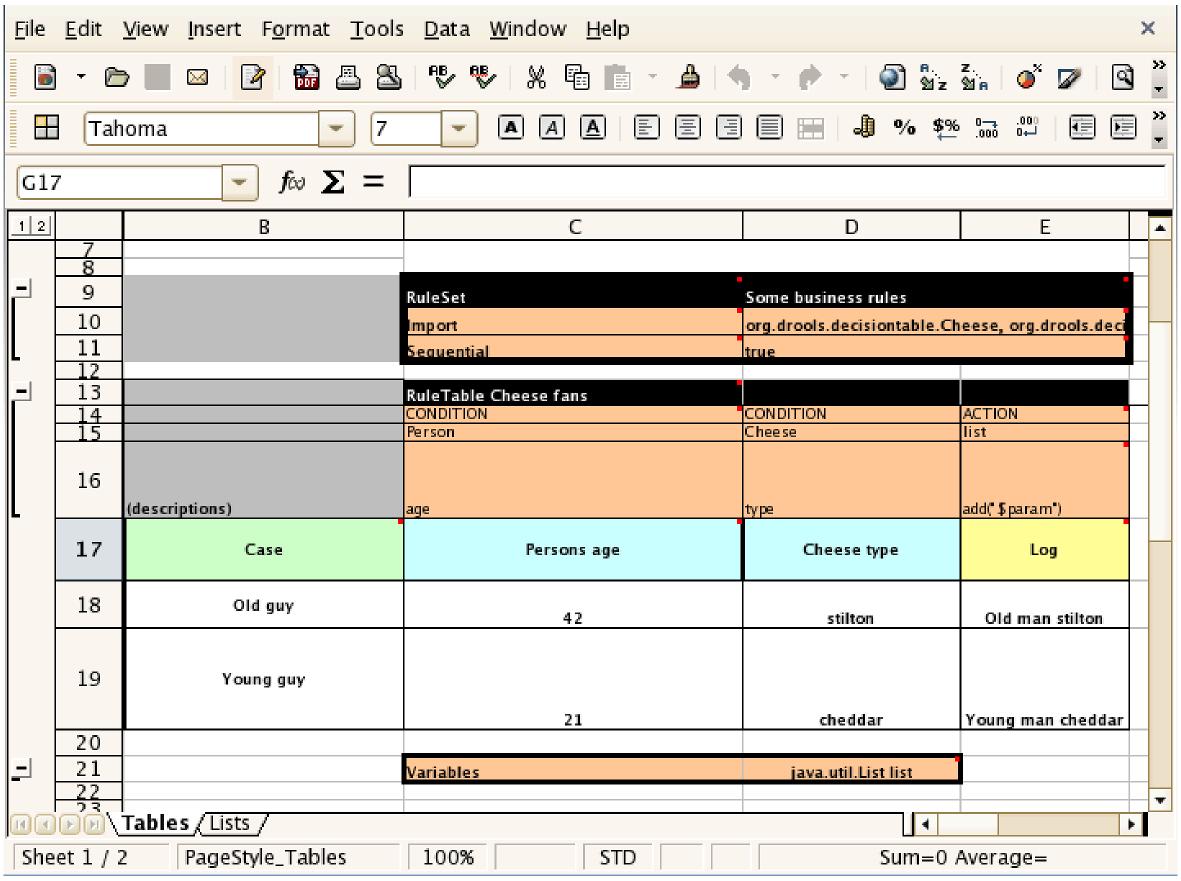
Each column may be a condition, or action etc.

Each row results in a rule

Figure 5.5. Rows and columns

The spreadsheet looks for the *RuleTable* keyword to indicate the start of a rule table (both the starting row and column). Other keywords are also used to define other package level attributes (covered later). It is important to keep the keywords in the one column. By convention the second column ("B") is used for this, but it can be any column (convention is to leave a margin on the left for notes). In the following diagram, C is actually the column where it starts. Everything to the left of this is ignored.

If we expand the hidden sections, it starts to make more sense how it works; note the keywords in column C.



	B	C	D	E
7				
8				
9		RuleSet	Some business rules	
10		Import	org.drools.decisiontable.Cheese, org.drools.deci	
11		Sequential	true	
12				
13		RuleTable Cheese fans		
14		CONDITION	CONDITION	ACTION
15		Person	Cheese	list
16	(descriptions)	age	type	add("$param")
17	Case	Persons age	Cheese type	Log
18	Old guy	42	stilton	Old man stilton
19	Young guy	21	cheddar	Young man cheddar
20				
21		Variables	java.util.List list	
22				

Figure 5.6. Expanded for rule templates

Now the hidden magic which makes it work can be seen. The RuleSet keyword indicates the name to be used in the *rule package* that all the rules will come under (the name is optional, it will have a default but it MUST have the *RuleSet* keyword) in the cell immediately to the right.

The other keywords visible in Column C are: Import, Sequential which will be covered later. The RuleTable keyword is important as it indicates that a chunk of rules will follow, based on some rule templates. After the RuleTable keyword there is a name - this name is used to prefix the generated rules names (the row numbers are appended to create unique rule names). The column of RuleTable indicates the column in which the rules start (columns to the left are ignored).

Note

In general the keywords make up name/value pairs.

Referring to row 14 (the row immediately after RuleTable): the keywords CONDITION and ACTION indicate that the data in the columns below are for either the LHS or the RHS parts of a rule. There are other attributes on the rule which can also be optionally set this way.

Row 15 contains declarations of *ObjectTypes* ; the content in this row is optional (if this option is not in use, a blank row must be left, however this option is usually found to be quite useful). When using this row, the values in the cells below (row 16) become constraints on that object type. In the above case, it will generate: Person(age=="42") etc (where 42 comes from row 18). In the above example, the "==" is implicit (if just a field name is given it will assume that it is to look for exact matches).

Note

An ObjectType declaration can span columns (via merged cells), meaning that all columns below the merged range will be combined into the one set of constraints.

Row 16 contains the rule templates themselves. They can use the "$para" place holder to indicate where data from the cells below will be populated ($param can be sued or $1, $2 etc to indicate parameters from a comma separated list in a cell below). Row 17 is ignored as it is textual descriptions of the rule template.

Row 18 to 19 shows data, which will be combined (interpolated) with the templates in row 15, to generate rules. If a cell contains no data, then its template is ignored (e.g. it means that condition, or action, does not apply for that rule-row). Rule rows are read until there is a BLANK row. Multiple RuleTables can exsist in a sheet. Row 20 contains another keyword, and a value. The row positions of keywords like this do not matter (most people put them at the top) but their column should be the same one where the RuleTable or RuleSet keywords should appear (in this case column C has been chosen to be significant, but column A could be used instead).

In the above example, rules would be rendered like the following (as it uses the "ObjectType" row):

```
//row 18
rule "Cheese_fans_18"
when
    Person(age=="42")
    Cheese(type=="stilton")
```

```
then
    list.add("Old man stilton");
end
```

Note

The [age=="42"] and [type=="stilton"] are interpreted as single constraints to be added to the respective ObjectType in the cell above (if the cells above were spanned, then there could be multiple constraints on one "column".

5.1.4. Keywords and syntax

5.1.4.1. Syntax of templates

The syntax of what goes in the templates is dependent on if it is a CONDITION column or ACTION column. In most cases, it is identical to *vanilla* DRL for the LHS or RHS respectively. This means in the LHS, the constraint language must be used, and in the RHS it is a snippet of code to be executed.

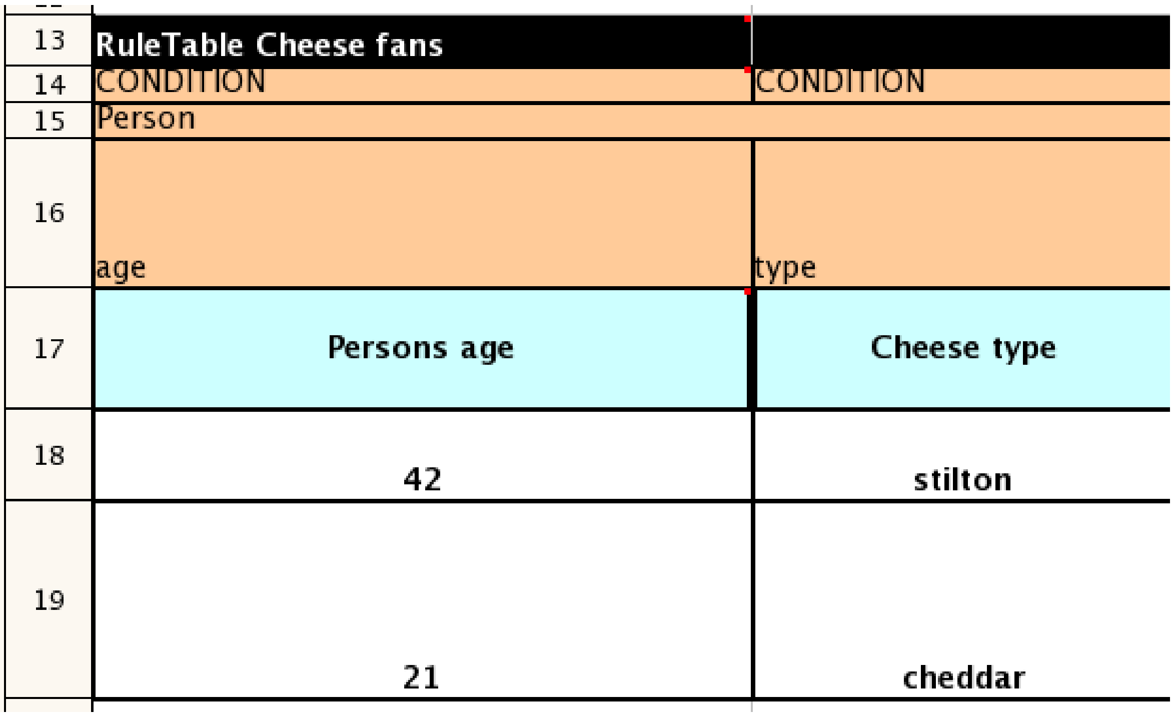
The `$param` place holder is used in templates to indicate where data form the cell will be interpolated. You can also use `$1` to the same effect. If the cell contains a comma separated list of values, $1 and $2 etc. may be used to indicate which positional parameter from the list of values in the cell will be used.

If the templates is [Foo(bar == $param)] and the cell is [42] then the result will be [Foo(bar == 42)] If the template is [Foo(bar < $1, baz == $2)] and the cell is [42,42] then the result will be [Foo(bar > 42, baz ==42)]

For conditions: How snippets are rendered depends on if there is anything in the row above (where ObjectType declarations may appear). If there is, then the snippets are rendered as individual constraints on that ObjectType. If there isn't, then they are just rendered as is (with values substituted). If just a plain field is entered (as in the example above) then it will assume this means equality. If another operator is placed at the end of the snippet, then the values will put interpolated at the end of the constraint, otherwise it will look for `$param` as outlined previously.

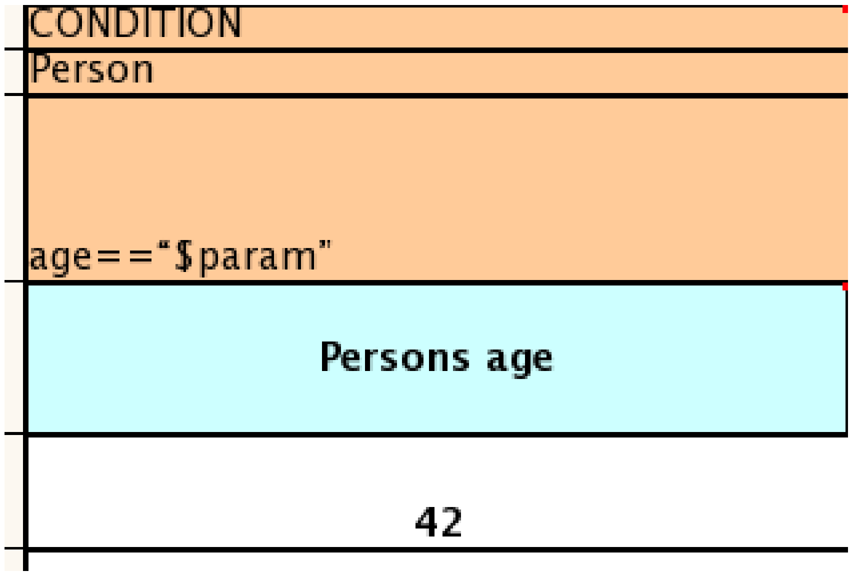
For consequences: How snippets are rendered also depends on if there is anything in the row immediately above it. If there is nothing there, the output is simple the interpolated snippets. If there is something there (which would typically be a bound variable or a global like in the example above) then it will append it as a method call on that object (refer to the above example).

This may be easiest to understand with some examples below.



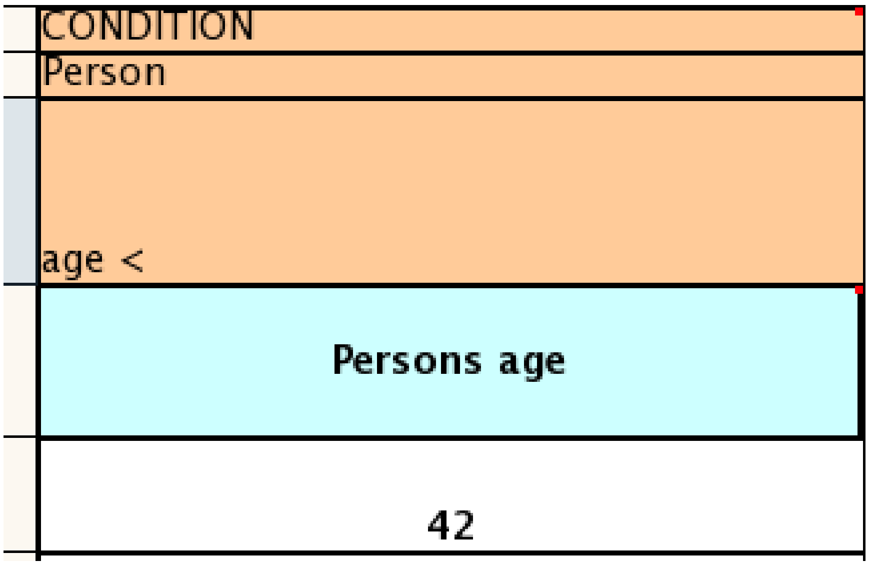
13	RuleTable Cheese fans	
14	CONDITION	CONDITION
15	Person	
16	age	type
17	Persons age	Cheese type
18	42	stilton
19	21	cheddar

The above shows how the Person ObjectType declaration spans 2 columns in the spreadsheet, thus both constraints will appear as Person(age == ... , type == ...). As before, as only the field names are present in the snippet, they imply an equality test.



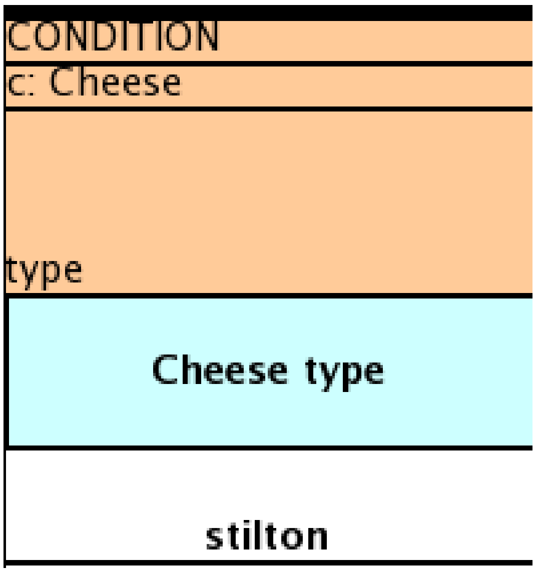
CONDITION
Person
age==“$param”
Persons age
42

The above condition example shows how you use interpolation to place the values in the snippet (in this case it would result in Person(age == "42")).



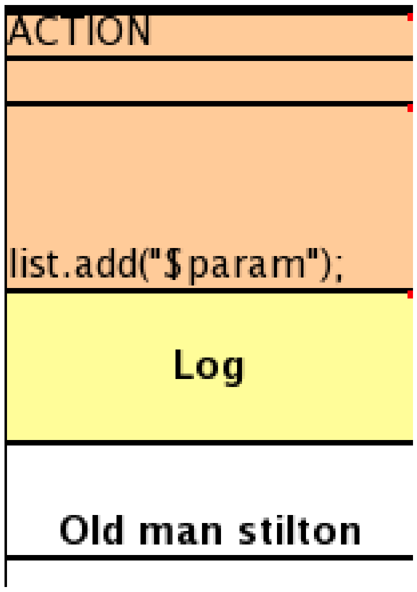
CONDITION
Person
age <
Persons age
42

The above condition example show that if you put an operator on the end by itself, the values will be placed after the operator automatically.



CONDITION
c: Cheese
type
Cheese type
stilton

A binding can be put in before the column (the constraints will be added from the cells below). Anything can be placed in the ObjectType row (e.g. it could be a pre condition for the columns in the spreadsheet columns that follow).



ACTION
list.add("$param");
Log
Old man stilton

This shows how the consequence could be done the by simple interpolation (just leave the cell above blank, the same applies to condition columns). With this style anything can be placed in the consequence (not just one method call).

5.1.4.2. Keywords

The following table describes the keywords that are pertinent to the rule table structure.

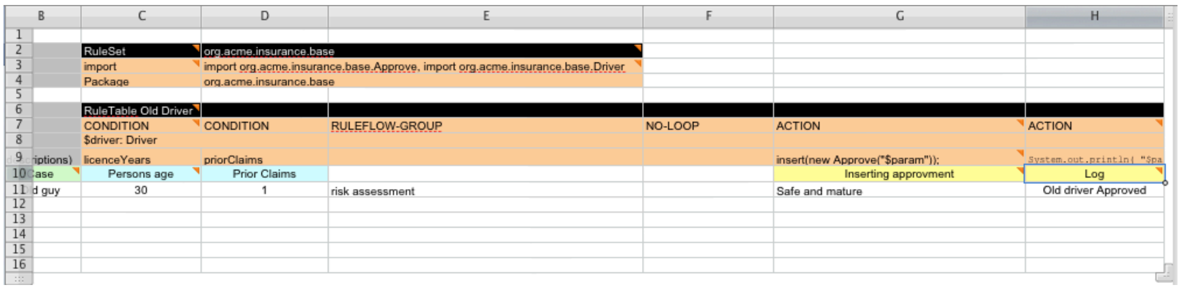
Keyword	Description	Inclusion Status
RuleSet	The cell to the right of this contains the ruleset name	One only (if left out, it will default)
Sequential	The cell to the right of this can be true or false. If true, then salience is used to ensure that rules fire from the top down	optional
Import	The cell to the right contains a comma separated list of Java classes to import	optional
RuleTable	A cell starting with RuleTable indicates the start of a definition of a rule table. The actual rule table starts the next row down. The rule table is read left-to-right, and top-down, until there is one BLANK ROW.	at least one. if there are more, then they are all added to the one ruleset
CONDITION	Indicates that this column will be for rule conditions	At least one per rule table
ACTION	Indicates that this column will be for rule consequences	At least one per rule table
PRIORITY	Indicates that this columns values will set the 'salience'	optional

Keyword	Description	Inclusion Status
	values for the rule row. Over-rides the 'Sequential' flag.	
DURATION	Indicates that this columns values will set the duration values for the rule row.	optional
NAME	Indicates that this columns values will set the name for the rule generated from that row	optional
Functions	The cell immediately to the right can contain functions which can be used in the rule snippets. JBoss Rules supports functions defined in the DRL, allowing logic to be embedded in the rule, and changed without hard coding, use with care. Same syntax as regular DRL.	optional
Variables	The cell immediately to the right can contain global declarations which JBoss Rules supports. This is a type, followed by a variable name. (if multiple variables are needed, comma separate them).	optional
No-loop or Unloop	Placed in the header of a table, no-loop or unloop will both complete the same function of not allowing a rule (row) to loop. For this option to function correctly, there must be a value (true or false) in the cell for the option to take effect. If the cell is left blank then this option will not be set for the row.	optional
XOR-GROUP	Cell values in this column mean that the rule-row belongs to the given XOR/activation group . An Activation group means that only one rule in the named group will fire (ie the first one to fire cancels the other rules activations).	optional
AGENDA-GROUP	Cell values in this column mean that the rule-row belongs to the given agenda group (that is one way of controlling flow between	optional

Keyword	Description	Inclusion Status
	groups of rules - see also "rule flow").	
RULEFLOW-GROUP	Cell values in this column mean that the rule-row belongs to the given rule-flow group.	optional
Worksheet	By default, the first worksheet is only looked at for decision tables.	N/A

Table 5.1. Keywords

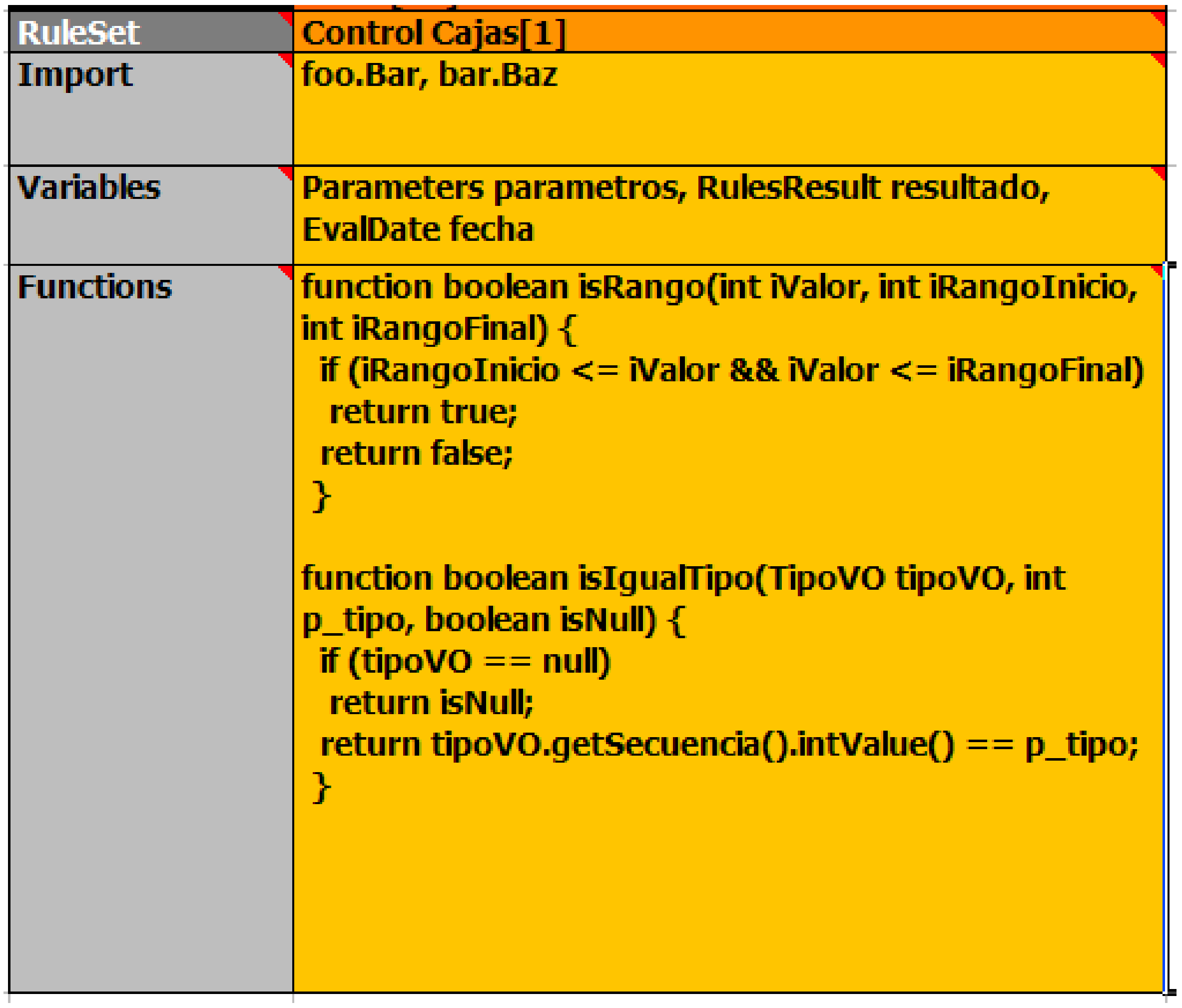
Below you will find examples of using the HEADER keywords, which effects the rules generated for each row. Note that the header name is what is important in most cases. If no value appears in the cells below it, then the attribute will not apply (it will be ignored) for that specific row.



	B	C	D	E	F	G	H
1							
2		RuleSet	org.acme.insurance.base				
3		import	import org.acme.insurance.base.Approve, import org.acme.insurance.base.Driver				
4		Package	org.acme.insurance.base				
5							
6		RuleTable Old Driver					
7		CONDITION	CONDITION	RULEFLOW-GROUP	NO-LOOP	ACTION	ACTION
8		$driver: Driver					
9	iptions)	licenceYears	priorClaims			insert(new Approve("$param"));	System.out.println("$pa
10	ase	Persons age	Prior Claims			Inserting approvment	Log
11	d guy	30	1	risk assessment		Safe and mature	Old driver Approved
12							
13							
14							
15							
16							

Figure 5.7. Example usage of keywords for imports, headers etc

The following is an example of Import (comma delimited), Variables (gloabls) - also comma delimited, and a function block (can be multiple functions - just the usual drl syntax). This can appear in the same column as the "RuleSet" keyword, and can be below all the rule rows if you desire.



RuleSet	Control Cajas[1]
Import	foo.Bar, bar.Baz
Variables	Parameters parametros, RulesResult resultado, EvalDate fecha
Functions	function boolean isRango(int iValor, int iRangoInicio, int iRangoFinal) { if (iRangoInicio <= iValor && iValor <= iRangoFinal) return true; return false; } function boolean isIgualTipo(TipoVO tipoVO, int p_tipo, boolean isNull) { if (tipoVO == null) return isNull; return tipoVO.getSecuencia().intValue() == p_tipo; }

Figure 5.8. Example usage of keywords for functions etc.

5.1.5. Creating and integrating Spreadsheet based Decision Tables

The API to use spreadsheet based decision tables is in the drools-decisiontables module. There is really only one class to look at: SpreadsheetCompiler. This class will take spreadsheets in various formats, and generate rules in DRL (which you can then use in the normal way). The SpreadsheetComiler can just be used to generate partial rule files if it is wished, and assemble it into a complete rule package after the fact (this allows the separation of technical and non-technical aspects of the rules if needed).

To get started, a sample spreadsheet can be used as base. Alternatively, if the plug-in is being used (Rule Workbench IDE), the wizard can generate a spreadsheet from a template (to edit it an xls compatible spreadsheet editor will need to be used).

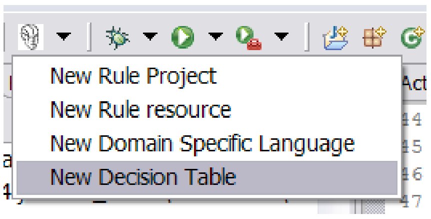


Figure 5.9. Wizard in the IDE

5.1.6. Managing business rules in decision tables.

5.1.6.1. Workflow and collaboration.

Spreadsheets are well established business tools (in use for over 25 years). Decision tables lend themselves to close collaboration between IT and domain experts, while making the business rules clear to business analysts, it is an ideal separation of concerns.

Typically, the whole process of authoring rules (coming up with a new decision table) would be something like:

1. Business analyst takes a template decision table (from a repository, or from IT)
2. Decision table business language descriptions are entered in the table(s)
3. Decision table rules (rows) are entered (roughly)
4. Decision table is handed to a technical resource, who maps the business language (descriptions) to scripts (this may involve software development of course, if it is a new application or data model)
5. Technical person hands back and reviews the modifications with the business analyst.
6. The business analyst can continue editing the rule rows as needed (moving columns around is also fine etc).
7. In parallel, the technical person can develop test cases for the rules (liaising with business analysts) as these test cases can be used to verify rules and rule changes once the system is running.

5.1.6.2. Using spreadsheet features

Features of applications like Excel can be used to provide assistance in entering data into spreadsheets, such as validating fields. Lists that are stored in other worksheets can be used to provide valid lists of values for cells, like in the following diagram.

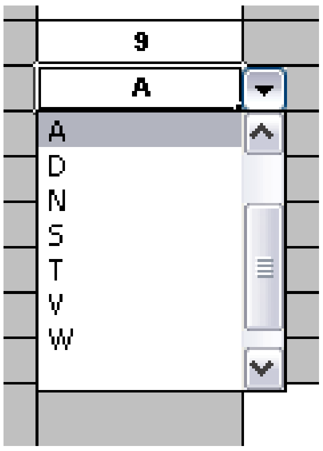


Figure 5.10. Wizard in the IDE

Some applications provide a limited ability to keep a history of changes, but it is recommended that an alternative means of revision control is also used. When changes are being made to rules over time, older versions are archived (many solutions exist for this which are also open source, such as Subversion). *http://www.drools.org/Business+rules+in+decision+tables+explained*

The Java Rule Engine API

6.1. Introduction

`JBoss Rules` provides an implementation of JSR94, the **`Java`** Rule Engine *Application Programming Interface* (API.) This implementation has the capacity to support multiple rule engines from a single API. JSR94 does not, in any way, deal with the rule language itself.

Note

The **`World Wide Web Consortium`** (W3C) is developing a *Rule Interchange Format* (RIF) *http://www.w3.org/TR/2006/WD-rif-ucr-20060323* and the **`Object Management Group`** (OMG) has started to create a standard based on *RuleML*, *http://ruleml.org*. In addition, **`Haley Systems`** has also recently proposed a rule language standard called RML.

It is important to remember that the JSR94 standard represents the "lowest common denominator" in terms of features across rule engines. . This means that there is less functionality in the JSR94 API than can be found in the standard JBoss Rules API. So, by using JSR94, you forfeit the advantage of using the full capabilities of the JBoss Rules Rule Engine.

Further functionality, (such as "globals" and support for DRL, DSL and XML), can only be exposed via property maps due to the very basic nature of JSR94. However, by doing this, non-portable functionality is introduced. Furthermore, as JSR94 does not provide a rule language, you are only reducing complexity by a small fraction when you switch rule engines, with very little to gain from the move. So, whilst **`Red Hat`** will provide support for JSR94 if one insists upon using it, it is strongly recommend that you instead program against the JBoss Rules API.

6.2. How To Use

There are two parts of JSR94. The first part is the administrative API, which is used to build and register `RuleExecutionSets`. The second part is the runtime session, which is used to execute those `RuleExecutionSets`.

6.2.1. Building and Registering RuleExecutionSets

The `RuleServiceProviderManager` manages the registration and retrieval of `RuleServiceProviders`. The JBoss Rules `RuleServiceProvider` implementation is automatically registered via a static block when the class is loaded using `Class.forNamem`. This occurs in much the same way as it does for JDBC drivers.

```
// RuleServiceProviderImpl is registered to "http://drools.org/"
// via a static initialization block
Class.forName("org.drools.jsr94.rules.RuleServiceProviderImpl");

// Get the rule service provider from the provider manager.
RuleServiceProvider ruleServiceProvider =
  RuleServiceProviderManager.getRuleServiceProvider("http://drools.org/");
```

Example 6.1. Automatic `RuleServiceProvider` Registration

The `RuleServiceProvider` provides access to the `RuleRuntime` and `RuleAdministration`APIs. The `RuleAdministration` provides an administration API for the management of `RuleExecutionSets`. This makes it possible to register a `RuleExecutionSet` that can then be retrieved via the `RuleRuntime`.

