Xtext User Guide

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Chapter 1. Overview

1.1. What is Xtext?

Xtext is a framework for the development of domain-specific languages and other textual programming languages. It is tightly integrated with the Eclipse Modeling Framework (EMF) and leverages the Eclipse Platform in order to provide a language-specific integrated development environment (IDE).

In contrast to common parser generators (like e.g. JavaCC or ANTLR), Xtext derives much more than just a parser and lexical analyzer (lexer) from an input grammar. The grammar language is used to describe and generate:

- an incremental, ANTLR 3 based parser and lexer to read your models from text,
- Ecore models (optional),
- a serializer to write your models back to text,
- a linker, to establish cross links between model elements,
- an implementation of the EMF Resource interface with full support for loading and saving EMF models, and
- an integration of the language into your Eclipse IDE.

Some of the IDE features, that are either derived from the grammar or easily implementable, are

- syntax coloring,
- model navigation (F3, etc.),
- code completion,
- outline view, and
- code templates.

The generated artifacts are wired up through Google Guice, a dependency injection framework which makes it easy to exchange certain functionality in a non-invasive manner.

Although Xtext aims at supporting fast iterative development of domain-specific languages, it can be used to implement IDEs for general purpose programming languages as well.

1.2. What is a domain-specific language

A domain-specific language (DSL) is a small programming language, which focuses on a particular domain. Such a domain can be more or less anything. The idea is that its concepts and notation is as close as possible to what you have in mind when you think about a solution in that domain. Of course we are talking about problems which can be solved or processed by computers somehow.

The opposite of a DSL is a so called GPL, a General Purpose Language such as Java or any other common programming language. With a GPL you can solve every computer problem, but it might not always be the best way to solve it.

Imagine you want to remove the core from an apple. You could of course use a Swiss army knife to cut it out, and this is reasonable if you have to do it just once or twice. But if you need to do that on a regular basis it might be more efficient to use an apple corer.

There are a couple of well-known examples of DSLs. For instance SQL is actually a DSL which focuses on querying relational databases. Other DSLs are regular expressions or even languages provided by tools like MathLab. Also most XML languages are actually domain-specific languages. The whole purpose of XML is to allow for easy creation of new languages. Unfortunately with XML you are not able to change the concrete syntax, which is the major problem with it. The concrete syntax of XML is way too verbose. Also a generic syntax for everything is a compromise.

Xtext is a sophisticated framework that helps to implement your very own DSL with appropriate IDE support. There is no such limitation as with XML, you are free to define your concrete syntax as you like. It may be as concise and suggestive as possible being a best match for your particular domain. The hard task of reading your model, working with it and writing it back to your syntax is greatly simplified by Xtext.

Chapter 2. Getting Started

In this mini-tutorial you will implement your first language with Xtext and create an editor from that. Later, we will create a code generator that is capable of reading the models you create with the DSL editor and process them.

2.1. Creating a DSL

Download and install the latest version of Xtext, set up a fresh workspace, take a deep breath and follow the instructions. As soon as you have finished this chapter you will have an editor that understands input files of the following format. We will refer to this snippet as an example of our “target syntax” later on:

```
type String
type Bool

entity Session {
  property Title: String
  property IsTutorial : Bool
}

entity Conference {
  property Name : String
  property Attendees : Person[]
  property Speakers : Speaker[]
}

entity Person {
  property Name : String
}

entity Speaker extends Person {
  property Sessions : Session[]
}
```

2.1.1. Create an Xtext project

Use the Xtext wizard to create a new project

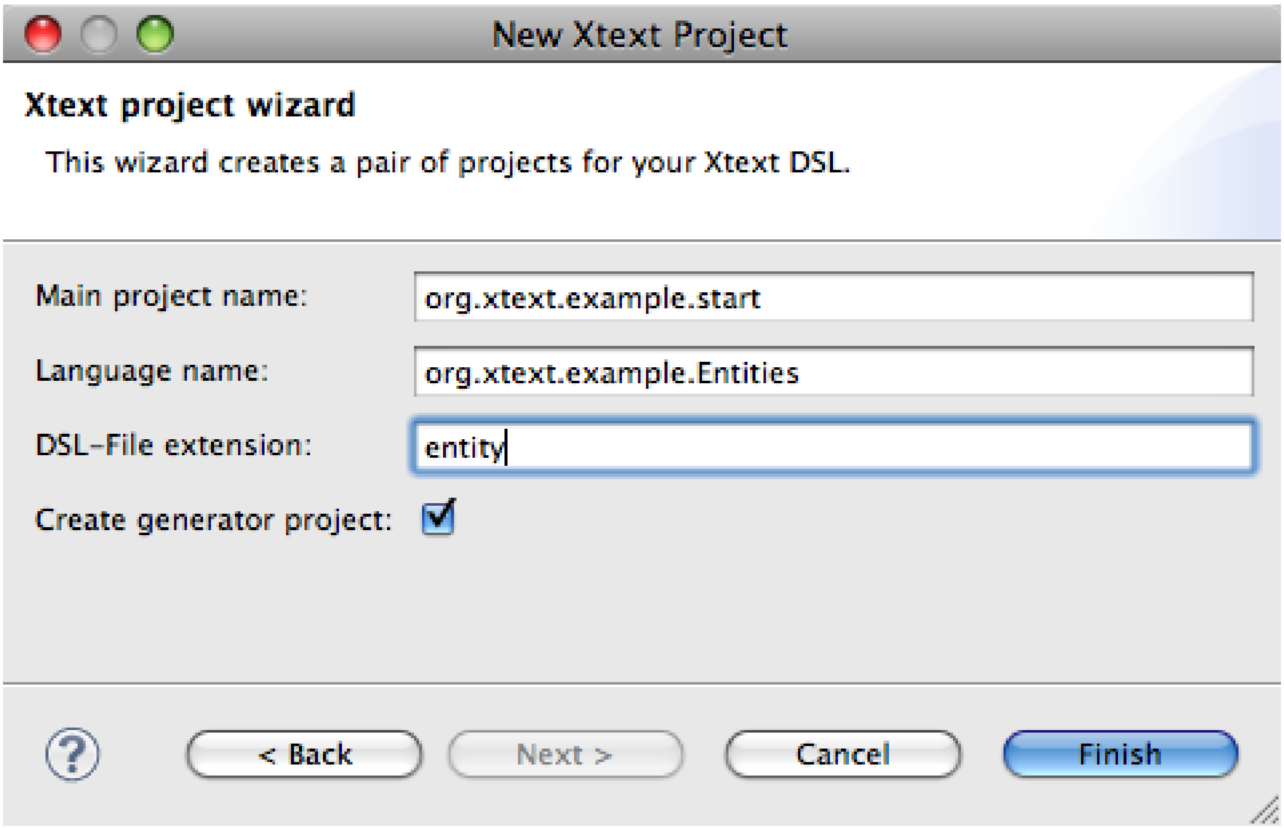
File -> *New* -> *Project...* -> *Xtext* -> *Xtext project*

Choose a meaningful project name, language name and file extension, e.g.

Main project name:	org.xtext.example.start
Language name:	org.xtext.example.Entities
DSL-File extension:	entity

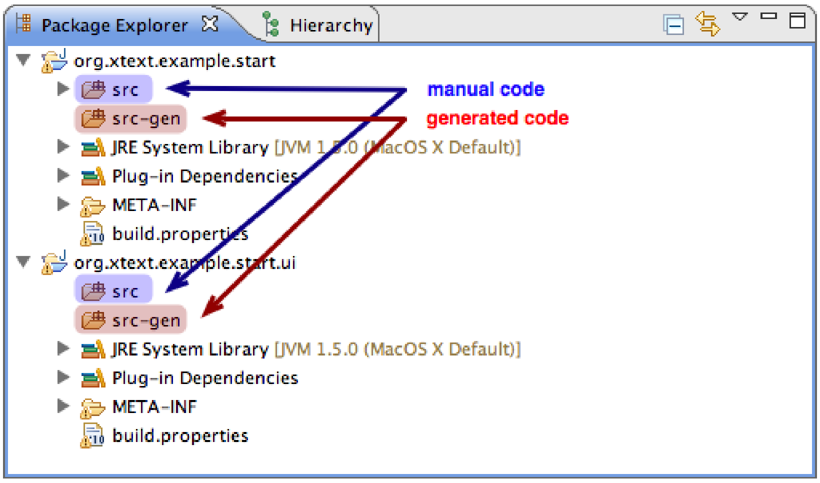
Keep “Create generator project” checked, as we will also create a code generator in a second step.

Click on *Finish* to create the projects.



2.1.2. Project layout

In the Package Explorer you can see three new projects. In `org.xtext.example.start` you can define the grammar and configure the runtime aspects of your language. The editor, outline view and code completion goes into `org.xtext.example.start.ui`. Both projects consist of generated classes derived from your grammar and manual code such as the grammar itself or further classes to differentiate from the default behavior.



It is good to be clear and unambiguous whether the code is generated or is to be manipulated by the developer. Thus, the generated code should be held separately from the manual code. We follow this pattern by having a folder src/ and a folder src-gen/ in each project. Keep in mind not to make changes in the src-gen/ folder. They will be overwritten by the generator.

A third project, `org.xtext.example.start.generator` will later contain a code generator that leverages the model created with the DSL editor.

2.1.3. Build your own grammar

The wizard will automatically open the example grammar file `Entities.xtext` from the first project in the editor. A grammar has two purposes. First, it is used to describe the concrete syntax of your language. Second, it contains information about how a parser shall create a model during parsing.

Ignore the generated sample grammar, delete everything after " `Model :`" to the end. The entry rule for the parser will be called `Model`. As a `Model` consists of one or more `Entity` entries, this rule delegates to another rule named `Entity`, which will be defined later on. As we can have one ore more entities within a model, the cardinality is "+". Each rule is terminated with a semicolon. So our first rule reads as

```
Model :
  Entity+;
```

***Please note**: If you encounter strange errors while copying and pasting these snippets to your Eclipse editor your documentation viewer most likely has inserted characters different from {space} into your clipboard. Reenter these "fillers" or type the text by hand to be sure everything works fine.*

An Xtext grammar does not only describe rules for the parser but also the structure of the resulting abstract syntax tree. Usually, each parser rule will create a new node in that tree. The type of that node can be specified after the rule name using the keyword `returns`. If the type's name is the same as the rule name, it can be omitted as in our case.

The parser will create a new element of type `Model` when it enters the rule `Model`, and a new element of type `Entity` every time it enters the rule `Entity`. To connect these AST elements, we have to define the name of a reference. In our case, we call that reference *entities*. We specify it using the assignment operator " `+=`", which denotes a multi valued feature.

As a result, we modify the first rule to

```
Model :
  (elements += Entity)+;
```

The next rule on our list is the rule `Entity`. Looking at our target syntax, each entity begins with the keyword `entity` followed by the entity's name and an opening curly brace (we will handle the `extends` clause in a second step). Then, an entity defines a number of properties and ends with a closing curly brace.

```
Entity returns Entity:
  'entity' name=ID '{'
    (properties+=Property)*
  '}'
;
```

Instead of creating a new AST node for the name, we rather want the name to be an attribute of the `Entity` class. Therefore we use the terminal rule `ID`, which results in a string. The assignment operator " `=`" denotes a single valued feature, and the asterisk a cardinality of 0..n. In our target syntax, some entities refer to an existing entity as their super type after the keyword `extends`. Note that this is a cross-reference, as the super type itself must be defined somewhere else. To define a cross-reference we use square brackets. Optional parts have the cardinality "?". The complete rule now reads:

```
Entity returns Entity:
  'entity' name=ID ('extends' extends=[Entity])? '{'
    (properties+=Property)*
  '}'
;
```

We have not specified the rule `Property`, yet. In our target syntax, properties can refer to simple types such as "String" or "Bool" as well as entities. To make this easy we will first introduce a common supertype `Type` each `Property` can refer to.

Change the rule `Model` and introduce a new rule `Type` and `SimpleType`:

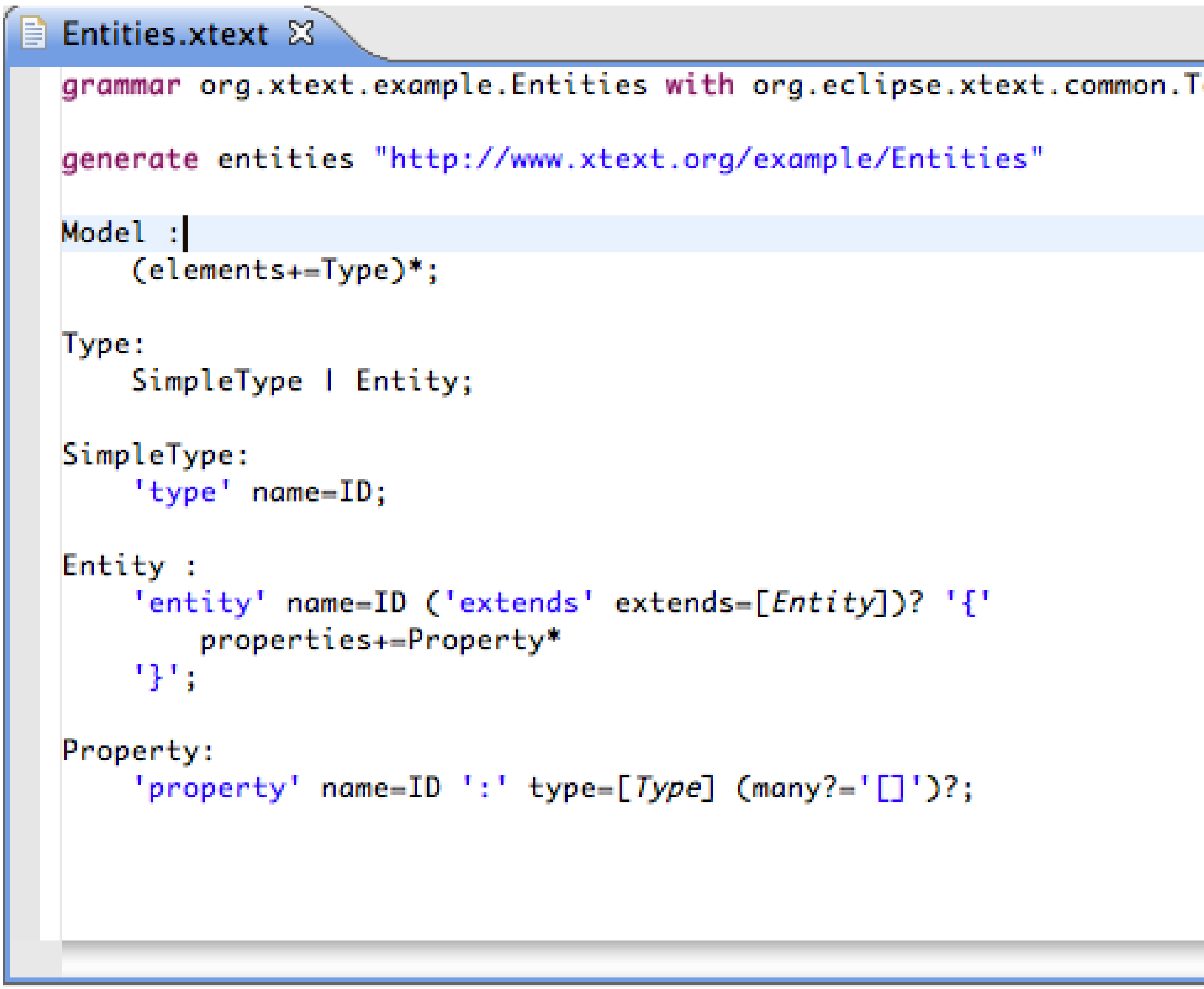
```
Model :
  (elements+=Type)*;

Type:
  SimpleType | Entity;

SimpleType:
  'type' name=ID;
```

Models new consist of types where a `Type` can either be a `SimpleType` or the `Entity` you already know. Our rule `Type` will just delegate to either of them, using the " `|`" alternatives operator. The combination of simple data types and entites this way introduces a common super type `Type` both `Entity` and `SimpleType` derive from. This allows you to refer to both types of elements with a single cross-reference.

A `Property` consist of a keyword, a name, a colon and a cross-reference to an arbitrary `Type`. The multiplicity is either many or one. The presence of the postfix “[]” (technically a keyword) should trigger a boolean flag in the AST model. This is the purpose of the assignment operator " `?=`". Our last parser rule is:

```
Property:
  'property' name=ID ':' type=[Type] (many?='[]')?;
```

In the end your grammar editor should look like this:



2.1.4. Generate language artifacts

Save the grammar and make sure that no error markers appear. Then, locate the file GenerateEntities.mwe next to the grammar file in the package explorer view. From its context menu, choose

Run As -> MWE Workflow.

That will trigger the Xtext language generator. You will see its logging messages in the Console view.

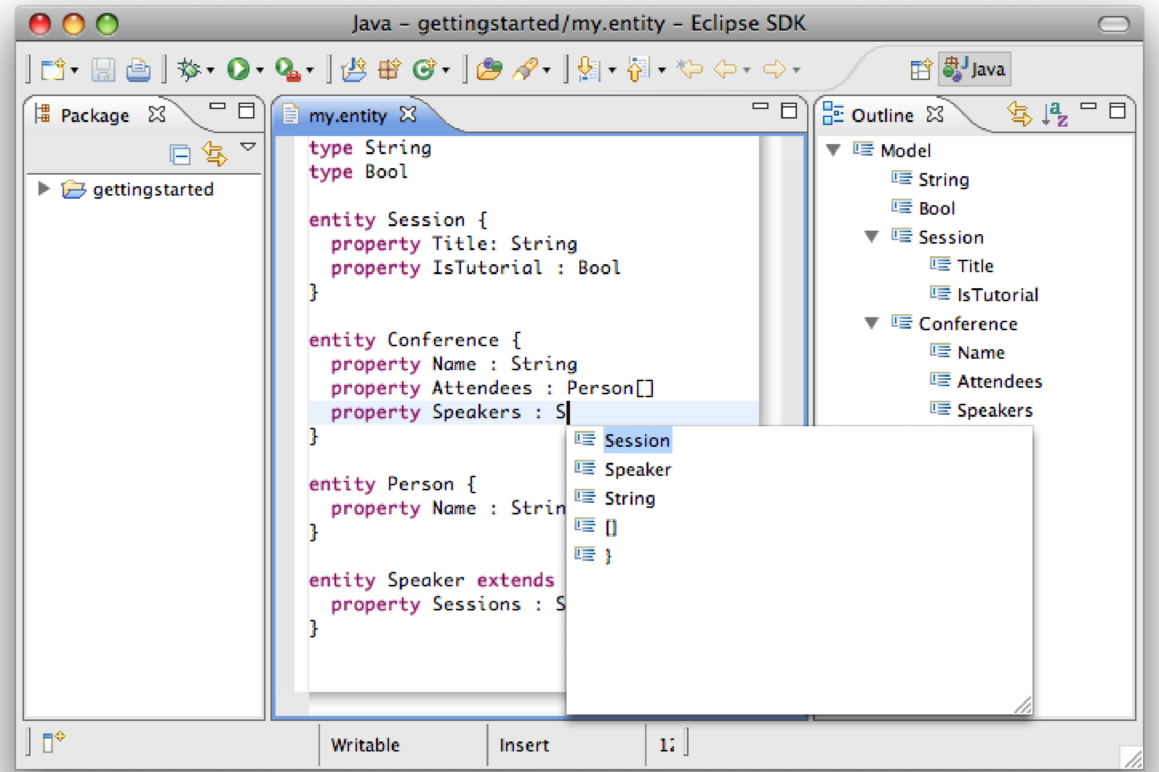
2.1.5. Run the generated editor

If code generation succeeded, right-click on the Xtext project and choose

Run As -> Eclipse Application.