You obviously need to create a `RuleExecutionSet` before it can be registered; `RuleAdministrator` provides factory methods to return either an empty `LocalRuleExecutionSetProvider` or `RuleExecutionSetProvider`. The `LocalRuleExecutionSetProvider` should be used to load a `RuleExecutionSet` from a local, non-serialisable source, such as a Stream. The `RuleExecutionSetProvider` can be used to load `RuleExecutionSets` from serializable sources, like DOM Elements or Packages.

Note

Both the "`ruleAdministrator.getLocalRuleExecutionSetProvider( null );`" and the "`ruleAdministrator.getRuleExecutionSetProvider( null );`" take "null" as a parameter. This is because the properties map for these methods is not currently used.

```
// Get the RuleAdministration
RuleAdministrator ruleAdministrator =
 ruleServiceProvider.getRuleAdministrator();
LocalRuleExecutionSetProvider ruleExecutionSetProvider =
  ruleAdministrator.getLocalRuleExecutionSetProvider( null );

// Create a Reader for the drl
URL drlUrl = new URL("http://mydomain.org/sources/myrules.drl");
Reader drlReader = new InputStreamReader(  drlUrl.openStream()  );

// Create the RuleExecutionSet for the drl
RuleExecutionSet ruleExecutionSet =
  ruleExecutionSetProvider.createRuleExecutionSet( drlReader, null );
```

Example 6.2. Registering a `LocalRuleExecutionSet` with the `RuleAdministrator` API

In the above example, "`ruleExecutionSetProvider.createRuleExecutionSet( reader, null )`" takes a null parameter for the properties map; however it can actually be used to provide configuration for the incoming source. When "null" is passed, the default is used to load the input as a DRL. The keys which are allowed for a map are "**source**" and "**dsl**". "**source**" takes "drl" or "xml" as its value. You set "**source**" to "drl" to load a DRL and, likewise, you set it to "xml" to load an XML source. ("xml" will ignore any "dsl" key/value settings.) The "**dsl**" key can take a Reader or a String (the contents of the DSL) as a value.

```
// Get the RuleAdministration
RuleAdministration ruleAdministrator =
 ruleServiceProvider.getRuleAdministrator();
LocalRuleExecutionSetProvider ruleExecutionSetProvider =
  ruleAdministrator.getLocalRuleExecutionSetProvider( null );

// Create a Reader for the drl
URL drlUrl = new URL("http://mydomain.org/sources/myrules.drl");
Reader drlReader = new InputStreamReader(  drlUrl.openStream()  );

// Create a Reader for the dsl and a put in the properties map
URL dslUrl = new URL("http://mydomain.org/sources/myrules.dsl");
Reader dslReader = new InputStreamReader( dslUrl.openStream()  );
Map properties = new HashMap();
properties.put( "source", "drl" );
properties.put( "dsl", dslReader );

// Create the RuleExecutionSet for the drl and dsl
RuleExecutionSet ruleExecutionSet =
  ruleExecutionSetProvider.createRuleExecutionSet( reader, properties );
```

Example 6.3. Specifying a DSL when registering a `LocalRuleExecutionSet`

You must specify the name to be used for the retrieval of a `RuleExecutionSet` when you register it. There is also a field for to "passing" properties; as this is currently unused, just pass "null."

```
// Register the RuleExecutionSet with the RuleAdministrator
String uri = ruleExecutionSet.getName();
ruleAdministrator.registerRuleExecutionSet(uri, ruleExecutionSet, null);
```

Example 6.4. Register the `RuleExecutionSet`

6.2.2. Using State-ful and Stateless `RuleSessions`

The Runtime, (obtained from the `RuleServiceProvider`), is used to create state-ful and stateless rule engine sessions.

```
RuleRuntime ruleRuntime = ruleServiceProvider.getRuleRuntime();
```

Example 6.5. Obtaining the `RuleRunTime`

In order to create a rule session, you must use one of the two public constants for `RuleRuntime`, namely "`RuleRuntime.STATEFUL_SESSION_TYPE`" or

"RuleRuntime.STATELESS_SESSION_TYPE." Additionally, you must provide the URI for the RuleExecutionSet for which you wish to instantiate a RuleSession. The properties map can be set to "null," or it can be used to specify globals, as shown in the next section. The createRuleSession(....) method returns a RuleSession instance which must then be cast to StatefulRuleSession or StatelessRuleSession.

```
(StatefulRuleSession) session =
  ruleRuntime.createRuleSession( uri,
                                 null,
                                 RuleRuntime.STATEFUL_SESSION_TYPE );
session.addObject( new PurchaseOrder( "lots of cheese" ) );
session.executeRules();
```

Example 6.6. State-ful Rule

The StatelessRuleSession has a very simple API; you can only call executeRules(List list) (which passes a list of objects), and an optional filter. The resulting objects are then returned.

```
(StatelessRuleSession) session =
  ruleRuntime.createRuleSession( uri,
                                 null,
                                 RuleRuntime.STATELESS_SESSION_TYPE );
List list = new ArrayList();
list.add( new PurchaseOrder( "even more cheese" ) );

List results = new ArrayList();
results = session.executeRules( list );
```

Example 6.7. Stateless Rule

6.2.2.1. Globals

It is possible to support globals with JSR94, albeit in a non-portable manner. This can be achieved by using a method whereby the properties map is passed to the RuleSession factory. Globals must be defined in either the DRL or XML file first, otherwise an exception will be thrown. The key represents the identifier declared in the DRL or XML and the value of the key is the instance that you wish be used in the execution. In the following example, the results are collected in a global java.util.List:

```
java.util.List globalList = new java.util.ArrayList( );
java.util.Map map = new java.util.HashMap( );
map.put( "list", globalList );
//Open a stateless Session
StatelessRuleSession srs =
  (StatelessRuleSession) runtime.createRuleSession( "SistersRules",
                                                    map,

 RuleRuntime.STATELESS_SESSION_TYPE );
...
// Persons added to List
// call executeRules( ) giving a List of Objects as parameter
// There are rules which will put Objects in the List
// fetch the list from the map
List list = (java.util.List) map.get("list");
```

Example 6.8. Globals

Do not forget to declare the global "list" in your DRL:

```
package SistersRules;
import org.drools.jsr94.rules.Person;
global java.util.List list
rule FindSisters
when
    $person1 : Person ( $name1:name )
    $person2 : Person ( $name2:name )
    eval( $person1.hasSister($person2) )
then
    list.add($person1.getName() + " and " + $person2.getName() +" are
 sisters");
    assert( $person1.getName() + " and " + $person2.getName() +" are
 sisters");
end
```

Example 6.9. Global List

6.3. References

If you need more information on JSR 94, please refer to the following references

1. Official JCP Specification for Java Rule Engine API (JSR 94)
    - *http://www.jcp.org/en/jsr/detail?id=94*
2. The Java Rule Engine API documentation
    - *http://www.javarules.org/api_doc/api/index.html*
3. The Logic From The Bottom Line: An Introduction to The Drools Project. By N. Alex Rupp, published on TheServiceSide.com in 2004

- *http://www.theserverside.com/articles/article.tss?l=Drools*

4. Getting Started With the Java Rule Engine API (JSR 94): Toward Rule-Based Applications. By Dr. Qusay H. Mahmoud, published on Sun Developer Network in 2005

    - *http://java.sun.com/developer/technicalArticles/J2SE/JavaRule.html*

5. Jess and the javax.rules API. By Ernest Friedman-Hill, published on TheServerSide.com in 2003

    - *http://www.theserverside.com/articles/article.tss?l=Jess*

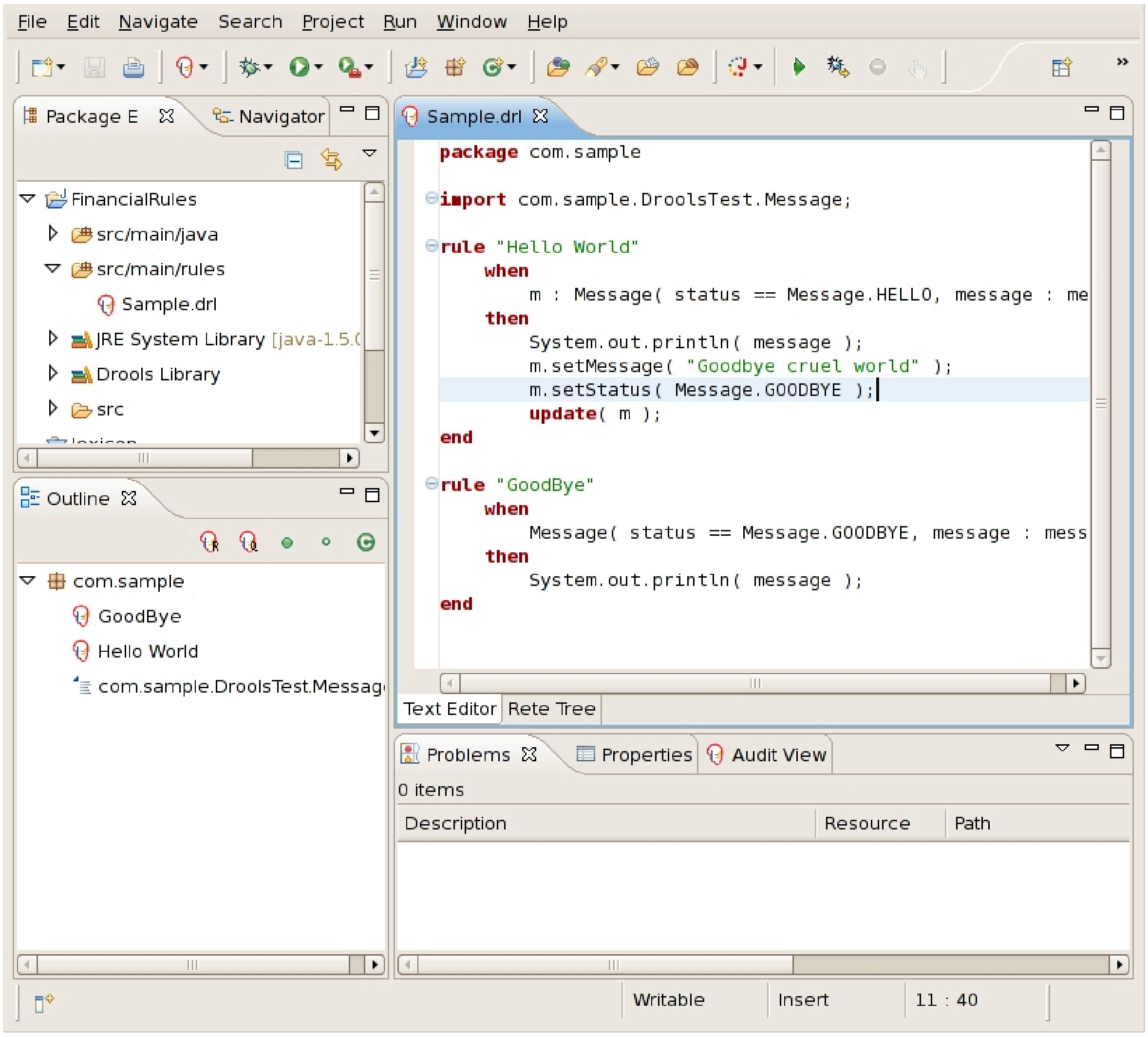
Updated The JBoss Rules IDE

The JBoss Developer Studio (JBDS) product is the supported *integrated development environment* (IDE) for JBoss Rules. It provides a set of features to ease the development of JBoss Rules assets.

Note

The JBoss Rules IDE components are also available separately as Eclipse plugins.

The authoring of JBoss Rules assets does not require the use of an IDE and the JBoss Rules engine is not dependent on the Eclipse environment.



```
package com.sample

import com.sample.DroolsTest.Message;

rule "Hello World"
	when
		m : Message( status == Message.HELLO, message : me
	then
		System.out.println( message );
		m.setMessage( "Goodbye cruel world" );
		m.setStatus( Message.GOODBYE );
		update( m );
end

rule "GoodBye"
	when
		Message( status == Message.GOODBYE, message : mess
	then
		System.out.println( message );
end
```

Figure 7.1. Overview

7.1. Outline of Features

The JBoss Rules IDE has the following features:

1. Textual/graphical rule editor

   a. An editor that is aware of DRL syntax, and provides content assistance (including an outline view)

   b. An editor that is aware of DSL (domain specific language) extensions, and provides content assistance.

2. RuleFlow graphical editor

   You can edit visual graphs which represent a process (a rule flow). The RuleFlow can then be applied to your rule package to have imperative control.

3. Wizards for fast creation of

   a. a "rules" project

   b. a rule resource, either as a DRL file or a "guided rule editor" file (.brl)

   c. a Domain Specific language

   d. a decision table

   e. a ruleflow

4. A domain specific language editor

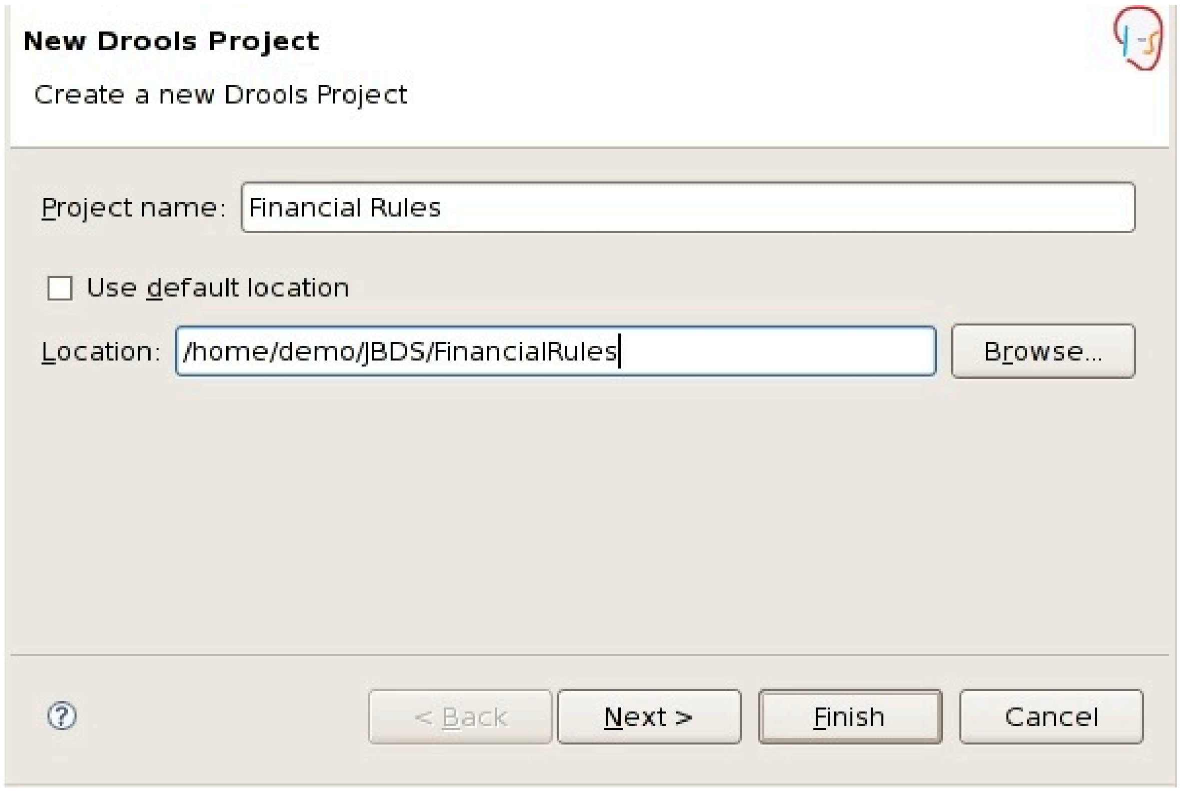
   a. Create and manage mappings from your user's language to the rule language

5. Rule validation

   a. As rules are entered, the rule is "built" in the background and errors reported via the problem view where possible

7.2. Creating a Rule Project

The aim of the new project wizard is to configure an executable "scaffold", with which once can start using rules immediately. This project will set-up a basic structure, classpath, sample rules and test case to start you on your way.



New Drools Project

Create a new Drools Project

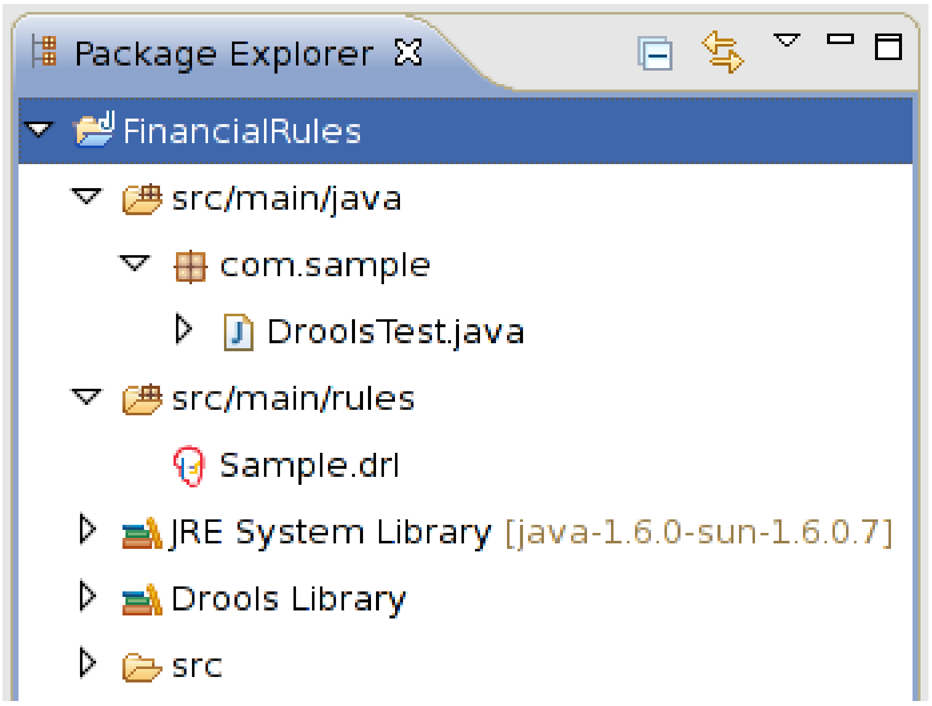
Project name: Financial Rules

☐ Use default location

Location: /home/demo/JBDS/FinancialRules

Figure 7.2. New Rule Project Scaffolding

When you choose to create a new "rule project" you will have the choice to add some default artifacts to it, like rules, decision tables, rule flows and so forth. These can serve as a starting point and will give you an executable almost immediately, which you can then modify. A simple "hello world" rule is shown below.



```
Package Explorer
FinancialRules
  src/main/java
    com.sample
      DroolsTest.java
  src/main/rules
    Sample.drl
  JRE System Library [java-1.6.0-sun-1.6.0.7]
  Drools Library
  src
```

Figure 7.3. New Rule Project Result

The newly created project contains an example rule file (**`Sample.drl`**) (which resides in the **`src/rules`** directory) and an example Java file (**`DroolsTest.java`**) that can be used to execute the rules in the JBoss Rules engine. This can be found in the **`src/java`** directory, (part of the `com.sample` package.) All the other **`.jars`** necessary for execution can also be added via a custom classpath container called **`JBoss Rules Library`**. Strictly speaking, rules do not have to be kept in "Java" projects at all but this is just a convenience for people who are already using JBDS or Eclipse as their Java IDE.

Important

The JBoss Developer Studio provides a feature called **`"JBoss Rules Builder"`** which automatically builds and validates your rules when their resources change. Projects created with the "Rule Project Wizard" have this enabled by default, but you can enable it manually on any project.

If you have any files with a large number of rules (500 or more) then this will generate a lot of processing since each rule will be rebuilt for all changes to those files. If this becomes a problem then you have two options. The easiest solution is to temporarily disable the builder. The other solution is to move the large rules into **`.rule`** files. The **`.rule`** files are ignored by the builder but you will need to run them in a unit test to validate the rules.

7.3. Creating a New Rule and Wizards

You can create a rule, by simply generating an empty text file with a "**`.drl`**". You can also use the wizard to do so. The wizard menu can be invoked with **`Control+N`**, or by choosing it from the toolbar, where there is a menu signified by the JBoss Rules icon.

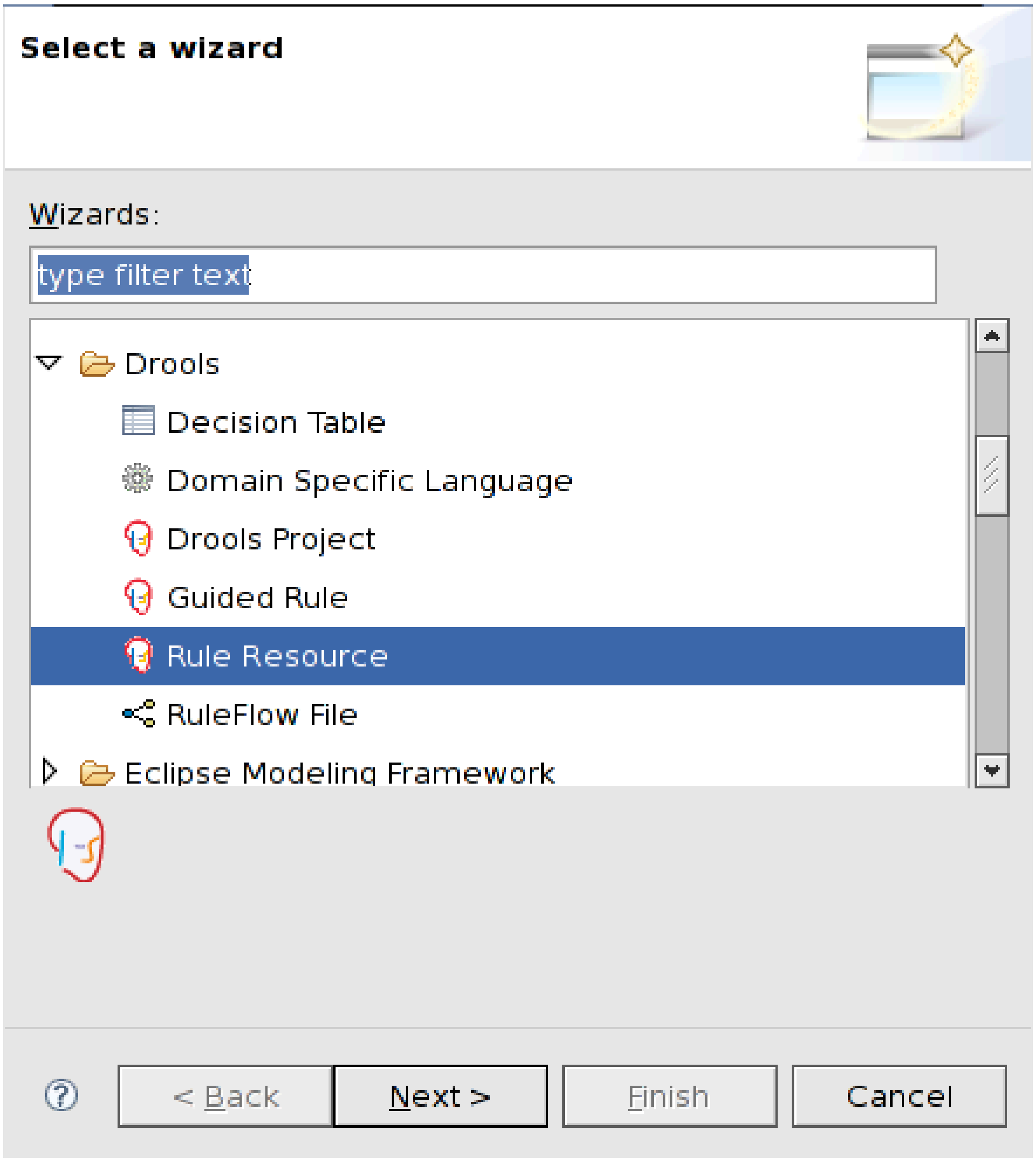
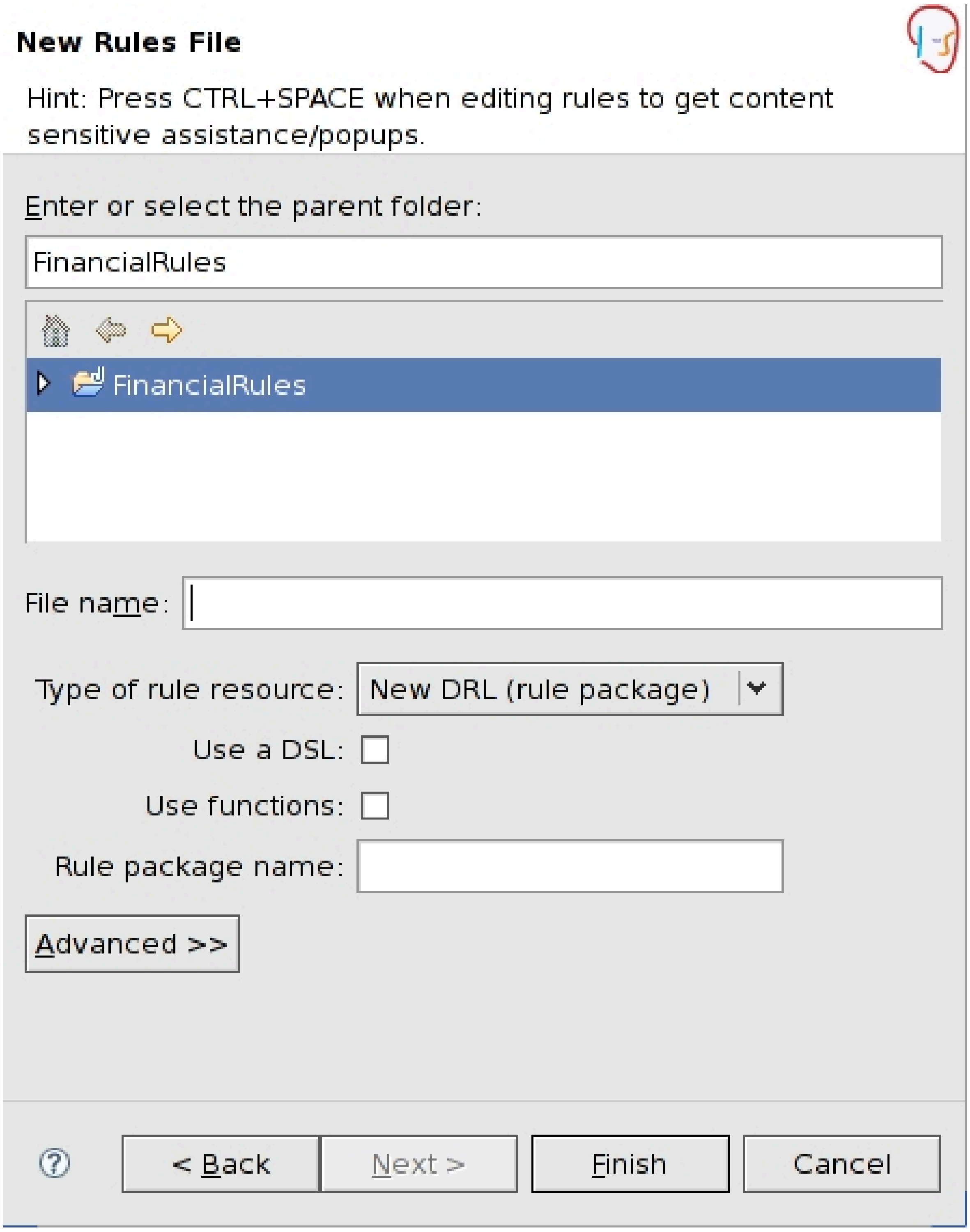


Figure 7.4. The Wizard Menu

The wizard will ask for some basic input for the options related to generating a rule resource. These are just hints: You can change your mind later. In order to storing rule files, you would typically create a directory called **`src/rules`** and add suitably named subdirectories. The package name is mandatory, and is similar to a package name in Java (in other words, it establishes a namespace for grouping related rules.)


New Rules File

Hint: Press CTRL+SPACE when editing rules to get content sensitive assistance/popups.

Enter or select the parent folder: FinancialRules

FinancialRules

File name:

Type of rule resource: New DRL (rule package)

Use a DSL: ☐

Use functions: ☐

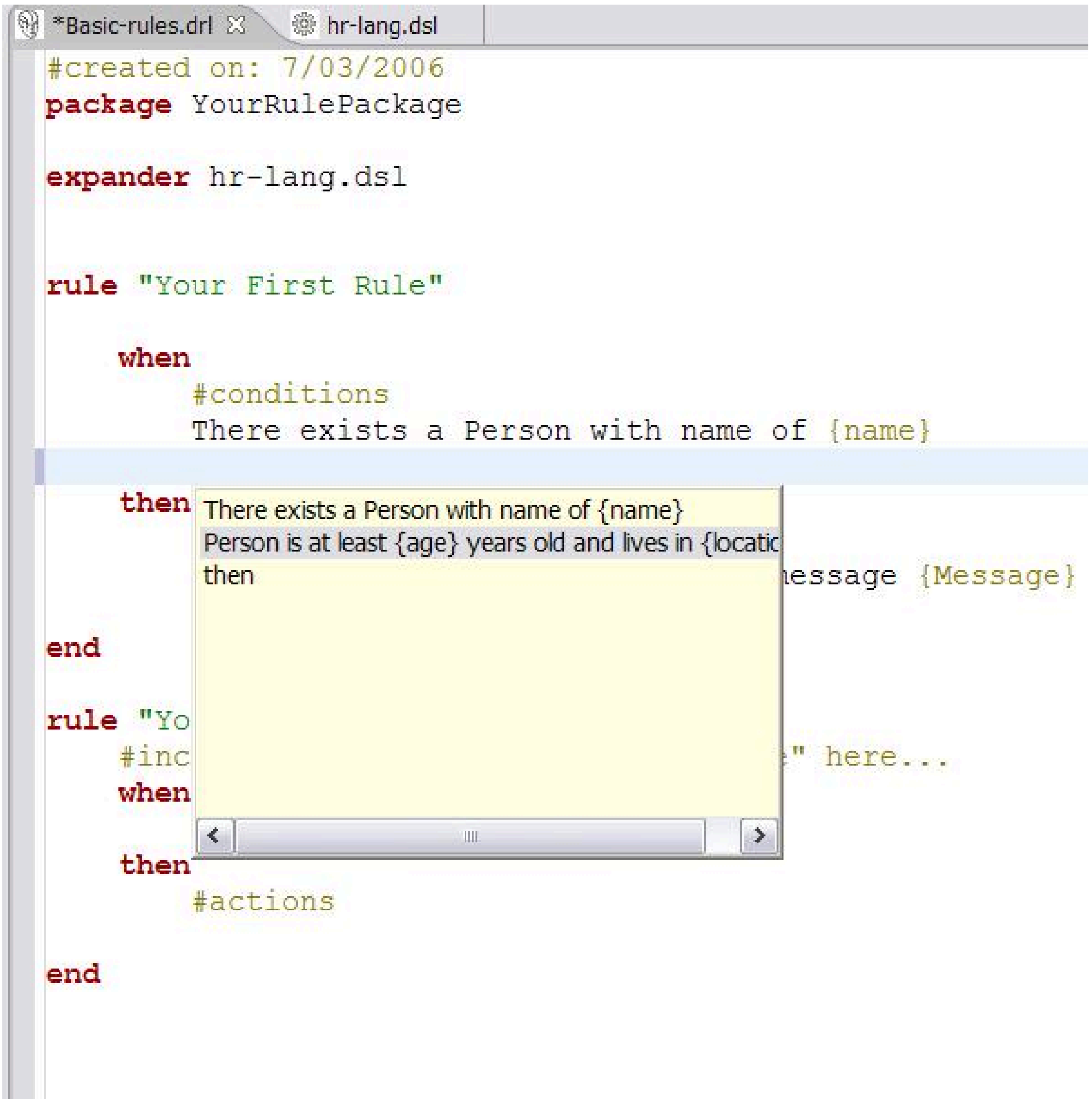
Rule package name:

Figure 7.5. New Rule Wizard

The result of running this wizard is a rule skeleton, which you can "flesh out." As with all wizards, it is merely an optional helper; you are not obligated to use it if you have no desire to do so.

7.4. Textual Rule Editor

The *Rule Editor* is the tool which rule managers and developers will be using most often. The Rule Editor follows the pattern of a normal text editor in Eclipse™ , as it has all of the customary features of such an application. On top of this, the rule editor provides "pop-up" content assistance. You can invoke pop-up content assistance in the normal way by pressing the Control and Space keys simultaneously.



```
#created on: 7/03/2006
package YourRulePackage

expander hr-lang.dsl


rule "Your First Rule"

    when
        #conditions
        There exists a Person with name of {name}

    then
                                             essage {Message}

end

rule "Yo
    #inc                                     " here...
    when

    then
        #actions

end
```

```
There exists a Person with name of {name}
Person is at least {age} years old and lives in {locatic
then
```

Figure 7.6. The Rule Editor in Action

The Rule Editor works on files that have a **`.drl`** (or **`.rule`**) extension. Usually these contain a number of related rules but it is also possible to have rules in individual files, grouped by virtue of being in the same package "namespace." These DRL files are plain text.

You can see from the example above that the rule group is using a domain specific language. Note the "`expander`" keyword, which tells the rule compiler to look for a **`.dsl`** file of that name, in order to resolve the rule language. Even with the Domain Specific Language (DSL) available, the rules are still stored as plain text mirroring what you see onscreen. This allows for much simpler management of rules and versions, when, for example, you are comparing versions of rules.

The editor has an outline view that is kept synchronised with the structure of the rules (it is updated when the file is saved.) This provides a quick way of navigating around rules by name, even in a file which may have hundreds of rules. By default, the items are sorted alphabetically.

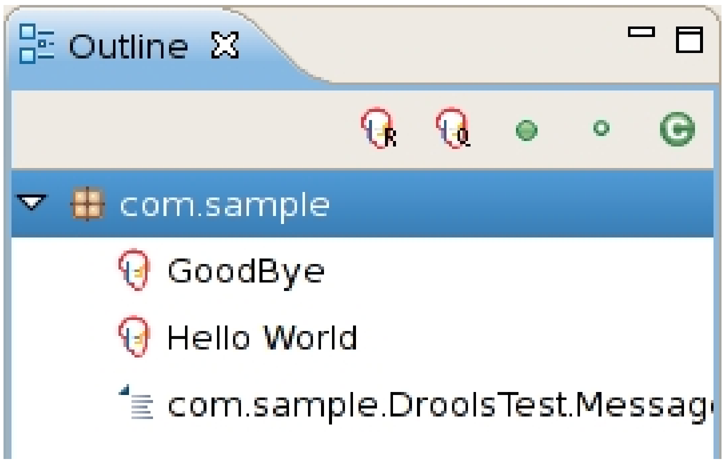


Figure 7.7. The Rule Outline View

7.5. The Guided Editor

A new JBoss Rules feature of JBoss Developer Studio is the *Guided Editor* for rules. This is similar to the web-based editor that is available in the BRMS. It allows you to build rules based on your object model in a graphically-driven fashion.

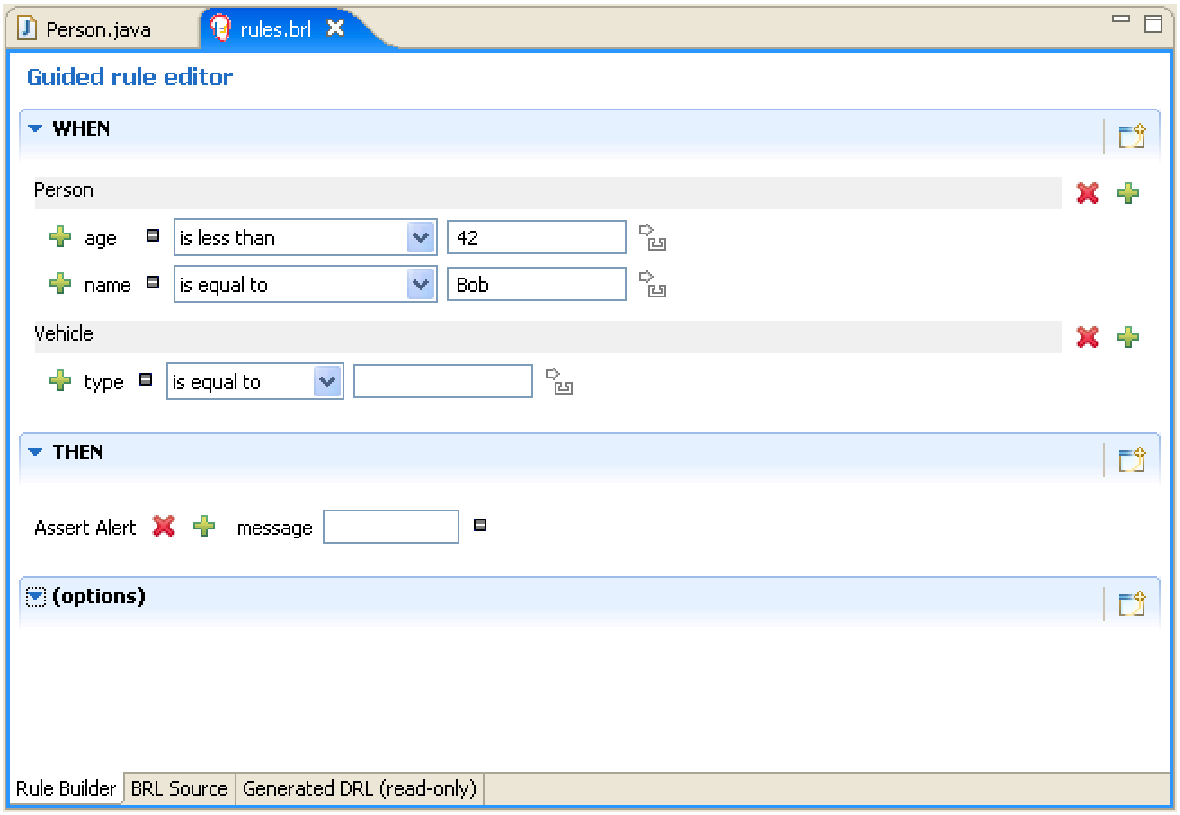


Figure 7.8. The Guided Editor

To create a rule this way, use the "Wizard" menu. From this, you create an instance of a **`.brl`** file and open it in the *Guided Editor*. This editor works via a **`.package`** file in the same directory as the **`.brl`** file. In this file there resides the package name and import statements, just like those you would find at the top of a normal **`.drl`** file. The first time you create a **`.brl`** rule, you will need to populate the package file with the "fact" classes in which you are interested. Once you have added this information, the Guided Editor will be able to prompt you with facts and their associated fields so that you can build rules graphically.

The Guided Editor works from the model or fact classes that have been configured by the user. It is then able to "render" the graphical representation of your rule to DRL. You can do this visually, which may be advantageous as a method to use in order to learn DRL. Alternatively, you can use it and then build rules in the business rules language directly. One way to do this is by using the `drools-ant` module, which is an **`ant`** task that creates all the rule assets as a rule package in a directory. This is so that you can then deploy it as a binary file. Alternatively, you can use the following snippet of code to convert the BRL to a **`.drl`** rule.

```
BRXMLPersitence read = BRXMLPersitence.getInstance();
BRDRLPersistence write = BRDRLPersistence.getInstance();
String brl = ... // read from the .brl file as needed...
String outputDRL = write.marshall(read.unmarshal(brl));
// Pass the outputDRL to the PackageBuilder, as usual
```

Example 7.1. Conversion Code

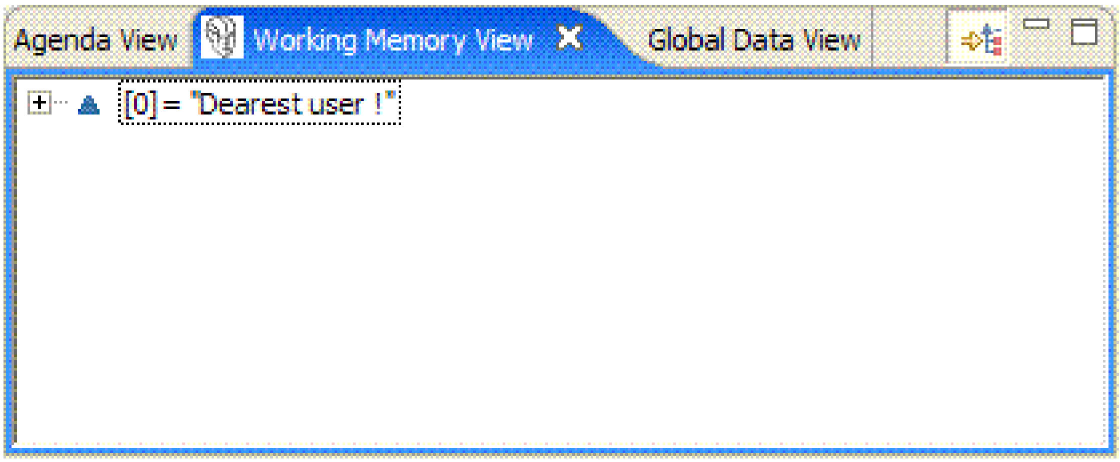
7.6. JBoss Rules Views

A number of views can be used to check the state of the JBoss Rules engine when you are debugging an application with it. These views are the Working Memory View, the Agenda View and the Global Data View. To use these views, create breakpoints in your code that invoke the working memory. For example, the line whereby you call `workingMemory.fireAllRules()` is a good candidate. If the debugger halts at that `joinpoint`, you should select the working memory variable in the Debugging Variables view. The following rules can then be used to show the details of the selected working memory:

1. The Working Memory View shows all of the elements in JBoss Rules' working memory.
2. The Agenda View shows all elements on the agenda. The name and bound variables are shown for each rule
3. The Global Data View shows all global data currently defined in the JBoss Rules working memory.

The Audit View is used to display, in a tree form, audit logs that were generated during the execution of a rules engine.

7.6.1. The Working Memory View



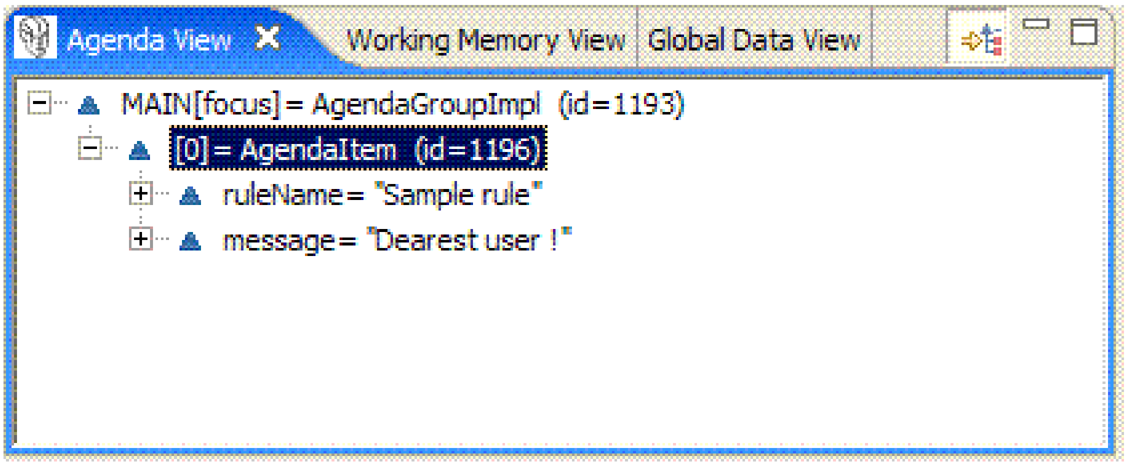
[0] = "Dearest user !"

The *Working Memory View* shows all of the elements in the working memory of the JBoss Rules engine.

In order to customise what is shown, an action is added to the right of the view:

1. The "Show Logical Structure" option toggles between two options, that of showing the logical structure of the elements in the working memory, and that of showing all of their details. Logical structures allow the user to visualise sets of elements more easily and clearly.

7.6.2. The Agenda View



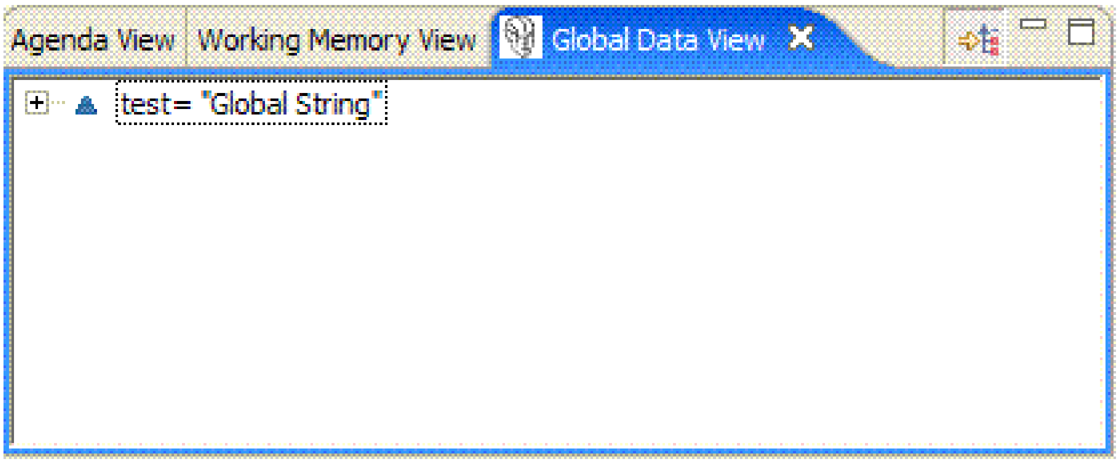
```
MAIN[focus] = AgendaGroupImpl (id=1193)
  [0] = AgendaItem (id=1196)
    ruleName= "Sample rule"
    message= "Dearest user !"
```

The *Agenda View* shows all elements on the agenda. The name and bound variables are shown for each rule.

An action is added to the right of the view, in order to customize that which is shown:

1. The "Show Logical Structure" option toggles between two options, that of showing the logical structure of the elements in the working memory, and that of showing all of their details. Logical structures allow the user to visualise sets of elements more easily and clearly. The logical structure of `AgendaItems` shows the rule that is represented by the `AgendaItem`, and the values of all the parameters used in the rule.

7.6.3. The Global Data View



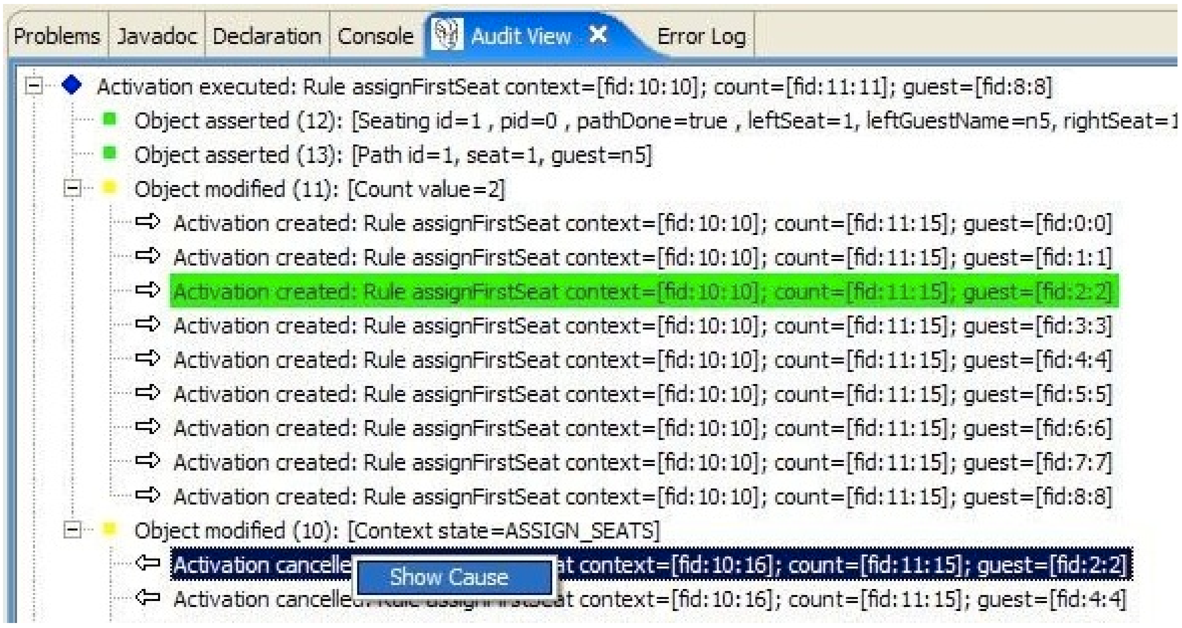
```
test= "Global String"
```

The *Global Data View* shows all of the global data currently defined in the JBoss Rules engine.

An action is added to the right of the view, to customize that information which is shown:

1. The "Show Logical Structure" option toggles between two options, that of showing the logical structure of the elements in the working memory, and that of showing all of their details. Logical structures allow the user to visualise sets of elements more easily and clearly.

7.6.4. The Audit View



```
Activation executed: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:11]; guest=[fid:8:8]
    Object asserted (12): [Seating id=1 , pid=0 , pathDone=true , leftSeat=1, leftGuestName=n5, rightSeat=1
    Object asserted (13): [Path id=1, seat=1, guest=n5]
    Object modified (11): [Count value=2]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:0:0]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:1:1]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:2:2]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:3:3]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:4:4]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:5:5]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:6:6]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:7:7]
        Activation created: Rule assignFirstSeat context=[fid:10:10]; count=[fid:11:15]; guest=[fid:8:8]
    Object modified (10): [Context state=ASSIGN_SEATS]
        Activation cancelle                 t context=[fid:10:16]; count=[fid:11:15]; guest=[fid:2:2]
        Activation cancelle                 t context=[fid:10:16]; count=[fid:11:15]; guest=[fid:4:4]
```

The *Audit View* displays an audit log that you can optionally create when you execute the rules engine. To create an audit log, simply use the following code:

```
WorkingMemory workingMemory = ruleBase.newWorkingMemory();
// Create a new Working Memory Logger, that logs to file.
WorkingMemoryFileLogger logger = new
 WorkingMemoryFileLogger(workingMemory);
// An event.log file is created in the subdirectory log (which must exist)
// of the working directory.
logger.setFileName( "log/event" );

workingMemory.assertObject(...);
workingMemory.fireAllRules();

// stop logging
logger.writeToDisk();
```

Example 7.2. Set Up Audit Log

Open the log by clicking the "Open Log" action (this is the first action in the Audit View) and select the file. The Audit View now displays all of the events that were logged during the executing of the rules. There are different types of events, each with a different icon. Here is a key to understanding the meaning of each:

1. Object inserted (green square)
2. Object updated (yellow square)
3. Object removed (red square)
4. Activation created (right arrow)

5. Activation cancelled (left arrow)
6. Activation executed (blue diamond)
7. Ruleflow started or ended ("process" icon)
8. Ruleflow group activated or deactivated ("activity" icon)
9. Rule package added or removed ("JBoss Rules" icon)
10. Rule added or removed (also the "JBoss Rules" icon)

All of these event records provide extra information about what has occurred. In the case of working memory events (such as insert, modify and retract), these details include the `id` and `toString` representation of the object. In case of an activation event (created, cancelled or executed), these include the name of the rule and all the variables bound in the activation.

Note

If an event occurs whilst an activation is being executed, it is depicted as a child of that execution.

You can retrieve the "cause" of some events:

1. The cause of an object "modification" or "retraction" is recorded as the last event for that object. This is either the "object asserted" or the last "object modified" event against that same object.
2. The cause of an "activation canceled" or "executed" event is the corresponding "activation created" event.

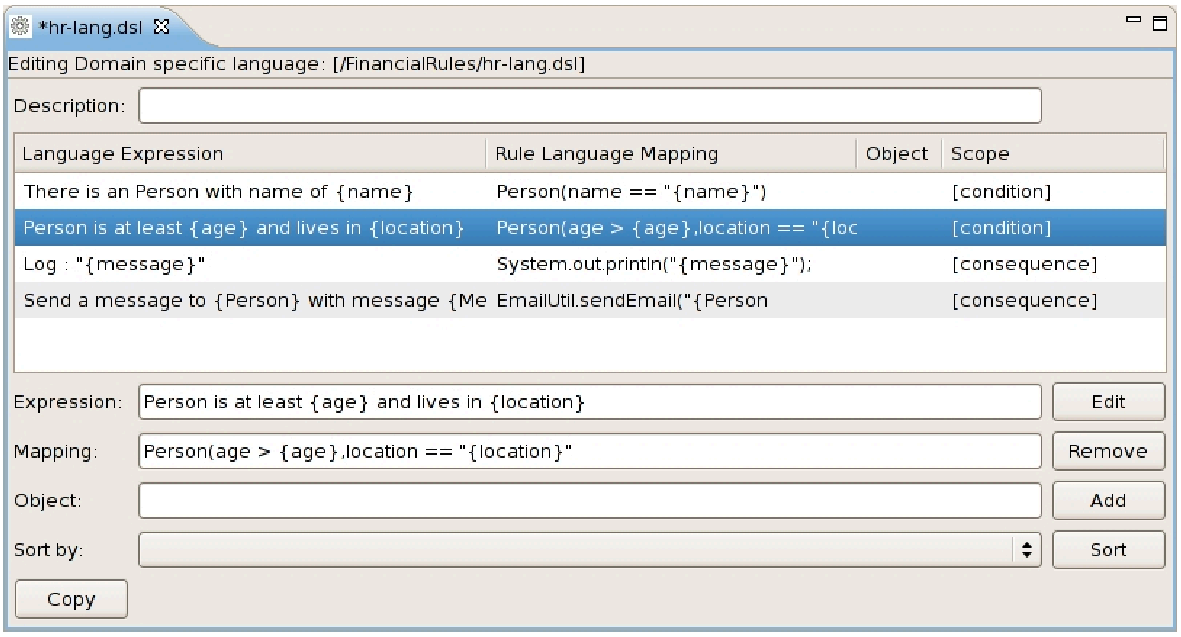
When you select an event, its cause, if visible, is shown in green in the Audit View. You can also right-click on the action and select the "Show Cause" menu item. This will scroll the display to the point where the cause is recorded.

7.7. Domain-Specific Languages

Domain-Specific Languages, (known as DSLs), allow you to create a custom language that allow you to write rules that look like English. More often than not, the domain-specific language reads like natural language. Typically, you note how a business analyst describes the rule in their own words, and then map this to your object model via rule constructs. An additional benefit of this is that it can provide an insulation layer between your domain objects, and the rules themselves. A domain-specific language will grow as the rules grow. It is most efficient when common terms are used repeatedly, albeit with different parameters.

To aid you in this work, the Rule Workbench provides an editor for domain-specific languages. (As the languages are stored in plain text format, you can use any editor you desire; the Rules Workbench tool simply has the advantage of providing a slightly-enhanced version of the "Properties" file format.) The editor will be invoked on any file with a **`.dsl`** extension (there is also a wizard to create a sample **`.dsl`** file).

7.7.1. Editing languages



Editing Domain specific language: [/FinancialRules/hr-lang.dsl]

Description:

Language Expression	Rule Language Mapping	Object	Scope
There is an Person with name of {name}	Person(name == "{name}")		[condition]
Person is at least {age} and lives in {location}	Person(age > {age},location == "{loc		[condition]
Log : "{message}"	System.out.println("{message}");		[consequence]
Send a message to {Person} with message {Me	EmailUtil.sendEmail("{Person		[consequence]

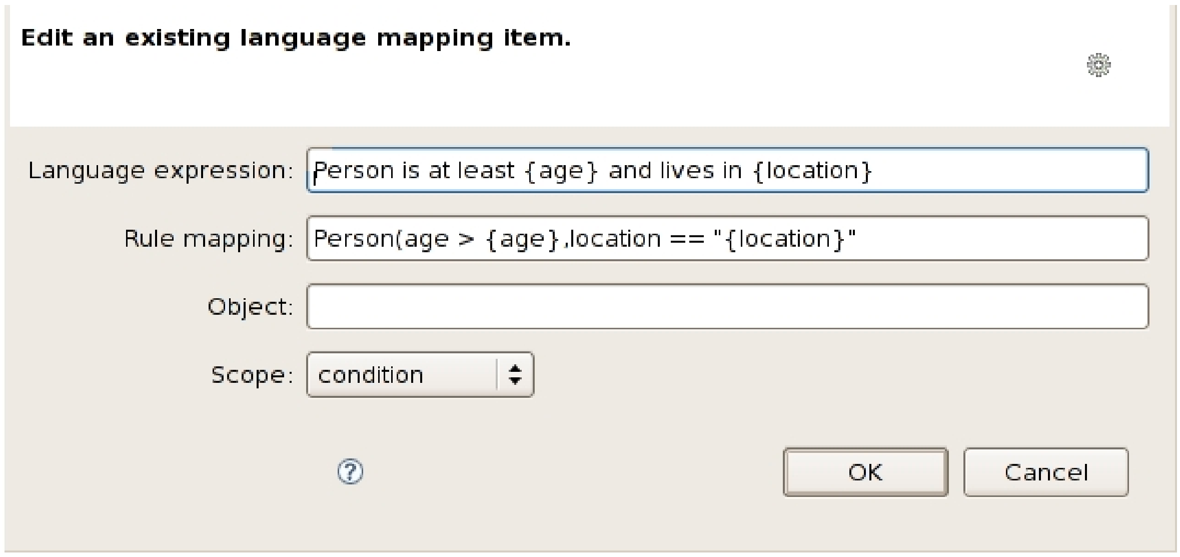
Expression:	Person is at least {age} and lives in {location}
Mapping:	Person(age > {age},location == "{location}"
Object:	
Sort by:	

Figure 7.9. The Domain-Specific Language Editor

The DSL Editor provides a tabular view of the mapping of Language-to-Rule expressions. The "Language Expressions" are those which are used in the rules. The DSL Editor also feeds the "content assistance" for the rule editor. This is so that it can suggest Language Expressions from the DSL configuration. (The Rule Editor loads the DSL configuration when the rule resource is opened for editing.) The "Rule" language mapping defines the "code" into which the Language Expressions will be compiled by the rule engine.

The form that a "Rule" language expression takes is dependent upon whether it is intended for the "condition" or the "action" part of the rule. (For the right-hand side it may. for instance, be a snippet of Java.) The "`scope`" item indicates where the expression belongs, "`when`" indicates the left-hand side, "`then`" the right-hand side, and "`*`" means "anywhere." It is also possible to create aliases for keywords.

When you select a mapping item (that is, a row in the table), you can see the expression and, indeed, the mapping itself, as per the "greyed-out" fields below. If you double-click or press the "edit" button, the "Edit" dialogue box will open. You can remove items, and add new ones. (Note that you should generally only remove items when you are certain that the expression is no longer in use.)


Edit an existing language mapping item.

Language expression: Person is at least {age} and lives in {location}

Rule mapping: Person(age > {age},location == "{location}"

Object:

Scope: condition

Figure 7.10. Language Mapping Editor Dialogue

The DSL translation process occurs in the following manner:

The parser reads the rule text in a DSL, line by line, and tries to match it against some "Language Expression", depending on the scope. After a match is made, the values that correspond to a placeholder between braces (such as **`{age}`**) are extracted from the rule source. The placeholders in the "Rule Expression" are replaced by their corresponding value. In the example above, the natural language expression maps to two constraints on a fact of the type "Person," based on the fields "age" and "location," and the **`{age}`** and **`{location}`** values that are extracted from the original rule text.

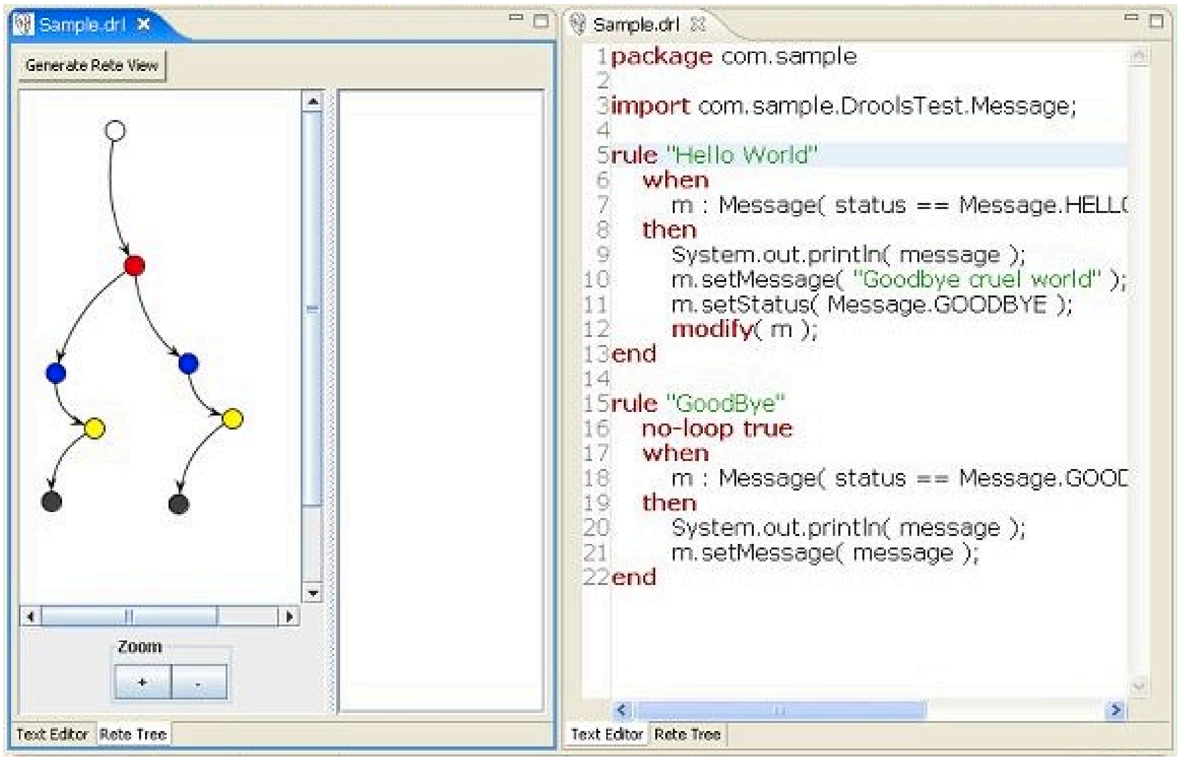
If you do not wish to use a language mapping for a particular rule in a **`.drl`** file, prefix the expression with > and the compiler will ignore it. Also, please note that Domain Specific Languages are optional. When the rule is compiled, the **`.dsl`** file will also need to be available.

7.8. The Rete View

The *Rete Tree View* shows you the current *Rete Network* for your **`.drl`** file. You can display it by clicking on the tab entitled "Rete Tree" at the bottom of the "DRL Editor" window. With the Rete Network visualization being open, you can "drag-and-drop" on individual nodes in order to arrange an optimal network overview. You can also select multiple nodes by dragging a rectangle over them; in that way, the entire group can be moved around. The Eclipse™ toolbar magnification icons can be used in the customary manner.