This will spawn a new Eclipse workbench with your projects as plug-ins installed. In the new workbench, create a new project (*File -> New -> Project... -> General -> Project*) and therein a new file with the file extension you chose in the beginning. This will open the generated entity editor.

To get some hands-on experience with your new DSL editor, type in the following model:



2.2. Writing a code generator

In this part of the tutorial, we will write a code generator that is capable of processing the models created with the DSL editor you developed in the previous section.

2.2.1. Creating the main template

One of the major goals of model driven software development is to raise the level of abstraction. The concepts in your meta model usually map to several artifacts in your source code. In our sample, we will generate the following things for each entity:

- a data access object (DAO), capable of loading and storing the entities
- a class holding all the attributes of the entity, annotated with JPA annotations

To provide for a better overview and to easier manage our code templates, we will choose the following template structure:

- Main.xpt – the main entry point, will dispatch to all other templates
- DAO.xpt – will generate the *DAO* class
- Entity.xpt – will generate the *Entity* class

In the project navigator, right click on *org.xtext.example.start.generator/src/templates* and select *New -> Other... -> Xpand Template*. Name the new template `Main.xpt` and click on *Finish*.

First, we need to import the meta model, as we're going to be working with the concepts from the meta model:

```
«IMPORT entities»
```

Next, we need to define a main template which will be invoked by the code generator. This template will then dispatch to two sub templates, `DAO::dao` and `Entity::entity`:

```
«DEFINE main FOR Model»
  «EXPAND DAO::dao FOREACH this.elements.typeSelect(Entity)»
  «EXPAND Entity::entity FOREACH this.elements.typeSelect(Entity)»
«ENDDEFINE»
```

By using the expression `this.elements.typeSelect(Entity)`, we make sure we only iterate over `Entity` elements, and skip `SimpleType` elements.

Your template `Main.xpt` should now look like this:

```
«IMPORT entities»
«DEFINE main FOR Model»
  «EXPAND DAO::dao FOREACH this.elements.typeSelect(Entity)»
  «EXPAND Entity::entity FOREACH this.elements.typeSelect(Entity)»
«ENDDEFINE»
```

2.2.2. Creating the template for the entity

Every data-oriented application needs a bunch of classes to hold the data. Usually referred to as entities, these classes are POJOs in our case. So, let's now create a template which helps us to create POJOs from our model.

Please add another Xpand template to your project by selecting *File -> New -> Other ... -> Xpand Template*. Name the new file `Entity.xpt`, making sure to save it to the same folder as `Main.xpt`.

Add the following code to `Entity.xpt`:

```
«IMPORT entities»

«DEFINE entity FOR Entity»
  «FILE this.name + ".java"»
    public class «this.name» {
      «EXPAND property FOREACH this.properties»
    }
  «ENDFILE»
«ENDDEFINE»

«DEFINE property FOR Property»
  private «this.type.name» «this.name»;

  public void set«this.name.toFirstUpper()»(«this.type.name» «this.name») {
    this.«this.name» = «this.name»;
  }

  public «this.type.name» get«this.name.toFirstUpper()»() {
    return this.«this.name»;
  }
«ENDDEFINE»
```

2.2.3. Creating the template for the DAO

To load entities from a database and save them back, we will need to write some entities, but again, this is something the generator can do for us.

Create a template `DAO.xpt` and insert this text:

```
«IMPORT entities»

«DEFINE dao FOR Entity»
  «FILE this.name + "DAO.java"»
    import java.util.Collection;
    import org.springframework.orm.hibernate3.support.HibernateDaoSupport;
    public class «this.name»DAO
      extends HibernateDaoSupport {
      «EXPAND crud FOR this»
    }
  «ENDFILE»
«ENDDEFINE»

«DEFINE crud FOR Entity»
  public «this.name» load(Long id) {
    return («this.name»)getHibernateTemplate().get(«this.name».class, id);
  }

  @SuppressWarnings("unchecked")
  public Collection<«this.name»> loadAll() {
    return getHibernateTemplate().loadAll(«this.name».class);
  }

  public «this.name» create(«this.name» entity) {
    return («this.name») getHibernateTemplate().save(entity);
  }

  public void update(«this.name» entity) {
    getHibernateTemplate().update(entity);
  }

  public void remove(«this.name» entity) {
    getHibernateTemplate().delete(entity);
  }
«ENDDEFINE»
```

2.2.4. Adjusting the generator workflow

You might have noticed the generator workflow `org.xtext.example.start.generator/src/workflow/EntitiesGenerator.mwe` will invoke a template named `Template.xpt`, so we need to change this to make sure the right templates get invoked. Open `/org.xtext.example.start.generator/src/workflow/EntitiesGenerator.mwe` and make sure it invokes `Main.xpt`:

```
<component class="org.eclipse.xpand2.Generator">
  <metaModel class="org.eclipse.xtend.typesystem.emf.EmfRegistryMetaModel"/>
  <fileEncoding value="ISO-8859-1"/>
  <expand value="templates::Main::main FOR model"/>
  <genPath value="${targetDir}"/>
</component>
```

2.2.5. Running the generator

In order to invoke the generator, select `EntitiesGenerator.mwe` (in `org.xtext.example.start.generator/src/workflow/`) and choose *Run As -> MWE Workflow* from the context menu. You'll see a bunch of log messages in the console view, and after a few seconds, you'll find a number of just generated files in `org.xtext.example.entity.generator/src-gen`.

Please note that you'll get a number of compile-time errors now, as the DAO classes depend on Hibernate. To get rid of them, just download Hibernate from http://www.hibernate.org and add it to the build class path of the project.

2.3. Where next?

This is the end of the "Getting Started" chapter of this documentation. The next part of this document is more detailed and compact at he same time. It discusses technical topics not always in an introductory way but acts as a comprehensive reference. You will find more material that introduces Xtext at the Xtext website .

Chapter 3. The Grammar Language

The grammar language is the corner stone of Xtext and is defined in itself. Actually it is a DSL to create DSLs, so what would be more helpful than developing the Xtext language with Xtext?

The grammar language is a domain-specific language, carefully designed for the description of textual languages based on LL(*)-Parsing that is like ANTLR3's parsing strategy. The main idea is to describe the concrete syntax and how an EMF-based in-memory model is created during parsing.

3.1. A first example

To get an idea of how it works we'll start by implementing a simple example introduced by Martin Fowler. It's mainly about describing state machines used as the (un)lock mechanism of secret compartments. People who have secret compartments control their access in a very old-school way, e.g. by opening the door first and turning on the light afterwards. Then the secret compartment, for instance a panel, opens up. One of those state machines could look like this:

```
events
  doorClosed  D1CL
  drawOpened  D2OP
  lightOn     L1ON
  doorOpened  D1OP
  panelClosed PNCL
end

resetEvents
  doorOpened
end

commands
  unlockPanel PNUL
  lockPanel   PNLK
  lockDoor    D1LK
  unlockDoor  D1UL
end

state idle
  actions {unlockDoor lockPanel}
  doorClosed => active
end

state active
  drawOpened => waitingForLight
  lightOn    => waitingForDraw
end

state waitingForLight
  lightOn => unlockedPanel
end

state waitingForDraw
  drawOpened => unlockedPanel
end

state unlockedPanel
  actions {unlockPanel lockDoor}
  panelClosed => idle
end
```

So, we have a bunch of declared events, commands and states. Within states there are references to declared actions, which should be executed when entering such a state. Also there are transitions consisting of a reference to an event and a state. Please read Martin's description if it is not clear enough.

In order to get a complete IDE for this little language from Xtext, you need to write the following grammar:

```
grammar my.pack.SecretCompartments
   with org.eclipse.xtext.common.Terminals

generate secretcompartment "http://www.eclipse.org/secretcompartment"

Statemachine :
  'events'
     (events+=Event)+
  'end'
  ('resetEvents'
     (resetEvents+=[Event])+
  'end')?
  'commands'
     (commands+=Command)+
  'end'
  (states+=State)+;

Event :
  name=ID code=ID;

Command :
  name=ID code=ID;

State :
  'state' name=ID
     ('actions' '{' (actions+=[Command])+ '}')?
     (transitions+=Transition)*
  'end';

Transition :
  event=[Event] '=>' state=[State];
```

3.2. The Syntax

In the following the different concepts of the grammar language are explained.

3.2.1. Language Declaration

The first line

```
grammar my.pack.SecretCompartments with org.eclipse.xtext.common.Terminals
```

declares the name of the grammar. Xtext leverages Java's class path mechanism. This means that the name can be any valid Java qualifier. The file name needs to correspond to the grammar name and have the file extension 'xtext'. This means that the name has to be `SecretCompartments.xtext` and must be placed in a package `my.pack` somewhere on your project's class path.

The first line is also used to declare any used language (for mechanism details see Grammar Mixins).

3.2.2. EPackage declarations

Xtext parsers instantiate Ecore models (aka meta model). An Ecore model basically consists of an EPackage containing EClasses, EDatatypes and EEnums. Xtext can infer Ecore models from a grammar (see Ecore model inference) but it is also possible to instantiate existing Ecore models. You can even mix this and use multiple existing Ecore models and infer some others from one grammar.

3.2.2.1. EPackage generation

The easiest way to get started is to let Xtext infer the Ecore model from your grammar. This is what is done in the secret compartment example. To do so just state:

```
generate secretcompartment 'http://www.eclipse.org/secretcompartment'
```

That statement means: generate an EPackage with the name `secretcompartment` and the nsURI `http://www.eclipse.org/secretcompartment`. Actually these are the properties that are required to create an EPackage. The whole algorithm used to derive complete Ecore models from Xtext grammars is described in the section Ecore model inference.

3.2.2.2. EPackage import

If you already have an existing EPackage, you can import it using either a namespace URI or a resource URI. An URI (Uniform Resource Identifier) provides a simple and extensible means for identifying an abstract or physical resource. For details about the EMF implementation of this concept, please see its documentation.

Using namespace URIs to import existing EPackages

You can import an existing EPackage with the following statement:

```
import 'http://www.eclipse.org/secretcompartment'
```

Note that if you use a namespace URI, the corresponding EPackage needs to be installed into the workbench. Otherwise the editor cannot find it. At runtime (i.e. when starting the generator) you need to make sure that the corresponding EPackage is registered in the `EPackage.Registry.INSTANCE`. If you use MWE to drive your code generator, you need to add the following lines to your workflow file:

```
<bean class="org.eclipse.emf.mwe.utils.StandaloneSetup"
  platformUri="${runtimeProject}/..">
  <registerGeneratedEPackage value="my.pack.SecretcompartmentPackage"/>
</bean>
```

Using namespace URIs is typically only interesting when common Ecore models are used, such as Ecore itself or the UML meta model. If you're developing the EPackage together with the DSL but don't want to have it derived from the grammar for some reason, we suggest to use a resource URI.

Using resource URIs to import existing EPackages

If the EPackage you want to use is somewhere in your workspace you should refer to it by a `platform:/resource/`-URI. Platform URIs are a special EMF concept, which allow for some kind of transparency between workspace projects and installed bundles. Consult the EMF documentation (we recommend the book) for details.

An import statement referring to an Ecore file by a platform:/resource/ URI looks like this:

```
import 'platform:/resource/project/src/my/pack/SecretCompartments.ecore'
```

If you want to mix generated and imported Ecore models you'll have to configure the generator fragment in your MWE file responsible for generating the Ecore classes (EcoreGeneratorFragment) with resource URIs that point to the genmodels for the referenced Ecore models. Example:

```
<fragment class="org.eclipse.xtext.generator.ecore.EcoreGeneratorFragment"
  genModels=
    "platform:/resource/project/src/my/pack/SecretCompartments.genmodel"/>
```

3.2.2.3. Ecore model aliases for packages

If you want to use multiple EPackages you need to specify aliases in the following way:

```
generate secretcompartment 'http://www.eclipse.org/secretcompartment'
import 'http://www.eclipse.org/anotherPackage' as another
```

When referring to a type somewhere in the grammar you need to qualify the reference using that alias (example `another::CoolType`). We'll see later where such type references occur.

It is also supported to put multiple EPackage imports into one alias. This is no problem as long as there are not any two EClassifiers with the same name. In such cases none of them can be referenced. It is even possible to 'import' multiple and 'generate' one Ecore model and all of them are declared for the same alias. If you do so, for a reference to an EClassifier first the imported EPackages are scanned before it is assumed that a type needs to by generated into the to-be-generated package.

Example:

```
generate toBeGenerated 'http://www.eclipse.org/toBeGenerated'
import 'http://www.eclipse.org/packContainingClassA'
import 'http://www.eclipse.org/packContainingClassB'
```

With the declaration above

1. a reference to type `ClassA` would be linked to the EClass contained in `http://www.eclipse.org/packContainingClassA`,
2. a reference to type `ClassB` would be linked to the EClass contained in `http://www.eclipse.org/packContainingClassB`,
3. a reference to type `NotYetDefined` would be linked to a newly created EClass in `http://www.eclipse.org/toBeGenerated`.

Note, that using this feature is not recommended, because it might cause problems, which are hard to track down. For instance, a reference to `classA` would as well be linked to a newly created EClass, because the corresponding type in `http://www.eclipse.org/packContainingClassA` is spelled with a capital letter.

3.2.3. Rules

The default parsing is based on a home-grown packrat parser. It is advised to substitute it by an ANTLR parser through the Xtext service mechanism. ANTLR is a sophisticated parser generator framework based on an LL(*) parsing algorithm, that works quite well for Xtext. Please download the plugin de.itemis.xtext.antlr (from update site `http://download.itemis.com/updates/`) and use the ANTLR Parser instead of the packrat parser (cf. Xtext Workspace Setup).

Basically parsing can be separated in the following phases.

1. lexing
2. parsing
3. linking
4. validation

3.2.3.1. Terminal Rules

In the first stage, i.e. lexing, a sequence of characters (the text input) is transformed into a sequence of so called tokens. In this context, a token is sort of a strongly typed part of the input sequence. It consists of one or more characters and was matched by a particular terminal rule or keyword and therefore represents an atomic symbol. Terminal rules are also referred to as token rules or lexer rules. There is an informal naming convention that names of terminal rules are all upper-case.

In the secret compartments example there are no explicitly defined terminal rules, since it only uses the ID rule which is inherited from the grammar `org.eclipse.xtext.common.Terminals` (cf. Grammar Mixins). Therein the ID rule is defined as follows:

```
terminal ID :
  ('^')?('a'..'z'|'A'..'Z'|'_') ('a'..'z'|'A'..'Z'|'_'|'0'..'9')*;
```

It says that a Token ID starts with an optional '^' character (caret), followed by a letter ('a'..'z'|'A'..'Z') or underscore ('_') followed by any number of letters, underscores and numbers ('0'..'9').

The caret is used to escape an identifier for cases where there are conflicts with keywords. It is removed by the ID rule's ValueConverter.

This is the formal definition of terminal rules:

```
TerminalRule :
  'terminal' name=ID ('returns' type=TypeRef)? ':'
    alternatives=TerminalAlternatives ';'
;
```

Note, that *the order of terminal rules is crucial for your grammar*, as they may hide each other. This is especially important for newly introduced rules in connection with mixed rules from used grammars.

If you for instance want to add a rule to allow fully qualified names in addition to simple IDs, you should implement it as a data type rule, instead of adding another terminal rule.

Return types

A terminal rule returns a value, which is a string (type `ecore::EString`) by default. However, if you want to have a different type you can specify it. For instance, the rule 'INT' is defined as:

```
terminal INT returns ecore::EInt :
  ('0'..'9')+;
```

This means that the terminal rule 'INT' returns instances of `ecore::EInt`. It is possible to define any kind of data type here, which just needs to be an instance of `ecore::EDataType`. In order to tell the parser how to convert the parsed string to a value of the declared data type, you need to provide your own implementation of IValueConverterService (cf. value converters). The value converter is also the point where you can remove things like quotes from string literals or the caret ('^') from identifiers. Its implementation needs to be registered as a service (cf. Service Framework).

3.2.3.2. Extended Backus-Naur form expressions

Token rules are described using "Extended Backus-Naur Form"-like (EBNF) expressions. The different expressions are described in the following. The one thing all of these expressions have in common is the cardinality operator. There are four different possible cardinalities

1. exactly one (the default, no operator)
2. one or none (operator "?")
3. any (zero or more, operator "*")
4. one or more (operator "+")

Keywords / Characters

Keywords are a kind of token rule literals. The 'ID' rule in `org.eclipse.xtext.common.Terminals` for instance starts with a keyword:

```
terminal ID : '^'? .... ;
```

The question mark sets the cardinality to "none or one" (i.e. optional) like explained above.

Note that a keyword can have any length and contain arbitrary characters.

Character Ranges

A character range can be declared using the '..' operator.

Example:

```
terminal INT returns ecore::EInt: ('0'..'9')+;
```

In this case an INT is comprised of one or more (note the '+' operator) characters between (and including) '0' and '9'.

Wildcard

If you want to allow any character you can simple write the wildcard operator '.' (dot): Example:

```
FOO : 'f' . 'o';
```

The rule above would allow expressions like 'foo', 'f0o' or even 'f\no'.