Note

A future version will include support for exporting the Rete Tree as an image. Until then if you require this then you can take a screenshot of it.



```
package com.sample

import com.sample.DroolsTest.Message;

rule "Hello World"
    when
        m : Message( status == Message.HELL
    then
        System.out.println( message );
        m.setMessage( "Goodbye cruel world" );
        m.setStatus( Message.GOODBYE );
        modify( m );
end

rule "GoodBye"
    no-loop true
    when
        m : Message( status == Message.GOOD
    then
        System.out.println( message );
        m.setMessage( message );
end
```

The Rete View is an advanced feature which takes full advantage of the Eclipse™ *Graphical Editing Framework* (GEF.)

Note that it only works in JBoss Rules Rule Projects, in which the JBoss Rules Builder is configured in the project´s properties.

If you are using JBoss Rules in another type of project whereby you have not created a Rule Project with the appropriate JBoss Rules Builder, you can use a workaround: Set up a little JBoss Rules Rule Project next to that on which you are working, put the needed libraries in it and also add the DRLs you want to inspect with the Rete View. Now, just click on the right tab in the DRL Editor below, then follow it by clicking on "Generate Rete View".

7.9. Large `.drl` Files

Depending on the JDK you use, it may be necessary to increase the "permanent generation" maximum size. Both **`SUN`** and **`IBM`**JDK have a permanent generation, whereas **`BEA`** JRockit™ does not.

To increase the permanent generation, start Eclipse™ with `-XX:MaxPermSize=###m`

Example: `c:\Eclipse\Eclipse.exe -XX:MaxPermSize=128m`

If you have sets of 4 000 or more rules, you should set the permanent generation to at least **`128 Mb`**.

Note

This may also apply more generally when you compiling large numbers of rules. This is because there are generally one or more classes per rule.

As an alternative to the above, you may put rules in a file with the "**`.rule`**" extension. If you do so, the background builder will not try to compile them upon each change, which may provide performance improvements, particularly if your IDE becomes sluggish when processing very large volumes of rules.

7.10. Debugging Rules

You can debug your rules during the execution of your JBoss Rules application. For instance, you can add break-points in the consequences of your rules, and whenever such a break-point is encountered during the execution of the rules, the processing is halted. You can then inspect the variables known at that point and use any of the default debugging actions to decide what should happen next, whether it be to step over, continue or so forth. You can also use the debugging views to inspect the content of the working memory and the agenda.

7.10.1. Creating Break-Points

You can add or remove rule break-points to **`.drl`** files in two ways, which are similar to adding breakpoints to Java files:

1. Double-click the ruler in the DRL Editor when you are on the line at which you want to add a break-point. Note that rule break-points can only be created in the consequence of a rule. Double-clicking on a line at which no break-point is allowed will do nothing.

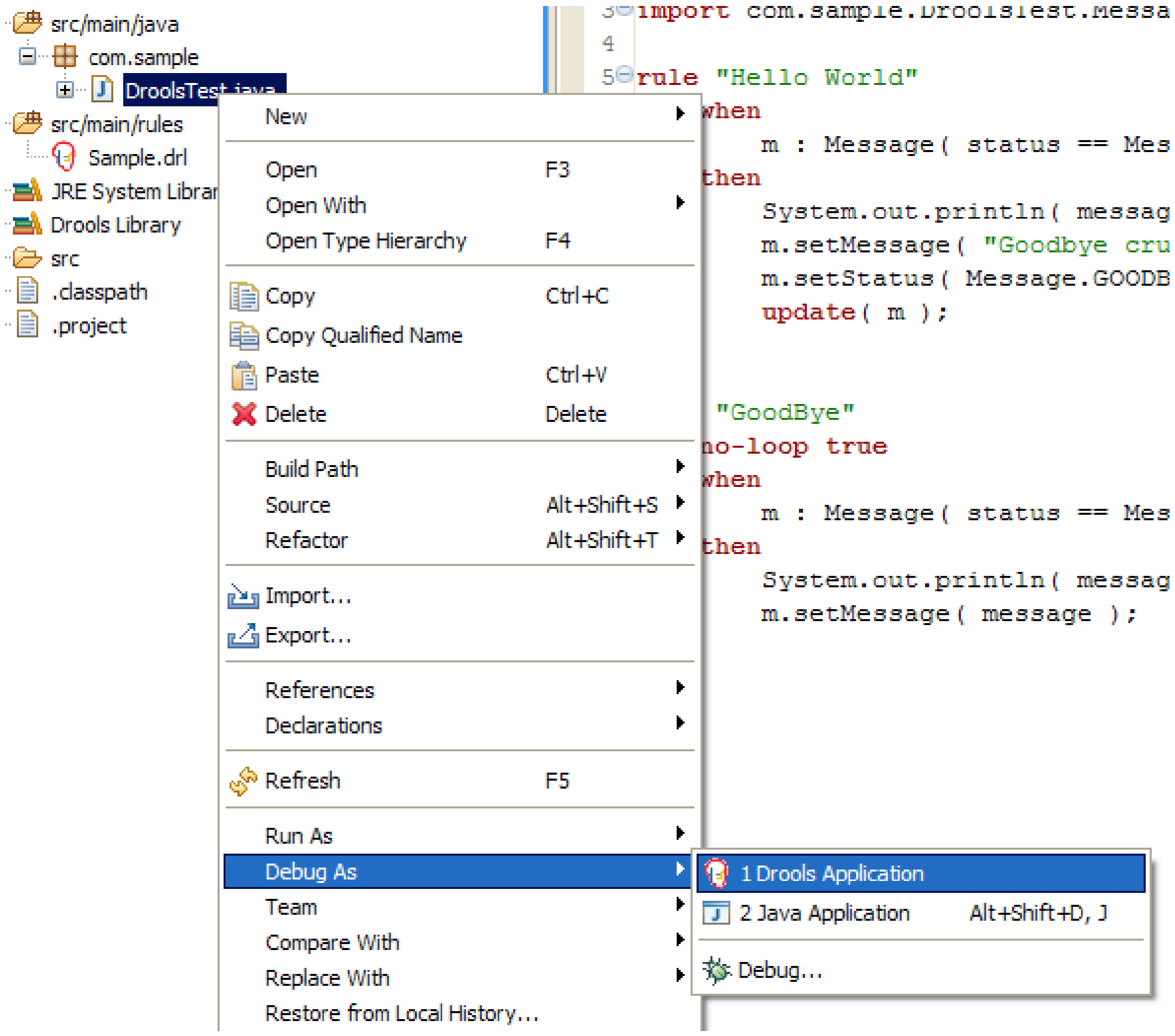
   A break-point can be removed by double-clicking the ruler once more.

2. If you right-click the ruler, a pop-up menu will present itself. It will contain the "Toggle Break-Point" option. Clicking the action will add a break-point at the selected line, or remove it if there was one already present.

The **`Debug Perspective`** contains a **`Break-Points View`** which can be used to see all defined break-points, obtain their properties, enable, disable or remove them and so forth.

7.10.2. Debugging Rules

Break-points are only enabled if you debug your program as a "JBoss Rules Application." You can do so like this:



```
import com.sample.DroolsTest.Messa

rule "Hello World"
when
    m : Message( status == Mes
then
    System.out.println( messag
    m.setMessage( "Goodbye cru
    m.setStatus( Message.GOODB
    update( m );


 "GoodBye"
no-loop true
when
    m : Message( status == Mes
then
    System.out.println( messag
    m.setMessage( message );
```

Figure 7.11. Debug as JBoss Rules Application

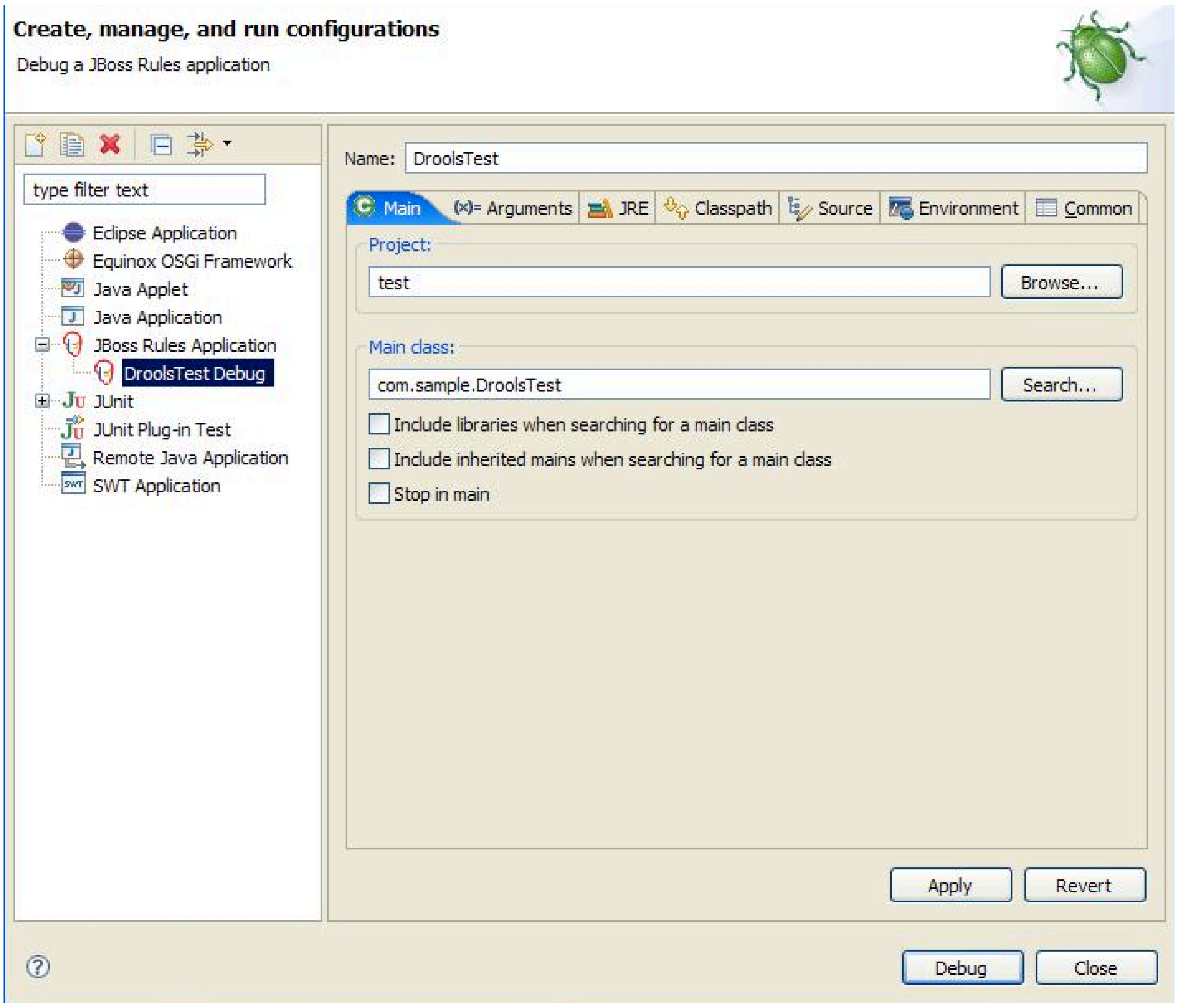
1. Select the main class of your application. Right click it and select the "**Debug As**" sub-menu and select "JBoss Rules Application." Alternatively, you can also select the "Debug ..." menu item to open a new dialog for creating, managing and running debug configurations (see the screenshot below.)

2. Select the "JBoss Rules Application" item in the left tree and click the "New launch configuration" button (leftmost icon in the toolbar above the tree). This will create a new configuration with some of the properties (like project and main class)already filled in, based on the main class you selected in the beginning. All properties shown here are the same as for any standard Java program.

3. Change the name of your debug configuration to something meaningful. You can just accept the defaults for all other properties. For more information about these properties, please check the Eclipse JDT documentation.

4. Click the "Debug" button on the bottom to start debugging your application. You only have to define your debug configuration once. The next time you run your JBoss Rules application, you don't have to create a new one but select the previously defined one in the tree on the left, as a sub-element of the "JBoss Rules Application" tree node, and then click the Debug button. The Eclipse toolbar also contains shortcut buttons to quickly re-execute one of your previous

configurations (at least when one of the Java, Java Debug, or JBoss Rules perspectives has been selected).


Create, manage, and run configurations

Debug a JBoss Rules application

Name: DroolsTest

Project: test

Main class: com.sample.DroolsTest

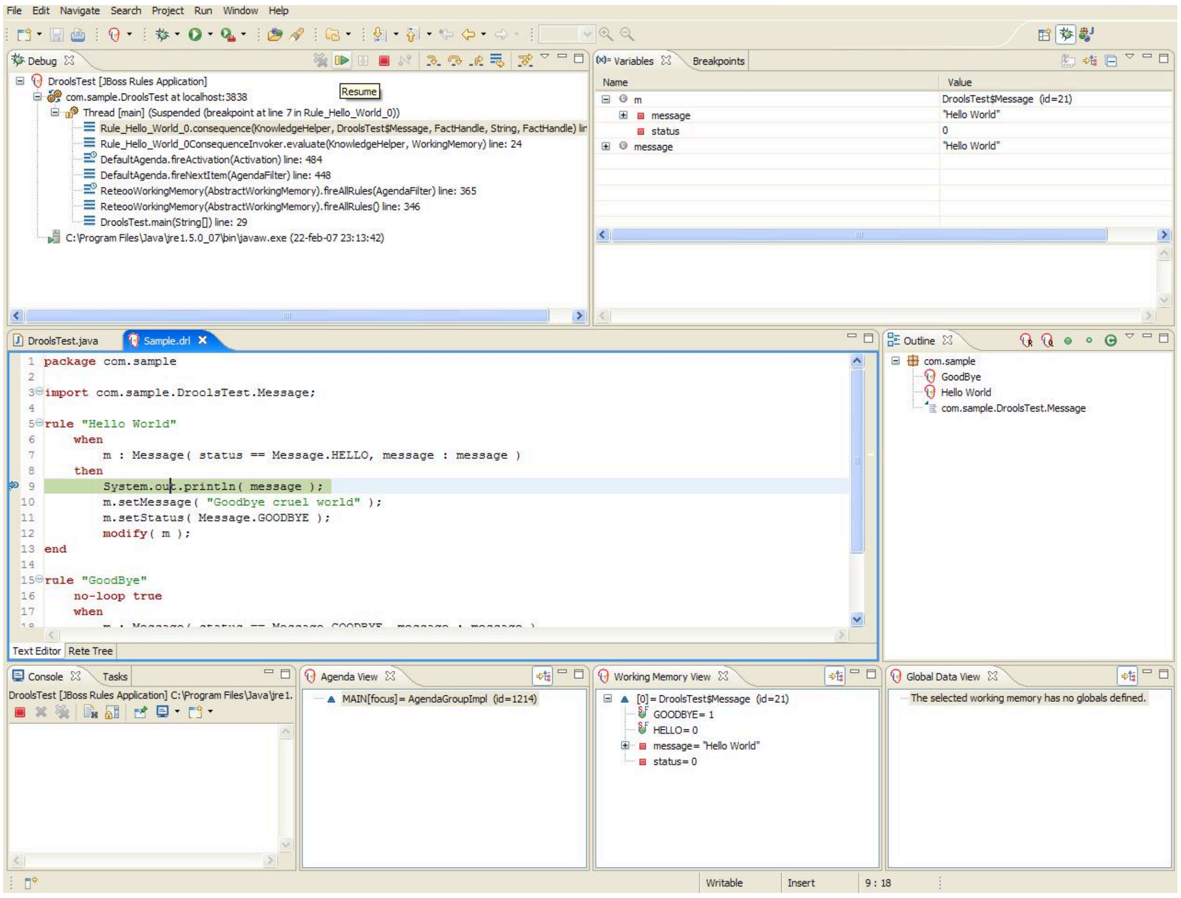
☐ Include libraries when searching for a main class

☐ Include inherited mains when searching for a main class

☐ Stop in main

Figure 7.12. "Debug as JBoss Rules Application" Configuration

After clicking the "Debug" button, the application starts executing and will halt if any break-point is encountered. This can be a JBoss Rules rule break-point, or any other standard Java break-point. Whenever a JBoss Rules rule break-point is encountered, the corresponding DRL file is opened and the active line is highlighted. The Variables view also contains all rule parameters and their value. You can then use the default Java debug actions to decide what to do next: resume, terminate, step over, etc. The debug view can also be used to inspect the contents of the Working Memory and the Agenda at that time as well. You don't have to select a Working Memory now, as the current executing working memory is automatically shown.



```
DroolsTest [JBoss Rules Application]
  com.sample.DroolsTest at localhost:3838
    Thread [main] (Suspended (breakpoint at line 7 in Rule_Hello_World_0))
      Rule_Hello_World_0.consequence(KnowledgeHelper, DroolsTest$Message, FactHandle, String, FactHandle) lir
      Rule_Hello_World_0ConsequenceInvoker.evaluate(KnowledgeHelper, WorkingMemory) line: 24
      DefaultAgenda.fireActivation(Activation) line: 484
      DefaultAgenda.fireNextItem(AgendaFilter) line: 448
      ReteooWorkingMemory(AbstractWorkingMemory).fireAllRules(AgendaFilter) line: 365
      ReteooWorkingMemory(AbstractWorkingMemory).fireAllRules() line: 346
      DroolsTest.main(String[]) line: 29
  C:\Program Files\Java\jre1.5.0_07\bin\javaw.exe (22-feb-07 23:13:42)
```

Name	Value
m	DroolsTest$Message (id=21)
message	"Hello World"
status	0
message	"Hello World"

```
package com.sample

import com.sample.DroolsTest.Message;

rule "Hello World"
    when
        m : Message( status == Message.HELLO, message : message )
    then
        System.out.println( message );
        m.setMessage( "Goodbye cruel world" );
        m.setStatus( Message.GOODBYE );
        modify( m );
end

rule "GoodBye"
    no-loop true
    when
```

```
com.sample
  GoodBye
  Hello World
  com.sample.DroolsTest.Message
```

DroolsTest [JBoss Rules Application] C:\Program Files\Java\jre1.

```
MAIN[focus] = AgendaGroupImpl  (id=1214)
```

```
[0] = DroolsTest$Message  (id=21)
  GOODBYE= 1
  HELLO= 0
  message= "Hello World"
  status= 0
```

The selected working memory has no globals defined.

Figure 7.13. Debugging

Updated. Examples

To use the examples which follow in this chapter, you need to download the **`Examples zip`** archive file. You can obtain this file from *http://download.jboss.org/drools/release/5.0.1.26597.FINAL/drools-5.0-examples.zip*

8.1. Hello World

Name:	HelloWorldExample
Main class:	**`org.drools.examples.HelloWorldExample`**
Type:	Java application
Objective:	Tutorial that demonstrates simple Rules usage.

The "**`Hello World`**" example shows a simple example of rules usage, and both the MVEL and **`Java`** dialects.

This example demonstrates how to build Knowledge Bases and Sessions. Also, the audit logging and debugging outputs are shown, which had been omitted from other examples, due to their similarity. A **`KnowledgeBuilder`** is used to turn a DRL source file into multiple **`Package`** objects which the Knowledge Base can consume. The "add" method takes a **`Resource`** interface and a "**`Resource Type`**" as parameters. The **`Resource`** can be used to retrieve a DRL source file from various locations; in this case, the DRL file is being retrieved from the classpath using a **`ResourceFactory`**, but it could come from a disk file or a URL. Here, we only add a single DRL source file, but multiple DRL files can be used. Also, DRL files with different namespaces can be added, whereby the Knowledge Builder creates a package for each namespace. Multiple packages of different namespaces can be added to the same Knowledge Base.

When all of the DRL files have been added, you should check the Builder for errors. Whilst the Knowledge Base will validate the package, it will only have access to the error information as a String, so if you wish to debug it, you should do so on the **`KnowledgeBuilder`** instance. Once you know that the Builder is error-free, obtain the **`Package`** collection, instantiate a **`KnowledgeBase`** from the **`KnowledgeBaseFactory`** and add the package collection.

```
final KnowledgeBuilder kbuilder =
 KnowledgeBuilderFactory.newKnowledgeBuilder();

// this will parse and compile in one step
kbuilder.add(ResourceFactory.newClassPathResource
 ("HelloWorld.drl",HelloWorldExample.class), ResourceType.DRL);

// Check the builder for errors
if (kbuilder.hasErrors())
{
 System.out.println(kbuilder.getErrors().toString());
 throw new RuntimeException("Unable to compile \"HelloWorld.drl\".");
}

// get the compiled packages (which are serializable)
final Collection<KnowledgePackage> pkgs = kbuilder.getKnowledgePackages();

// add the packages to a knowledgebase (deploy the knowledge packages).
final KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
kbase.addKnowledgePackages(pkgs);

final StatefulKnowledgeSession ksession =
 kbase.newStatefulKnowledgeSession();
```

Example 8.1. **`HelloWorld`** Example: Creating the **`KnowledgeBase`** and Session

`JBoss Rules` has an event model that exposes much of that which is occurs internally. Two default debug listeners are supplied that print out debug event information to the error console, namely **`DebugAgendaEventListener`** and **`DebugWorkingMemoryEventListener`**. Adding listeners to a session is relatively trivial and is discussed later. The **`KnowledgeRuntimeLogger`** is a specialised implementation built on the Agenda and Working Memory listeners. It provides execution auditing, the result pf which can be viewed in a graphical display. When the engine has finished executing, **`logger.close()`** must be called.

Note

Most of the examples use the audit logging features of **`JBoss Rules`** to record execution flow for future inspection.

```
// setup the debug listeners
ksession.addEventListener( new DebugAgendaEventListener() );
ksession.addEventListener( new DebugWorkingMemoryEventListener() );

// setup the audit logging
KnowledgeRuntimeLogger logger =
 KnowledgeRuntimeLoggerFactory.newFileLogger(ksession,"log/helloworld");
```

Example 8.2. **`HelloWorld`** Example: Event Logging and Auditing

The single class used in this example is rather simple as it has only two fields, these being the message, which is a String, and the status, which can be either the integer **HELLO** or the integer **GOODBYE**.

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

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

Example 8.3. **HelloWorld** Example:Message Class

A single Message object is created. It contains the message "Hello World" and status of "**HELLO**." It is then inserted into the engine, at which point `fireAllRules()` is executed. Remember that all of the network evaluation is undertaken during the insert period, in order that by the time the program execution reaches the `fireAllRules()` method call, the engine already knows which rules are full matches and it is able to fire.

```
final Message message = new Message();
message.setMessage("Hello World");
message.setStatus(Message.HELLO);
ksession.insert(message);

ksession.fireAllRules();

logger.close();

ksession.dispose();
```

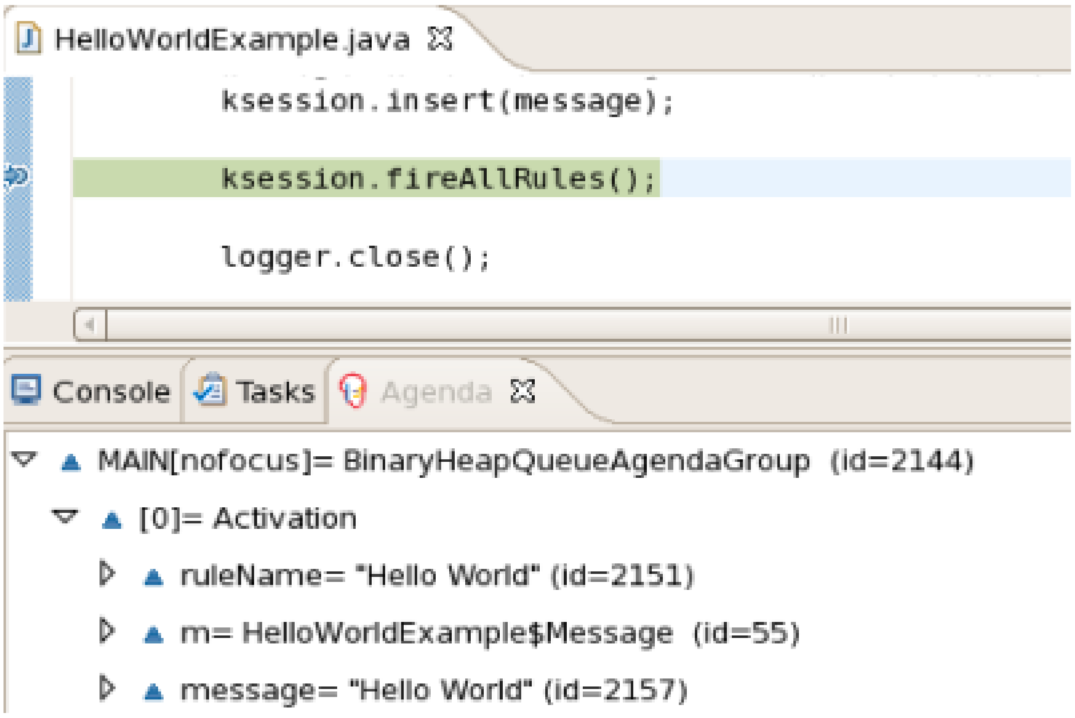
Example 8.4. Execution

In order to execute the example as a **Java** application, follow these steps:

1. Open the class entitled **org.drools.examples.HelloWorldExample** in your **Eclipse** IDE.

2. Right-click the class an select "Run as..." and then "Java application."

If you put a breakpoint on the `fireAllRules()` method and select the "**ksession**" variable, you can see that the "**Hello World**" view is already activated and on the Agenda. This confirms that all of the pattern-matching work was already undertaken during the insert.



```
ksession.insert(message);

ksession.fireAllRules();

logger.close();
```

```
MAIN[nofocus]= BinaryHeapQueueAgendaGroup  (id=2144)
    [0]= Activation
        ruleName= "Hello World" (id=2151)
        m= HelloWorldExample$Message  (id=55)
        message= "Hello World" (id=2157)
```

Figure 8.1. **`fireAllRules`** **`Agenda`** View

Any application print-outs go to **`System.out`**, whilst the debug listener print-outs go to **`System.err`**.

```
Hello World
Goodbye cruel world
```

Example 8.5. **`System.out`** in the Console Window

```
==>[ActivationCreated(0): rule=Hello World;

tuple=[fid:1:1:org.drools.examples.HelloWorldExample$Message@17cec96]]
[ObjectInserted: handle=[fid:1:1:org.drools.examples.HelloWorldExample
$Message@17cec96];
object=org.drools.examples.HelloWorldExample$Message@17cec96]
[BeforeActivationFired: rule=Hello World;

tuple=[fid:1:1:org.drools.examples.HelloWorldExample$Message@17cec96]]

==>[ActivationCreated(4): rule=Good Bye;
tuple=[fid:1:2:org.drools.examples.HelloWorldExample$Message@17cec96]]
[ObjectUpdated: handle=[fid:1:2:org.drools.examples.HelloWorldExample
$Message@17cec96];
old_object=org.drools.examples.HelloWorldExample$Message@17cec96;

new_object=org.drools.examples.HelloWorldExample$Message@17cec96]
[AfterActivationFired(0): rule=Hello World]
[BeforeActivationFired: rule=Good Bye;

tuple=[fid:1:2:org.drools.examples.HelloWorldExample$Message@17cec96]]
[AfterActivationFired(4): rule=Good Bye]
```

Example 8.6. **`System.err`** in the Console Window

The left-hand portion of the rule (after "**`when`**") states that it will be activated for each Message object inserted into the working memory whose status is "`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 right-hand side (after "**`then`**") is the "consequence" part of the rule. It is written using the MVEL expression language, as declared by the rule's attribute dialect. 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." This is achieved via MVEL's `modify` statement, which allows you to apply a block of assignments all at once, with the engine being automatically notified of the changes at the end of the block.

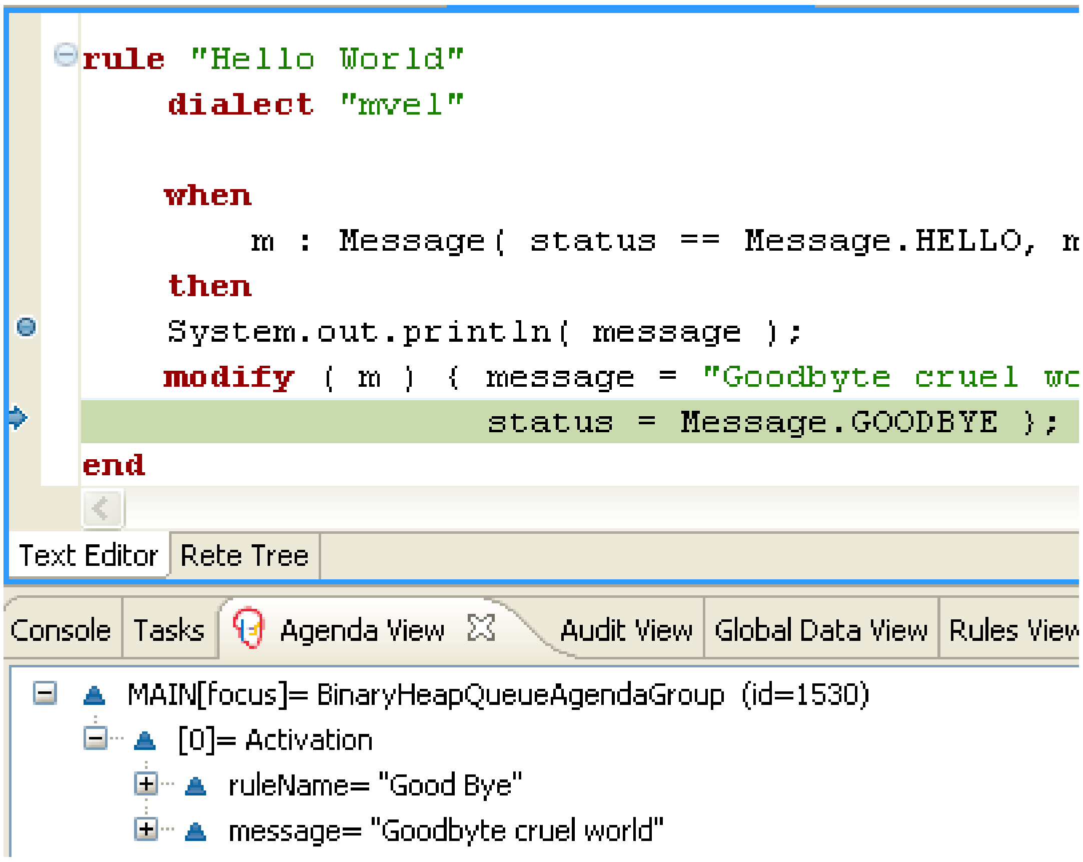
```
rule "Hello World"
 dialect "mvel"
when
 m : Message( status == Message.HELLO, message : message )
then
 System.out.println( message );
 modify (m) { message="Goodbye cruel world", status=Message.GOODBYE };
end
```

Example 8.7. Rule "**`Hello World`**"

You can set a breakpoint in the DRL, on the "`modify`" call. You can then inspect the **`Agenda`** view again during the execution of the rule's consequence. This time, start the execution via "Debug As" and "**`JBoss Rules`** application" rather than by running a "**`Java`** application."

1. Open the class **`org.drools.examples.HelloWorldExample`** in your **`Eclipse`** IDE.
2. Right-click the class and select "Debug as..." and then the "**`JBoss Rules`** application."

Now we can see that the other rule, "**`Good Bye`**," which uses the **`Java`** dialect is activated and placed on the agenda.



```
rule "Hello World"
    dialect "mvel"

    when
        m : Message( status == Message.HELLO, m
    then
    System.out.println( message );
    modify ( m ) { message = "Goodbyte cruel wo
                   status = Message.GOODBYE };
end
```

```
MAIN[focus]= BinaryHeapQueueAgendaGroup (id=1530)
  [0]= Activation
    ruleName= "Good Bye"
    message= "Goodbyte cruel world"
```

Figure 8.2. Rule "**`Hello World`**" Agenda View

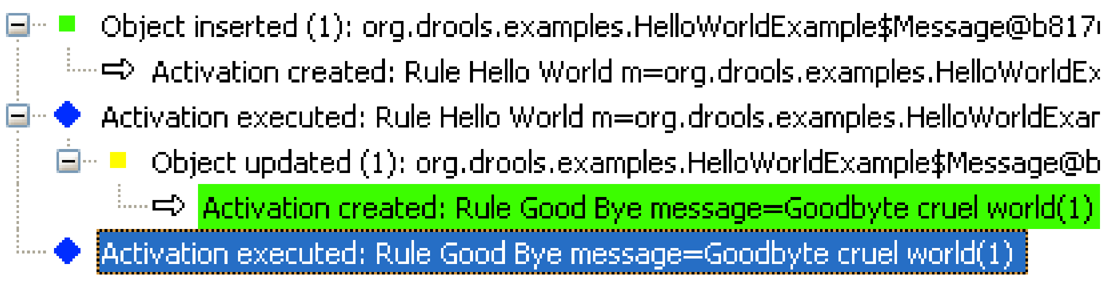
The "**`Good Bye`**" rule, which specifies the "**`Java`**" dialect, is similar to the "**`Hello World`**" rule except that it matches Message objects whose status is "`Message.GOODBYE`."

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

Example 8.8. Rule "**`Good Bye`**"

You may recall the **`Java`** code which used the `KnowledgeRuntimeLoggerFactory` method `newFileLogger` to create a `KnowledgeRuntimeLogger`. It then called `logger.close()` at the end. In doing so, it created an audit log file that can be seen in the Audit view. (The Audit view is used in many of the examples in order to demonstrate the execution flow.)

In the screen shot below, you can see that the object is inserted, which creates an activation for the "**Hello World**" rule; the activation is then executed which updates the `Message` object which subsequent;y causes the "**Good Bye**" rule to activate and execute. Selecting an event in the Audit view highlights the origin event in green. In this example, the "**Activation created**" event is highlighted in green as the origin of the "**Activation executed**" event.



```
Object inserted (1): org.drools.examples.HelloWorldExample$Message@b817
    Activation created: Rule Hello World m=org.drools.examples.HelloWorldEx
Activation executed: Rule Hello World m=org.drools.examples.HelloWorldExar
    Object updated (1): org.drools.examples.HelloWorldExample$Message@b
        Activation created: Rule Good Bye message=Goodbyte cruel world(1)
Activation executed: Rule Good Bye message=Goodbyte cruel world(1)
```

Figure 8.3. Audit View

8.2. State Example

Three different versions of this example are implemented in order to demonstrate alternative ways of implementing the same basic behaviour, called "*forward chaining*. Forward chaining is the ability of the engine to evaluate, activate and fire rules in sequence, based on changes to the facts in working memory.

8.2.1. Understanding the State Example

Name:	State Example
Main class:	**org.drools.examples.StateExampleUsingSalience**
Type:	**Java** application
Rules file:	**StateExampleUsingSalience.drl**
Objective:	Demonstrate basic rule use and conflict resolution for rule firing priority.

There are fields for the name and current status of each "State" class (see **org.drools.examples.State**.) The two possible states for each object are:

- `NOTRUN`
- `FINISHED`

```
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...
}
```

Example 8.9. State Class

Ignoring the `PropertyChangeSupport`, which will be explained later, you can see the creation of four `State` objects named A, B, C and D. Initially, their states are set to `NOTRUN`, which is the default for the used constructor. Each instance is asserted, in turn, into the Session and then `fireAllRules()` is called.

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

// By setting dynamic to TRUE, JBoss Rules will use JavaBean
// PropertyChangeListeners so you do not have to call modify or update().
boolean dynamic = true;

session.insert( a, dynamic );
session.insert( b, dynamic );
session.insert( c, dynamic );
session.insert( d, dynamic );

session.fireAllRules();
session.dispose(); // Stateful rule session must always be disposed when
 finished</programlisting>
```

Example 8.10. Salience State Example Execution

In order to execute the application:

1. Open the class called **`org.drools.examples.StateExampleUsingSalience`** in your **`Eclipse`**IDE.

2. Right-click the class and select "Run as..." followed by "**`Java`** application."

The following output is displayed in the **`Eclipse`** console window:

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

Example 8.11. Salience State Console Output

There are four rules in total. First, the `Bootstrap` rule fires, setting A to the state of `FINISHED`, which then causes B to also change its state to `FINISHED`. C and D are both dependent on B, causing a temporary conflict which is resolved by the salience values. The next step is to examine the way in which this process was executed.

The best way to understand what is happening is to use the **`Audit Logging`** feature. This allows one to graphically view the results of each operation. To view the Audit log generated by a run of this example:

1. If the **`Audit View`** is not visible, click on "**`Window`**" and then select "**`Show View`**", then "**`Other...`**" and "**`JBoss Rules`**" and finally "**`Audit View`**".
2. In the "**`Audit View`**" click the "**`Open Log`**" button and select the file entitled **`drools-examples-drl-dir>/log/state.log`**.

At this point, the "**`Audit View`**" on your screen should resemble like the following screenshot:

Figure 8.4. Salience State Example **`Audit View`**

Reading the log in the "**`Audit View`**", from top to bottom, one can see that every action and the corresponding changes it has wrought in working memory. This way one can observe that the assertion of the State object A in the state `NOTRUN` activates the `Bootstrap` rule, whilst the assertions of the other `State` objects have no immediate effect.

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

Example 8.12. Salience State: Rule "**`Bootstrap`**"

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

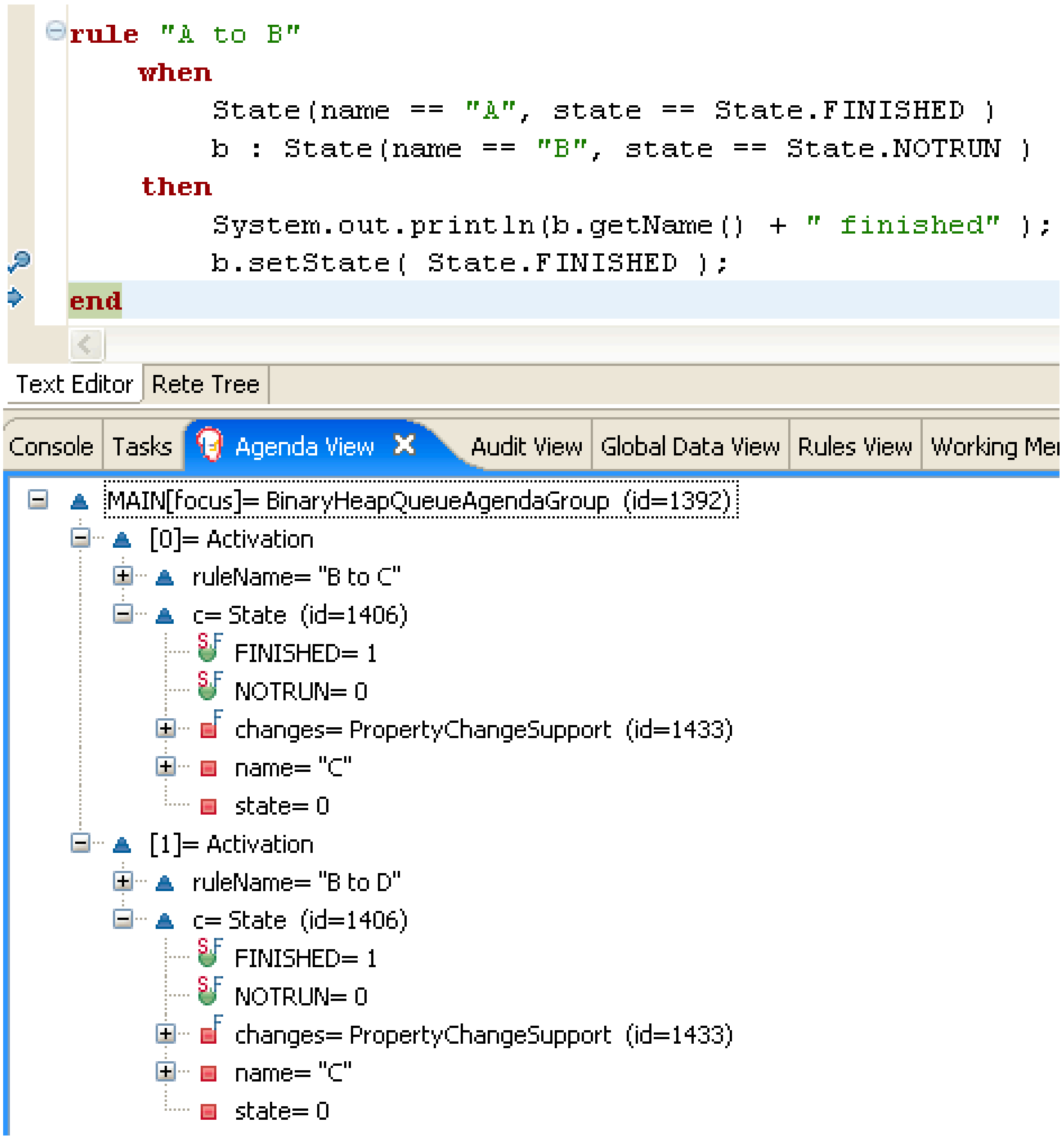
```
rule "A to B"
when
 State(name == "A", state == State.FINISHED )
 b : State(name == "B", state == State.NOTRUN )
then
 System.out.println(b.getName() + " finished" );
 b.setState( State.FINISHED );
end
```

Example 8.13. Rule "`A to B`"

The execution of rule "`A to B`" changes the state of "B" to `FINISHED`, which, in turn, activates both rules "`B to C`" and "`B to D`", placing their Activations onto the Agenda.

From this moment on, both rules may fire and, therefore, they are said to be "in conflict". The conflict resolution strategy allows the engine's agenda to decide which rule to fire. As rule "`B to C`" has the higher salience value of ten (as opposed to the default value of zero), it fires first, modifying object "C" to state `FINISHED`.

The Audit view depicted above shows the modification of the `State` object in the rule "`A to B`", which results in two activations being in conflict. The **`Agenda View`** can also be used to investigate the state of the agenda, as it allows one to place debugging points within the rules themselves with the **`Agenda View`** opened. The screen-shot below shows the break-point in the rule "`A to B`." It also illustrates the state of the agenda with the two conflicting rules.



```
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
```

```
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
```

Figure 8.5. State Example: **`Agenda View`**

```
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
```

Example 8.14. Rule "`B to C`"

The "`B to D`" rule fires last, modifying the "D" object to state `FINISHED`.

```
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
```

Example 8.15. Rule "`B to D`"

At this point in time, there are no more rules to execute and, thus, the engine stops.

Another notable facet of this example is the use of *dynamic facts*, which are based upon `PropertyChangeListener` objects. In order for the engine to "see" and react to changes in "fact" properties, the application must inform it that changes have occurred. This can either be undertaken explicitly via the rules by using the `modify` statement or, implicitly, by letting the engine know that the facts have implemented `PropertyChangeSupport` (as defined in the *JavaBeans specification*.)

This example demonstrates how to use `PropertyChangeSupport` so that one can avoid the need to use explicit "`modify`" statements in one's rules. To make use of this feature, ensure that your facts implement `PropertyChangeSupport`, in the same way that the class entitled `org.drools.example.State` does. Then, use the following code to insert the facts into working memory:

```
// By setting dynamic to TRUE, JBoss Rules will use JavaBean
// PropertyChangeListeners so that one does not have to call modify or
 update().
final boolean dynamic = true;

session.insert( fact, dynamic );
```

Example 8.16. Inserting a Dynamic Fact

When using `PropertyChangeListener` objects, each "setter" must implement a little extra code for the notification. Here is the setter for `state` in the class called **`org.drools.examples`**:

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

Example 8.17. "Setter" Example with `PropertyChangeSupport`

There are two other classes in this example. They are called `StateExampleUsingAgendGroup` and `StateExampleWithDynamicRules`. Both execute from "`A to B`" to "`C to D`", as just shown. The `StateExampleUsingAgendGroup` uses agenda-groups to control the rule conflict and to determine which one fires first. `StateExampleWithDynamicRules` shows how an additional rule can be added to an already-running working memory session whilst applying all the existing data to it at run-time.

"*Agenda groups*" are used to partition the agenda into groups and to determine which of these groups have permission to execute. By default, all rules are in the agenda group entitled "**`MAIN`**." The "`agenda-group`" attribute lets one specify a different agenda group for the rule. Initially, the Agenda group "MAIN" is the focus of working memory. A group's rules will only fire when the group receives the focus. This can be achieved either by using the method called `setFocus()` or the rule attribute "`auto-focus`." With the latter method, the rule automatically sets the focus to its agenda group when it is matched and activated, hence the name "`auto-focus`". It is this method that enables rule "`B to C`" to fire before "`B to D`".

```
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
```

Example 8.18. Agenda Group State Example: Rule "`B to C`"

The rule "`B to C`" calls `setFocus()` on the agenda group "`B to D`." This allows it to fire its active rules, which, in turn, allows the "`B to D`" to fire.

```
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
```

Example 8.19. Agenda Group State Example: Rule "`B to D`"

The example `StateExampleWithDynamicRules` adds another rule to the base after `fireAllRules()`. The added rule is just another state transition.

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

Example 8.20. Dynamic State Example: Rule "`D to E`"

This produces the following output, which is as one would expect:

```

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

Example 8.21. Dynamic Sate Example Output

8.3. Fibonacci Example

Name:	Fibonacci
Main class:	**`org.drools.examples.FibonacciExample`**
Type:	java application
Rules file:	**`Fibonacci.drl`**
Objective:	Demonsrate Recursion, 'not' CEs and Cross Product Matching.

The Fibonacci Numbers (see *http://en.wikipedia.org/wiki/Fibonacci_number*) discovered by Leonardo of Pisa (see *http://en.wikipedia.org/wiki/Fibonacci*) are a sequence that start with zero and one. The next Fibonacci number is obtained by adding the two preceding ones together. Therefore, the Fibonacci sequence begins with 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, 4181, 6765, 10946,... The Fibonacci Example demonstrates recursion and conflict resolution with salience values.

The single fact class, "`Fibonacci`," is used in this example. It has two fields, namely, sequence and value. The sequence field is used to indicate the position of the object in the Fibonacci number sequence. The value field shows the value of that Fibonacci object for that sequence position, using "minus one" to indicate a value that still needs to be computed.

```
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...

```

Example 8.22. Fibonacci Class

Execute the example:

1. Open the class **`org.drools.examples.FibonacciExample`** in your **`Eclipse`** IDE
2. Right-click the class and select "Run as..." and then, "Java application."

The following output is displayed in the **`Eclipse`** console window (with "...snip..." indicating lines that were removed to save space):

```

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

```

Example 8.23. Fibonacci Example: Console Output

To activate this from **`Java`**, you need only insert a single Fibonacci object with a sequence field of fifty. A recursive rule is then used to insert the other forty-nine `Fibonacci` objects. This example does not use `PropertyChangeSupport`. Rather, it uses the MVEL dialect, which means you can utilise the "**`modify`**" keyword. This keyword allows you to use a "block setter action," and also notifies the engine of changes.

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

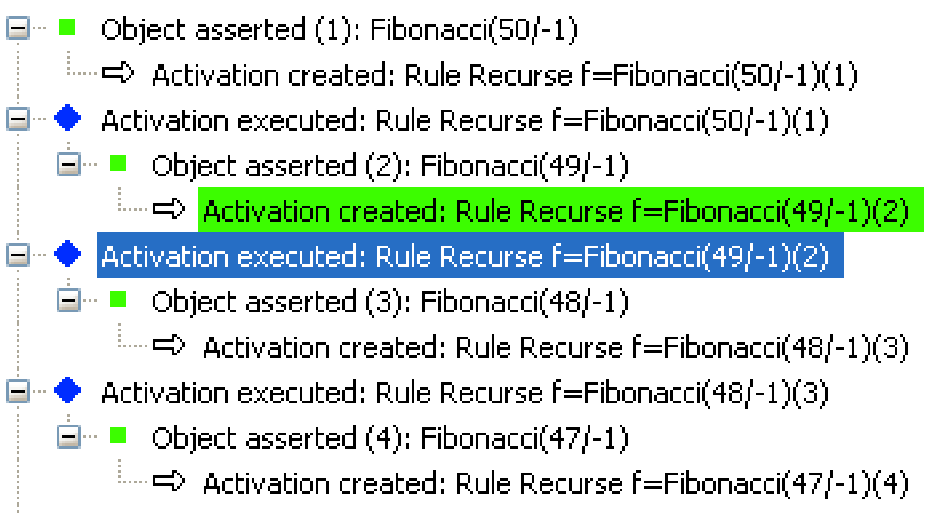
Example 8.24. Fibonacci Example: Execution

The **`Recurse`** rule is very simple. It matches each asserted Fibonacci object with a value of "-1," thereby creating and asserting a new Fibonacci object with a sequence of one less than the current one. Each time a Fibonacci object is added whilst that 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's matching once you have all fifty Fibonacci objects in memory. The rule also has a salience value, because you need to have all fifty `Fibonacci` objects asserted before you execute the **`Bootstrap`** rule.

```
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
```

Example 8.25. Fibonacci Example: "Recurse" Rule

The "**`Audit`**" view shows the original assertion of the Fibonacci object with a sequence field of 50, undertaken from **`Java`** code. From there on, the **`Audit`** view shows the continual recursion of the rule, whereby each asserted Fibonacci object causes the **`Recurse`** rule to become activated and to process again.



```
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)
```

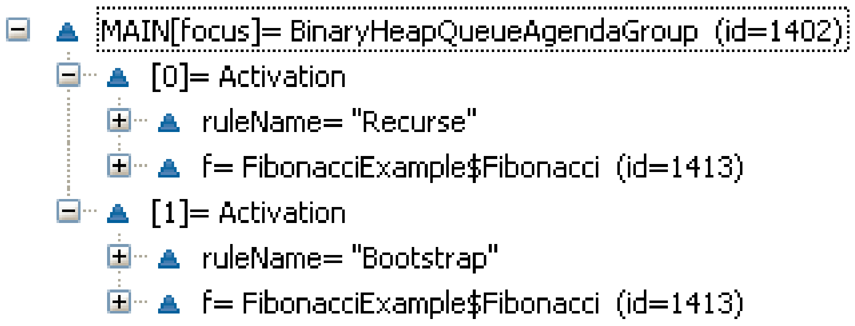
Figure 8.6. Fibonacci Example: "**`Recurse`**" **`Audit`** View One

When a Fibonacci object with a sequence field of "2" is asserted, the "**`Bootstrap`**" rule is matched and activated along with the "Recurse" rule.Note the multi-restriction on the field sequence, testing for equality with "1" or "2."

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

Example 8.26. Fibonacci Example: Rule "**`Bootstrap`**"

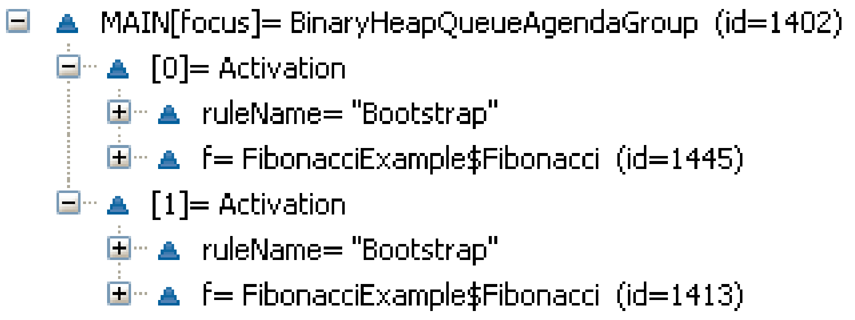
At this point, the agenda looks as per the following figure. However the "**`Bootstrap`**" rule does not fire because the "**`Recurse`**" rule has a higher salience.



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

Figure 8.7. Fibonacci Example: "**`Recurse`**" Agenda View One

When a Fibonacci object with a sequence of "1" is asserted, the **`Bootstrap`** rule is matched again, causing it to activate twice. Note that the "**`Recurse`**" rule does not match and activate because the "**`not`**" conditional element prevents the rules from matching as soon as a Fibonacci object with a sequence of "1" exists.



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

Figure 8.8. Fibonacci Example: "**`Recurse`**" Agenda View Two

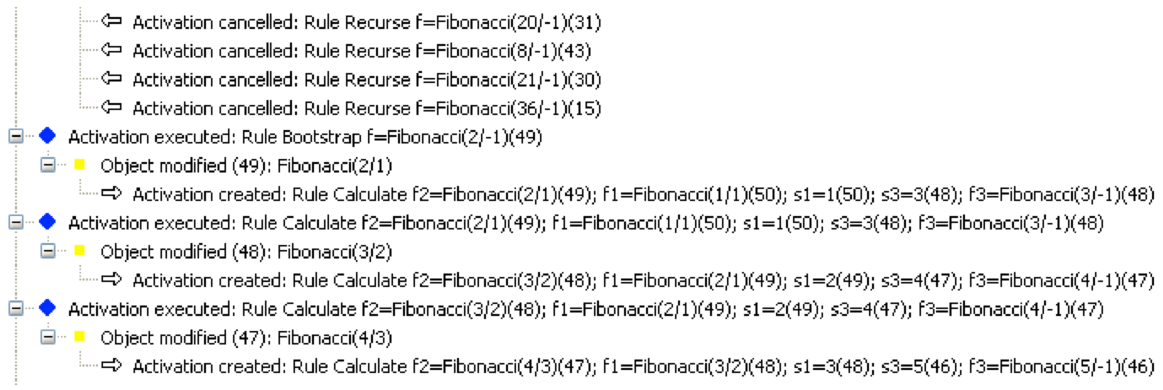
Once we have two Fibonacci objects with values that do not equal "-1," the "**`Calculate`**" rule is used to match them. It was the "**`Bootstrap`**" rule that set the objects with sequence "1" and "2" to values of "1." At this point, you have fiftyFibonacci objects in working memory. Now you need to select a suitable "triple" to calculate the values of each in turn. If you use three Fibonacci patterns in a rule without field constraints to confine the possible cross-products, you will ultimately have 50x49x48 possible combinations, leading to about 125,000 possible rule firings, most of which would be incorrect. The

"**`Calculate`**" rule uses field constraints to correctly constraint the three Fibonacci patterns in the correct order; this technique is called "*cross product matching*." The first pattern finds any Fibonacci with a value **`!= -1`** and binds both the pattern and the field. The second Fibonacci does this, too, but, in addition, it adds an extra field constraint. This is in order to ensure that its sequence is greater by one than the Fibonacci bound to `f1`. When this rule fires for the first time, only sequences "1" and "2" have values of "1" and the two constraints ensure that `f1` references sequence "1" and `f2` references sequence "2." The final pattern finds the Fibonacci with a value equal to "-1" and with a sequence one greater than `f2`. At this point, you have three Fibonacci objects correctly selected from the available cross products, and we can calculate the value for the third Fibonacci object that is bound to `f3`.

```
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 rechniques.
        modify ( f3 ) { value = f1.value + v2 };
        System.out.println( s3 + " == " + f3.value );
end
```

Example 8.27. Fibonacci Example: Rule "**`Calculate`**"

The **`Modify`** statement updated the value of the Fibonacci object bound to `f3`. This means that you now have another new Fibonacci object with a value that does not equal "-1," thereby allowing the "**`Calculate`**" rule to re-match and process the next Fibonacci number. The **`Audit`** view below shows how the firing of the last "**`Bootstrap`**" modifies the `Fibonacci` object, enabling the "**`Calculate`**" rule to match. This then modifies another Fibonacci object allowing the "**`Calculate`**" rule to match again. This continues until the value is set for all `Fibonacci` objects.



```
        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)
```

Figure 8.9. Fibonacci Example: "**`Bootstrap`**" **`Audit`** View

8.4. Banking Tutorial

Name:	Banking Tutorial

Main class:	**`org.drools.tutorials.banking`**
Type:	java application
Rules file:	**`org.drools.tutorials.banking.`**
Objective:	Increase knowledge of pattern matching, basic sorting and calculation rules.

This tutorial demonstrates the process of developing a complete personal banking application to handle credits and debits on multiple accounts. It uses a set of design patterns that have been created for this process.

The class, "**`RuleRunner`**", is a simple harness used to execute one or more DRL files against a set of data. It compiles the packages and creates the Knowledge Base for each execution. This allows you to easily execute each scenario and inspect the outputs. Note that, in reality, this is not a good solution for a production system, where the Knowledge Base should be built just once and cached. However, for the purposes of this tutorial it shall suffice.

```
public class RuleRunner {

 public RuleRunner() {}

 public void runRules(String[] rules,Object[] facts) throws Exception
 {
  KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
  KnowledgeBuilder kbuilder =
   KnowledgeBuilderFactory.newKnowledgeBuilder();

  for ( int i = 0; i < rules.length; i++ ) {
   String ruleFile = rules[i];
   System.out.println( "Loading file: " + ruleFile );
   kbuilder.add( ResourceFactory.newClassPathResource
    ( ruleFile, RuleRunner.class ),ResourceType.DRL );
  }

    Collection<KnowledgePackage> pkgs = kbuilder.getKnowledgePackages();
       kbase.addKnowledgePackages( pkgs );
       StatefulKnowledgeSession ksession =
   kbase.newStatefulKnowledgeSession();

  for ( int i = 0; i < facts.length; i++ ) {
   Object fact = facts[i];
   System.out.println( "Inserting fact: " + fact );
   ksession.insert( fact );
  }
  ksession.fireAllRules();
 }
}
```

Example 8.28. Banking Tutorial: **`RuleRunner`**

The first of our sample **`Java`** classes loads and executes a single DRL file, namely **`Example.drl`**; however, it does so without inserting any data.

```
public class Example1
{
 public static void main(String[] args) throws Exception
 {
  new RuleRunner().runRules(new String[]{"Example1.drl"},
   new Object[0] );
 }
}
```

Example 8.29. Banking Tutorial: **`Java`** Example One

This is the first simple rule to execute. It has a single "eval" condition that will always be true. Therefore, it will always match and "fire" once, after starting.

```
rule "Rule 01"
when
 eval( 1==1 )
then
 System.out.println( "Rule 01 Works" );
end
```

Example 8.30. Banking Tutorial: Rule in **`Example1.drl`**

The output for the rule is below, showing that the rule matches and executes the single print statement:

```
Loading file: Example1.drl
Rule 01 Works
```

Example 8.31. Banking Tutorial: Output of **`Example1.java`**

The next step is to assert some simple facts and print them out:

```
public class Example2
{
 private static Integer wrap(int i) {return new Integer(i);}

 public static void main(String[] args) throws Exception
 {
  Number[] numbers = new Number[] {wrap(3), wrap(1), wrap(4),
   wrap(1), wrap(5)};
  new RuleRunner().runRules(new String[] { "Example2.drl" },numbers);
 }
}
```

Example 8.32. Banking Tutorial: **`Java`** Example Two

This does not use any specific facts. Rather, it asserts a set of **`java.lang.Integer`**s. This is not considered "best practice" as a number of a collection is not a "fact" nor a "thing." A bank acount has a number, (its balance), therefore the account is the "fact." Initially, asserting integers shall suffice for demonstration purposes as the complexity of the example is built up.

Now you can create a simple rule to print out these numbers:

```
rule "Rule 02"
when
 Number( $intValue : intValue )
then
 System.out.println("Number found with value: " + $intValue);
end
```

Example 8.33. Banking Tutorial: Rule in **`Example2.drl`**

Once again, this rule does nothing special. It identifies any facts that are numbers and prints out the values. Note the use of interfaces here; you inserted integers but the pattern-matching engine is able to match the interfaces and super classes of the asserted objects.

The output shows the DRL being loaded, the facts inserted and then the rules being matched and fired. You can see that each inserted number is matched and fired and, thus, printed.

```
Loading file: Example2.drl
Inserting fact: 3
Inserting fact: 1
Inserting fact: 4
Inserting fact: 1
Inserting fact: 5
Number found with value: 5
Number found with value: 1
Number found with value: 4
Number found with value: 1
Number found with value: 3
```

Example 8.34. Banking Tutorial: Output of **`Example2.java`**

There are certainly many better ways to sort numbers than using rules, but since you will need to apply some cashflows in date order when you commence looking at banking rules, you will now develop a simple technique.

```
public class Example3
{
    private static Integer wrap(int i) {return new Integer(i);}

 public static void main(String[] args) throws Exception
 {
  Number[] numbers = new Number[] {wrap(3), wrap(1), wrap(4),
   wrap(1), wrap(5)};

  new RuleRunner().runRules(new String[]{ "Example3.drl"},numbers);
 }
}
```

Example 8.35. Banking Tutorial: **`Example3.java`**

Again you insert your Integers but this time the rule is slightly different:

```

rule "Rule 03"
when
 $number : Number( )
 not Number( intValue &lt; $number.intValue )
then
 System.out.println("Number found with value: "+$number.intValue() );
 retract( $number );
end
```

Example 8.36. Banking Tutorial: Rule in **`Example3.drl`**

The first line of the rule identifies a number and extracts the value. The second line ensures that there does not exist a smaller number than that found by the first pattern. You may possibly expect to match only one number, the smallest in the set. However, the retraction of the number after it has been printed means that the smallest number has been removed, revealing the next smallest number, and so on.