Until Token

With the until token it is possible to state that everything should be consumed until a certain token occurs. The multiline comment is implemented this way:

```
terminal ML_COMMENT : '/*' -> '*/';
```

This is the rule for Java-style comments that begin with '/*' and end with '*/'.

Negated Token

All the tokens explained above can be inverted using a preceding exclamation mark:

```
terminal ML_COMMENT : '/*' (!'*/')+;
```

Rule Calls

Rules can refer to other rules. This is done by writing the name of the rule to be called. We refer to this as rule calls. Rule calls in terminal rules can only point to terminal rules.

Example:

```
terminal QUALIFIED_NAME : ID ('.' ID)*;
```

Alternatives

Using alternatives one can state multiple different alternatives. For instance, the whitespace rule uses alternatives like this:

```
terminal WS : (' '|'\t'|'\r'|'\n')+;
```

That is a WS can be made of one or more whitespace characters (including ‘ ’,‘\t’,‘\r’,‘\n’).

Groups

Finally, if you put tokens one after another, the whole sequence is referred to as a group. Example:

```
terminal ASCII : '0x' ('0'..'7') ('0'..'9'|'A'..'F');
```

That is the 2-digit hexadecimal code of ascii characters.

3.2.4. Parser Rules

The parser reads a sequence of terminals and walks through the parser rules. Hence a parser rule – contrary to a terminal rule – does not produce a single terminal token but a tree of non-terminal and terminal tokens. They lead to a so called parse tree (in Xtext it is also referred as node model). Furthermore, parser rules are handled as kind of a building plan for the creation of the EObjects that form the semantic model (the linked abstract syntax graph or AST). Due to this fact, parser rules are even called production rules. The different constructs like actions and assignments are used to derive types and initialize the semantic objects accordingly.

3.2.4.1. Extended Backus-Naur Form expressions

Not all the expressions that are available in terminal rules can be used in parser rules. Character ranges, wildcards, the until token and the negation are only available for terminal rules.

The elements that are available in parser rules as well as in terminal rules are

1. groups,
2. alternatives,
3. keywords and
4. rule calls.

In addition to these elements, there are some expressions used to direct how the AST is constructed, which are listed and explained in the following.

Assignments

Assignments are used to assign the parsed information to a feature of the current object. The type of the current object, its EClass, is specified by the return type of the parser rule. If it is not explicitly stated it is implied that the type’s name equals the rule’s name. The type of the feature is infered from the right hand side of the assignment.

Example:

```
State :
  'state' name=ID
    ('actions' '{' (actions+=[Command])+ '}')?
    (transitions+=Transition)*
  'end'
;
```

The syntactic declaration for states in the state machine example starts with a keyword ‘state’ followed by an assignment:

```
name=ID
```

The left hand side refers to a feature ' `name`' of the current object (which has the EClass 'State' in this case). The right hand side can be a rule call, a keyword, a cross reference (explained later) or even an alternative comprised by the former. The type of the feature needs to be compatible with the type of the expression on the right. As ID returns an EString in this case, the feature ' `name`' needs to be of type EString as well.

Assignment Operators

There are three different assignment operators, each with different semantics.

1. The simple equal sign "=" is the straight forward assignment, and used for features which take only one element.
2. The "+=" sign (the add operator) expects a multi valued feature and adds the value on the right hand to that feature, which is a list feature.
3. The "?=" sign (boolean assignment operator) expects a feature of type EBoolean and sets it to true if the right hand side was consumed independently from the concrete value of the right hand side.

The used assignment operator does not effect the cardinality of the expected symbols on the right hand side.

Cross References

A unique feature of Xtext is the ability to declare crosslinks in the grammar. In traditional compiler construction the crosslinks are not established during parsing but in a later linking phase. This is the same in Xtext, but we allow to specify crosslink information in the grammar. This information is used by the linker. The syntax for crosslinks is:

```
CrossReference :
  '[' type=TypeRef ('|' ^terminal=CrossReferenceableTerminal )? ']'
;
```

For example, the transition is made up of two cross references, pointing to an event and a state:

```
Transition :
  event=[Event] '=>' state=[State]
;
```

It is important to understand that the text between the square brackets does not refer to another rule, but to a type! This is sometimes confusing, because one usually uses the same name for the rules and the returned types. That is if we had named the type for events differently like in the following the cross reference needs to be adapted as well:

```
Transition :
  event=[MyEvent] '=>' state=[State]
;

Event returns MyEvent : ....;
```

Looking at the syntax definition of cross references, there is an optional part starting with a vertical bar (pipe) followed by 'CrossReferenceableTerminal'. This is the part describing the concrete text, from which the crosslink later should be established. If the terminal is omitted, it is expected to be an ID.

You may even use alternatives as the referencable terminal. This way, either an ID or a STRING may be used as the referencable terminal, as it is possible in many SQL dialects.

```
TableRef: table=[Table|(ID|STRING)];
```

Have a look at the linking section in order to understand how linking is done.

Simple Actions

By default the object to be returned by a parser rule is created lazily on the first assignment. Then the type of the EObject to be created is determined from the specified return type or the rule name if no explicit return type is specified. With Actions however, the creation of returned EObject can be made explicit. Xtext supports two kinds of Actions:

1. simple actions, and
2. assigned actions.

If at some point you want to enforce the creation of a specific type you can use alternatives or simple actions. In the following example TypeB must be a subtype of TypeA. An expression `A ident` should create an instance of TypeA, whereas `B ident` should instantiate TypeB.

Example with alternatives:

```
MyRule returns TypeA :
  "A" name=ID |
  MyOtherRule
;

MyOtherRule returns TypeB :
  "B" name = ID
;
```

Example with simple actions:

```
MyRule returns TypeA :
  "A" name=ID |
  "B" {TypeB} name=ID
;
```

Generally speaking, the instance is created as soon as the parser hits the first assignment. However, actions allow to explicitly instantiate any EObject. The notation `{TypeB}` will create an instance of TypeB and assign it to the result of the parser rule. This allows parser rules without any assignment and object creation without the need to introduce unnecessary rules.

Unassigned rule calls

We previously explained, that the EObject to be returned is created lazily when the first assignment occurs or when a simple action is evaluated. There is another way one can set the EObject to be returned, which we call an “unassigned rule call”.

Unassigned rule calls (the name suggests it) are rule calls to other parser rules, which are not used within an assignment. If there is no feature the returned value shall be assigned to, the value is assigned to the “to-be-returned” result of the calling rule.

With unassigned rule calls one can, for instance, create rules which just dispatch between several other rules:

```
AbstractToken :
  TokenA |
  TokenB |
  TokenC
;
```

As `AbstractToken` could possibly return an instance of `TokenA`, `TokenB` or `TokenC` its type must by a super type of these types. It is now for instance as well possible to further change the state of the AST element by assigning additional things.

Example:

```
AbstractToken :
  ( TokenA |
    TokenB |
    TokenC ) (cardinality=('?'|'+'|'*'))?
;
```

This way the ‘cardinality’ is optional (last question mark) and can be represented by a question mark, a plus, or an asterisk. It will be assigned to either an EObject of type `TokenA`, `TokenB`, or `TokenC` which are all subtypes of `AbstractToken`. The rule in this example will never create an instance of `AbstractToken` directly.

Assigned Actions

LL parsing has some significant advantages over LR algorithms. The most important ones for Xtext are, that the generated code is much simpler to understand and debug and that it is easier to recover from errors. Especially ANTLR has a very nice generic error recovery mechanism. This allows to construct an AST even if there are syntactic errors in the text. You wouldn't get any of the nice IDE features as soon as there is one little error, if we hadn't error recovery.

However, LL also has some drawbacks. The most important one is that it does not allow left recursive grammars. For instance, the following is not allowed in LL based grammars, because “Expression '+' Expression” is left recursive:

```
Expression :
  Expression '+' Expression |
  '(' Expression ')' |
  INT
;
```

Instead one has to rewrite such things by “left-factoring” it:

```
Expression :
  TerminalExpression ('+' TerminalExpression)?
;

TerminalExpression :
  '(' Expression ')' |
  INT
;
```

In practice this is always the same pattern and therefore not that problematic. However, by simply applying the Xtext AST construction features we've covered so far, a grammar ...

```
Expression :
  {Operation} left=TerminalExpression (op='+' right=TerminalExpression)?
;

TerminalExpression returns Expression:
  '(' Expression ')' |
  {IntLiteral} value=INT
;
```

... would result in unwanted elements in the AST. For instance the expression “ (42) ” would result in a tree like this:

```
Operation {
  left=Operation {
    left=IntLiteral {
      value=42
    }
  }
}
```

Typically one would only want to have one instance of `IntLiteral` instead.

One can solve this problem using a combination of unassigned rule calls and assigned actions:

```
Expression :
  TerminalExpression ({Operation.left=current}
    op='+' right=Expression)?
;

TerminalExpression returns Expression:
  '(' Expression ')' |
  {IntLiteral} value=INT
;
```

In the example above `{Operation.left=current}` is a so called tree rewrite action, which creates a new instance of the stated EClass (Operation in this case) and assigns the element currently to-be-returned (`current` variable) to a feature of the newly created object (in this case feature ‘left’ of the Operation instance). In Java these semantics could be expressed as:

```
Operation temp = new Operation();
temp.setLeft(current);
current = temp;
```

3.2.5. Hidden terminal symbols

Because parser rules describe not a single token, but a sequence of patterns in the input, it is necessary to define the interesting parts of the input. Xtext introduces the concept of hidden tokens to handle semantically unimportant things like whitespaces, comments, etc. in the input sequence gracefully. It is possible to define a set of terminal symbols, that are hidden from the parser rules and automatically skipped when they are recognized. Nevertheless, they are transparently woven into the node model, but not relevant for the semantic model.

Hidden terminals may (or may not) appear between any other terminals in any cardinality. They can be described per rule or for the whole grammar. When reusing a single grammar its definition of hidden tokens is reused as well. The grammar `org.eclipse.xtext.common.Terminals` comes with a reasonable default and hides all comments and whitespace from the parser rules.

If a rule defines hidden symbols, you can think of a kind of scope that is automatically introduced. Any rule that is called from the declaring rule uses the same hidden terminals as the calling rule, unless it defines other hidden tokens itself.

```
Person hidden(WS, ML_COMMENT, SL_COMMENT):
  name=Fullname age=INT ';'
;

Fullname:
  (firstname=ID)? lastname=ID
;
```

The sample rule “Person” defines multiline comments (ML_COMMENT), single-line comments (SL_COMMENT), and whitespace (WS) to be allowed between the ‘Fullname’ and the ‘age’. Because the rule ‘Fullname’ does not introduce another set of hidden terminals, it allows the same symbols to appear between ‘firstname’ and ‘lastname’ as the calling rule ‘Person’. Thus, the following input is perfectly valid for the given grammar snippet:

```
John /* comment */ Smith // line comment
/* comment */
      42       ; // line comment
```

A list of all default terminals like WS can be found in section Grammar Mixins.

3.2.6. Data type rules

Data type rules are parsing-phase rules, which create instances of EDataType instead of EClass. Thinking about it, one may discover that they are quite similar to terminal rules. However, the nice thing about data type rules is that they are actually parser rules and are therefore

1. context sensitive and
2. allow for use of hidden tokens.

If you, for instance, want to define a rule to consume Java-like qualified names (e.g. “foo.bar.Baz”) you could write:

```
QualifiedName :
  ID ('.' ID)*
;
```

This looks similar to the terminal rule we’ve defined above in order to explain rule calls. However, the difference is that because it is a parser rule and therefore only valid in certain contexts, it won’t conflict with the rule ID. If you had defined it as a terminal rule, it would possibly hide the ID rule.

In addition when this has been defined as a data type rule, it is allowed to use hidden tokens (e.g. “/* comment **/”) between the IDs and dots (e.g. `foo/* comment */. bar . Baz"`)

Return types can be specified in the same way as in terminal rules:

```
QualifiedName returns ecore::EString :
  ID ('.' ID)*
;
```

Note that if a rule does not call another parser rule and does neither contain any actions nor assignments, it is considered to be a data type rule and the data type EString is implied if none has been explicitly declared.

For conversion again value converters are responsible (cf. value converters).

3.2.7. Enum Rules

Enum rules return enumeration literals from strings. They can be seen as a shortcut for data type rules with specific value converters. The main advantage of enum rules is their simplicity, type safety and therefore nice validation. Furthermore it is possible to infer enums and their respective literals during the Ecore model transformation.

If you want to define a ChangeKind org.eclipse.emf.ecore.change/model/Change.ecore with 'ADD', 'MOVE' and 'REMOVE' you could write:

```
enum ChangeKind :
  ADD | MOVE | REMOVE
;
```

It is even possible to use alternative literals for your enums or reference an enum value twice:

```
enum ChangeKind :
  ADD = 'add' | ADD = '+' |
  MOVE = 'move' | MOVE = '->' |
  REMOVE = 'remove' | REMOVE = '-'
;
```

Please note, that Ecore does not support unset values for enums. If you formulate a grammar like

```
Element: "element" name=ID (value=SomeEnum)?;
```

with the input of

```
element Foo
```

the resulting value of the element `Foo` will hold the enum value with the internal representation of '0' (zero). When generating the EPackage from your grammar this will be the first literal you define. As a workaround you could introduce a dedicated none-value or order the enums accordingly. Note that it is not possible to define an enum literal with an empty textual representation.

```
enum Visibility:
  package | private | protected | public
;
```

You can overcome this by modifying the infered Ecore model through a model to model transformation.

3.3. Ecore model inference

The Ecore model (or meta model) of a textual language describes the structure of its abstract syntax trees (AST).

Xtext uses Ecore's EPackages to define Ecore models. Ecore models are declared to be either inferred (generated) from the grammar or imported. By using the 'generate' directive, one tells Xtext to derive an EPackage from the grammar.

3.3.1. Type and Package Generation

Xtext creates

- an EPackage
  - for each generate-package declaration. After the directive 'generate' a list of parameters follows. The 'name' of the EPackage will be set to the first parameter, its 'nsURI' to the second parameter.

An optional alias as the third parameter allows to distinguish generated EPackages later. Only one generated package declaration per alias is allowed.

- an EClass
  - for each return type of a parser rule. If a parser rule does not define a return type, an implicit one with the same name as the rule itself is assumed. You can specify more than one rule that return the same type but only one EClass will be generated.
  - for each type defined in an action or a cross reference.
- an EEnum
  - for each return type of an enum rule.
- an EDatatype
  - for each return type of a terminal rule or a data type rule.

All EClasses, EEnums and EDatatypes are added to the EPackage referred to by the alias provided in the type reference they were created from.

3.3.2. Feature and Type Hierarchy Generation

While walking through the grammar, the algorithm keeps track of a set of the currently possible return types to add features to.

- Entering a parser rule the set contains only the return type of the rule.
- Entering a group in an alternative the set is reset to the same state it was in when entering the first group of this alternative.
- Leaving an alternative the set contains the union of all types at the end of each of its groups.
- After an optional element, the set is reset to the same state it was before entering it.
- After a mandatory (non-optional) rule call or mandatory action the set contains only the return type of the called rule or action.
- An optional rule call does not modify the set.
- A rule call is optional, if its cardinality is ‘?’ or ‘*’.

While iterating the parser rules Xtext creates

- an EAttribute in each current return type
  - of type EBoolean for each feature assignment using the ‘?=’ operator. No further EReferences or EAttributes will be generated from this assignment.
  - for each assignment with the ‘=’ or ‘+=’ operator calling a terminal rule. Its type will be the return type of the called rule.
- an EReference in each current return type
  - for each assignment with the ‘=’ or ‘+=’ operator in a parser rule calling a parser rule. The EReference’s type will be the return type of the called parser rule.
  - for each assigned action. The reference’s type will be set to the return type of the current calling rule.

Each EAttribute or EReference takes its name from the assignment or action that caused it. Multiplicities will be 0...1 for assignments with the ‘=’ operator and 0...* for assignments with the ‘+=’ operator.

Furthermore, each type that is added to the currently possible return types automatically extends the current return type of the parser rule. You can specify additional common super types by means of “artificial” parser rules, that are never called, e.g.

```
CommonSuperType:
  SubTypeA | SubTypeB | SubTypeC;
```

3.3.3. Enum Literal Generation

For each alternative defined in an enum rule, the transformer creates an enum literal, when another literal with the same name cannot be found. The ‘literal’ property of the generated enum literal is set to the right hand side of the declaration. If it is omitted, you will get an enum literal with equal ‘name’ and ‘literal’ attributes.

```
enum MyGeneratedEnum:
  NAME = 'literal' | EQUAL_NAME_AND_LITERAL;
```

3.3.4. Feature Normalization

In the next step the generator examines all generated EClasses and lifts up similar features to super types if there is more than one subtype and the feature is defined in every subtypes. This does even work for multiple super types.

3.3.5. Customized Post Processing

As a last step, the generator invokes the post processor for every generated Ecore model. The post processor expects an Xtend file with name `<MyDsl>PostProcessor.ext` (if the name of the grammar file is `MyDsl.xtext`) in the same folder as the grammar file. Further, for a successful invocation, the Xtend file must declare an extension with signature `process(xtext::GeneratedMetamodel)`. E.g.

```
process(xtext::GeneratedMetamodel this) :
  process(ePackage)
;

process(ecore::EPackage this) :
  ... do something
;
```

The invoked extension can then augment the generated Ecore model in place. Some typical use cases are to:

- set default values for attributes,
- add container references as opposites of existing containment references, or
- add operations with implementation using a body annotation.

Great care must be taken to not modify the Ecore model in a way preventing the Xtext parser from working correctly (e.g. removing or renaming model elements).

3.3.6. Error Conditions

The following conditions cause an error

- An EAttribute or EReference has two different types or different cardinality.
- There is an EAttribute and an EReference with the same name in the same EClass.
- There is a cycle in the type hierarchy.
- An new EAttribute, EReference or super type is added to an imported type.
- An EClass is added to an imported EPackage.
- An undeclared alias is used.
- An imported Ecore model cannot be loaded.