The generated output is shown in the following example. Note that the numbers are now sorted numerically.

```

Loading file: Example3.drl
Inserting fact: 3
Inserting fact: 1
Inserting fact: 4
Inserting fact: 1
Inserting fact: 5
Number found with value: 1
Number found with value: 1
Number found with value: 3
Number found with value: 4
Number found with value: 5
```

Example 8.37. Banking Tutorial: Output of **`Example3.java`**

Now you can start developing your personal accounting rules. The first step is to create a Cashflow object.

```
public class Cashflow
{
    private Date   date;
    private double amount;

    public Cashflow() {}

    public Cashflow(Date date,double amount)
 {
    this.date = date;this.amount = amount;
 }

    public Date getDate()   { return date;  }
    public void setDate(Date date) { this.date = date; }

    public double getAmount()     { return amount;   }
    public void setAmount(double amount) { this.amount = amount; }

    public String toString()
 {
  return "Cashflow[date=" + date + ",amount=" + amount + "]";
 }
}
```

Example 8.38. Banking Tutorial: Class Cashflow

The Cashflow has two simple attributes: A date and an amount. A **`toString`** method has been added, in order to print it. (Note that using the type `double` for monetary units is generally *not* a good idea because floating points cannot represent most numbers accurately.)There is also an "overloaded" the constructor to set the values. The following example inserts five Cashflow objects with varying dates and amounts.

```
public class Example4
{
    public static void main(String[] args) throws Exception
 {
        Object[] cashflows = {
            new Cashflow(new SimpleDate("01/01/2007"), 300.00),
            new Cashflow(new SimpleDate("05/01/2007"), 100.00),
            new Cashflow(new SimpleDate("11/01/2007"), 500.00),
            new Cashflow(new SimpleDate("07/01/2007"), 800.00),
            new Cashflow(new SimpleDate("02/01/2007"), 400.00),
        };

        new RuleRunner().runRules(new String[] {"Example4.drl"},cashflows;
 }
}
```

Example 8.39. Banking Tutorial: **`Example4.java`**

The convenience class "**`SimpleDate`**" extends **`java.util.Date`**, providing a constructor that takes a String as input and defines a date format. The code is listed below:

```
public class SimpleDate extends Date
{
    private static final SimpleDateFormat format =
     new SimpleDateFormat("dd/MM/yyyy");

    public SimpleDate(String datestr) throws Exception
 {
        setTime(format.parse(datestr).getTime());
 }
}
```

Example 8.40. Banking Tutorial: Class **`SimpleDate`**

Now, examine the **`rule04.drl`** file in order to determine how you print the sorted Cashflows:

```
rule "Rule 04"
when
 $cashflow : Cashflow( $date : date, $amount : amount )
 not Cashflow( date &lt; $date)
then
 System.out.println("Cashflow: "+$date+" :: "+$amount);
 retract($cashflow);
end
```

Example 8.41. Banking Tutorial: Rule in **`Example4.drl`**

Here, you can identify a `Cashflow` and extract the date and the amount. In the second line of the rule, ensure that there is no Cashflow with an earlier date than the one found. In the consequence, you print the `Cashflow` that satisfies the rule and then retract it, making way for the next earliest `Cashflow`. So, the output you generate is:

```
Loading file: Example4.drl
Inserting fact: Cashflow[date=Mon Jan 01 00:00:00 GMT 2007,amount=300.0]
Inserting fact: Cashflow[date=Fri Jan 05 00:00:00 GMT 2007,amount=100.0]
Inserting fact: Cashflow[date=Thu Jan 11 00:00:00 GMT 2007,amount=500.0]
Inserting fact: Cashflow[date=Sun Jan 07 00:00:00 GMT 2007,amount=800.0]
Inserting fact: Cashflow[date=Tue Jan 02 00:00:00 GMT 2007,amount=400.0]
Cashflow: Mon Jan 01 00:00:00 GMT 2007 :: 300.0
Cashflow: Tue Jan 02 00:00:00 GMT 2007 :: 400.0
Cashflow: Fri Jan 05 00:00:00 GMT 2007 :: 100.0
Cashflow: Sun Jan 07 00:00:00 GMT 2007 :: 800.0
Cashflow: Thu Jan 11 00:00:00 GMT 2007 :: 500.0
```

Example 8.42. Banking Tutorial: Output of **`Example4.java`**

Next, you will extend your `Cashflow`, resulting in a `TypedCashflow` which can be eitehr a credit or a debit operation. (Normally, you would just add this to the `Cashflow` type, but here you will use the extension to keep the previous version of the class intact.)

```java
public class TypedCashflow extends Cashflow {
    public static final int CREDIT = 0;
    public static final int DEBIT  = 1;

    private int type;

    public TypedCashflow() { }

    public TypedCashflow(Date date, int type, double amount)
 {
        super( date, amount );
        this.type = type;
    }

    public int getType()
 {
        return type;
    }

    public void setType(int type)
 {
        this.type = type;
    }

    public String toString()
 {
        return "TypedCashflow[date=" + getDate()
  + ",type=" + (type == CREDIT ? "Credit" : "Debit")
  + ",amount=" + getAmount()
  + "]";
    }
}
```

There are a multitude of ways to improve this code, but for the sake of the example this will suffice for the present.

You will now create Example Five, a class for running your code.

```
public class Example5
{
    public static void main(String[] args) throws Exception
 {
        Object[] cashflows = {
            new TypedCashflow(new SimpleDate("01/01/2007"),
         TypedCashflow.CREDIT, 300.00),
            new TypedCashflow(new SimpleDate("05/01/2007"),
                                TypedCashflow.CREDIT, 100.00),
            new TypedCashflow(new SimpleDate("11/01/2007"),
                                TypedCashflow.CREDIT, 500.00),
            new TypedCashflow(new SimpleDate("07/01/2007"),
                                TypedCashflow.DEBIT, 800.00),
            new TypedCashflow(new SimpleDate("02/01/2007"),
                                TypedCashflow.DEBIT, 400.00),
        };

        new RuleRunner().runRules(
   new String[] { "Example5.drl" }, cashflows );
    }
}
```

Example 8.43. Banking Tutorial: **`Example5.java`**

Here, we simply create a set of `Cashflow` objects which are either credit or debit operations. We supply them, along with **`Example5.drl`**, to the **`RuleEngine`**.

Now, you can take the time to examine a rule which prints the sorted `Cashflow` objects.

```
rule "Rule 05"
when
 $cashflow : TypedCashflow( $date : date, $amount : amount,
  type == TypedCashflow.CREDIT )
 not TypedCashflow( date &lt; $date, type == TypedCashflow.CREDIT )
then
 System.out.println("Credit: "+$date+" :: "+$amount);
 retract($cashflow);
end
```

Example 8.44. Banking Tutorial: Rule in **`Example5.drl`**

Here, you can identify a `Cashflow` fact with a type of `CREDIT` and extract the date and the amount. In the second line of the rule, you ensure that there is no `Cashflow` of the same type with a date earlier than that which is found. In the consequence, print the cashflow satisfying the patterns and then retract it, making way for the next earliest cashflow of type `CREDIT`.

The generated output is described in the following example:

```
Loading file: Example5.drl
Inserting fact: TypedCashflow[date=Mon Jan 01 00:00:00 GMT
 2007,type=Credit,amount=300.0]
Inserting fact: TypedCashflow[date=Fri Jan 05 00:00:00 GMT
 2007,type=Credit,amount=100.0]
Inserting fact: TypedCashflow[date=Thu Jan 11 00:00:00 GMT
 2007,type=Credit,amount=500.0]
Inserting fact: TypedCashflow[date=Sun Jan 07 00:00:00 GMT
 2007,type=Debit,amount=800.0]
Inserting fact: TypedCashflow[date=Tue Jan 02 00:00:00 GMT
 2007,type=Debit,amount=400.0]
Credit: Mon Jan 01 00:00:00 GMT 2007 :: 300.0
Credit: Fri Jan 05 00:00:00 GMT 2007 :: 100.0
Credit: Thu Jan 11 00:00:00 GMT 2007 :: 500.0
```

Example 8.45. Banking Tutorial: Output of **`Example5.java`**

Continuing the banking exercise, you are now going to process both credits and debits on two bank accounts, calculating the account balance. In order to do this, you will create two separate `Account` objects and inject them into the `Cashflows` before passing them to the **`RuleEngine`**. The reason for this is to provide easy access to the correct account without having to resort to helper classes. Examine the `Account` class first. This is a simple Java object with an account number and balance:

```
public class Account
{
    private long   accountNo;
    private double balance = 0;

    public Account() { }

    public Account(long accountNo)
 {
        this.accountNo = accountNo;
    }

    public long getAccountNo()
 {
        return accountNo;
    }

    public void setAccountNo(long accountNo)
 {
        this.accountNo = accountNo;
    }

    public double getBalance()
 {
        return balance;
    }

    public void setBalance(double balance)
 {
        this.balance = balance;
    }

    public String toString()
 {
        return "Account[" + "accountNo=" + accountNo
   + ",balance=" + balance + "]";
    }
}
```

Now you can extend your `TypedCashflow`, resulting in `AllocatedCashflow`, to include an `Account` reference.

```
public class AllocatedCashflow extends TypedCashflow
{
 private Account account;

 public AllocatedCashflow() {}

 public AllocatedCashflow(Account account, Date date,
  int type, double amount)
 {
  super( date, type, amount );
  this.account = account;
 }

 public Account getAccount()
 {
  return account;
 }

 public void setAccount(Account account)
 {
  this.account = account;
 }

 public String toString()
 {
  return "AllocatedCashflow["
   + "account=" + account
   + ",date=" + getDate()
   + ",type=" + (getType() == CREDIT ? "Credit" : "Debit")
   + ",amount=" + getAmount()
   + "]";
 }
}
```

Example 8.46. Class AllocatedCashflow

The **Java** code of **`Example5.java`** creates two `Account` objects and passes one of them into each cashflow, in the constructor call.

```
public class Example6
{
 public static void main(String[] args) throws Exception
 {
  Account acc1 = new Account(1);
  Account acc2 = new Account(2);

  Object[] cashflows =
  {
   new AllocatedCashflow(acc1,new SimpleDate("01/01/2007"),
           TypedCashflow.CREDIT, 300.00),
   new AllocatedCashflow(acc1,new SimpleDate("05/02/2007"),
           TypedCashflow.CREDIT, 100.00),
   new AllocatedCashflow(acc2,new SimpleDate("11/03/2007"),
           TypedCashflow.CREDIT, 500.00),
   new AllocatedCashflow(acc1,new SimpleDate("07/02/2007"),
           TypedCashflow.DEBIT,  800.00),
   new AllocatedCashflow(acc2,new SimpleDate("02/03/2007"),
           TypedCashflow.DEBIT,  400.00),
   new AllocatedCashflow(acc1,new SimpleDate("01/04/2007"),
           TypedCashflow.CREDIT, 200.00),
   new AllocatedCashflow(acc1,new SimpleDate("05/04/2007"),
           TypedCashflow.CREDIT, 300.00),
   new AllocatedCashflow(acc2,new SimpleDate("11/05/2007"),
           TypedCashflow.CREDIT, 700.00),
   new AllocatedCashflow(acc1,new SimpleDate("07/05/2007"),
           TypedCashflow.DEBIT,  900.00),
   new AllocatedCashflow(acc2,new SimpleDate("02/05/2007"),
           TypedCashflow.DEBIT,  100.00)
  };

  new RuleRunner().runRules(new String[]{"Example6.drl"},cashflows);
 }
}
```

Example 8.47. Banking Tutorial: **`Example5.java`**

Now, take look at the rule in **`Example6.drl`** to see how you should apply each cashflow in date order and then calculate and print out the balance.

```
rule "Rule 06 - Credit"
when
 $cashflow : AllocatedCashflow( $account : account,
  $date : date, $amount : amount, type==TypedCashflow.CREDIT )
 not AllocatedCashflow( account == $account, date < $date)
then
 System.out.println("Credit: " + $date + " :: " + $amount);
 $account.setBalance($account.getBalance()+$amount);
 System.out.println("Account: " + $account.getAccountNo() +
  " - new balance: " + $account.getBalance());
 retract($cashflow);
```

```
end

rule "Rule 06 - Debit"
when
 $cashflow : AllocatedCashflow( $account : account,
 $date : date, $amount : amount, type==TypedCashflow.DEBIT )
 not AllocatedCashflow( account == $account, date < $date)
then
 System.out.println("Debit: " + $date + " :: " + $amount);
 $account.setBalance($account.getBalance() - $amount);
 System.out.println("Account: " + $account.getAccountNo() +
  " - new balance: " + $account.getBalance());
 retract($cashflow);
end
```

Although you have separate rules for credits and debits, you will not specify a type when checking for earlier cashflows. This is so that all cashflows are applied in date order, regardless of type. In the conditions, you identified the account with which to work, and in the consequences, you have updated it with the cashflow amount.

```
Loading file: Example6.drl
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Mon Jan 01
 00:00:00 GMT 2007,type=Credit,amount=300.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Mon Feb 05
 00:00:00 GMT 2007,type=Credit,amount=100.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=2,balance=0.0],date=Sun Mar 11
 00:00:00 GMT 2007,type=Credit,amount=500.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Wed Feb 07
 00:00:00 GMT 2007,type=Debit,amount=800.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=2,balance=0.0],date=Fri Mar 02
 00:00:00 GMT 2007,type=Debit,amount=400.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Sun Apr 01
 00:00:00 BST 2007,type=Credit,amount=200.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Thu Apr 05
 00:00:00 BST 2007,type=Credit,amount=300.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=2,balance=0.0],date=Fri May 11
 00:00:00 BST 2007,type=Credit,amount=700.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=1,balance=0.0],date=Mon May 07
 00:00:00 BST 2007,type=Debit,amount=900.0]
Inserting fact:
 AllocatedCashflow[account=Account[accountNo=2,balance=0.0],date=Wed May 02
 00:00:00 BST 2007,type=Debit,amount=100.0]
```

```
Debit: Fri Mar 02 00:00:00 GMT 2007 :: 400.0
Account: 2 - new balance: -400.0
Credit: Sun Mar 11 00:00:00 GMT 2007 :: 500.0
Account: 2 - new balance: 100.0
Debit: Wed May 02 00:00:00 BST 2007 :: 100.0
Account: 2 - new balance: 0.0
Credit: Fri May 11 00:00:00 BST 2007 :: 700.0
Account: 2 - new balance: 700.0
Credit: Mon Jan 01 00:00:00 GMT 2007 :: 300.0
Account: 1 - new balance: 300.0
Credit: Mon Feb 05 00:00:00 GMT 2007 :: 100.0
Account: 1 - new balance: 400.0
Debit: Wed Feb 07 00:00:00 GMT 2007 :: 800.0
Account: 1 - new balance: -400.0
Credit: Sun Apr 01 00:00:00 BST 2007 :: 200.0
Account: 1 - new balance: -200.0
Credit: Thu Apr 05 00:00:00 BST 2007 :: 300.0
Account: 1 - new balance: 100.0
Debit: Mon May 07 00:00:00 BST 2007 :: 900.0
Account: 1 - new balance: -800.0
```

8.5. Pricing Rule Decision Table Example

The *Pricing Rule Decision Table* demonstrates the use of a "decision table" in a spreadsheet. It uses **`Microsoft Excel`**'s .XLS format to calculate the retail cost of an insurance policy. The purpose of the provided set of rules is to calculate a base price and a discount for a car driver who is applying for a specific policy. The driver's age, history and the policy type all contribute to the basic premium amount. A number of additional rules then refine this by calculating a discount percentage.

Name:	Example Policy Pricing
Main class:	**`org.drools.examples.PricingRuleDTExample`**
Type:	**`Java`** application
Rules file:	**`ExamplePolicyPricing.xls`**
Objective:	Demonstrate spreadsheet based decision tables.

8.5.1. Executing the Example

Open the file **`PricingRuleDTExample.java`** and execute it as a **`Java`** application. The following output should flow to the Console window:

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

The code written to execute the example follows the usual pattern. The rules are loaded, the facts inserted and a Stateless Session is created. The different lies in how the rules are added.

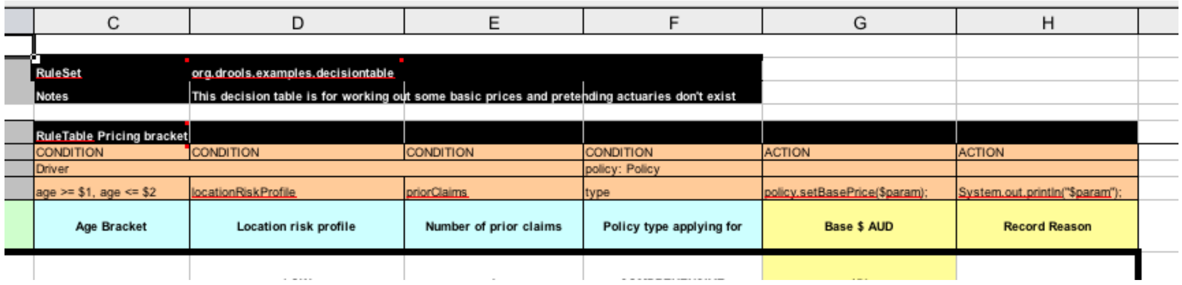
```
DecisionTableConfiguration dtableconfiguration =
    KnowledgeBuilderFactory.newDecisionTableConfiguration();
        dtableconfiguration.setInputType( DecisionTableInputType.XLS );

        KnowledgeBuilder kbuilder =
 KnowledgeBuilderFactory.newKnowledgeBuilder();

        Resource xlsRes =
 ResourceFactory.newClassPathResource( "ExamplePolicyPricing.xls",

 getClass() );
        kbuilder.add( xlsRes,
                      ResourceType.DTABLE,
                      dtableconfiguration );
```

Note the use of the `DecisionTableConfiguration` object. Its input type is set to `DecisionTableInputType.XLS`. If you use the BRMS, all this is, of course, taken care of for you.

There are two fact types used in this example, namely `Driver` and `Policy`. The default values of both are used. The `Driver` is thirty years of age, has had no prior claims and has a "`LOW`" risk profile. The `Policy` for which the driver is applying is "`COMPREHENSIVE`." It has not yet been approved.

8.5.2. The Decision Table

In this decision table, each row represents a rule and each column represents either a condition or an action.



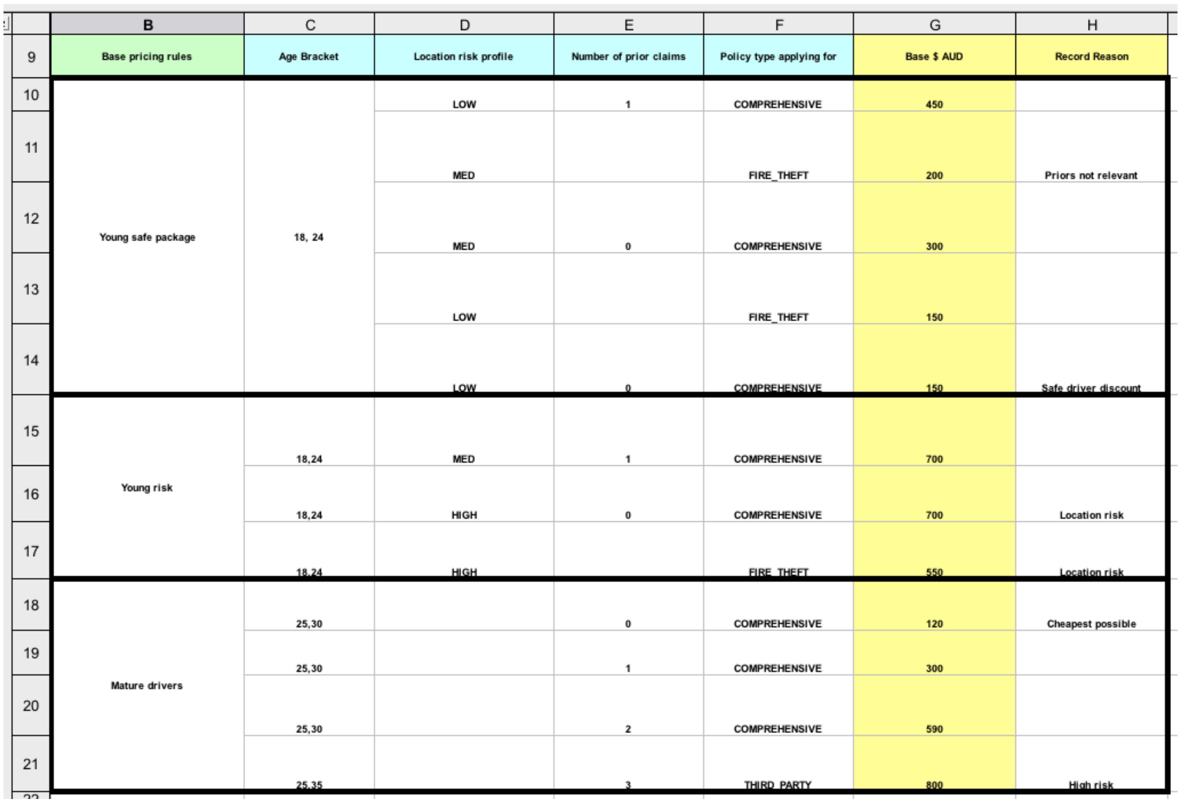
	C	D	E	F	G	H
	RuleSet	org.drools.examples.decisiontable				
	Notes	This decision table is for working out some basic prices and pretending actuaries don't exist				
	RuleTable Pricing bracket					
	CONDITION	CONDITION	CONDITION	CONDITION	ACTION	ACTION
	Driver			policy: Policy		
	age >= $1, age <= $2	locationRiskProfile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

Figure 8.10. Decision Table Configuration

If you refer to the spreadsheet shown above, you can see the `RuleSet` declaration, which provides the package name. There are also other optional items you can add here, such as `Variables` for global variables, and `Imports` (used to import classes.) In this case, the rules name-space is the same as that of the fact classes being employed, so it can, therefore, be omitted.

Further down, you can see the `RuleTable` declaration. The name written after this (**`Pricing Bracket`**) is used as the prefix for all the generated rules. Below that, there is the "**`CONDITION or ACTION`**" which indicate the purpose of the column, in other words, as to whether it forms part of the condition or the consequence of the rule that will be generated.

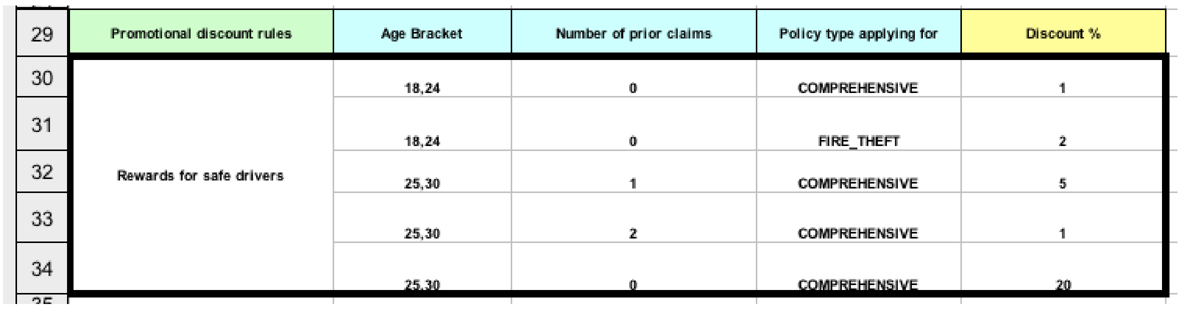
You can see that the data about the car driver is spanned across three cells. This means that the template expressions below each fact apply to it. You can observe the driver's age range (which uses $1 and $2 with comma-separated values), `locationRiskProfile`, and `priorClaims` in the respective columns. In the action columns, the policy base price is set. A message can also be logged here.



	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			LOW	1	COMPREHENSIVE	450	
11			MED		FIRE_THEFT	200	Priors not relevant
12	Young safe package	18, 24	MED	0	COMPREHENSIVE	300	
13			LOW		FIRE_THEFT	150	
14			LOW	0	COMPREHENSIVE	150	Safe driver discount
15		18,24	MED	1	COMPREHENSIVE	700	
16	Young risk	18,24	HIGH	0	COMPREHENSIVE	700	Location risk
17		18,24	HIGH		FIRE_THEFT	550	Location risk
18		25,30		0	COMPREHENSIVE	120	Cheapest possible
19		25,30		1	COMPREHENSIVE	300	
20	Mature drivers	25,30		2	COMPREHENSIVE	590	
21		25,35		3	THIRD_PARTY	800	High risk

Figure 8.11. Base Price Calculation

In the preceding spreadsheet section, there are broad category brackets, (which are indicated by the comment in the leftmost column.) As you know the details of the drivers and their policies, with a little thought you can quickly deduct that they should match row eighteen, (as they have had no prior accidents), and that they are thirty years of age. This gives you a base price of 120.



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

Figure 8.12. Discount Calculation

The section above contains the conditions for the discount that you may grant the driver. The discount results from the Age bracket, the number of prior claims, and the policy type. In this example case, the driver is thirty, has had no prior claims and is applying for a "`COMPREHENSIVE`" policy. This means that you can grant a discount of 20%. (Note that this is actually a separate table in the same worksheet. This is so that different templates apply.)

Note

It is important to understand that decision tables generate rules. This means they do not simply employ top-down logic. Rather, think of them as a means to capture data that results in rules. This is a subtle difference that confuses some people. The evaluation of the rules is not necessarily in the given order, since all the normal mechanics of the rule engine still apply.

8.6. Pet Store Example

Name:	Pet Store
Main class:	**`org.drools.examples.PetStore`**
Type:	java application
Rules file:	**`PetStore.drl`**
Objective:	Demonstrate use of Agenda Groups, Global Variables and integration with a GUI (including callbacks from within the Rules).

The "Pet Store" example shows how to integrate Rules with a GUI (in this case a **`Swing`**-based desktop application). Within the **`Rules`** file, there is a demonstration of how to use agenda groups and "auto-focus" in order to control which of a set of rules is allowed to fire at any given time. It also shows mixing of **`Java`** and MVEL dialects within the rules, along with the use of "accumulate" functions and calling of **`Java`** functions from within the rule-set.

All the **`Java`** code is contained in one file, **`PetStore.java`**, which defines the following principal classes (in addition to several minor classes which are used to handle **`Swing`** Events):

- **`Petstore`** - containing the `main()` method that you will look at shortly.
- **`PetStoreUI`** - responsible for creating and displaying the **`Swing`**-based GUI. It contains several smaller classes , mainly for responding to various GUI events such as mouse and button clicks.
- **`TabelModel`** - holds the table data. Consider it a **`JavaBean`** that extends the **`Swing AbstractTableModel`** class.
- **`CheckoutCallback`** - allows the GUI to interact with the Rules.
- **`Ordershow`** - holds the items that you wish to buy.
- **`Purchase`** - stores details of the order and the products being bought.
- **`Product`** - is a **`JavaBean`** holding details and pricing information related to the product available for purchase.

Much of the code is either in the form of plain **`JavaBeans`** or **`Swing`**-based. Only a few points relating to **`Swing`** will be discussed in this section, but a good tutorial about it can be found on **`Sun`**'s website: *`http://java.sun.com/docs/books/tutorial/uiswing/`*.

The pieces of **`Java`** code in the **`Petstore.java`** file that relate to rules and facts are shown below:

```
KnowledgeBuilder kbuilder = KnowledgeBuilderFactory.newKnowledgeBuilder();

kbuilder.add( ResourceFactory.newClassPathResource( "PetStore.drl",
                                                    PetStore.class ),
              ResourceType.DRL );
KnowledgeBase kbase = KnowledgeBaseFactory.newKnowledgeBase();
kbase.addKnowledgePackages( kbuilder.getKnowledgePackages() );

// 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( kbase ) );
ui.createAndShowGUI();
```

Example 8.48. Creating the PetStore RuleBase in PetStore.main

The code shown above loads the rules from a DRL file on the classpath. Unlike other examples, in which the facts are asserted and executed immediately, this example defers that step until later. The way it does this is via the second last line where a `PetStoreUI` object is created using a constructor accepting the `Vector` object `stock` collecting our products and an instance of the `CheckoutCallback` class containing the Rule Base that you have just loaded.

The actual **Javacode** that fires the rules is within the **`CheckoutCallBack.checkout()`** method. This is eventually triggered when the "Checkout" button is clicked by the user.

```
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

    StatefulKnowledgeSession ksession =
 kbase.newStatefulKnowledgeSession();
    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 );
    ksession.fireAllRules();

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

Two items are passed into this method. One is the handle to the `JFrame` **`Swing`** component surrounding the output text frame, at the bottom of the GUI. The second is a list of order items; this comes from the `TableModel` storing the information from the "Table" area at the top 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 **`PetStore.java`**. Note that it would be possible to refer to the **`Swing`** dataset directly within the rules, but it is better coding practice to do it this way, using simple **`Java`** objects. It means that you are not tied to **`Swing`** if you wanted to transform the sample into a Web application.

It is important to note that all states in this example are stored in the **`Swing`** components and that the rules are effectively "stateless." Each time the "Checkout" button is pressed, this code copies the contents of the Swing `TableModel` into the session's working memory.

Within this code, there are nine calls to the working memory. The first of these creates a new working memory (as a Stateful Knowledge Session from the Knowledge Base.) Remember that you passed in this Knowledge Base when you created the `CheckoutCallBack` class in the `main()` method. The next two calls pass in two objects that you will hold as global variables in the rules. These are the **`Swing`** text area and the **`Swing`** frame. These are used for writing messages.

More inserts put information on products into the Working Memory, as well as the order list. The final call is the standard `fireAllRules()`. Next, we look at what this method causes to happen within the rules file.

```
package org.drools.examples

import org.drools.WorkingMemory
import org.drools.examples.PetStore.Order
import org.drools.examples.PetStore.Purchase
import org.drools.examples.PetStore.Product
import java.util.ArrayList
import javax.swing.JOptionPane;

import javax.swing.JFrame

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

Example 8.49. Package, Imports, Globals and Dialect - Extracts from the **`PetStore.drl`**

The first part of the **`PetStore.drl`** file contains the standard package and import statements used to make various Java classes available to the rules. In addition, there are the two globals, **`frame`**

and textArea. These hold references to the **Swing JFrame** and Textarea components that were previous passed by the **Java** code that called the **setGlobal()** method. Unlike variables in Rules, which expire as soon as they have been fired, global variables retain their value for the lifetime of the session, which, in this case, is "stateful."

The following example is taken from the **end** of the **PetStore.drl** file. It contains two functions that are referenced by the rules that you will study shortly.

```
function void doCheckout(JFrame frame, WorkingMemory workingMemory)
{
 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) {workingMemory.setFocus( "checkout" );}
}

function boolean requireTank(JFrame frame, WorkingMemory workingMemory,
 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 );
  workingMemory.insert( purchase );
  order.addItem( purchase );
  System.out.println( "Yes" );
 } else {
  System.out.println( "No" );
 }
 return true;
}
```

Having these functions in the rules file simply makes the Pet Store example more compact. In real life, you will probably have the functions in a file of their own, within the same rules package or as a static method on a standard Java class, and import them, using `import function my.package.Foo.hello`.

The purpose of these two functions is as follows:

- **`doCheckout()`** - displays a dialogue box that asks the user if they wish to check out. If they do, focus is set to the **`checkOut`** agenda-group, allowing rules in that group to (potentially) fire.

- **`requireTank()`** - displays a dialogue box that asks the user if they wish to buy a tank. If so, a new **`FishTankProduct`** is added to the order list in working memory.

Later, you will be taught the rules that call upon these functions. The next set of examples are, themselves, derived from the Pet Store rules. The first extract is that which runs first, (partly because it the **`auto-focus`** attibute has been set to **`true`**.)

```
/// Insert each item in the shopping cart into the Working Memory
// 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
```

Example 8.50. Putting Items into Working Memory - Extract from the **`PetStore.drl`** File

This rule matches against all orders that do not yet have their `Order.grossTotal` calculated . It loops for each purchase item in order. Some parts of the "`Explode Cart`" rule should be familiar, these being the rule name, the salience (suggesting the order in which rules should be fired) and the dialect set to **`Java`**. There are also three new items in the rule:

- **`agenda-group "init"`** - the name of the agenda group. In this case, there is only one rule in the group. However, neither the **`Java`** code nor a rule consequence sets the focus to this group, and therefore it relies on the next attibute 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.

- **`drools.setFocus()`** - sets the focus to the "`show items`" and "`evaluate`" agenda groups in turn, permitting the execution of their rules. In practice, on order all items are looped. This inserts them into memory, subsequently firing the other rules each time.

The next two listings shows the rules within the "**`show items`**" and "**`evaluate`**" agenda groups. They shall be discussed in the order in which they are called.

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

Example 8.51. Show Items in the GUI - Extract from the **`PetStore.drl`** File

The "**`show items`**" agenda group has only one rule, which is called "**`Show Items`**" (note the difference in case). It logs details to the text area (at the bottom of the GUI), for each purchase on the order currently in the working memory session. The "**`textArea`**" variable used to do this is one of the Globals discussed earlier.

The "**`evaluate`**" agenda group also gains focus from the "**`explode cart`**" listed previously. This agenda group has two rules: "**`Free Fish Food Sample`** " and "**`Suggest Tank`**." These are discussed below.

```
// Free Fish Food sample when we buy a Gold Fish if we have not already
//bought Fish Food and dont already have a Fish Food Sample
rule "Free Fish Food Sample"
 agenda-group "evaluate"
 dialect "mvel"
when
 $order : Order()
 not ( $p : Product( name == "Fish Food") &&
 Purchase( product == $p ) )
  not ( $p : Product( name == "Fish Food Sample") &&
  Purchase( product == $p ) )
  exists ( $p : Product( name == "Gold Fish") &&
  Purchase( product == $p ) )
  $fishFoodSample : Product( name == "Fish Food Sample" );
then
 System.out.println( "Adding free Fish Food Sample to cart" );
 purchase = new Purchase($order, $fishFoodSample);
 insert( purchase );
 $order.addItem( purchase );
end

// Suggest a tank if we have bought more than 5 gold fish and do not
// already have one
rule "Suggest Tank"
 agenda-group "evaluate"
 dialect "java"
when
 $order : Order()
 not ( $p : Product( name == "Fish Tank") &&
 Purchase( product == $p ) )
 ArrayList( $total : size &gt; 5 ) from collect( Purchase
 ( product.name == "Gold Fish" ) )
 $fishTank : Product( name == "Fish Tank" )
then
 requireTank(frame, drools.getWorkingMemory(),
 $order, $fishTank, $total);
end
```

Example 8.52. Evaluate Agenda Group: Extract from the **`PetStore.drl`** File

The "**`Free Fish Food Sample`**" rule will only execute if:

- You do notalready have any fish food;
- You do not already have a free fish food sample and
- You **do** have a Gold Fish in your order.