3.4. Importing existing Ecore models

With the import directive in Xtext you can refer to existing Ecore models and reuse the types that are declared in an EPackage. Xtext uses this technique itself to leverage Ecore data types.

```
import 'http://www.eclipse.org/emf/2002/Ecore' as ecore
```

Specify an explicit return type to reuse such imported types. Note that this even works for terminal rules.

```
terminal INT returns ecore::EInt : ('0'..'9')+;
```

3.5. Grammar Mixins

Xtext supports the reuse of existing grammars. Grammars that are created via the Xtext wizard use `org.eclipse.xtext.common.Terminals` by default which introduces a common set of terminal rules and defines reasonable defaults for hidden terminals.

```
grammar org.xtext.example.MyDsl with org.eclipse.xtext.common.Terminals

generate myDsl 'http://www.xtext.org/example/MyDsl'

... some rules
```

Mixing in another grammar makes the rules defined in that grammar referable. It is also possible to overwrite rules from the used grammar.

Example :

```
grammar my.SuperGrammar
...
RuleA : "a" stuff=RuleB;
RuleB : "{" name=ID "}";

grammar my.SubGrammar with my.SuperGrammar

Model : (ruleAs+=RuleA)*;

// overrides my.SuperGrammar.RuleB
RuleB : '[' name=ID ']';
```

Note that declared terminal rules always get a higher priority then imported terminal rules.

3.6. Default tokens

Xtext ships with a default set of predefined, reasonable and often required terminal rules. This grammar is defined as follows:

```
grammar org.eclipse.xtext.common.Terminals
  hidden(WS, ML_COMMENT, SL_COMMENT)

import "http://www.eclipse.org/emf/2002/Ecore" as ecore

terminal ID :
  '^'?('a'..'z'|'A'..'Z'|'_') ('a'..'z'|'A'..'Z'|'_'|'0'..'9')* ;
terminal INT returns ecore::EInt: ('0'..'9')+ ;
terminal STRING :
  '"' ( '\\' ('b'|'t'|'n'|'f'|'r'|'"'|"'"|'\\') | !('\\'|'"') )* '"' |
  "'" ( '\\' ('b'|'t'|'n'|'f'|'r'|'"'|"'"|'\\') | !('\\'|"'") )* "'";
terminal ML_COMMENT : '/*' -> '*/' ;
terminal SL_COMMENT  : '//' !('\n'|'\r')* ('\r'? '\n')? ;
terminal WS  : (' '|'\t'|'\r'|'\n')+ ;
terminal ANY_OTHER: . ;
```

Chapter 4. Configuration

4.1. The Generator

Xtext provides lots of generic implementations for your language's infrastructure but also uses code generation to generate some of the components. Those generated components are for instance the parser, the serializer, the inferred Ecore model (if any) and a couple of convenient base classes for content assist, etc.

The generator also contributes to shared project resources such as the plugin.xml, Manifest.MF and the Guice modules.

Xtext's generator leverages MWE2 – the modeling workflow engine from EMFT to configure the generator.

4.1.1. A short introduction to MWE2

MWE2 allows to compose object graphs declaratively in a very compact manner. The nice thing about it is that it just instantiates Java classes and the configuration is done through public setter and adder methods as one is used to from Java Beans encapsulation principles. An in-depth documentation can be found in the chapter "MWE2"#MWE2.

Given the following simple Java class (POJO):

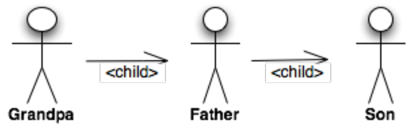
```
package com.mycompany;

public class Person {

  private String name;

  public void setName(String name) {
    this.name = name;
  }

  private final List<Person> children = new ArrayList<Person>();

  public void addChild(Person child) {
    this.children.add(child);
  }
}
```

One can create a family tree with MWE2 easily by describing it in a declarative manner without writing a single line of Java code and without the need to compile classes:

```
module com.mycompany.CreatePersons

Person {
 name = "Grandpa"
 child = com.mycompany.Person {
  name = "Father"
  child = {
   name = "Son"
  }
 }
}
```

These couple of lines will, when interpreted by MWE2, result in an object tree consisting of three instances of `com.mycompany.Person`. The interpreter will basically do the same as the following `main` method:

```
package com.mycompany;

public class CreatePersons {
 public static void main(String[] args) {
  Person grandpa = new Person();
  grandpa.setName("Grandpa");
  Person father = new Person();
  father.setName("Father");
  grandpa.addChild(father);
  Person son = new Person();
  son.setName("Son");
  father.addChild(son);
 }
}
```



The root element is a class-name following the Java class-path visibility rules. As the module is a sibling to the class `com.mycompany.Person` it is not necessary to use use fully qualified name. There are other packages implicitly imported into this workflow as well to make it convenient to instantiate actual workflows and components, but these ones are covered in depth in the appropriate chapther. The constructed objects are furthermore configured according to the declaration in the module, e.g. a second instance of Person will be created and added to the list of children of “Grandpa” while the third person - the class is inferred from the assigned feature – becomes a child of “Father”. All three instances will have their respective `name` assigned via a reflective invocation `setName`. If one wants to add another child to “Father”, she can simply repeat the child assignment:

```
child = com.mycompany.Person {
 name = "Father"
 child = {
   name = "Son"
 }
 child = {
  name = ..
 }
}
```

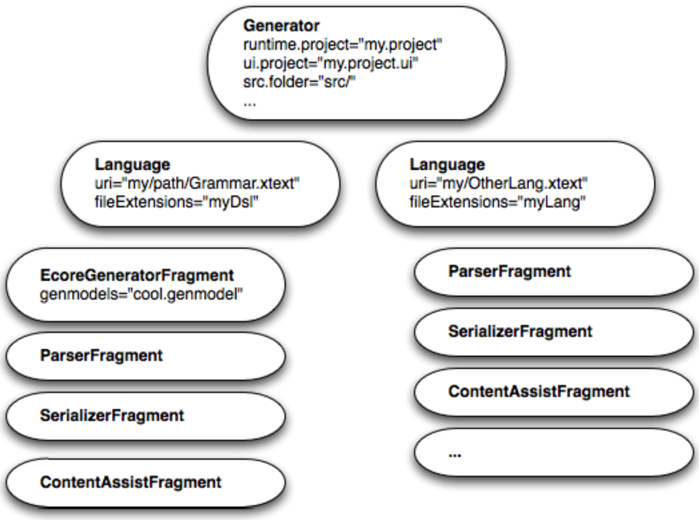
As you can see in the example above MWE2 can be used to instantiate arbitrary Java object models without any depedency or limitation to MWE2 specific implementations. This is conceptually very close to the dependency injection mechanism and the XML language in the Spring Framework.

Tip *Whenever you are in an *.mwe2 file and wonder what kind of configuration the underlying component may accept: Just use the Content Assist in the MWE2 Editor or navigate directly to the declaration of the underlying Java implemenation by means of F3 (Go To Declaration).*

This is the basic idea of the MWE2 language. There are of course a couple of additional concepts and features in the language and we also have not yet talked about the runtime workflow model. Please refer to the dedicated MWE2 reference documentation for additional information.

4.1.2. General Architecture

Now that you know a bit about MWE2, you are ready to learn about the concepts and architecture of Xtext’s language generator. An instance of Xtext’s generator is configured with general information about source folders and projects and consists of any number of language configurations. For each language configuration a URI pointing to its grammar file and the file extensions for the DSL must be provided. In addition, a language is configured with a list of IGeneratorFragments. The whole generator is composed of theses fragments. We have fragments for generating parsers, the serializer, the EMF code, the outline view, etc.



4.1.2.1. Generator Fragments

Each fragment gets the grammar of the language as an EMF model passed in. A fragment is able to generate code in one of the configured locations and contribute to several shared artifacts. The main interface IGeneratorFragment is supported by a convenient abstract base class AbstractGeneratorFragment, which by default delegates to an Xpand template with the same qualified name as the class and delegates some of the calls to Xpand template definitions.

We suggest to have a look at the fragment we have written for label providers (LabelProviderFragment). It is pretty trivial and at the same time uses the most important call backs. In addition, the structure is not cluttered with too much extra noise so that the whole package can serve as a template to write your own fragment.

4.1.2.2. Configuration

As already explained we use MWE2 from EMFT in order to instantiate, configure and execute this structure of components. In the following we see an exemplary Xtext generator configuration written in MWE2 configuration code:

```
module org.xtext.example.MyDsl

import org.eclipse.emf.mwe.utils.*
import org.eclipse.xtext.generator.*
import org.eclipse.xtext.ui.generator.*

var grammarURI = "classpath:/org/xtext/example/MyDsl.xtext"
var file.extensions = "mydsl"
var projectName = "org.xtext.example.mydsl"
var runtimeProject = "../${projectName}"

Workflow {
 bean = StandaloneSetup {
  platformUri = "${runtimeProject}/.."
 }

 component = DirectoryCleaner {
  directory = "${runtimeProject}/src-gen"
 }

 component = DirectoryCleaner {
  directory = "${runtimeProject}.ui/src-gen"
 }

 component = Generator {
  pathRtProject = runtimeProject
  pathUiProject = "${runtimeProject}.ui"
  projectNameRt = projectName
  projectNameUi = "${projectName}.ui"

  language = {
   uri = grammarURI
   fileExtensions = file.extensions

   // Java API to access grammar elements (required by several other fragments)
   fragment = grammarAccess.GrammarAccessFragment {}

   /* more fragments to configure the language */
   ...
  }
 }
}
```

Here the root element is `Workflow` which accepts *bean* s and *component* s. The `var` declaration is a first class concept of MWE2's configuration language and defines the interface of the module. They allow to externalize some common configuration parameters. This comes especially handy in String variables where one can easily use `${variable}` to concatenate values.

The method `Workflow.addBean(Object)` does nothing but provides a means to apply global side-effects, which unfortunately is required by some projects. In this example we do a so called *EMF stand-alone setup*. This class initializes a bunch of things for a non-OSGi environment that are otherwise configured by means of extension points, e.g. it allows to populate EMF's singletons like the `EPackage.Registry`.

Following the `bean` assignment there are three `component` elements. The `Workflow.addComponent()` method accepts instances of `IWorkflowComponent`, which is the primary concept of MWE2's workflow model. Xtext's generator itself is an instance of `IWorkflowComponent` and can therefore be used within MWE2 workflows.

4.1.3. Standard generator fragments

In the following table the most important standard generator fragments are listed. Please refer to the Javadocs for more detailed documentation.

Class	Generated Artifacts	Related Documentation
EcoreGeneratorFragment	EMF code for generated models	Model inference
XtextAntlrGeneratorFragment	ANTLR grammar, parser, lexer and related services	
GrammarAccessFragment	Access to the grammar	
ResourceFactoryFragment	EMF resource factory	
ParseTreeConstructorFragment	Model-to-text serialization	Serialization
JavaScopingFragment	Java-based scoping	Java-based scoping
JavaValidatorFragment	Java-based model validation	Java-based validation
CheckFragment	Xpand/Check-based model validation	Check-based validation
FormatterFragment	Code formatter	Declarative formatter
LabelProviderFragment	Label provider	Label provider
OutlineNodeAdapterFactoryFragment	Outline view configuration	Outline
TransformerFragment	Outline view configuration	Outline
JavaBasedContentAssistFragment	Java-based content assist	Content assist
XtextAntlrUiGeneratorFragment	Content assist helper based on ANTLR	Content assist
SimpleProjectWizardFragment	New project wizard	Project wizard

Important *Due to IP-Problems with the code generator shipped with ANTLR 3 we're not allowed to ship this fragment at Eclipse. Therefore you'll have to download it separately from http://download.itemis.com or use the update site at* ***http://download.itemis.com/updates/****.*

4.2. Dependency Injection in Xtext with Google Guice

In Xtext, there are many Java classes which implement logic, behavior, or supply configuration. These classes implement Java interfaces and are typically only supposed to be accessed through these interfaces, which makes their implementations interchangeable. This is where Xtext utilizes Google Guice:

- Guice manages the instantiation of the classes: instead of constructing a class with `new`, the `@Inject` annotation instructs Guice to supply an object for a certain interface. Such an object is called Service.
- Guice allows to configure which implementations are to be supplied for which interface. This configuration consists of so-called modules.

4.2.1. Services

The most parts of Xtext are implemented as *services*. A service is an object which implements a certain interface and which is instantiated and provided by Guice. Nearly every concept of the Xtext framework can be understood as this sort of *service*: The XtextEditor, the XtextResource, the IParser and even fine grained concepts as the PrefixMatcher for the content assist are configured and provided by Guice.

Xtext ships with generic default implementations for most of the services or uses generator fragments to automatically generate service implementations for a grammar. Thereby, Xtext strives to provide meaningful implementations out of the box and to allow customization wherever needed. Developers are encouraged to subclass existing services and configure them for their languages in their modules.

When Guice instantiates an object, it also supplies this instance with all its dependent services. All a service does is to request "some implementation for a certain interface" using the `@Inject`-annotation. Based on the modules configuration Guice decides which class to instantiate or which object to reuse.

For example, Guice can automatically initialize member variables with the needed services.

```
public class MyLanguageLinker extends Linker {

  @Inject
  private IScopeProvider scopeProvider;

  @Inject(optional=true)
  private IXtext2EcorePostProcessor postProcessor;

  (...)
}
```

Furthermore, Guice can pass the needed services as method parameters or event into a constructor call.

```
public class MyLanguageGrammarAccess implements IGrammarAccess {

  private final GrammarProvider grammarProvider;

  private TerminalsGrammarAccess gaTerminals;

  @Inject
  public MyLanguageGrammarAccess(GrammarProvider grammarProvider,
    TerminalsGrammarAccess gaTerminals) {
    this.grammarProvider = grammarProvider;
    this.gaTerminals = gaTerminals;
  }

  (...)
}
```

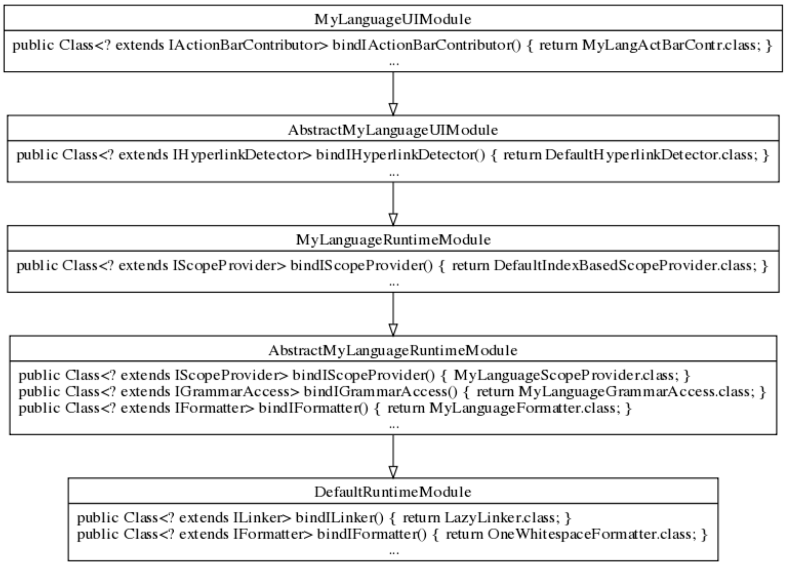
For further details, please refer to the Google Guice Documentation

4.2.2. Modules

The configuration of services for a language built with Xtext is done via modules:

- Modules bind arbitrary Java interfaces to their implementation classes or directly to instances of their implementation classes. Such a binding is sort of a configurable mapping.
- A module itself is a plain Java class.
- Modules can inherit from each other and override bindings that are declared in super-modules. This concept is put on top of plain Guice modules by Xtext.
- In Xtext, there is a generic default module for all languages, there are automatically generated modules and there are modules which are intended to be customized manually.
- Furthermore, Xtext distinguishes between modules for runtime-services and modules related to services needed for the user interface. The UI module extends the runtime module.

In total, this leads to five modules for a typical Xtext Language. They are visualized in the image below. The image is further explained in the following subsections.



4.2.2.1. Modules intended for customization

When the generator runs the first time, it creates two modules named `<MyLanguage>RuntimeModule` and `<MyLanguage>UIModule`. They are placed in the language's root-package in the `src/`-folder of the language's runtime-project and the language's UI-project. Both are initially empty and will never be overwritten by the generator. They are intended for customization. By default, they extend a generated module.

4.2.2.2. Generated Modules

The fully generated modules are called `Abstract<MyLanguage>RuntimeModule` and `Abstract<MyLanguage>UiModule` respectively. They contain all components which have been generated specifically for the language at hand. What goes into these modules depends on the fragments you use in the generator.

Note: *This modules are replaced on every subsequent execution of the generator. Don't put any custom code into them. Manually written code has go into the concrete subclasses.*

4.2.2.3. Default Module

Finally the fully generated modules extend the DefaultRuntimeModule, which contains all the default configuration. The default configuration consists of all components for which we have generic default implementations.

4.2.2.4. Changing Configuration

We use the primary modules (`<MyLanguage>RuntimeModule` and `<MyLanguage>UiModule`) in order to change the configuration. These classes are initially empty and have been generated to allow customization.

In order to provide a simple and convenient way, the default module extends the AbstractGenericModule. It does not provide any bindings itself but comes up with a convenient and declarative way to specify mappings. The default API provided by Guice is based on fluent API and a builder pattern. This is also very readable but does not allow submodules to change any of the bindings. The AbstractGenericModule allows to declare and override bindings in all subclasses like this:

```
public Class<? extends IFooService> bindIFooService() {
     return MyFooServiceImpl.class;
}
```

Such a method will be interpreted as a binding from `IFooService` to `MyFooServiceImpl.class`. Note that you simply have to override a method from a super class (e.g. from the generated or default module) in order to change the respective binding. For example, in the picture above, the `DefaultRuntimeModule` configures the IFormatter to be implemented by the

OneWhitespaceFormatter. The `AbstractMyLanguageModule` overrides this binding by mapping the IFormatter to `MyLanguageFormatter`. The type to type binding will create a new instance of the given target type for each dependency. If you want to make it a singleton and thereby ensure only one instance to be created and reused for all dependencies you can add the following annotation:

```
@SingletonBinding
public Class<? extends IFooService> bindIFooService() {
  return MyFooServiceImpl.class;
}
```

In addition if the creation of the type causes any necessary side effects, so you want it to be instantiated eagerly, you can set the `eager` property to true. This is shown in the following snippet:

```
@SingletonBinding(eager=true)
public Class<? extends IFooService> bindIFooService() {
  return MyFooServiceImpl.class;
}
```

One more way of specify a binding is currently supported: If you need to control the way, the instance is created, you can declare a type to object mapping:

```
public IFooService bindIFooService() {
  return new MyFooServiceImpl();
}
```

Note that, although this is a convenient and simple way, you have of course also the full power of Guice, i.e. you can override the Guice method `void configure(Binder)` and use the afore mentioned fluent API to do whatever you want.

Chapter 5. Runtime Concepts

TMF Xtext itself and every language infrastructure developed with Xtext is configured and wired-up using dependency injection. Xtext may be used in different environments which introduce different constraints. Especially important is the difference between OSGi managed containers and plain vanilla Java programs. To honor these differences Xtext uses the concept of `ISetup`-implementations in normal mode and uses Eclipse's extension mechanism when it should be configured in an OSGi environment.

5.1. Runtime setup (ISetup)

For each language there is an implementation of `ISetup` generated. It implements a method called `doSetup()`, which can be called to do the initialization of the language infrastructure. This class is intended to be used for runtime and unit testing, only.

The setup method returns an `Injector`, which can further be used to obtain a parser, etc. It also registers the ResourceFactory and generated EPackages at the respective global registries provided by EMF. So basically you can just run the setup and start using EMF API to load and store models of your language.

5.2. Setup within Eclipse-Equinox (OSGi)

Within Eclipse we have a generated `Activator`, which creates a Guice injector using the modules. In addition an `IExecutableExtensionFactory` is generated for each language, which is used to create `ExecutableExtensions`. This means that everything which is created via extension points is managed by Guice as well, i.e. you can declare dependencies and get them injected upon creation.

The only thing you have to do in order to use this factory is to prefix the class with the factory `<MyLanguageName>ExecutableExtensionFactory` name followed by a colon.

```
<extension
  point="org.eclipse.ui.editors">
  <editor
    class="<MyLanguageName>ExecutableExtensionFactory:
      org.eclipse.xtext.ui.core.editor.XtextEditor"
    contributorClass=
      "org.eclipse.ui.editors.text.TextEditorActionContributor"
    default="true"
    extensions="ecoredsl"
    id="org.eclipse.xtext.example.EcoreDsl"
    name="EcoreDsl Editor">
  </editor>
</extension>
```

5.3. Logging

Xtext uses Apache's log4j for logging. It is configured using a so called log4j.properties, which is looked up in the root of the Java classpath. If you want to change or provide configuration at runtime (i.e. non-OSGI), all you have to do is putting such a log4j.properties in place and make sure that it is not overridden by other log4j.properties in previous class path entries.

In OSGi you provide configuration by creating a fragment for org.apache.log4j. In this case you need to make sure that there's no second fragment contributing a log4j.properties file.

5.4. Validation

Static analysis or validation is one of the most interesting aspects when developing a programming language. The users of your languages will be grateful if they get informative feedback as they type. In Xtext there are basically three different kinds of validation.

5.4.1. Syntactical Validation

The syntactical correctness of any textual input is validated automatically by the parser. The error messages are generated by the underlying parser technology and cannot be customized using a general hook. Any syntax errors can be retrieved from the Resource using the common EMF API:

- `org.eclipse.emf.ecore.resource.Resource.getErrors()`
- `org.eclipse.emf.ecore.resource.Resource.getWarnings()`

5.4.2. Crosslink Validation

Any broken crosslinks can be checked generically. As crosslink resolution is done lazily (see linking), any broken links are resolved lazily as well. If you want to validate whether all links are valid, you will have to navigate through the model so that all installed EMF proxies get resolved. This is done automatically in the editor.

Any unresolvable crosslinks will be reported and can be obtained through:

- `org.eclipse.emf.ecore.resource.Resource.getErrors()`
- `org.eclipse.emf.ecore.resource.Resource.getWarnings()`

5.4.3. Custom Validation

In addition to the afore mentioned kinds of validation, which are more or less done automatically, you can specify additional constraints specific for your Ecore model. We leverage existing EMF API (mainly `EValidator`) and have put some convenience stuff on top. Basically all you need to do is to make sure that an `EValidator` is registered for your `EPackage`. The registry for `EValidators` (`EValidator.Registry.INSTANCE`) can only be filled programmatically. That means contrary to the EPackage and `Resource.Factory` registries there is no Equinox extension point to populate the validator registry.

For Xtext we provide a generator fragment for the convenient Java-based `EValidator` API. Just add the following fragment to your generator configuration and you are good to go:

```
<fragment class=
  "org.eclipse.xtext.generator.validation.JavaValidatorFragment"/>
```

The generator will provide you with two Java classes. An abstract class generated to `src-gen/` which extends the library class `AbstractDeclarativeValidator`. This one just registers the EPackages for which this validator introduces constraints. The other class is a subclass of that abstract class and is generated to the `src/` folder in order to be edited by you. That's where you put the constraints in.

The purpose of the `AbstractDeclarativeValidator` is to allow you to write constraints in a declarative way – as the class name already suggests. That is instead of writing exhaustive if-else constructs or extending the generated EMF switch you just have to add the `@Check` annotation to any method and it will be invoked automatically when validation takes place. Moreover you can state for what type the respective constraint method is, just by declaring a typed parameter. This also lets you avoid any type casts. In addition to the reflective invocation of validation methods the `AbstractDeclarativeValidator` provides a couple of convenient assertions.

All in all this is very similar to how JUnit works. Here is an example:

```
public class DomainmodelJavaValidator
  extends AbstractDomainmodelJavaValidator {

  @Check
  public void checkTypeNameStartsWithCapital(Type type) {
    if (!Character.isUpperCase(type.getName().charAt(0)))
      warning("Name should start with a capital",
        DomainmodelPackage.TYPE__NAME);
  }
}
```

5.4.4. Quickfixes

For validations written using the `AbstractDeclarativeValidator` it is possible to provide corresponding quickfixes in the editor. To be able to implement a quickfix for a given diagnostic (a warning or error) the underlying *cause* of the diagnostic must be known (i.e. what actual problem does the diagnostic represent?), otherwise the fix doesn't know what needs to be done. As we don't want to deduce this from the diagnostic's error message we associate a problem specific *code* with the diagnostic.

In the following example (from DomainmodelJavaValidator) the diagnostic's *code* is given by the last argument to the `warning()` method and it is a reference to the static `String` field `INVALID_TYPE_NAME` in the validator class.

```
      warning("Name should start with a capital",
        DomainmodelPackage.TYPE__NAME, INVALID_TYPE_NAME, type.getName());
```

Now that the validation has a unique code identifying the problem we can register quickfixes against it. We start by adding the `org.eclipse.xtext.ui.generator.quickfix.QuickfixProviderFragment` to our workflow and after regenerating the code we should find an empty class `MyDslQuickfixProvider` in our DSL's UI project.

Continuing with the `INVALID_TYPE_NAME` problem from the Domainmodel example we add a method with which the problem can be fixed (see also DomainmodelQuickfixProvider):

```
@Fix(DomainmodelJavaValidator.INVALID_TYPE_NAME)
public void fixName(final Issue issue, IssueResolutionAcceptor acceptor) {
  acceptor.accept(issue, "Capitalize name", "Capitalize name  of '" + issue.getData()[0] +
  public void apply(IModificationContext context) throws BadLocationException {
   IXtextDocument xtextDocument = context.getXtextDocument();
   String firstLetter = xtextDocument.get(issue.getOffset(), 1);
   xtextDocument.replace(issue.getOffset(), 1, Strings.toFirstUpper(firstLetter));
 }
 });
}
```

By using the correct signature (see below) and annotating the method with the `Fix` annotation referencing the code we specified in the validator, Xtext knows that this method implements a fix for the problem. This also allows us to annotate multiple methods as fixes for the same problem.

The first three parameters given to the IssueResolutionAcceptor define the UI representation of the quickfix. As the document is not necessarily loaded when the quickfix is offered, we need to provide any additional data from the model that we want to refer to in the UI when creating the issue in the validator above. In this case, we provided the existing type name.

The actual model modification is implemented in the ${org.eclipse.xtext.ui/src/org/eclipse/xtext/ui/editor/model/edit/IModification}. The ${org.eclipse.xtext.ui/src/org/eclipse/xtext/ui/editor/model/edit/IModificationContext} provides access to the erroneous document.

If you prefer to implement the quickfix in terms of the semantic model use a ${org.eclipse.xtext.ui/src/org/eclipse/xtext/ui/editor/model/edit/ISemanticModification.java} instead. Its `apply(EObject, IModificationContext)` method will be invoked inside a modification transaction and the first argument will be the erroneous semantic element. This makes it very easy for the fix method to modify the model as necessary. After the method returns the model as well as the Xtext editor's content will be updated accordingly. If the method fails (throws an exception) the change will not be committed.

5.4.5. Validation with the Check language

In addition to the Java-based validation code you can use the language Check (from M2T/Xpand) to implement constraint checks against your model. To do so, you have to configure the generator with the CheckFragment. Please note, that you can combine both types of validation in your project.

```
<fragment class=
  "org.eclipse.xtext.generator.validation.CheckFragment"/>
```

After regenerating your language artifacts you will find three new files "YourLanguageChecks.chk", "YourLanguageFastChecks.chk" and "YourLanguageExpensiveChecks.chk" in the `src/` folder in the sub-package `validation`. The checks in these files will be executed when saving a file, while typing (FastChecks) or when triggering the validation explicitly (ExpensiveChecks). When using Check the example of the previous chapter could be written like this.

```
context Type#name WARNING "Name should start with a capital":
  name.toFirstUpper() == name;
```

Each check works in a specific context (here: `Type`) and can further denote a feature to which a warning or error should be attached to (here: `name`). Each check could either be a `WARNING` or an `ERROR` with a given string to explain the situation. The essential part of each check is an invariant that must hold true for the given context. If it fails the check will produce an issue with the provided explanation.
Please read more about the Check language as well as the underlying expression language in Xpand's reference documentation which is shipped as Eclipse help.

5.4.6. Test Validators

If you have implemented your validators by extending AbstractDeclarativeValidator, there are helper classes which may assist you when testing your validators.

Testing validators typicallally works as follows:

1. The test creates some models which intentionally violate some constraints.
2. The test runs some choosen @Check-methods from the validator.
3. The test asserts whether the @Check-methods have raised the expected warnings and errors.

To create models, you can either use EMF's `ResourceSet` to load models from your hard disk or you can utilize the `<MyLanguage>Factory` (which EMF generates for each `EPackage`) to construct the needed model elements manually. While the fist option has the advantages that you can edit your models in your textual concrete syntax, the second option has the advantage that you can create partial models.

To run the @Check-methods and ensure they raise the intended errors and warnings, you can utilize ValidatorTester as shown by the following example:

Validator:

```
public class MyLanguageValidator extends AbstractDeclarativeValidator {
  @Check
  public void checkFooElement(FooElement element) {
    if(element.getBarAttribute().contains("foo"))
      error("Only Foos allowed", element, MyLanguagePackage.FOO_ELEMENT__BAR_ATTRIBUTE, 10
  }
}
```

JUnit-Test:

```
public class MyLanguageValidatorTest extends TestCase {

  private ValidatorTester<MyLanguageValidator> tester;

  @Override
  public void setUp() {
    MyLanguageValidator val = new MyLanguageValidator();
    new MyLanguageStandaloneSetup().createInjectorAndDoEMFRegistration().injectMembers(val
    tester = new ValidatorTester<TestingValidator>(val);
  }

  public void testError() {
    FooElement model = MyLanguageFactory.eINSTANCE.createFooElement()
    model.setBarAttribute("barbarbarbarfoo");

    tester.validator().checkFooElement(model);
    tester.diagnose().assertError(101);
  }

  public void testError2() {
    FooElement model = MyLanguageFactory.eINSTANCE.createFooElement()
    model.setBarAttribute("barbarbarbarfoo");

    tester.validate(model).assertError(101);
  }
}
```

This example uses JUnit 3, but since the involved classes from Xtext have no dependency on JUnit whatsoever, JUnit 4 and other testing frameworks will work as well. JUnit runs the `setUp()`-method before each testcase and thereby helps to create some common state. In this example, the validator (`MyLanguageValidator`) is instantiated manually and initialized via Google Guice's dependency injection. Then the `ValidatorTester` is created. It acts as a wrapper for the validator, ensures that the validator has a valid state and provides convenient access to the validator itself (`tester.validator()`) as well as to the utility classes which assert diagnostics created by the validator (`tester.diagnose()`). Please be aware that you have to call `validator()` before you can call `diagnose()`. However, you can call `validator()` multiple times in a row.

While `validator()` allows to call the validator's @Check-methods directly, `validate(model)` leaves it to the framework to call the applicable @Check-methods. However, to avoid side-effects between tests, it is recommended to call the @Check-methods directly.

`diagnose()` and `validate(model)` return an object of type @{org.eclipse.xtext/src/org/eclipse/xtext/validation/AssertableDiagnostics} which provides several `assert`-methods to verify whether the expected diagnostics are present:

- `assertError(int code)`: There must be one diagnostic with severity ERROR and the supplied error code.
- `assertErrorContains(String messageFragment)`: There must be one diagnostic with severity ERROR and its message must contain `messageFragment`.
- `assertError(int code, String messageFragment)`: Verifies severity, error code and messageFragment.
- `assertWarning(...)`: This method is available for the same combination of parameters as `assertError()`.
- `assertOK()`: Expects that no diagnostics (errors, warnings etc.) have been raised.
- `assertDiagnostics(int severity, int code, String messageFragment)`: Verifies severity, error code and messageFragment.
- `assertAll(DiagnosticPredicate... predicates)`: Allows to describe multiple diagnostics at the same time and verifies that all of them are present. Class @{org.eclipse.xtext/src/org/eclipse/xtext/validation/AssertableDiagnostics} contains static `error()` and `warning()`-methods which help to create the needed `DiagnosticPredicate`. Example: `assertAll(error(123), warning("some part of the message"))`.

- `assertAny(DiagnosticPredicate predicate)`: Asserts that a diagnostic exists which matches the predicate.

5.5. Linking

The linking feature allows for specification of cross references within an Xtext grammar. The following things are needed for the linking:

1. declaration of a crosslink in the grammar (at least in the Ecore model)
2. specification of linking semantics (usually provided via the scoping API)

5.5.1. Declaration of crosslinks

In the grammar a cross reference is specified using square brackets.

```
CrossReference :
  '[' ReferencedEClass ('|' terminal=AbstractTerminal)? ']'
;
```

Example:

```
ReferringType :
  'ref' referencedObject=[Entity|(ID|STRING)]
;
```

The Ecore model inference would create an `EClass` ‘ReferringType’ with an `EReference` ‘referencedObject’ of type ‘Entity’ (containment=false). The referenced object would be identified either by an ID or a STRING and the surrounding information in the current context (see scoping). If you do not use “generate” but “import” an existing ecore model, the class `ReferringType` (or one of its super types) would need to have an EReference of type Entity (or one of its super types) declared. Also the EReference’s containment property needs to be set to `false`.

5.5.2. Default runtime behavior / lazy linking

Xtext uses lazy linking by default and we encourage users to stick to this, because it provides a lot of advantages. One is improved performance in all scenarios where you don’t have to load the whole closure of all transitively referenced resources. Also it automatically solves situation where one link relies on other links. Though cyclic linking dependencies are not supported by Xtext at all.

When parsing a given input string, say

```
ref Entity01
```

The LazyLinker first creates an EMF proxy and sets on the corresponding EReference. In EMF a proxy is described by a URI, which points to the real EObject. In the case of lazy linking the stored URI comprises of the context information given at parse time, which is the EObject containing the cross reference, the actual EReference, the index (in case it’s a multi-valued cross reference) and the string which represented the cross link in the concrete syntax. The latter usually corresponds to the name of the referenced EObject. In EMF a URI consists of information about the resource the EObject is contained in as well as a so called fragment part, which is used to find the EObject within that resource. When an EMF proxy is resolved, the current ResourceSet is asked. The resource set uses the first part to obtain (i.e. load if it is not already loaded) the resource. Then the resource is asked to return the EObject based on the fragment in the URI. The actual cross reference resolution is done by `LazyLinkingResource.getEObject(String)` which receives the fragment and delegates to the implementation of the `ILinkingService`. The default implementation in turn delegates to the “scopes API”#scoping.

A simple implementation of the linking service (the DefaultLinkingService) is shipped with Xtext and used for any grammar per default. Usually any necessary customization of the linking behavior can best be described using the “scopes API”#scoping.

5.6. Scoping

Using the scoping API one defines which elements are referable from a certain reference. For instance, using the introductory example (fowler’s state machine language) a transition contains two cross reference one to a declared event and one to a declared state.

Example:

```
events
  nothingImportant  MYEV
end

state idle
  nothingImportant => idle
end
```

The grammar rule for transitions looks like this:

```
Transition :
  event=[Event] '=>' state=[State];
```

The grammar only states that for the reference `event` only instances of the type `Event` are allowed and that for the EReference `state` only instances of type `State` can be referenced. However, this simple declaration doesn't say anything about where to find the states or events. That is the duty of scopes.

An `IScopeProvider` is responsible for providing an `IScope` for a given context `EObject` and `EReference`. The returned `IScope` should contain all target candidates for the given object and cross reference.

```
public interface IScopeProvider {

 /**
  * Returns a scope for the given context. The scope provides access to the compatible
  * visible EObjects for a given reference.
  *
  * @param context the element from which an element shall be referenced
  * @param reference the reference to be used to filter the elements.
  * @return {@link IScope} representing the inner most {@link IScope} for the
  *         passed context and reference. Note for implementors: The result may not be <co
  *         Return <code>IScope.NULLSCOPE</code> instead.
  */
 IScope getScope(EObject context, EReference reference);

}
```

A single `IScope` represents an element of a linked list of scopes. That means that a scope can be nested within an outer scope. Each scope works like a symbol table or a map where the keys are strings and the values are so called IEObjectDescription, which is effectively an abstract description of a real EObject.

5.6.1. Global Scopes and IResourceDescriptions

In the state machine example we don't have cross file references. Also there is no such thing as name spaces or other concepts which make scoping a bit more complicated. Basically every `State` and every `Event` declared in the same resource is visible by their name. However in the real world things are most likely not that simple. What if you want to reuse certain declared states and events across different state machines and you want to share those as library between different users? You would want to introduce some kind of cross resource reference. Defining what is visible from outside the current resource is the responsibility of global scopes. Defining what things of the current resource can be seen from outside (i.e. is publicly referenceable) is the duty of the so called `IResourceDescriptions.Manager`.