If the rule does fire, it creates a new product ("**`Fish Food Sample`**") and adds it to the order in working memory.

The **Suggest Tank** rule will only fire if:

- You do not already have a Fish Tank in your order;
- If you can find more than five Gold Fish products in your order.

If the rule does fire, it calls the `requireTank()` function about which you read earlier. This shows a dialogue box to the user and adds a tank to the order/working memory if confirmed. The rule passes the global **frame** variable when it calls the `requireTank()` function. This is so that the function has a handle on the **Swing** graphical user interface.

The next rule for you to learn is the "**do checkout**."

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

Example 8.53. Undertaking the Checkout: Extract from the **PetStore.drl** File

The "**do checkout**" rule has no set agenda-group or auto-focus attribute. As such, it is deemed part of the default agenda-group. This group receives focus by default when all of the rules in agenda-groups that had been set to receive explicit focus have completed.

There is no left hand-side to the rule, so the right hand-side will always call the **doCheckout()** function. When calling the **doCheckout()** function, the rule passes the global **frame** variable to give the function a handle on the **Swing** graphical user interface. As you observed earlier, the `doCheckout()` function displays a confirmation dialogue box to the user. If confirmed, the function sets the focus to the **checkout** agenda-group, allowing the next set of rules to execute.

```
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 &gt;= 10 &amp;&amp; &lt; 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 &gt;= 20 )
then
 $order.discountedTotal = $order.grossTotal * 0.90;
 textArea.append("discountedTotal total="+$order.discountedTotal+"\n");
end
```

Example 8.54. Checkout Rules: Extract from the **`PetStore.drl`** File

There are three rules in the "Checkout" agenda-group:

- **`Gross Total`** - if we haven't already calculated the gross total, accumulates the product prices into a total, puts this total into working memory, and displays it via the Swing TextArea (using the **`textArea`** global variable yet again).
- If the gross total is between ten and twenty, "`Apply 5% Discount`" calculates the discounted total and adds it to working memory and displays it in the text area.
- If our gross total is not less than 20, "`Apply 10% Discount`" calculates the discounted total, adds it to the working memory and displays it in the text area.

Now that you understand how the code works in theory, you can have a look at what happens in practice. The file named **`PetStore.java`** contains a `main()` method, so that it can be run as a standard **`Java`** application, either from the command line or via the IDE. (This assumes that you have your classpath set correctly.) See the start of the examples section for more information.

The first screen contains the Pet Store Demo. It has a list of available products (top left), an empty list of selected products (top right), checkout and reset buttons (middle) and an empty system messages area (bottom).

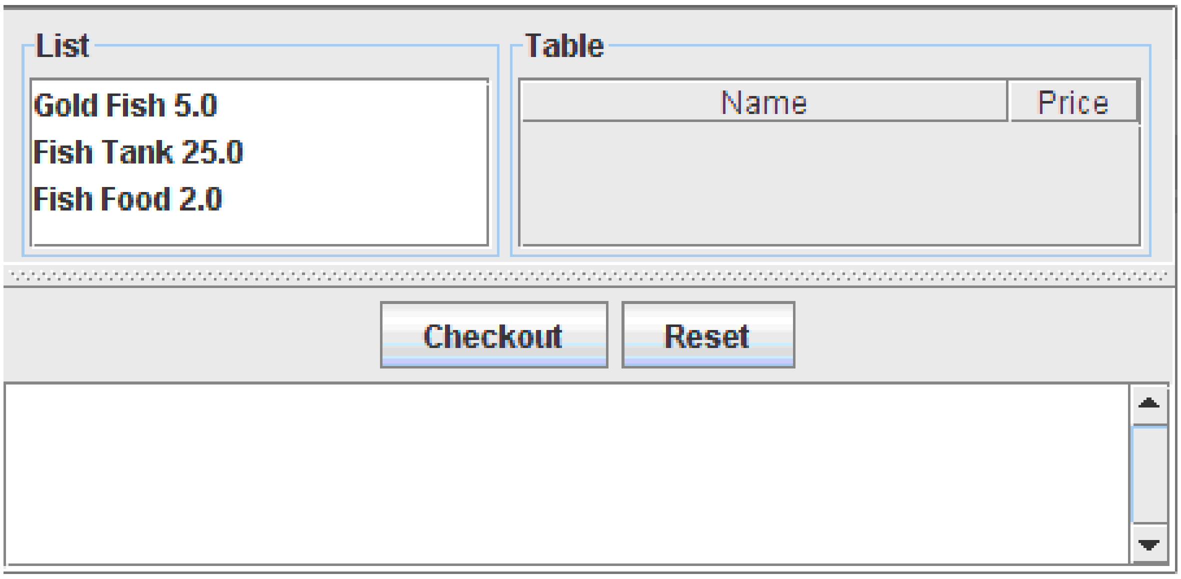


Figure 8.13. Depiction of Pet Store Demonstration Immediately After Launch

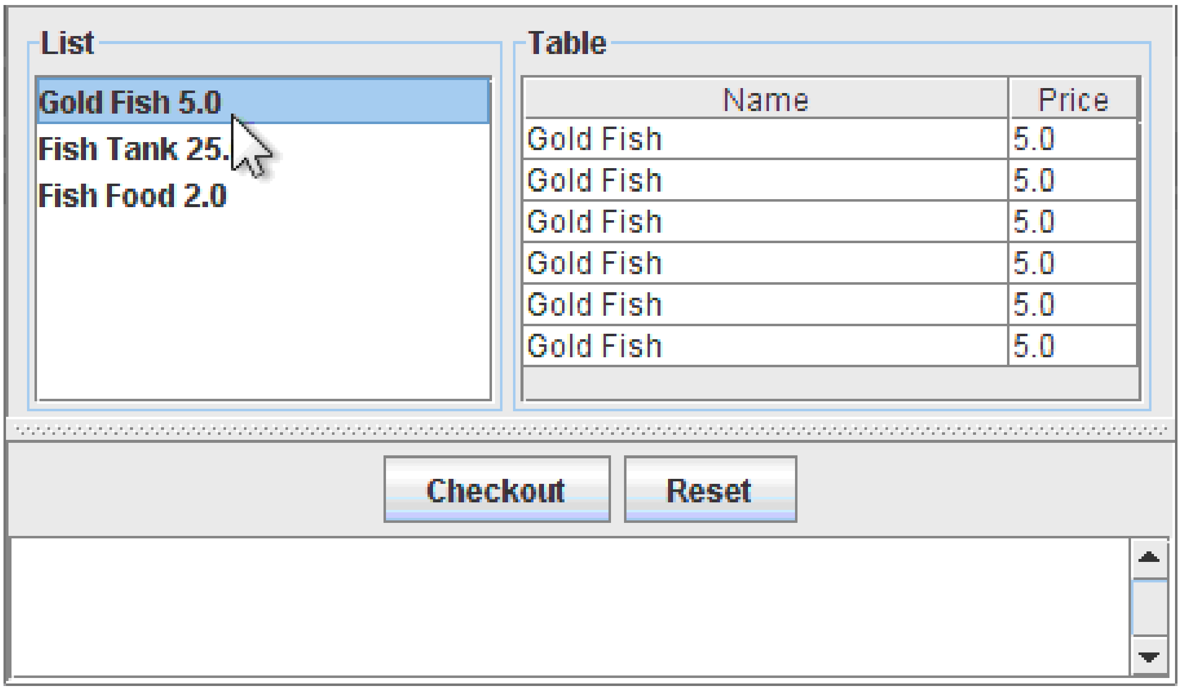
In order to reach this point, the following things have occurred:

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

2. A new `PetStoreUI` object has been created and given a handle on the Rule Base, which it will use later.

3. Various **`Swing`** components perform their operations and then, the above screen is shown and **`waits for user input`**.

Clicking on various products from the list will give you screens similar to those shown one below.



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

Figure 8.14. Depiction of Pet Store Demonstration with Products Selected

Please note that no rules code has been fired here. This is only **`Swing`** code, whose role it is to "listen" for mouse click events and, subsequently, add some selected products to the `TableModel` object for display in the top, right-hand section. (As an aside, note that this is a classic use of the Model View Controller design pattern.)

It is only when "**`Checkout`**" is clicked that the business rules are executed, in roughly the same order as that described earlier.

1. The `CheckOutCallBack.checkout()` method is eventually called by the **`Swing`** class that has been awaiting the click on the "Checkout" button. It inserts the data from the `TableModel` object (top right-hand side of the graphical user interface), and also palces it in the session's working memory. It then fires the rules.

2. The "`Explode Cart`" rule is the first to fire, because its auto-focus setting has a vlaue of "true." It loops through all the products in the cart, ensuring that they are in the working memory. It then gives the "`Show Items`" and `Evaluation` agenda groups a chance to fire. The rules in these groups add the contents of the cart to the text area (at the bottom of the window), decide whether or not to give the customer free fish food and ask us them whether or not they desire buy a fish tank. This is depicted below:

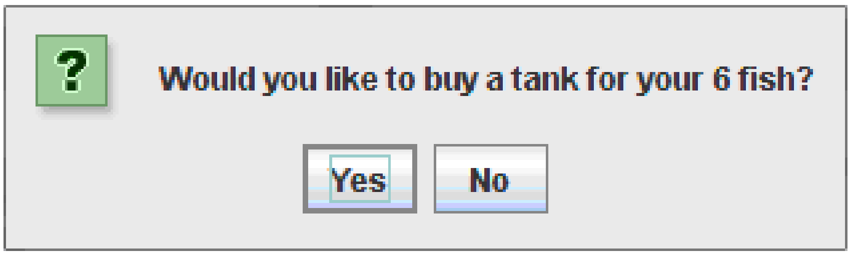

Would you like to buy a tank for your 6 fish?

Figure 8.15. Do You Want to Buy a Fish Tank?

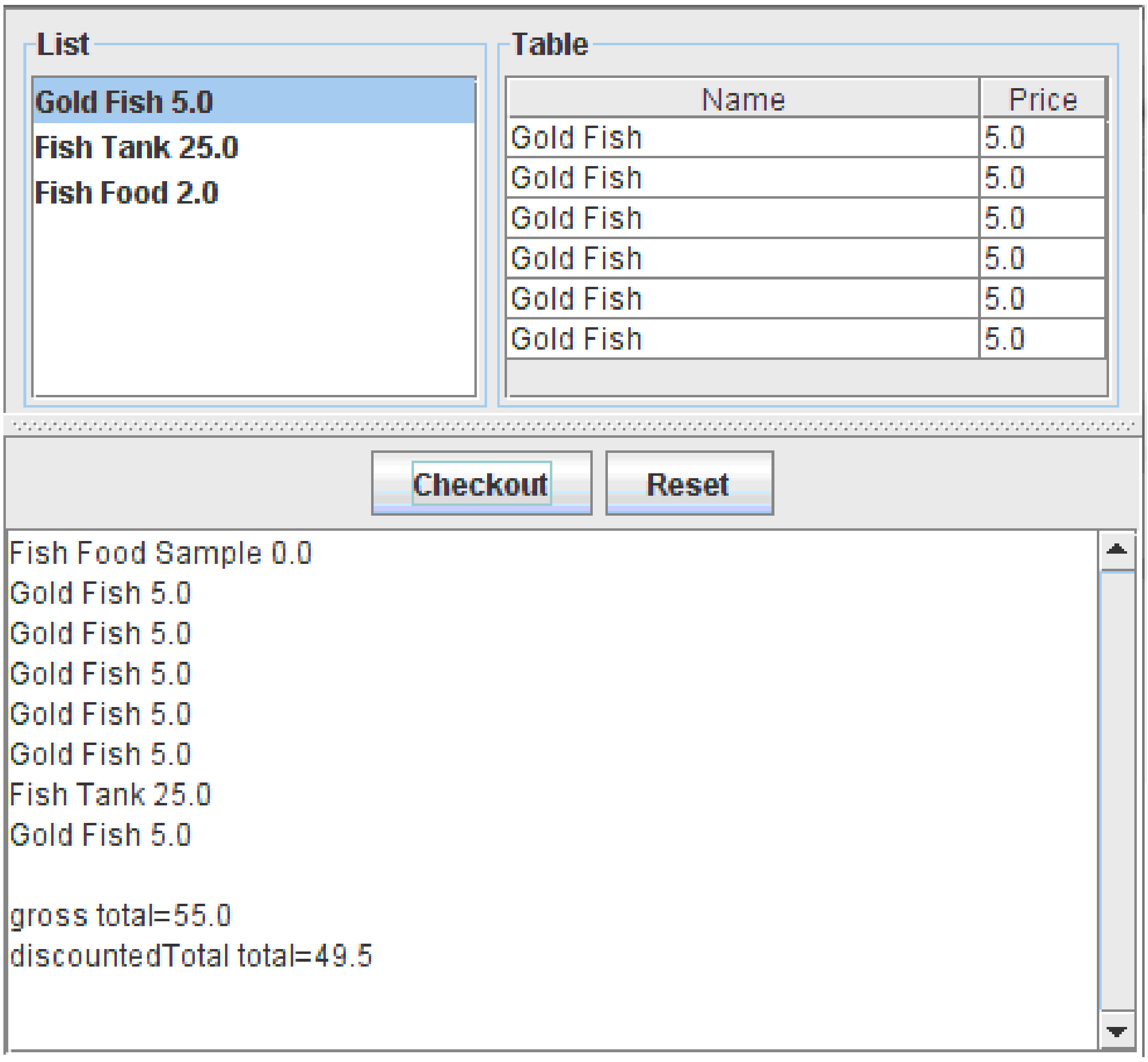
3. The "`Do Checkout` rule is the next to fire as, firstly, no other agenda group currently has focus and, secondly it is part of the default agenda group. It always calls the `doCheckout()` function, which displays a dialogue box containing the question "Would you like to Checkout?"

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

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 the checkout agenda group display the contents of the cart and apply the appropriate discount.

6. **`Swing`** then waits for user input, based uponn which it will either check out more products (and to cause the rules to fire again) or close the graphical user interface, as per the final image:



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
```

Figure 8.16. Pet Store Demonstraton After All Rules Have Fired.

Should we choose, we could add more System.out calls to demonstrate this flow of events. The current output of the console of the above sample is as per the listing below.

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

Example 8.55. Console (System.out) from running the PetStore GUI

8.7. Sudoku Example

Name:	Sudoku
Main class:	**`org.drools.examples.sudoku.Main`**
Type:	**`Java`** application
Rules file:	**`sudokuSolver.drl, sudokuValidator.drl`**
Objective:	Demonstrates the solving of logic problems, and complex pattern matching.

This example demonstrates how **`JBoss Rules`** can be used to find an answers in a potentially large "solution-space," based on a number of constraints. It also shows how **`JBoss Rules`** can be integrated into a graphical user interface and use callbacks in order to update the display based on changes in the working memory at runtime.

8.7.1. Overview of Sudoku

Sudoku is a logic-based number placement puzzle, originating in Japan. 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 one to nine once and once only.

The creator of the puzzle provides a partially-completed grid and the solver's task is to complete it whilst abiding by the constraints of the rules.

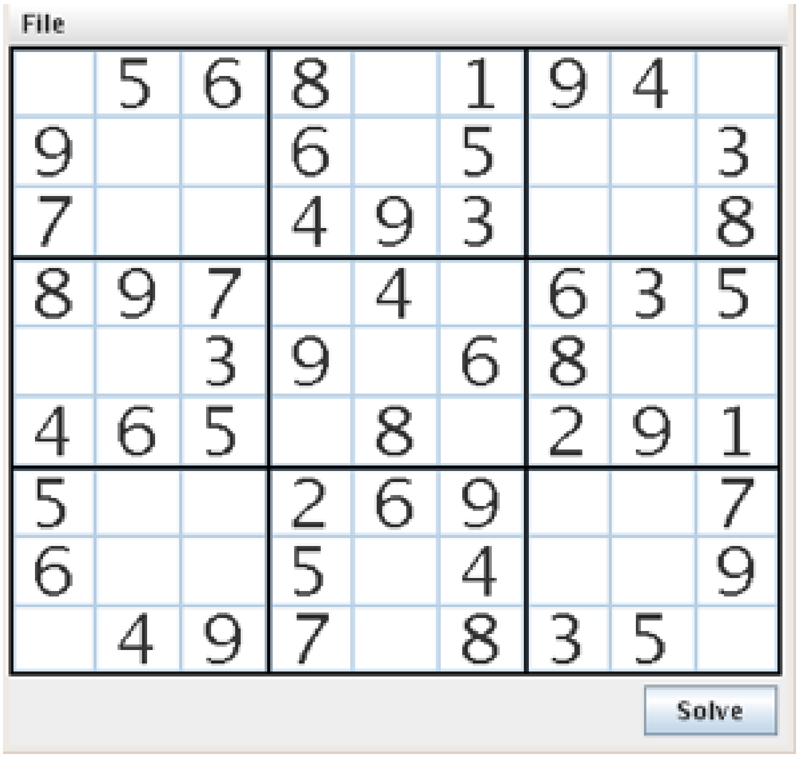
The general strategy to solve the problem is to ensure that when you insert a new number it should be unique in its particular row, column and 3x3 square,

You can refer to *http://en.wikipedia.org/wiki/Sudoku* for a more detailed description of the rules.

8.7.2. Running the Example

Download and install **`drools-examples`** as per the procedure described earlier. Then execute **`java org.drools.examples.sudoku.Main`**. This example requires **`Java 5`**.

A relatively simple, partially-filled grid will be displayed in a window.



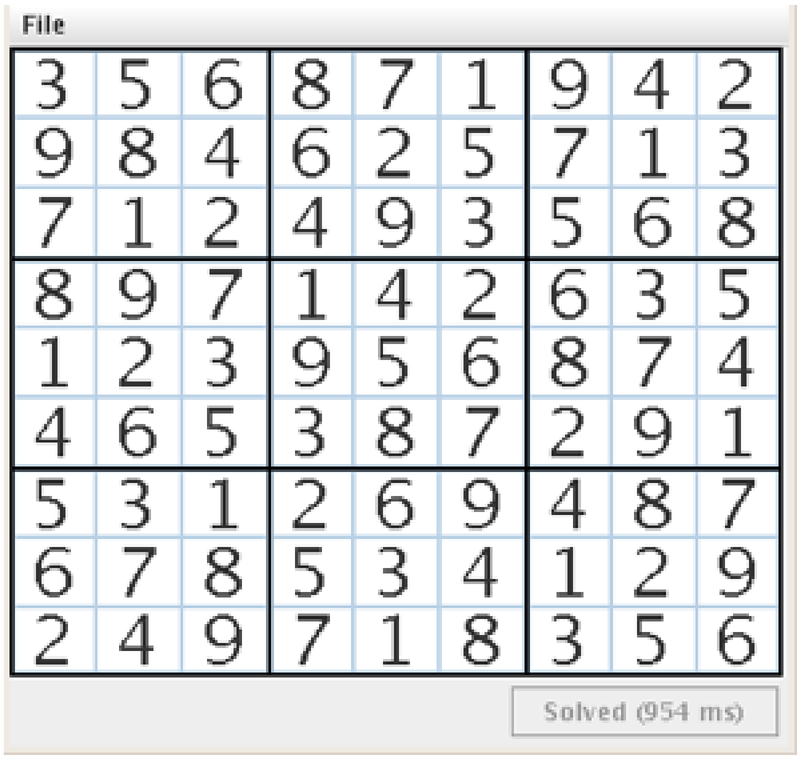
	5	6	8		1	9	4	
9			6		5			3
7			4	9	3			8
8	9	7		4		6	3	5
		3	9		6	8		
4	6	5		8		2	9	1
5			2	6	9			7
6			5		4			9
	4	9	7		8	3	5	

Figure 8.17. Partially-Filled Grid

Click on the "**`Solve`**" button and the Rules Engine will fill in the remaining values. The console will display detailed information of the rules as they are are executed. This is to show, in a human-readable form, how the puzzle is solved.

```
Rule #3 determined the value at (4,1) could not be 4 as this value already
 exists in the same column at (8,1)
Rule #3 determined the value at (5,5) could not be 2 as this value already
 exists in the same row at (5,6)
Rule #7 determined (3,5) is 2 as this is the only possible cell in the
 column that can have this value
Rule #1 cleared the other PossibleCellValues for (3,5) as a
 ResolvedCellValue of 2 exists for this cell.
Rule #1 cleared the other PossibleCellValues for (3,5) as a
 ResolvedCellValue of 2 exists for this cell.
...
Rule #3 determined the value at (1,1) could not be 1 as this value already
 exists in the same zone at (2,1)
Rule #6 determined (1,7) is 1 as this is the only possible cell in the row
 that can have this value
Rule #1 cleared the other PossibleCellValues for (1,7) as a
 ResolvedCellValue of 1 exists for this cell.
Rule #6 determined (1,1) is 8 as this is the only possible cell in the row
 that can have this value
```

Once all of the rules pertaining to the "solving logic" have been activated and executed, the engine then processes a second rule base. This checks that the solution is complete and valid. In this example, it finds that all is well, and the "**`Solve`**" button is, consequentially, disabled. The screen displays the text "**`Solved (1052ms)`**".

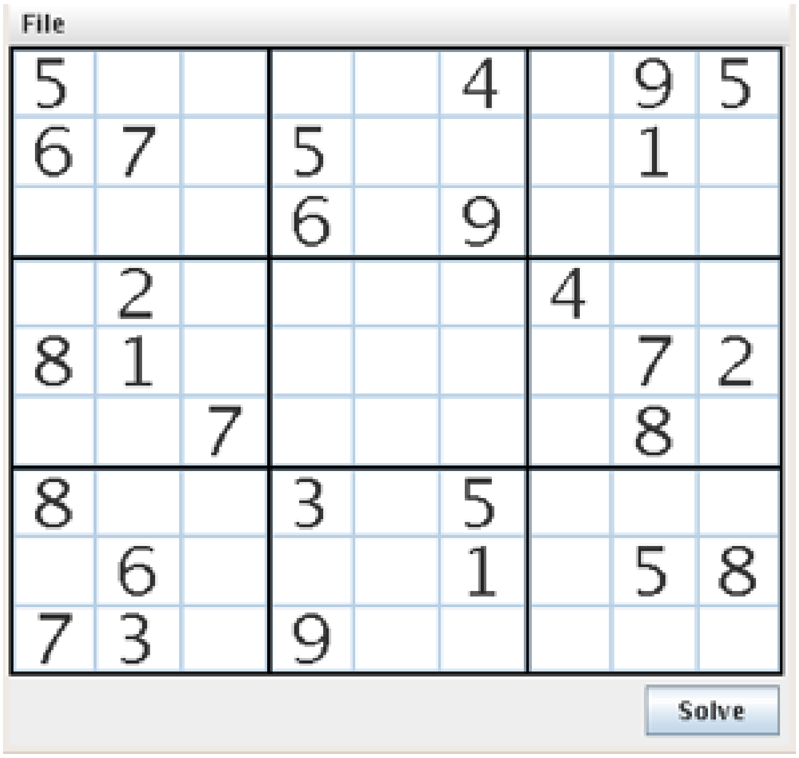


3	5	6	8	7	1	9	4	2
9	8	4	6	2	5	7	1	3
7	1	2	4	9	3	5	6	8
8	9	7	1	4	2	6	3	5
1	2	3	9	5	6	8	7	4
4	6	5	3	8	7	2	9	1
5	3	1	2	6	9	4	8	7
6	7	8	5	3	4	1	2	9
2	4	9	7	1	8	3	5	6

Figure 8.18. Solved Grid

The example comes with a number of grids which can be loaded and solved. Click on "File", then "Samples" and "Medium" to load a more challenging grid. Note that the "**`Solve`**" button is enabled when the new grid is loaded.

Now, you are going to load a Sudoku grid that is deliberately invalid. Click on "File", "Samples" and "!DELIBERATELY BROKEN!". Note that this grid has some errors: For example, the value "5" appears twice in the first row.



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

Figure 8.19. Broken Grid

Despite this, click on the "Solve" button to apply the "solving rules" to this invalid grid. Note that the "**`Solve`**" button is relabeled to indicate that the resulting solution is invalid.

In addition, the Validation Rule Set outputs all of the issues it has discovered to the console.

```
There are two cells on the same column with the same value at (6,0) and
 (4,0)
There are two cells on the same column with the same value at (4,0) and
 (6,0)
There are two cells on the same row with the same value at (2,4) and (2,2)
There are two cells on the same row with the same value at (2,2) and (2,4)
There are two cells on the same row with the same value at (6,3) and (6,8)
There are two cells on the same row with the same value at (6,8) and (6,3)
There are two cells on the same column with the same value at (7,4) and
 (0,4)
There are two cells on the same column with the same value at (0,4) and
 (7,4)
There are two cells on the same row with the same value at (0,8) and (0,0)
There are two cells on the same row with the same value at (0,0) and (0,8)
There are two cells on the same column with the same value at (1,2) and
 (3,2)
There are two cells on the same column with the same value at (3,2) and
 (1,2)
There are two cells in the same zone with the same value at (6,3) and (7,3)
There are two cells in the same zone with the same value at (7,3) and (6,3)
There are two cells on the same column with the same value at (7,3) and
 (6,3)
```