5.6.1.1. Resource and `EObject` Descriptions (`IResourceDescription`, `IEObjectDescription`)

In order to make states and events of one file referenceable from another file you need to export them as part of a so called IResourceDescription. Such a description can be obtained by an implementation of `IResourceDescription.Manager` which is provided by the IResourceServiceProvider for your language.

A `IResourceDescription` contains information about the resource itself (primarily a `URI`), a list of exported `EObjects` (in the form of IEObjectDescription) as well as information about outgoing cross references and qualified names it references. The cross references contain only resolved references, while the list of imported qualified names also contain those names, which couldn't be resolved. This information is important in order to compute the transitive hull of dependent resources, which the shipped index infrastructure automatically does for you.

For users and especially in the context of scoping the most important information is the list of exported `EObjects`. An `IEObjectDescription` contains information about the `URI` to the actual `EObject` and the qualified name of that element as well as the corresponding `EClass`. In addition one can export arbitrary information using the so called user data map.

A language is configured with a default implementation of `IResourceDescription.Manager` which computes the list of exported `IEObjectDescription` s by iterating the whole EMF model and applying the `getQualifiedName(EObject obj)` from IQualifiedNameProvider on each `EObject`. If it returns a name an `IEObjectDescription` is created and exported (i.e. added to the list). If an `EObject` doesn't have a qualified name, the element is considered to be not referenceable from outside the resource.

There are also two different implementations of `IQualifiedNameProvider`. Both work by looking up an `EAttribute` with the name 'name'. The SimpleNameProvider just returns the plain value, while the DefaultDeclarativeQualifiedNameProvider concats the simple name with the qualified name of its parent exported `EObject`. This effectively simulates the qualified name computation of most name space based languages (like e.g. Java).

As mentioned above, in order to obtain an `IResourceDescription` for a resource you need to ask the `IResourceDescription.Manager`. Here's some Java code showing how to do that:

```
Manager manager = // obtain an instance of IResourceDescription.Manager.class
  IResourceDescription description = manager.getResourceDescription(resource);
  for (IEObjectDescription eObjDescription : description.getExportedObjects()) {
    System.out.println(eObjDescription.getQualifiedName());
  }
```

In order to obtain an `IResourceDescription.Manager` it is best to ask the corresponding IResourceServiceProvider. That is because each language might have a totally different implementation and as you might refer to from your language to a different language you can't reuse your language's `IResourceDescription.Manager`. One basically asks the `IResourceServiceProvider.Registry` (there is usually one global instance) for an `IResourceServiceProvider`, which in turn provides an `IResourceDescription.Manager` along other useful services.

If you're running in a Guice enabled scenario, the code looks like this:

```
@Inject private IResourceServiceProvider.Registry resourceServiceProviderRegistry;

  private IResourceDescription.Manager getManager(Resource res) {
  IResourceServiceProvider resourceServiceProvider = resourceServiceProviderRegistry.getRe
  return resourceServiceProvider.getResourceDescriptionManager();
 }
```

If you don't run in a Guice enabled context you will likely have to directly access the singleton:

```
private IResourceServiceProvider.Registry resourceServiceProviderRegistry = IResourceServi
```

However, we strongly encourage you to use dependency injection. Now, that we know how to export elements to be referenceable from other resources, we need to learn how those exported `IEObjectDescriptions` can be made available to the referencing resources. That is the responsibility of global scoping (i.e. IGlobalScopeProvider) which is described in the following.

5.6.1.2. Global Scopes based on explicit imports (ImportURI mechanism)

A simple and straight forward solution is to have explicit references to other resources in your file by explicitly listing pathes (or `URIs`) to all referenced resources in your model file. That is for instance what most include mechanisms use. In Xtext we provide a handy implementation of an `IGlobalScopeProvider` which is based on naming convention and makes this semantics very easy to use. Talking of the introductory example and given you would want to add support for referencing external `States` and `Events` from within your state machine, all you'ld had to do is add something like the following to the grammar definition:

```
Statemachine :
  (imports+=Import)* // allow imports
  'events'
     (events+=Event)+
  'end'
  ('resetEvents'
     (resetEvents+=[Event])+
  'end')?
  'commands'
     (commands+=Command)+
  'end'
  (states+=State)+;

Import :
  'import' importURI=STRING;
```

This effectively allows import statements to be declared before the events section. In addition you'll have to make sure that you have bound the ImportUriGlobalScopeProvider for the type `IGlobalScopeProvider` by the means of Guice:#dependencyInjection. That implementation looks up any `EAttributes` named 'importURI' in your model and interprets their values as imports. That is it adds the corresponding resources to the current resource's resource set. In addition the scope provider uses the `IResourceDescription.Manager`#resource_descriptions of that imported resource to compute all the `IEObjectDescriptions` returned by the `IScope`.

5.6.1.3. Global Scopes based on external configuration (e.g. classpath-based)

The other possibility is to have some kind of external configuration in order to define what is visible outside a resource. Java for instances uses the notion of classpaths to define containers (jars and class folders) which contain any referenceable elements. In the case of Java also the order of such entries is important. Since version 1.0.0 Xtext provides support for this kind of global scoping. Actually by default Xtext leverages the classpath mechanism since it is well designed and already understood by most of our users. Also the available tooling provided by JDT and PDE to configure the classpath is of high value. However it is just a default you can reuse the infrastructure without reusing Java and therefore depending on JDT.

In order to know what is available in the "world" a global scope provider which relies on external configuration needs to read that configuration in and be able to find all candidates for a certain EReference in those containers. If you don't want to force users to have a folder and file name structure reflecting the actual qualified names of the referenceable `EObjects`, you'll have to load all resources up front and either keep holding them in memory or remembering all information which is needed for reference resolution. In Xtext that information is provided by a so called `IEObjectDescription`#resource_descriptions.

Xtext ships with an index which remembers all `IResourceDescriptions` and its `IEObjectDescriptions`. In the IDE-context (i.e. when running the editor, etc.) the index is updated incrementally by an incremental project builder. At runtime however, you typically do not have to deal with changes so that the infrastructure can be much simpler. In both situations the global index state is hold by an implementation of IResourceDescriptions (Note the plural form!).

Of containers and its manager

As mentioned above all this stuff is best explained along Java's class path mechanism, because we assume that you have an idea of its concepts and how it works. At least if not and we haven't written enough information down, there are other resources you could consult. The index is just a flat list of instances of `IResourceDescription` the index itself doesn't know about containers. That is because we think the notion of containers is something which is defined by the referencing language. The very same resource could be loaded from Java by the means of ClassLoader.loadResource() (i.e. using the classpath mechanism) but could be loaded from some other language by using the file system paths.

This means that the information about to what container a resource belongs depends on the context. Therefore an `IResourceServiceProvider` provides another interesting service, which is called `IContainer.Manager`. An `IContainer.Manager` provides you with the IContainer a certain `IResourceDescripition` belongs to as well as with a list of all `IContainers` which are visible from a certain `IResourceDescription`. Note that while the index (`IResourceDesciptions`) is globally shared (between all languages) the `IContainer.Manager` adds the semantic of containers and its implementation can be very different depending on the language.

By default Xtext provides either leveraging the Java class path mechanism, which allows to reuse a lot of nice Java things (jars, OSGi, maven, etc.) or define containers based on Eclipse projects. At runtime the only alternative is configured with a list of pathes to scan. Such pathes can either point to folders or archives.

Java based container manager

TODO Explain how to setup Java and project based container state in the ui. TODO Explain how to setup a resourcesetbased IResourceDescriptions for runtime.

5.6.2. Local Scoping

TODO TODO TODO We now know how the outer world of referenceable elements can be defined in Xtext.

For instance Java has multiple kinds of scopes (object scope, type scope, etc.).

For Java one would create the scope hierarchy as commented in the following example:

```
// file contents scope
import static my.Constants.STATIC;

public class ScopeExample { // class body scope
  private Object field = STATIC;

  private void method(String param) { // method body scope
    String localVar = "bar";
    innerBlock: { // block scope
      String innerScopeVar = "foo";
      Object field = innerScopeVar;
      // the scope hierarchy at this point would look like this:
      //  blockScope{field,innerScopeVar}->
      //  methodScope{localVar, param}->
      //  classScope{field}-> ('field' is overlayed)
      //  fileScope{STATIC}->
      //  classpathScope{'all qualified names of accessible static fields'} ->
      //  NULLSCOPE{}
      //
    }
    field.add(localVar);
  }
}
```

In fact the class path scope should also reflect the order of class path entries. For instance:

```
classpathScope{stuff from bin/}
-> classpathScope{stuff from foo.jar/}
-> ...
-> classpathScope{stuff from JRE System Library}
-> NULLSCOPE{}
```

Please find the motivation behind this and some additional details in [this blog post](#) .

The default implementation would produce this hierarchy of scopes for the model from the last example in the [previous chapter](#):

```
//file model.dsl
import "model1.dsl";
import "model2.dsl";

ref Foo;
entity Bar;
```

```
//file model1.dsl
entity Stuff;
```

```
//file model2.dsl
entity Foo;
```

```
Scope (model.dsl) {
  parent : Scope (model1.dsl) {
    parent : Scope (model2.dsl) {}
  }
}
```

When enumerating the scope's content, the first, most specialized scope would return `Bar`, its parent would provide `Stuff` and the outermost scope adds `Foo`. The linker will iterate the scope in that order and abort when it finds a matching `ScopedElement`.

5.6.3. Default linking semantics

The default implementation for all languages looks within the current file for an EObject of the respective type. In the example above this would be an "Entity" which by convention has a `name` attribute set to 'Entity01'.

Given the grammar :

```
Model :
  (stuff+=(Ref|Entity))*
;

Ref :
  'ref' referencedObject=[Entity|ID] ';'
;

Entity :
  'entity' name=ID ';'
;
```

In the following model:

```
ref Entity01;
entity Entity01;
```

the `ref` would be linked to the declared entity (`entity  Entity01;`). Nearly any aspect is configurable, especially the name of the identifying attribute may be overridden for a particular type.

5.6.3.1. Default Imports

There is a default implementation for inter-resource references, which as well uses convention. Each string in a model which is assigned to an EAttribute with the name `importURI`, will be interpreted as an URI and used to be loaded using the `ResourceSet` of the current resource.

For example, given the following grammar :

```
Model :
  (imports+=Import)*
  (stuff+=(Ref|Entity))*
;

Import :
  'import' importURI=STRING ';'
;

Ref :
  'ref' referencedObject=[Entity|ID] ';'
;

Entity :
  'entity' name=ID ';'
;
```

It would be possible to write three files in that language where the first references the other two, like this:

```
//file model.dsl
import "model1.dsl";
import "model2.dsl";

ref Foo;
entity Bar;
```

```
//file model1.dsl
entity Stuff;
```

```
//file model2.dsl
entity Foo;
```

The linking candidates for the reference `Foo` will be `Bar`, `Stuff` and `Foo` in that order. They will be computed by the ScopeProvider.

5.6.4. DeclarativeScopeProvider

As always there is an implementation that allows to specify scoping in a declarative way. It looks up methods which have either of the following two signatures:

```
IScope scope_<RefDeclaringEClass>_<Reference>(<ContextType> ctx, EReference ref)
```

```
IScope scope_<TypeToReturn>(<ContextType> ctx, EReference ref)
```

The former is used when evaluating the scope for a specific cross reference and here `<ContextReference>` corresponds to the name of this reference (prefixed with the name of the reference's declaring type and separated by an underscore). The `ref` parameter represents this cross reference.

The latter method signature is used when computing the scope for a given element type and is applicable to all cross references of that type. Here `<TypeToReturn>` is the name of that type which also corresponds to the `type` parameter.

So if you for example have a state machine with a *Transition* object owned by its source *State* and you want to compute all reachable states (i.e. potential target states), the corresponding method could be declared as follows (assuming the cross reference is declared by the *Transition* type and is called *target*):

```
IScope scope_Transition_target(Transition this, EReference ref)
```

If such a method does not exist, the implementation will try to find one for the context object's container. Thus in the example this would match a method with the same name but *State* as the type of the first parameter. It will keep on walking the containment hierarchy until a matching method is found. This container delegation allows to reuse the same scope definition for elements in different places of the containment hierarchy. Also it may make the method easier to implement as the elements comprising the scope are quite often owned or referenced by a container of the context object. In the example the *State* objects could for instance be owned by a containing *StateMachine* object.

If no method specific to the cross reference in question was found for any of the objects in the containment hierarchy, the implementation will start looking for methods matching the other signature (with the *EClass* parameter). Again it will first attempt to match the context object. Thus in the example the signature first matched would be:

```
IScope scope_State(Transition this, EReference ref)
```

If no such method exists, the implementation will again try to find a method matching the context object's container objects. In the case of the state machine example you might want to declare the scope with available states at the state machine level:

```
IScope scope_State(StateMachine this, EReference ref)
```

This scope can now be used for any cross references of type *State* for context objects owned by the state machine.

There are currently two different scope provider implmentations available which support these semantics:

1. AbstractDeclarativeScopeProvider
2. AbstractDeclarativeQualifiedNameScopeProvider

5.6.5. QualifiedNameScopeProvider

The qualified name scoping is based on qualified names and name spaces. It adds name space support to your language, which is comparable and similar to the one in Scala and C#. Scala and C# both allow to have multiple nested packages within one file and you can put imports per namespace, so that imported names are only visible within that namespace. See the domain model example its scope provider extends AbstractDeclarativeQualifiedNameScopeProvider.

5.6.5.1. IQualifiedNameProvider

The QualifiedNameScopeProvider makes use of the so called IQualifiedNameProvider service. It computes qualified names for EObjects. The default implementation (DefaultDeclarativeQualifiedNameProvider) uses a simple name look up and concats the result to the qualified name of its parent object. See its JavaDoc and the code for more details.

5.6.5.2. Importing name spaces

The QualifiedNameScopeProvider looks up EAttributes with name 'importNamespace' and interprets such as import statements. By default qualified names with or without a wildcard at the end are supported. For an import of a qualified name the simple name is made available as we know from e.g. Java, where

```
import java.util.Set;
```

makes it possible to refer to 'java.util.Set' by its simple name 'Set'. Contrary to Java the import is not active for the whole file but only for the namespace it is declared in and its child namespaces. That is why you can write the following in the example DSL:

```
package foo {
  import bar.Foo
  entity Bar extends Foo {
  }
}

package bar {
  entity Foo {}
}
```

Of course the declared elements within a package are as well referable by their simple name:

```
package bar {
  entity Bar extends Foo {}
  entity Foo {}
}
```

Of course the following would as well be ok:

```
package bar {
  entity Bar extends bar.Foo {}
  entity Foo {}
}
```

As the name suggests it uses the EMF index to find any EObjects which are not located in the current resource. The IndexBasedScopeProvider supports nested namespaces (similar to C# and Scala) and is used in the Domainmodel example (project org.eclipse.xtext.example.domainmodel). There is support for declarative overwriting of the default semantics if you subclass AbstractDeclarativeIndexBasedScopeProvider.

See the JavaDocs and this blog post for details.

5.7. Value Converter

Value converters are registered to convert the parsed text into a certain data type instance and vice versa. The primary hook is called IValueConverterService and the concrete implementation can be registered via the runtime Guice module. To do so override the corresponding binding in your runtime module like shown in this example:

```
@Override
public Class<? extends IValueConverterService> bindIValueConverterService() {
  return MySpecialValueConverterService.class;
}
```

5.7.1. Annotation based value converters

The most simple way to register additional value converters is to make use of AbstractDeclarativeValueConverterService, which allows to declaratively register an `IValueConverter` via an annotated method.

The implementation for the default token grammar looks like

```
public class DefaultTerminalConverters
    extends AbstractDeclarativeValueConverterService {

  (..)

  @ValueConverter(rule = "ID")
  public IValueConverter<String> ID() {
    return new AbstractNullSafeConverter<String>() {
      @Override
      protected String internalToValue(String string, AbstractNode node) {
        return string.startsWith("^") ? string.substring(1) : string;
      }

      @Override
      protected String internalToString(String value) {
        if (GrammarUtil.getAllKeywords(getGrammar()).contains(value)) {
          return "^" + value;
        }
        return value;
      }
    };
  }
  ...  some other value converter
}
```

If you use the common terminals grammar `org.eclipse.xtext.common.Terminals` you should subclass `DefaultTerminalConverters` and override or add additional value converters by adding the respective methods.

Imagine, you would want to add a rule BIG_DECIMAL creating BigDecimals, it would look like this one:

```
@ValueConverter(rule = "BIG_DECIMAL")
public IValueConverter<BigDecimal> BIG_DECIMAL() {
  return new AbstractToStringConverter<BigDecimal>() {
    @Override
    protected BigDecimal internalToValue(String string, AbstractNode node) {
      return BigDecimal.valueOf(string);
    }
  };
}
```

5.8. Serialization

Serialization is the process of transforming an EMF model into its textual representation. Thereby, serialization complements parsing and lexing.

In Xtext, the process of serialization is split into three steps:

1. Matching the model elements with the grammar rules and creating a stream of tokens. This is done by the parse tree constructor.
2. Mixing existing hidden tokens (whitespace, comments, etc.) into the token stream. This is done by the hidden token merger.
3. Adding needed whitespace or replacing all whitespace using a formatter.

Serialization is invoked when calling XtextResource `.save(...)`. Furthermore, SerializerUtil provides resource-independent support for serialization.

5.8.1. The Contract

The contract of serialization says that a model that is serialized to its textual representation and then loaded (parsed) again should yield a loaded model that equals the original model. Please be aware that this does *not* imply, that loading a textual representation and serializing it back produces identical textual representations. For example, this is the case when a default value is used in a textual representation and the assignment is optional. Another example is:

```
MyRule:
  (xval+=ID | yval+=INT)*;
```

`MyRule` in this example reads `ID`- and `INT`-elements which may occur in an arbitrary order in the textual representation. However, when serializing the model all `ID`-elements will be written first and then all `INT`-elements. If the order is important it can be preserved by storing all elements in the same list – which may require wrapping the `ID`- and `INT`-elements into objects.

5.8.2. Parse Tree Constructor

The parse tree constructor usually does not need to be customized since it is automatically derived from the Xtext Grammar. However, it can be a good idea to look into it to understand its error messages and its runtime performance.