```
There are two cells on the same column with the same value at (6,3) and
 (7,3)
```

You will learn more about the Solving Rule Set later in this section but, for the moment, you should note that some theoretically-solvable puzzles cannot be deduced by the engine in its current state. Click on "File", "Samples" and then "Hard 3" to load a sparsely-populated grid.

Now click on the "**Solve**" button. Note that the current rules are unable to complete the grid, even though you, yourself, may be able to see a way to the solution.

Up until the present time, the solution have been achieved by the use of a ten rule set. This rule set can now be extended in order to enable the engine to tackle the more complex logic to solve puzzles such as this one.

8.7.3. Java Source and Rules Overview

The **Java** source code can be found in the **/src/main/java/org/drools/examples/sudoku** directory. The two DRL files defining the rules are located in the **/src/main/rules/org/drools/examples/sudoku** directory.

The package `org.drools.examples.sudoku.swing` contains a set of classes which implement a framework for Sudoku puzzles. Note that this package does not have any dependencies on the **JBoss Rules** libraries.

SudokuGridModel defines an interface which can be implemented in order to store a Sudoku puzzle as a 9x9 grid of integervalues, some of which may be null. These indicate that the value for the cell has not yet been resolved.

`SudokuGridView` is a **Swing** component that can depict any implementation of `SudokuGridModel`.

`SudokuGridEvent` and `SudokuGridListener` are used to communicate "state" changes between the model and the view; events are fired when a cell's value is resolved or changed. If you are familiar with the model-view-controller patterns in other Swing components such as **JTable**, then this pattern should be familiar. `SudokuGridSamples` provides a number of partially-completed Sudoku puzzles for demonstration purposes.

The package entitled `org.drools.examples.sudoku.rules` contains an implementation of `SudokuGridModel`, based upon **JBoss Rules**. Two **Java** objects are used, both of which extend `AbstractCellValue` and represent a value for a specific cell in the grid. These include the row and column location of the cell, an index of the 3x3 zone in which the cell is contained, thirdly, and the value of the cell.

`PossibleCellValue` indicates that the value of a cell is currently unknown. There can be anywhere from two to nine possible cell values for a given cell.

`ResolvedCellValue` indicates that we have determined what must become the value of the cell. There can only be one resolved value for a given cell.

`DroolsSudokuGridModel` implements `SudokuGridModel`. It is responsible for converting an initially two-dimensional array of partially-specified cells into a set of `CellValue` **Java** objects. This creates a working memory session based on **solverSudoku.drl**. It also inserts the `CellValue` objects into the working memory.

When the `solve()` method is called, it, in turn, calls `fireAllRules()`, which will try to solve the puzzle.

`DroolsSudokuGridModel` attaches a `WorkingMemoryListener` to the working memory, which allows it to be called back on insert and retract events as the puzzle is solved. When a new `ResolvedCellValue` is inserted into the Working Memory, this callback allows the implementation to fire a `SudokuGridEvent` to its `SudokuGridListener` clientele, which can then update themselves in real time.

Once all the rules fired by the "Solver" working memory have executed, `DroolsSudokuGridModel` runs a second set of rules, based on **`validatorSudoku.drl`**. These work with the same set of **`Java`** objects to determine if the resulting grid is a valid and a full solution.

The class **`org.drools.examples.sudoku.Main`** implements a **`Java`** application that combines the described components.

The package, `org.drools.examples.sudoku`, contains two .DRL files. These are, firstly, **`solverSudoku.drl`**, which defines the rules that attempt to solve a Sudoku puzzle and, secondly, **`validator.drl`**, which defines the rules which determine whether the current state of the working memory represents a valid solution. Both use `PossibleCellValue` and `ResolvedCellValue` objects as their facts. Also, they both output information to the Console window as their rules fire. In a real-world situation, you would insert logging information and use the `WorkingMemoryListener` to display this to a user, rather than use the console in this fashion.

8.7.4. Sudoku Validator Rules (`validatorSudoku.drl`)

The first rule simply checks that no `PossibleCellValue` objects remain in the working memory. Once the puzzle is solved, only `ResolvedCellValue` objects should be present, one for each cell.

The other three rules match all of the `ResolvedCellValue` objects and bind them to the variable entitled `$resolved1`. They then look for the `ResolvedCellValues` that both contain the same value and are located, respectively, in the same row, column and 3x3 zone.

If these rules are fired, they add a message to a global list of strings that describes the reason the solution is invalid. `DroolsSudokoGridModel` injects this list before it runs the rule set. It also checks whether or not the list is empty after having called `fireAllRules()`. If it is not empty, then it prints all the strings in the list and sets a flag to indicate that the grid is not solved.

8.7.5. Sudoku Solving Rules (`solverSudoku.drl`)

Now you are ready to study the more complex rule set used to solve Sudoku puzzles.

Rule #1 is used for book-keeping purposes. Several of the other rules insert `ResolvedCellValues` into the working memory at specific rows and columns after they have determined that a given cell must have a certain value.

At this point, it is important to clear the working memory of any inserted `PossibleCellValues` that correspond with rows and columns holding invalid values. This rule is, therefore, given a higher salience than the remaining rules to ensure that as soon as the left-hand side is "true," activations are moved to the top of the agenda and fired.

This, in turn, prevents the spurious firing of other rules, due to the combination of a `ResolvedCellValue` and one or more `PossibleCellValues` being present in the same cell.

This rule also calls `update()` on the `ResolvedCellValue`. This happens even though it has not, in fact, been modified to ensure that **`JBoss Rules`** fires an event to any `WorkingMemoryListeners` attached to the working memory. Firing such an event would enable them to update themselves. In this case, it would be so that the graphical user interface can display the new state of the grid.

Rule #2 identifies cells in the grid which have only one possible value. The first line of the "`when`" clause matches all of the `PossibleCellValue` objects in the working memory. The second line demonstrates a use of the "`not`" keyword. This rule will only fire if there are no other `PossibleCellValue` objects in the working memory at the same row and column with differing values.

When the rule fires, the single `PossibleCellValue` located at the row and column is retracted from the working memory. It is replaced by a new `ResolvedCellValue` with the same value at that location.

Rule #3 removes `PossibleCellValues` from a row when they have the same value as a `ResolvedCellValue`. In other words, when a cell is filled with a resolved value, you need to remove the possibility of any other cell on the same row having this value. The first line of the "`when`" clause matches all `ResolvedCellValue` objects in the working memory. The second line matches `PossibleCellValues` which have both the same row and the same value as these `ResolvedCellValue` objects. If any are found, the rule activates and, when fired, it retracts the `PossibleCellValue` which can no longer be the correct solution for that cell.

Rules #4 and #5 act in the same way as Rule #3 but check for redundant `PossibleCellValues` in either a given column or zone of the grid as a `ResolvedCellValue` respectively.

Rule #6 checks for the scenario whereby a cell's possible value appears only once in a given row. The first line of the left hand-side matches against all `PossibleCellValue` facts in the working memory and stores the results in a number of local variables. The second line checks that no other `PossibleCellValue` objects with the same value exist on this row. The third to fifth lines check that there is not a `ResolvedCellValue` with the same value in the same zone, row or column. This so that this rule does not fire prematurely. It is interesting to note that you could remove lines three to five and give rules #3, #4 and #5 a higher salience to make sure they always fire before rules #6, #7 and #8. When the rule fires, `$possible` must represent the value for the cell; so, as in Rule #2, you retract `$possible` and replace it with the equivalent, new `ResolvedCellValue`.

Rules #7 and #8 act in the same way as Rule #2 but check for single `PossibleCellValues` in a given column of the grid and in a given zone of the grid respectively.

Rule #9 represents the most complex currently implemented rule. This rule implements the logic that dictates, "If we know that a pair of given values can only occur in two cells on a specific row, (for example we have determined the values of 4 and 6 can only appear in the first row in cells [0,3] and [0,5]) and this pair of cells can not hold other values, then, although we do not know which of the pair contains a four and which contains a six, we do know that these two values must be in these two cells. Hence we can remove the possibility of them occurring anywhere else in the same row."

Rules #10 and #11 act in the same way as rule #9 but check for the existence of only two possible values in a given column or a given zone respectively.

In order to solve more difficult grid puzzles, one would have to extend the rule set further with additional laws that would encapsulate more complex reasoning.

8.7.6. Suggestions for Future Developments

There are a number of ways in which this example could be developed. The reader is encouraged to consider the following propositions as possible exercises.

- `Agenda-group`: Agenda groups are an ideal declarative tool for phased execution. In this example, it is easy to see there are two phases, namely "resolution" and "validation". At present, they are executed by creating two separate rule bases, one for each "job". It would be better to define agenda-groups for all the rules, by splitting them into "resolution" and "validation" categories. These would all be loaded from a single rule base. The engine would execute resolution and immediately afterwards, validation.
- `Auto-focus`: This is a method for handling exceptions to the regular execution of rules. In the present case, if you detect an inconsistency in either the input data or the resolution rules, why should time be wasted in continuing the execution if it will be invalid anyway? It would most likely be better to report the inconsistency immediately. To do that, now that there is a single rule-base, you simply need to define the auto-focus attribute for all rules which validate puzzle consistency.
- `Logical insert`: An inconsistency only exists whilst wrong data is in working memory. As such, one could state that the validation rules logically insert inconsistencies and, as soon as the offending data is retracted, the inconsistency no longer exists.
- `session.iterateObjects()`: Although it is a valid use case to have a global list for the purpose of recording problems, it would be more interesting to ask the stateful session to call the desired issues by using **`session.iterateObjects( new ClassObjectFilter( Inconsistency.class ) )`**. Having the inconsistency class can also allow us to paint the offending cells a colour (such as red), making them easy to spot in the graphical user interface.
- `kcontext.getKnowledgeRuntime().halt()`: Even if the software reports the error as soon as it is found, one needs a way to tell the engine to stop evaluating rules. You can do that by creating a rule that, in the presence of inconsistencies, calls the `halt()` code.
- Queries: By looking at the method `getPossibleCellValues(int row, int col)` in `DroolsSudokuGridModel`, one can see that it iterates over all `CellValue` objects, searching for the few that it actually wants. This process can be improved if one uses a **`JBoss Rules`** query. Simply define a query to return the objects you want and cleanly iterate over it. Other queries may be defined as needed.
- Globals as services: The main objective of this change is to facilitate that which follows, but it is also useful in its own right. In order to teach the use of "globals" as services, it would be nice to set up a callback. This is so that each rule that finds the `ResolvedCellValue` for a given cell can "call," in order to notify and update the corresponding cell in the graphical user interface. This would provide immediate feedback for the user. Also, the number in the last cell found could be "painted" a different colour in order to quickly identify the conclusions of the different rules.
- Step-by-step execution: Now that immediate user feedback has been obtained, you can make use of the "restricted run" feature in **`JBoss Rules`**. In other words, you could add a button to the graphical user interface, that, when activated, would causes the execution of a single rule, by calling `fireAllRules( 1 )`. That way, the user would see what the engine is doing "step-by-step."

8.8. Miss Manners and Benchmarking

Name:	Miss Manners
Main class:	**`org.drools.benchmark.manners.MannersBenchmark`**
Type:	java application

Rules file:	**`manners.drl`**
Objective:	Advanced walk-through of the Manners benchmark, covers Depth conflict resolution in depth.

8.8.1. Introduction

Miss Manners is throwing a party and, being a good host, she wants to arrange seating appropriately. Her initial design arranges everyone in male-female pairs but then she worries that people may not have mutual topics of interest to discuss. What is a good host to do? She decides to note the hobby of each guest. She can then arrange them by alternating gender and ensure that everybody is seated next to someone on at least one side, with whom they have a common hobby.

8.8.1.1. Bench Marking

- **`Manners`**

  uses a depth-first search approach to determine the seating arrangements alternating women and men, whilst ensuring one common hobby for neighbours.

- **`Waltz`**

  establishes a three-dimensional interpretation of a line drawing by line labeling by constraint propagation.

- **`WaltzDB`**

  is a more general version of Waltz, in that it supports the junctions of more than three lines and uses a database.

- ARP

  is a route planner for a robotic vehicle. It uses the **`A*`** search algorithm.

- **`Weavera`**

  is a VLSI router for channels and boxes. It uses a blackboard technique.

`Manners` has become the de facto rule engine benchmark. Its behaviour, however, is now well-known and many engines optimise for it, thereby negating its usefulness as a benchmark. This is why **`Waltz`** is becoming more highly favoured.

8.8.1.2. Miss Manners Execution Flow

After the first seating arrangement has been assigned, the system executes "depth-first" recursion. This repeatedly processes correct seating arrangements until the last seat is assigned. **`Manners`** uses a `Context` instance to control execution flow. The activity diagram is partitioned in order to show the relation of the rule execution to the current `Context` state.

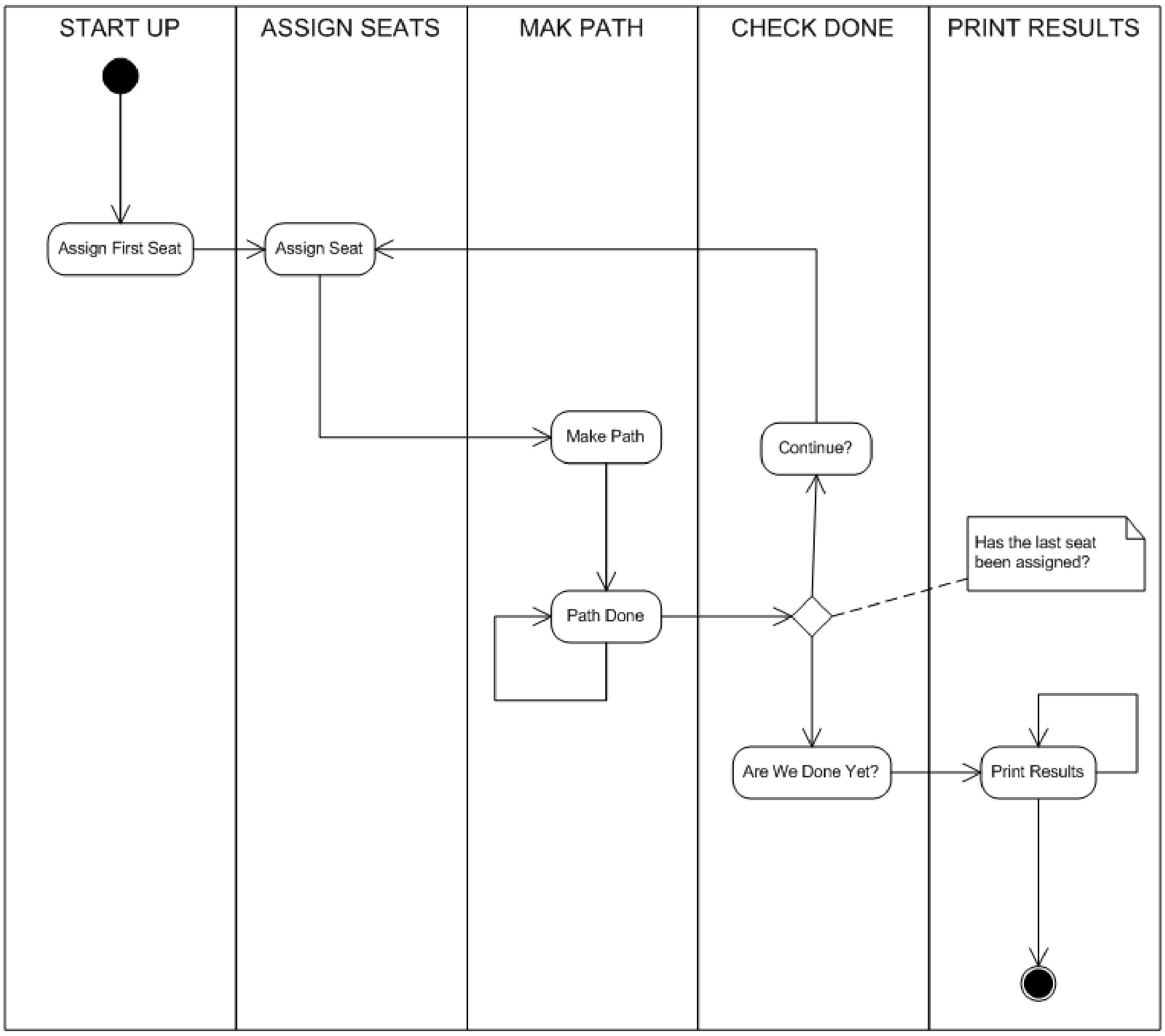


Figure 8.20. **`Manners`** Activity Diagram

8.8.1.3. The Data and Results

Before exploring the rules in detail, you are going to take a look at the asserted data and the resulting seating arrangement. The data is a simple set of five guests who are to be arranged so that genders are alternating and neighbours have a common hobby.

8.8.1.4. The Data

The data is given in OPS5 syntax. Each attribute has a parenthesised list of name and value pairs. Each person has only one hobby.

```
(guest (name n1) (sex m) (hobby  h1)  )
(guest (name n2) (sex f) (hobby  h1)  )
(guest (name n2) (sex f) (hobby  h3)  )
(guest (name n3) (sex m) (hobby  h3)  )
(guest (name n4) (sex m) (hobby  h1)  )
(guest (name n4) (sex f) (hobby  h2)  )
(guest (name n4) (sex f) (hobby  h3)  )
(guest (name n5) (sex f) (hobby  h2)  )
```

```
(guest (name n5) (sex f) (hobby  h1)  )
(last_seat (seat 5)  )
```

8.8.1.5. The Results

Each line of the results list is printed upon execution of the "Assign Seat" rule. They key element to which you should pay attention is that each line has a "pid" value one greater than that of the last. (The significance of this will be explained in the discussion of the rule "Assign Seating".) The "ls", "rs", "ln" and "rn" refer to the left and right seat and neighbour's name, respectively. The actual implementation uses longer attribute names (such as, `leftGuestName`, but in this manual you will read the notation from the original implementation.

```
[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[Seating id=2, pid=1, done=false, ls=1, ln=n5, rs=2, rn=n4]
[Seating id=3, pid=2, done=false, ls=2, ln=n4, rs=3, rn=n3]
[Seating id=4, pid=3, done=false, ls=3, rn=n3, rs=4, rn=n2]
[Seating id=5, pid=4, done=false, ls=4, ln=n2, rs=5, rn=n1]
```

8.8.2. In-Depth Analysis

8.8.2.1. Cheating

`Manners` has been designed to exercise cross-product joins and Agenda activities. Some people, from not understanding this, tend to "tweak" the example to achieve better performance. This makes their port of the Manners benchmark pointless. Known cheats or porting errors for Miss Manners are:

- Using arrays for a guest's hobbies, instead of asserting each one as a single fact. This massively reduces the cross products.
- Altering the sequence of data which reduces the amount of matching, thereby increasing execution speed.
- It is possible to change the "**`not`**" conditional element so that the test algorithm only uses the "first-best-match." This is, basically, transforming the test algorithm to "backward chaining." The results are only comparable to other backward chaining rule engines or ports of **`Manners`**.
- Removing the context so the rule engine matches the guests and seats prematurely. A proper port will prevent facts from matching via the context start.
- It is possible to prevent the rule engine from performing "combinational" pattern-matching.
- The port is incorrect if no facts are retracted in the reasoning cycle as a result of "`NOT CE`."

8.8.2.2. Conflict Resolution

The Manners benchmark was written for OPS5, which has two conflict resolution strategies, LEX and MEA. LEX is a chain of several strategies including salience, "recency" and complexity. The recency aspect of the strategy drives the "depth first" (LIFO) firing order. The *Clips Reference Manual* documents the recency strategy as per the following extract:

> Every fact and instance is marked internally with a "time tag" to indicate its relative recency with respect to every other fact and instance in the system. The pattern entities associated with each rule activation are sorted in descending order for determining placement. An activation with a more recent pattern entities is placed before activations with less recent pattern entities. To determine the placement order of two activations, compare the sorted time tags of the two activations one by one starting with the largest time tags. The comparison should continue until one activation's time tag is greater than the other activation's corresponding time tag. The activation with the greater time tag is placed before the other activation on the agenda. If one activation has more pattern entities than the other activation and the compared time tags are all identical, then the activation with more time tags is placed before the other activation on the agenda.

However, **`Jess`** and **`Clips`** both use the "Depth" strategy, which is simpler and lighter. This is what **`JBoss Rules`** also adopted. The *Clips Reference Manual* documents the Depth strategy as:

> Newly activated rules are placed above all rules of the same salience. For example, given that fact-a activates rule-1 and rule-2 and fact-b activates rule-3 and rule-4, then if fact-a is asserted before fact-b, rule-3 and rule-4 will be above rule-1 and rule-2 on the agenda. However, the position of rule-1 relative to rule-2 and rule-3 relative to rule-4 will be arbitrary.

The initial **`JBoss Rules`** implementation for the Depth strategy would not work for **`Manners`** without the use of salience on the "`make_path`" rule. Indeed, someone on the CLIPS Support Forum had this to say:

> The default conflict resolution strategy for CLIPS, depth, is different than the default conflict resolution strategy used by OPS5. Therefore if you directly translate an OPS5 program to CLIPS, but use the default depth conflict resolution strategy, you're only likely to get the correct behavior by coincidence. The lex and mea conflict resolution strategies are provided in CLIPS to allow you to quickly convert and correctly run an OPS5 program in CLIPS

An investigation of the CLIPS code reveals that there is undocumented functionality in the Depth strategy, in the form of an accumulated time tag; it is not an extensive fact-by-fact comparison as in the recency strategy as it simply adds the total of all the time tags for each activation and compares.

8.8.2.3. Assign First Seat

Once the context is changed to START_UP, Activations are created for all asserted guests. Because all Activations are created as the result of a single working memory action, they all have the same Activation time tag. The last asserted Guest would have a higher fact time tag and its Activation would fire, because it has the highest accumulated fact time tag. The execution order in this rule has little importance, but has a big impact in the rule "Assign Seat". The activation fires and asserts the first `Seating` arrangement and a `Path`, and then sets the `Context` attribute `state` to create an activation for rule `findSeating`.

```
rule assignFirstSeat
when
 context : Context( state == Context.START_UP )
 guest : Guest()
 count : Count()
```

```
then
 String guestName = guest.getName();

 Seating seating =  new Seating( count.getValue(),
         1,
         true,
         1,
         guestName,
         1,
         guestName);
 insert( seating );

 Path path = new Path( count.getValue(), 1, guestName );
 insert( path );

 modify( count ) { setValue ( count.getValue() + 1 )  }

 System.out.println( "assign first seat :  "+seating+" : "+path);

 modify( context ) { setState( Context.ASSIGN_SEATS ) }
end
```

8.8.2.4. Rule "findSeating"

This rule determines the seating arrangements. The rule creates cross-product solutions for all asserted `Seating` arrangements against all of the asserted guests except against itself and any already-assigned chosen solutions.

```
rule findSeating
when
 context : Context( state == Context.ASSIGN_SEATS )
 $s      : Seating( pathDone == true )
 $g1     : Guest( name == $s.rightGuestName )
 $g2     : Guest( sex != $g1.sex, hobby == $g1.hobby )
 count   : Count()
 not ( Path( id == $s.id, guestName == $g2.name) )
 not ( Chosen( id == $s.id, guestName == $g2.name, hobby == $g1.hobby) )
then
 int rightSeat = $s.getRightSeat();
 int seatId = $s.getId();
 int countValue = count.getValue();

 Seating seating = new Seating( countValue,
         seatId,
         false,
         rightSeat,
         $s.getRightGuestName(),
         rightSeat + 1,
         $g2.getName()
         );
 insert( seating );
 Path path = new Path( countValue, rightSeat + 1, $g2.getName()  );
 insert( path );

 Chosen chosen = new Chosen( seatId, $g2.getName(), $g1.getHobby() );
 insert( chosen  );

 System.err.println( "find seating : "+seating+" : "+path+" : "+chosen);

 modify( count ) {setValue(  countValue + 1 )}
 modify( context ) {setState( Context.MAKE_PATH )}
end
```

```
=>[ActivationCreated(35): rule=findSeating
[fid:19:33]:[Seating id=3, pid=2, done=true, ls=2, ln=n4, rs=3, rn=n3]
[fid:4:4]:[Guest name=n3, sex=m, hobbies=h3]
[fid:3:3]:[Guest name=n2, sex=f, hobbies=h3]

=>[ActivationCreated(35): rule=findSeating
[fid:15:23]:[Seating id=2, pid=1, done=true, ls=1, ln=n5, rs=2, rn=n4]
[fid:5:5]:[Guest name=n4, sex=m, hobbies=h1]
[fid:2:2]:[Guest name=n2, sex=f, hobbies=h1]

=>[ActivationCreated(35): rule=findSeating
[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1]
[fid:1:1]:[Guest name=n1, sex=m, hobbies=h1]
```

The creation of these redundant activations might seem pointless but it must be remembered that **`Manners`** is not about good rule design; it was intentionally designed as a bad ruleset to fully stress-test the cross-product matching process and the Agenda. Note that each activation has the same time tag of 35. This is because they were all activated by the change in the `Context` object to ASSIGN_SEATS. With OPS5 and LEX, it would correctly fire the activation with the `Seating` asserted last. With Depth, the "accumulated fact" time-tag ensures that the activation with the last asserted `Seating` fires.

8.8.2.5. Rules "`makePath`" and "`pathDone`"

Rule `makePath` must always fire before `pathDone`. A `Path` object is asserted for each `Seating` arrangement, up to the last asserted `Seating`. Note that the conditions in `pathDone` are a subset of those in `makePath`, which may lead you to wonder about how it is that you can ensure that `makePath` fires first.

```
rule makePath
when
 Context( state == Context.MAKE_PATH )
 Seating( seatingId:id, seatingPid:pid, pathDone == false )
 Path( id == seatingPid, pathGuestName:guestName, pathSeat:seat )
 not Path( id == seatingId, guestName == pathGuestName )
then
```

```
 insert( new Path( seatingId, pathSeat, pathGuestName ) );
end
```

```
rule pathDone
when
 context : Context( state == Context.MAKE_PATH )
 seating : Seating( pathDone == false )
then
 modify( seating ) {setPathDone( true )}
 modify( context ) {setState( Context.CHECK_DONE)}
end
```

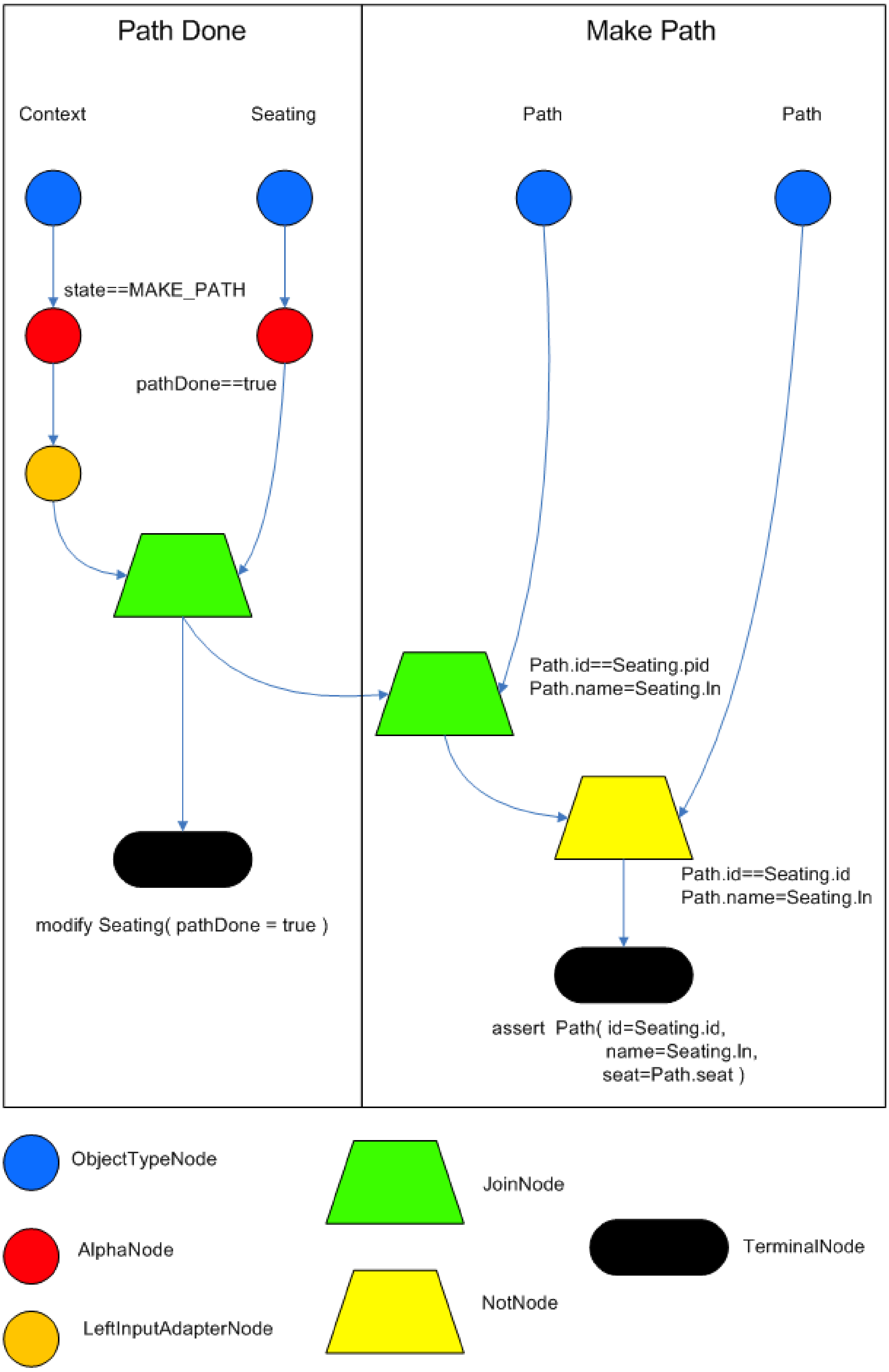


Figure 8.21. Rete Diagram

Both rules end up on the Agenda in conflict and with identical activation time tags. However, the "accumulate fact" time-tag is greater for "Make Path" so it receives the higher priority.

8.8.2.6. "Continue" and "Are We Done?"

"Are We Done" only activates when the last seat is assigned, at which point both rules will be activated. For the same reason that "Make Path" always wins over "Path Done", "Are We Done" will take priority over "Continue".

```
rule areWeDone
when
 context : Context( state == Context.CHECK_DONE )
 LastSeat( lastSeat: seat )
 Seating( rightSeat == lastSeat )
then
 modify( context ) {setState(Context.PRINT_RESULTS )}
end
```

```
rule continue
when
 context : Context( state == Context.CHECK_DONE )
then
 context.setState( Context.ASSIGN_SEATS );
 update( context );
end
```

8.8.3. Output Summary

```
Assign First Seat

=>[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
=>[fid:14:14]:[Path id=1, seat=1, guest=n5]

==>[ActivationCreated(16): rule=findSeating
[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1]
[fid:1:1]:[Guest name=n1, sex=m, hobbies=h1]

==>[ActivationCreated(16): rule=findSeating
[fid:13:13]:[Seating id=1 , pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1]
[fid:5:5]:[Guest name=n4, sex=m, hobbies=h1]*

Assign Seating

=>[fid:15:17] :[Seating id=2 , pid=1 , done=false, ls=1, lg=n5, rs=2,
 rn=n4]
=>[fid:16:18]:[Path id=2, seat=2, guest=n4]
=>[fid:17:19]:[Chosen id=1, name=n4, hobbies=h1]
```

```
=>[ActivationCreated(21): rule=makePath
[fid:15:17] : [Seating id=2, pid=1, done=false, ls=1, ln=n5, rs=2, rn=n4]
[fid:14:14] : [Path id=1, seat=1, guest=n5]*

==>[ActivationCreated(21): rule=pathDone
[Seating id=2, pid=1, done=false, ls=1, ln=n5, rs=2, rn=n4]*

Make Path

=>[fid:18:22:[Path id=2, seat=1, guest=n5]]

Path Done

Continue Process

=>[ActivationCreated(25): rule=findSeating
[fid:15:23]:[Seating id=2, pid=1, done=true, ls=1, ln=n5, rs=2, rn=n4]
[fid:7:7]:[Guest name=n4, sex=f, hobbies=h3]
[fid:4:4] : [Guest name=n3, sex=m, hobbies=h3]*

=>[ActivationCreated(25): rule=findSeating
[fid:15:23]:[Seating id=2, pid=1, done=true, ls=1, ln=n5, rs=2, rn=n4]
[fid:5:5]:[Guest name=n4, sex=m, hobbies=h1]
[fid:2:2]:[Guest name=n2, sex=f, hobbies=h1], [fid:12:20] : [Count value=3]

=>[ActivationCreated(25): rule=findSeating
[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1]
[fid:1:1]:[Guest name=n1, sex=m, hobbies=h1]

Assign Seating

=>[fid:19:26]:[Seating id=3, pid=2, done=false, ls=2, lnn4, rs=3, rn=n3]]
=>[fid:20:27]:[Path id=3, seat=3, guest=n3]]
=>[fid:21:28]:[Chosen id=2, name=n3, hobbies=h3}]

=>[ActivationCreated(30): rule=makePath
[fid:19:26]:[Seating id=3, pid=2, done=false, ls=2, ln=n4, rs=3, rn=n3]
[fid:18:22]:[Path id=2, seat=1, guest=n5]*

=>[ActivationCreated(30): rule=makePath
[fid:19:26]:[Seating id=3, pid=2, done=false, ls=2, ln=n4, rs=3, rn=n3]
[fid:16:18]:[Path id=2, seat=2, guest=n4]*

=>[ActivationCreated(30): rule=done
[fid:19:26]:[Seating id=3, pid=2, done=false, ls=2, ln=n4, rs=3, rn=n3]*

Make Path

=>[fid:22:31]:[Path id=3, seat=1, guest=n5]
```

```
Make Path

=>[fid:23:32] [Path id=3, seat=2, guest=n4]

Path Done

Continue Processing

=>[ActivationCreated(35): rule=findSeating
[fid:19:33]:[Seating id=3, pid=2, done=true, ls=2, ln=n4, rs=3, rn=n3]
[fid:4:4]:[Guest name=n3, sex=m, hobbies=h3]
[fid:3:3]:[Guest name=n2, sex=f, hobbies=h3], [fid:12:29]*

=>[ActivationCreated(35): rule=findSeating
[fid:15:23]:[Seating id=2, pid=1, done=true, ls=1, ln=n5, rs=2, rn=n4]
[fid:5:5]:[Guest name=n4, sex=m, hobbies=h1]
[fid:2:2]:[Guest name=n2, sex=f, hobbies=h1]

=>[ActivationCreated(35): rule=findSeating
[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1], [fid:1:1] : [Guest name=n1,
 sex=m, hobbies=h1]

Assign Seating

=>[fid:24:36]:[Seating id=4, pid=3, done=false, ls=3, ln=n3, rs=4, rn=n2]]
=>[fid:25:37]:[Path id=4, seat=4, guest=n2]]
=>[fid:26:38]:[Chosen id=3, name=n2, hobbies=h3]

==>[ActivationCreated(40): rule=makePath
[fid:24:36]:[Seating id=4, pid=3, done=false, ls=3, ln=n3, rs=4, rn=n2]
[fid:23:32]:[Path id=3, seat=2, guest=n4]*

==>[ActivationCreated(40): rule=makePath
[fid:24:36]:[Seating id=4, pid=3, done=false, ls=3, ln=n3, rs=4, rn=n2]
[fid:20:27]:[Path id=3, seat=3, guest=n3]*

=>[ActivationCreated(40): rule=makePath
[fid:24:36]:[Seating id=4, pid=3, done=false, ls=3, ln=n3, rs=4, rn=n2]
[fid:22:31]:[Path id=3, seat=1, guest=n5]*

=>[ActivationCreated(40): rule=done
[fid:24:36]:[Seating id=4, pid=3, done=false, ls=3, ln=n3, rs=4, rn=n2]*

Make Path

=>fid:27:41:[Path id=4, seat=2, guest=n4]

Make Path
=>fid:28:42]:[Path id=4, seat=1, guest=n5]]

Make Path

=>fid:29:43]:[Path id=4, seat=3, guest=n3]]

Path Done

Continue Processing

=>[ActivationCreated(46): rule=findSeating
[fid:15:23]:[Seating id=2, pid=1, done=true, ls=1, ln=n5, rs=2, rn=n4]
[fid:5:5]:[Guest name=n4, sex=m, hobbies=h1], [fid:2:2]
[Guest name=n2, sex=f, hobbies=h1]

=>[ActivationCreated(46): rule=findSeating
[fid:24:44]:[Seating id=4, pid=3, done=true, ls=3, ln=n3, rs=4, rn=n2]
[fid:2:2]:[Guest name=n2, sex=f, hobbies=h1]
[fid:1:1]:[Guest name=n1, sex=m, hobbies=h1]*

=>[ActivationCreated(46): rule=findSeating
[fid:13:13]:[Seating id=1, pid=0, done=true, ls=1, ln=n5, rs=1, rn=n5]
[fid:9:9]:[Guest name=n5, sex=f, hobbies=h1]
[fid:1:1]:[Guest name=n1, sex=m, hobbies=h1]

Assign Seating

=>[fid:30:47]:[Seating id=5, pid=4, done=false, ls=4, ln=n2, rs=5, rn=n1]
=>[fid:31:48]:[Path id=5, seat=5, guest=n1]
=>[fid:32:49]:[Chosen id=4, name=n1, hobbies=h1]
```

Appendix A. Revision History

Revision 1.1	Tue Oct 6 2009	David Le Sage *dlesage@redhat.com*

5.01 updates. First phase of grammar clean-up of this document.

Revision 1.0	Mon May 18 2009	Darrin Mison *dmison@redhat.com*

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