For serialization to succeed, the parse tree constructor must be able to *consume* every element of the to-be-serialized EMF model. To *consume* means, in this context, to write the element to the textual representation of the model. This can turn out to be a not-so-easy to fulfill requirement, since a grammar usually introduces implicit constraints to the EMF model. Example:

```
MyRule:
  (sval+=ID ival+=INT)*;
```

This example introduces the constraint `sval.size() == ival.size()`. Models which violate this constraint are sort of valid EMF models, but they can not be serialized. To check whether a model complies with all constraints introduced by the grammar, the only way is currently to invoke the parse tree constructor. If this changes at some day, there will be news in bugzilla 239565.

For the parse tree constructor, this can lead to the scenarios, where

- a model element can not be consumed. This can have the following reasons/solutions:
  - The model element should not be stored in the model.

  - The grammar needs an assignment which would consume the model element.
  - The [transient value service] could be used to indicate that this model element should not be consumed.
- an assignment in the grammar has no corresponding model element. The parse tree constructor considers a model element not to be present if it is *unset* or equals its default value. However, the parse tree constructor may serialize default values if this is required by a grammar constraint to be able to serialize another model element. The following solution may help to solve such a scenario:
  - A model element should be added to the model.
  - The assignment in the grammar should be made optional.

To understand error messages and performance issues of the parse tree constructor it is important to know that it implements a backtracking algorithm. This basically means that the grammar is used to specify the structure of a tree in which one path (from the root node to a leaf node) is a valid serialization of a specific model. The parse tree constructor's task is to find this path – with the condition, that all model elements are consumed while walking this path. The parse tree constructor's strategy is to take the most promising branch first (the one that would consume the most model elements). If the branch leads to a dead end (for example, if a model element needs to be consumed that is not present in the model), the parse tree constructor goes back the path until a different branch can be taken. This behavior has two consequences:

- In case of an error, the parse tree constructor has found only dead ends but no leaf. It cannot tell which dead end is actually erroneous. Therefore, the error message lists dead ends of the longest paths, a fragment of their serialization and the reason why the path could not be continued at this point. The developer has to judge on his own which reason is the actual error.
- For reasons of performance, it is critical that the parse tree constructor takes the most promising branch first and detects wrong branches early. One way to achieve this is to avoid having many rules which return the same type and which are called from within the same alternative in the grammar.

5.8.3. Transient Values

Transient values are values or model elements which are not persisted (written to the textual representation in the serialization phase). If a model contains model elements which can not be serialized with the current grammar, it is critical to mark them transient using the [ITransientValueService], or serialization will fail. The default implementation marks all model elements transient, that are *unset* or equal to their default value.

5.8.4. Unassigned Text

Unassigned text can be necessary due to data type rule calls or terminal rule calls which do not reside within an assignment. Example:

```
PluralRule:
  'contents:' count=INT Plural;

terminal Plural:
  'item' | 'items';
```

Valid models for this example are `contents 1 item` or `contents 5 items`. However, it is not stored in the semantic model whether the keyword `item` or `items` has been parsed. This is due to the fact that the rule call `Plural` is unassigned. However, the [parse tree constructor] needs to decide which value to write during serialization. This decision can be be made by implementing the [IUnassignedTextSerializer].

5.8.5. Cross Reference Serializer

The cross reference serializer specifies which values are to be written to the textual representation for cross references. This behavior can be customized by implementing [ICrossReferenceSerializer]. The default implementation delegates to [ILinkingService], which may be the better place for customization.

5.8.6. Hidden Token Merger

After the [parse tree constructor] has done its job to create a stream of tokens which are to be written to the textual representation, the hidden token merger ([IHiddenTokenMerger]) mixes existing hidden tokens into this token stream. The default implementation uses the hidden tokens (whitespace, line breaks, comments) from the node model. The IHiddenTokenMerger is the factory for a token stream which is fed by the parse tree constructor and which writes to another token stream.

5.8.7. Token Stream

The parse tree constructor, the hidden token merger and the formatter use an ITokenStream for their output, and the latter two for their input as well. This makes them chainable. Token streams can be converted to a `String` using the TokenStringBuffer and to an `OutputStream` using the TokenOutputStream. Maybe there will be an implementation to reconstruct a node model as well at some point in the future. While providing fast output due to the stream pattern, token streams allow easy manipulation of the stream, such as mixing in whitespace or manipulating them.

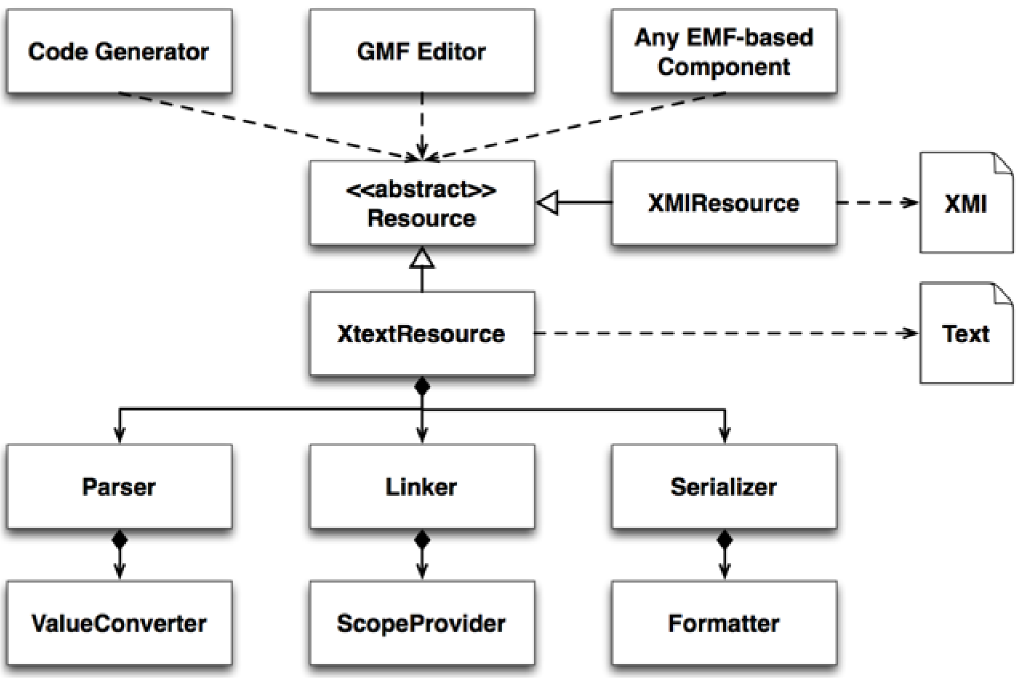
```
public interface ITokenStream {
  public void close() throws IOException;
  public void writeHidden(
    EObject grammarElement, String value) throws IOException;
  public void writeSemantic(
    EObject grammarElement, String value) throws IOException;
}
```

5.9. Integration with EMF

Xtext relies heavily on EMF internally, but it can also be used as the serialization back-end of other EMF-based tools.

5.9.1. XtextResource Implementation

Xtext provides an implementation of EMF's resource, the XtextResource. This does not only encapsulate the parser that converts text to an EMF model but also the serializer working the opposite direction. That way, an Xtext model just looks like any other Ecore-based model from the outside, making it amenable for the use by other EMF based tools. In fact, the Xpand templates in the generator plug-in created by the Xtext wizard do not make any assumption on the fact that the model is described in Xtext, and they would work fine with any model based on the same Ecore model of the language. So in the ideal case, you can switch the serialization format of your models to your self-defined DSL by just replacing the resource implementation used by your other modeling tools.



The generator fragment ResourceFactoryFragment registers a factory for the XtextResource to EMF's resource factory registry, such that all tools using the default mechanism to resolve a resource implementation will automatically get that resource implementation.

Using a self-defined textual syntax as the primary storage format has a number of advantages over the default XMI serialization, e.g.

- You can use well-known and easy-to-use tools and techniques for manipulation, such as text editors, regular expressions, or stream editors.
- You can use the same tools for version control as you use for source code. Merging and diffing is performed in a syntax the developer is familiar with.
- It is impossible to break the model such that it cannot be reopened in the editor again.
- Models can be fixed using the same tools, even if they have become incompatible with a new version of the Ecore model.

Xtext targets easy to use and naturally feeling languages. It focuses on the lexical aspects of a language a bit more than on the semantic ones. As a consequence, a referenced Ecore model can contain more concepts than are actually covered by the Xtext grammar. As a result, not everything that is possibly expressed in the EMF model can be serialized back into a textual representation with regards to the grammar. So if you want to use Xtext to serialize your models as described above, it is good to have a couple of things in mind:

- Prefer optional rule calls (cardinality `?` or `*`) to mandatory ones (cardinality `+` or default), such that missing references will not obstruct serialization.
- You should not use an Xtext-Editor on the same model instance as a self-synchronizing other editor, e.g. a canonical GMF editor (see :#gmf_integration_stage_1 for details). The Xtext parser replaces re-parsed subtrees of the AST rather than modifying it, so elements will become stale. As the Xtext editor continuously re-parses the model on changes, this will happen rather often. It is safer to synchronize editors more loosely, e.g. on file changes.
- Implement an `IFragmentProvider`:#fragmentProvider to make the XtextResource return stable fragments for its contained elements, e.g. based on composite names rather than order of appearance.
- Implement an `IQualifiedNameProvider` and an `IScopeProvider`:#scoping to make the names of all linkable elements in cross-references unique.
- Provide an `IFormatter`:#formatting to improve the readability of the generated textual models.
- Register an `IReferableElementsUnloader` to turn deleted/replaced model elements into EMF proxies. Design the rest of your application such that it does never keep references to `EObjects` or to cope with proxies. That will improve the stability of your application drastically.
- Xtext will register an EMF `ResourceFatory`, so resources with the file extension you entered when generating the Xtext plug-ins will be automatically loaded in an `XtextResource` when you use EMF's `ResourceSet` API to load it.

5.9.2. Integration with GMF

To illustrate how to build a graphical editor on top of an `XtextResource` we have provided an example. It consists of a number of plug-ins

Plug-in	Framework	Purpose	Contents
org.eclipse.xtext.example.gmf	Xtext	Xtext runtime plug-in	Grammar, derived metamodel and language infrastructure
org.eclipse.xtext.example.gmf.ui	Xtext	Xtext UI plug-in	Xtext editor and services
org.eclipse.xtext.example.gmf.edit	EMF	EMF.edit plug-in	UI services generated from the metamodel
org.eclipse.xtext.example.gmf.models	GMF	GMF design models	Input for the GMF code generator

org.eclipse.xtext.example.gmf.diagram	GMF	GMF diagram editor	Purely generated from the GMF design models
org.eclipse.xtext.example.gmf.diagram.extensions	GMF / Xtext	Manual extensions to the generated GMF editor for integration with Xtext	
org.eclipse.xtext.gmf.glue	Xtext/GMF	Glue code	Generic code to integrate Xtext and GMF

5.9.2.1. Stage 1: Make GMF read and write the semantic model as text

A diagram editor in GMF by default manages two resources: One for the semantic model, that is the model we're actually interested in for further processing. In our example it is a model representing entities and datatypes. The second resource holds the notation model. It represents the shapes you see in the diagram and their graphical properties. Notation elements reference their semantic counterparts. An entity's name would be in the semantic model, while the font to draw it in the diagram would be stored the notation model. Note that in the integration example we're only trying to represent the semantic resource as text.

To keep the semantic model and the diagram model in sync, GMF uses a so called `CanonicalEditPolicy`. This component registers as a listener to the semantic model and automatically updates diagram elements when their semantic counterparts change, are added or are removed. Some notational information can be derived from the semantic model by some default mapping, but usually there is a lot of graphical stuff that the user wants to change to make the diagram look better.

In an Xtext editor, changes in the text are transfered to the underlying `XtextResource` by a call to the method `org.eclipse.xtext.resource.XtextResource.update(int, int, String)`, which will trigger a partial parsing of the dirty text region and a replacement of the corresponding subtree in the AST model (semantic model).

Having an Xtext editor and a canonical GMF editor on the same resource can therefore lead to loss of notational information, as a change in the Xtext editor will remove a subtree in the AST, causing the `CanonicalEditPolicy` to remove all notational elements, even though it was customized by the user. The Xtext rebuilds the AST and the notation model is restored using the default mapping. It is therefore not recommended to let an Xtext editor and a canonical GMF editor work on the same resource.

In this example, we let each editor use its own memory instance of the model and synchronize on file changes only. Both frameworks already synchronize with external changes to the edited files out-of-the-box. In the glue code, a `org.eclipse.xtext.gmf.glue.concurrency.ConcurrentModificationObserver` warns the user if she tries to edit the same file with two different model editors concurrently.

In the example, we started with writing an Xtext grammar for an entity language. As explained above, we preferred optional assignments and rather covered mandatory attributes in a validator. Into the bargain, we added some services to improve the EMF integration, namely a formatter, a fragment provider and an unloader. Then we let Xtext generate the language infrastructure. From the derived Ecore model and its generator model, we generated the edit plug-in (needed by GMF) and added some fancier icons.

From the GMF side, we followed the default procedure and created a gmfgraph model, a gmftool model and a gmfmap model referring to the Ecore model derived form the Xtext grammar. We changed some settings in the gmfgen model derived by GMF from the gmfmap model, namely to enable printing and to enable validation and validation decorators. Then we generated the diagram editor.

Voilà, we now have a diagram editor that reads/writes its semantic model as text. Also note that the validator from Xtext is already integrated in the diagram editor via the menu bar.

5.9.2.2. Stage 2: Calling the Xtext parser to parse GMF labels

GMF's generated parser for the labels is a bit poor: It will work on attributes only, and will fail for cross-references, e.g. an attibute's type. So why not use the Xtext parser to process the user's input?

An `XtextResource` keeps track of it's concrete syntax representation by means of a so called node model (see :#parser_rules for a more detailed description). The node model represents the parse tree and provides information on the offset, length and text that has been parsed to create a semantic model element. The nodes are attached to their semantic elements by means of a node adapter.

We can use the node adapter to access the text block that represents an attribute, and call the Xtext parser to parse the user input. The example code is contained in `org.eclipse.xtext.gmf.glue.edit.part.AntlrParserWrapper`. `org.eclipse.xtext.example.gmf.diagram.edit.part.SimplePropertyWrapperEditPartOver` shows how this is integrated into the generated GMF editor. Use the `EntitiesEditPartFactoryOverride` to instantiate it and the `EntitiesEditPartProviderOverride` to create the overridden factory, and register the latter to the extension point. Note that this is a non-invasive way to extend generated GMF editors.

When you test the editor, you will note that the node model will be corrupt after editing a few labels. This is because the node model is only updated by the Xtext parser and not by the serializer. So we need a way to automatically call the (partial) parser every time the semantic model is changed. You will find the required classes in the package ${org.eclipse.xtext.gmf.glue/src/org.eclipse.xtext.gmf.glue.editingdomain}. To activate node model reconciling, you have to add a line

```
org.eclipse.xtext.gmf.glue.editingdomain.XtextNodeModelReconciler.adapt(editingDomain);
```

in the method `createEditingDomain()` of the generated `EntitiesDocumentProvider`. To avoid changing the generated code, you can modify the code generation template for that class by setting

```
Dynamic Templates -> true
    Template Directory -> "org.eclipse.xtext.example.gmf.models/templates"
```

in the `GenEditorGenerator` and

```
Required Plugins -> "org.eclipse.xtext.gmf.glue"
```

in the `GenPlugin` element of the gmfgen before generating the diagram editor anew.

5.9.2.3. Stage 3: A Popup Xtext Editor (experimental)

`SimplePropertyPopupXtextEditorEditPartOverride` demonstrates how to spawn an Xtext editor to edit a model element. The editor pops up in its control and shows only the section of the selected element. It is a fully fledged Xtext editor, with support of validation, code assist and syntax highlighting. The edited text is only transfered back to the model if it does not have any errors.

Note that there still are synchronization issues, that’s why we keep this one marked as experimental.

5.9.3. Fragment Provider (referencing Xtext models from other EMF artifacts)

Although inter-Xtext linking is not done by URIs, you may want to be able to reference your `EObject` from non-Xtext models. In those cases URIs are used, which are made up of a part identifying the resource. Each `EObject` contained in a resource can be identified by a so called *fragment*.

A fragment is a part of an EMF URI and needs to be unique per resource.

The generic XMI resource shipped with EMF provides a generic path-like computation of fragments. With an XMI or other binary-like serialization it is also common and possible to use UUIDs.

However with a textual concrete syntax we want to be able to compute fragments out of the given information. We don’t want to force people to use UUIDs (i.e. synthetic identifiers) or relative generic paths (very fragile), in order to refer to `EObjects`.

Therefore one can contribute a so called `IFragmentProvider` per language.

```
public interface IFragmentProvider extends ILanguageService {

  /**
   * Computes the local ID of the given object.
   * @param obj
   *            The EObject to compute the fragment for
   * @return the fragment, which can be an arbitrary string but must be
   *         unique within a resource. Return null to use default
   *         implementation
   */
  String getFragment(EObject obj);

  /**
   * Locates an EObject in a resource by its fragment.
   * @return the EObject
   */
  EObject getEObject(Resource resource, String fragment);
}
```

Note that the currently available default fragment provider does nothing (i.e. falls back to the default behavior of EMF).

5.10. Encoding in Xtext

Encoding, AKA *character set*, describes the way characters are encoded into bytes and vice versa. Famous standard encodings are “UTF-8” or “ISO-8859-1”. The list of available encodings can be determined by calling `java.nio.Charset.availableCharsets()`. There is also a list of encodings and their canonical Java names in the API docs.

Unfortunately, each platform and/or spoken language tends to define its own native encoding, e.g. `Cp1258` on Windows in Vietnamese or `MacIceland` on Mac OS X in Icelandic.

In an Eclipse workspace, files, folders, projects can have individual encodings, which are stored in the file `.settings/org.eclipse.core.resources.prefs` in each project. If a resource does not have an explicit encoding, it inherits the one from its parent recursively. Eclipse chooses the native platform encoding as the default for the workspace root. You can change the default workspace encoding in the Eclipse preferences *Preferences->Workspace->Default text encoding*. If you develop on different platforms, you should consider choosing an explicit common encoding for your text or code files, especially if you use special characters.

While Eclipse allows to define and inspect the encoding of a file, your file system usually doesn’t. Given an arbitrary text file there is no general strategy to tell how it was encoded. If you deploy an Eclipse project as a jar (even a plug-in), any encoding information not stored in the file itself is lost, too. Some languages define the encoding of a file explicitly, as in the first processing instruction of an XML file. Most languages don’t. Others imply a fixed encoding or offer enhanced syntax for character literals, e.g. `\uXXXX` in Java.

As Xtext is about textual modeling, it allows to tweak the encoding in various places.

5.10.1. Encoding at Language Design Time

The plug-ins created by the *New Xtext Project* wizard are by default encoded in the workspace’s standard encoding. The same holds for all files that Xtext generates in there. If you want to change that, e.g. because your grammar uses/allows special characters, you should manually set the encoding in the properties of these projects after their creation. Do this before adding special characters to your grammar or at least make sure the grammar reads correctly after the encoding change. To tell the Xtext generator to generate files in the same encoding, set the encoding property in the workflow next to your grammar, e.g.

```
Generator {
 encoding ="UTF-8"
 ...
```

5.10.2. Encoding at Language Runtime

As each language could handle the encoding problem differently, Xtext offers a service here. The ${org.eclipse.xtext/src/org/eclipse/xtext/parser/IEncodingProvider} has a single method `getEncoding(URI)` to define the encoding of the resource with the given URI. Users can implement their own strategy but keep in mind that this is not intended to be a long running method. If the encoding is stored within the model file itself, it should be extractable in an easy way, like from then first line in an XML file. The default implementation returns the default Java character set in the runtime scenario.

In the UI scenario, when there is a workspace, users will expect the encoding of the model files to be settable the same way as for other files in the workspace. The default implementation of the `IEncodingProvider` in the UI scenario Xtext therefore returns the file's workspace encoding for files in the workspace and delegates to the runtime implementation for all other resources, e.g. models in a jar or from a deployed plug-in. Keep in mind that you are going to loose the workspace encoding information as soon as you leave this workspace, e.g. deploy your project.

Unless you want to enforce a uniform encoding for all models of your language, we advise to override the runtime service only. It is bound in the runtime module using the binding annotation `Runtime`. For the uniform encoding, bind the plain `IEncodingProvider` to the same implementation in both modules.

5.10.3. Encoding of an XtextResource

An ${org.eclipse.xtext/src/org/eclipse/xtext/resource/XtextResource} uses the `IEncodingProvider` of your language by default. You can override that by passing an option on load and save, e.g.

```
Map<?,?> options = new HashMap();
options.put(XtextResource.OPTION_ENCODING, "UTF-8");
myXtextResource.load(options);
options.put(XtextResource.OPTION_ENCODING, "ISO-8859-1");
myXtextResource.save(options);
```

5.10.4. Encoding in New Model Projects

The ${org.eclipse.xtext.generator/src/org/eclipse/xtext/ui/generator/projectWizard/SimpleProjectWizardFragment} generates a wizard that clients of your language can use to create model projects. This wizard expects its templates to be in the encoding of the Generator that created it (see above). As every new project wizard, its output will be encoded in the default encoding of the target workspace.

5.10.5. Encoding of Xtext source code

The source code of the Xtext framework itself is completely encoded in “ISO 8859-1”, which is necessary to make the Xpand templates work everywhere (they use french quotation markup). That encoding is hard coded into the Xtext generator code. You are likely never going to change that.

Chapter 6. MWE2

The Modeling Workflow Engine 2 (MWE2) is a rewritten backwards compatible implementation of the Modeling Workflow Engine (MWE). It is a declarative, externally configurable generator engine. Users can describe arbitrary objects compositions by means of a simple, concise syntax that allows to declare object instances, attribute values and references. One use case – that's where the name had its origins – is the definition of workflows. Such a workflow consists usually of a number of components that interact with each other. There are components available, that read EMF resources, perform operations (transformations) on them and write them back or generate any number of other artifacts out of the information. Workflows are typically executed in a single JVM. However there are no constraints the prevent implementors to provide components that spawn multiple threads or new processes.

6.1. Examples

Let's start with a couple of examples to demonstrate some usage scenarios for MWE2. The first examples is a simple `HelloWorld` module that does nothing but print a message to standard out. The second module is assembled of three components that read an ecore file, transform the contained classifier-names to upper-case and serialize the resource back to a new file. The last examples uses the life-cycle methods to print the execution time of the workflow.

6.1.1. The simplest Workflow

The arguably shortest MWE2 module may look like the following snippet.

```
module HelloWorld

SayHello {
  message = "Hello World!"
}
```

It configures a very simple workflow component with a message that should be printed to `System.out` when the workflow is executed. The module begins with a declaration of its name. It must fulfill the Java conventions for fully qualified class-names. That's why the module `HelloWorld` has to be placed into the default package of a Java source folder. The second element in the module is the class-name `SayHello` which introduces the root element of the module. The interpreter will create an instance of the referenced type and configure it as declared between the curly braces. E.g. the assignment `message = "Hello World!"` in the module will be interpreted as an invocation of the `setMessage(String)` on the instantiated object. As one can easily imagine, the implementation of the class `SayHello` looks straight forward:

```
import org.eclipse.emf.mwe2.runtime.workflow.IWorkflowComponent;
import org.eclipse.emf.mwe2.runtime.workflow.IWorkflowContext;

public class SayHello implements IWorkflowComponent {

  private String message = "Hello World!";
  public void setMessage(String message) {
    this.message = message;
  }
  public String getMessage() {
    return message;
  }

  public void invoke(IWorkflowContext ctx) {
    System.out.println(getMessage());
  }

  public void postInvoke() {}
  public void preInvoke() {}
}
```

It looks like a simple POJO and that's the philosophy behind MWE2. It is easily possible to assemble completely independent objects in a declarative manner. To make the workflow executable with the `WorkflowRunner`, the component `SayHello` must be nested in a root workflow:

```
module HelloWorld

Workflow {
 component = SayHello {
  message = "Hello World!"
 }
}
```

The class `Workflow` is actually `org.eclipse.emf.mwe2.runtime.workflow.Workflow` but its package is implicitly imported in MWE2 modules to make the the modules more concise. The execution result of this workflow will be revealed after a quick `Run As .. -> MWE2 Workflow` in the console as

```
Hello World!
```

6.1.2. A simple Transformation

6.1.3. A Stop-watch

6.2. Language Reference

MWE2 has a few well defined concepts which can be combined to assemble arbitrary object graphs in a compact and declarative manner.

- A MWE2 file defines a *module* which exposes its root *component* as reusable artifact.
- *Properties* can be used to extract reusable, configurable parts of the workflow.
- Components are mapped to plain vanilla *Java objects*. Arbitrary *set- and add-methods* are used to configure them.

Let’s consider the follow short example module and `SampleClass` to explain these concepts.

```
module com.mycompany.Example

import java.util.*

SampleClass {
  singleValue = 'a string'
  multiValue = ArrayList {}
  child = {}
}
```

```
package com.mycompany;

import java.util.List;

public class SampleClass {
  public void setSingleValue(String value) {..}
  public void addMultiValue(List<?> value) {..}
  public void addChild(SampleClass value) {..}
}
```

6.2.1. Mapping to Java Classes

The module `com.mycompany.Example` defines a root component of type `com.mycompany.SampleClass`. It is possible to use the simple class-name because MWE2 uses the very same visibility rules as the Java compiler. Classes that are in the same package as the module can be referenced by their simple name. The same rule applies for classes from the `java.lang` package. For convenience reasons is the package `org.eclipse.emf.mwe2.runtime.workflow` implicitly imported as well as it exposes some library workflow components. However, the imports are more flexible since MWE2-imports can be relative, e.g. the `import java.*` resolves the reference `util.ArrayList` to `java.util.ArrayList`.

The root instance of type `SampleClass` has to be configured after it has been created. Therefore the method `setSingleValue` will be called at first. The parameter given parameter is `'a string'`.

The method is identified by its name which starts with `set`. To allow to assign multi-value properties, MWE provides access to methods call `add*` as well.

If the right side of the assignment in the workflow file does not define an explicit class, its type is inferred from the method parameter. The line `child = {}` is equivalent to `child = SampleClass {}` and creates a new instance of `SampleClass`.

MWE2 ships with a nice tool support. The editor will provide content assist for the allowed types and highlight incompatible assignments. The available properties for Java classes will be proposed as well.

6.2.2. Module

As MWE2 modules have a fully qualified name, it is possible to refer to them from other modules. The type of the module is derived from the type of its root component. The `com.mycompany.Example` can be assigned at any place where a `com.mycompany.SampleClass` is expected.

Let's create a second module `com.mycompany.Second` like this:

```
module com.mycompany.sub.Second

import com.mycompany.*

SampleClass {
  child = @Example {}
}
```

The `child` value will be assigned to an instance of `SampleClass` that is configured as in the first example workflow. This enables nice composition and a very focused, reusable component design.

As the same rules apply in MWE2 like in Java, the module `com.mycompany.sub.Second` has to be defined in a file called `Second.mwe2` in the package `com.mycompany.sub`. The import semantic for other modules is the same as for classes. The import statement allows to refer to `com.mycompany.Example` with a shortened name.

6.2.3. Properties

MWE2 allows to extract arbitrary information into properties to ensure that these pieces are not cluttered around the workflow and to allow for easier external customization. The exemplary component definition was only changed slightly by introducing a property `value`.

```
module com.mycompany.Example

var value = 'a string'

SampleClass {
  singleValue = value
}
```

The type of the property will be derived from the default value similar to the mechanism that is already known from `set`- and `add`-methods. If no default value is given, `java.lang.String` will be assumed. However, properties are not limited to strings. The second built in type is boolean via the familiar literals `true` and `false`. More flexibility is available via actual component literals.

```
module com.mycompany.Example

var childInstance = SampleClass {
                      singleValue = "child"
                    }

SampleClass {
  child = childInstance
}
```

If one wants to define string properties that are actual reusable parts for other properties, she may use defined variables inside other literals like this:

```
var aString = "part"
var anotherString = "reuse the ${part} here"
```

This is especially useful for file paths in workflows as one would usually want to define some common root directories only ones in the workflow and reuse this fragment across certain other file locations.

6.2.4. Mandatory Properties

It is not always feasible to define default values for properties. That is where mandatory properties come into play. Modules define their interface not only via their fully qualified name and the type of the root component but also by means of the defined properties.

```
module com.mycompany.Example

var optional = 'a string'
var mandatory

SampleClass {
  singleValue = optional
  child = {
    singleValue = mandatory
  }
}
```

This version of the example module exposes two externally assignable properties. The second one has no default value assigned and is thereby considered to be mandatory. The mandatory value must be assigned if we reuse `org.mycompany.Example` in another module like this:

```
module com.mycompany.Second

var newMandatory

@Example {
  mandatory = "mandatoryValue"
  optional = newMandatory
}
```

Note that it is even possible to reuse another module as the root component of a new module. In this case we set the mandatory property of `Example` to a specific constant value while the previously optional value is now redefined as mandatory by means of a new property without a default value.

It is not only possible to define mandatory properties for MWE2 modules but for classes as well. Therefore MWE2 ships with the `Mandatory` annotation. If a `set`- or `add`-method is marked as `mandatory`, the module validation will fail if no value was assigned to that feature.

6.2.5. Named Components

Properties are not the only way to define something that can be reused. It is possible to assign a name to any instantiated component being it created from a class literal or from another component. This allows to refer to previously created and configured instances. Named instances can come handy for notification and call-back mechanisms or more general in terms of defined life-cylce events.

If we wanted to assign the created instance to a property of itself, we could use the following syntax:

```
module com.mycompany.Example

SampleClass : self {
  child = self
}
```

A named component can be referenced immediately after its creation but it is not possible to define forward references in a MWE2 file.

6.2.6. Auto Injection

Existing modules or classes often expose a set of properties that will be assigned to features of its root component or set- and add- methods respectively. In many cases its quite hard to come up with yet another name for the very same concept which leads to the situation where the properties itself have the very same name as the component's feature. To avoid the overall repetition of assignments, MWE2 offers the possibility to use the `auto-inject` modifier on the component literal:

```
module com.mycompany.Example

var child = SampleClass {}

SampleClass auto-inject {
}
```

This example will implicitly assign the value of the property `child` to the feature `child` of the root component. This is especially useful for highly configurable workflows that expose dozens of optional parameters each of which can be assigned to one or more components.

The `auto-inject` modifier can be used for a subset of the available features as well. It will suppressed for the explicitly set values of a component.

6.2.7. Factory Support

6.3. Syntax Reference

The following chapter serves as a reference for the concrete syntax of MWE2. The building blocks of a module will be described in a few words.

MWE2 is not sensitive to white-space and allows to define line-comments and block comments everywhere. The syntax is the same as one is used to from the Java language:

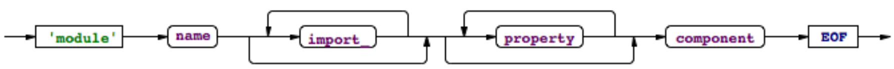
```
// This is a comment
/*
  This is another one.
*/
```

Every name in MWE2 can be a fully qualified identifier and must follow the Java conventions. However, in contrast to Java identifiers it is not allowed to use German umlauts or Unicode escape sequences in identifiers. A valid id-segment in MWE2 starts with a letter or an underscore and is followed by any number of letters, numbers or underscores. An identifier is composed from one or more segments which are delimited by a '.' dot.

```
Name: ID ('.' ID)*;
ID: ('a'..'z'|'A'..'Z'|'_') ('a'..'z'|'A'..'Z'|'_'|'0'..'9')*;
```

MWE2 does not use a semicolon as statement delimiter at any place.

6.3.1. Module



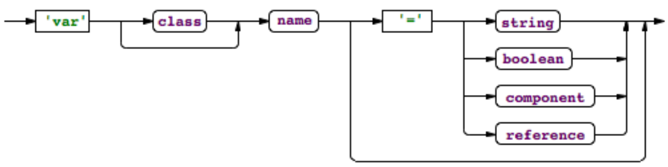
A `module` consists of four parts. The very first statement in a `*.mwe2` file is the module declaration. The name of the module must follow the naming convention for Java classes. That MWE2 file's name must therefore be the same as the last segment of the module-name and it has to be placed in the appropriate package of a Java source path.

It is allowed to define any number of import statements in a module. Imports are either suffixed by a wild-card or concrete for a class or module. MWE2 can handle relative imports in case one uses the wild-card notation:

```
'import' name '.*'?
```

6.3.2. Property

The list of declared properties follows the optional import section. It is allowed to define modules without any properties.

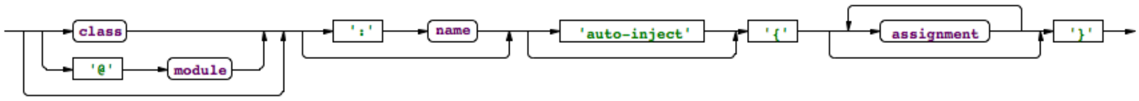


Each declared property is locally visible in the module. It furthermore defines an assignable feature of the module in case one refers to it from another module. Properties may either have a default value or they are considered to be mandatory. If the type of property is omitted it will be inferred from the default value. The default type of a property is `java.lang.String` so if no default value is available, the property is mandatory and of type `String`.

There are four types of values available in MWE2. One may either define a string, boolean or component literal or a reference to a previously defined property.

6.3.3. Component

The last part of a module is the root component. It defines the externally visible type of the module and may either be created from a Java type or from another module.

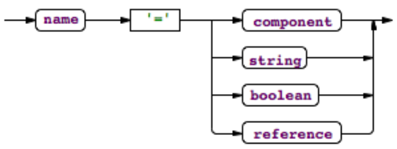


The type of the component can be derived in many cases except for the root component. That's why it's optional in the component literal. If no type is given, it will be inferred from the left side of the assignment. The assigned feature can either be a declared property of the module or a `set`- or `add`-method of a Java class.

Components can be named to make them referable in subsequent assignments. Following the ':' keyword, one can define an identifier for the instantiated component. The identifier is locally visible in the module and any assignment that is defined after the named component can refer to this identifier and thereby point to exactly the instantiated object.

The next option for a component is `auto-inject`. If this modifier is set on a component, any available feature of the component that has the same name as a property or previously created named component will be automatically assigned.

The core of a component is the list of assignments between the curly braces. An arbitrary number of values can be set on the component by means of feature-to-value pairs.



The available constructs on the right hand side of the assignment are the same as for default values for properties.

6.3.4. String Literals

String values are likely to be the most used literals in MWE2. There is a convenient syntax for string concatenation available due to the high relevance in a description object composition and configuration language. MWE2 strings are multi-line strings and can be composed of several parts.

```
var aString = 'a value'
var anotherString = 'It is possible to embed ${aString} into
 a multi-line string'
```

This is especially convenient for path-substitution if one defines e.g. a common root directory and wants to specify other paths relative to the base.

There are two different delimiters available for strings. Users are free to either use single- or double-quotes to start and end strings. If a certain string contains a lot of single-quotes one would better choose double-quotes as delimiter and vice versa. There is no semantic difference between both notations.

The escape character in MWE2 is the back-slash `"\"`. It can be used to write line-breaks or tabular characters explicitly and to escape the beginning of substitution variables `${` and the quotes itself. Allowed escape sequences are:

```
\n  .. line break
\r  .. carriage return
\t  .. tabular character
\'  .. single-quote (can be omitted in double-quoted strings)
\"  .. double-quote (can be omitted in single-quoted strings)
\${ .. escape the substitution variable start ${
\\  .. the back-slash itself
```

Other escape sequence are illegal in MWE2 strings.

6.3.5. Boolean Literals

MWE2 has native support for the boolean type. The literals are `true` and `false`.

6.3.6. References

Each assigned value in MWE2 either as default for properties or in a component assignment can be a reference to a previously declared property or named component. The can be referenced intuitively by their name.

6.4. Workflow API

6.5. Workflow SPI

Chapter 7. IDE concepts

For the following part we will refer to a concrete example grammar in order to explain certain aspect of the UI more clearly. The used example grammar is as follows:

```
grammar org.eclipse.text.documentation.Sample
    with org.eclipse.xtext.common.Terminals

generate gen 'http://www.eclipse.org/xtext/documentation/Sample' as gen

Model :
  "model" intAttribute=INT (stringDescription=STRING)? "{"
     (rules += AbstractRule)*
  "}"
;

AbstractRule:
  RuleA | RuleB
;

RuleA :
   "RuleA" "(" name = ID ")" ;

RuleB return gen::CustomType:
   "RuleB" "(" ruleA = [RuleA] ")" ;
```

7.1. Label Provider

A nice part of the Eclipse tooling that comes with Xtext is the outline view. It shows the structure of your model as a tree and allows quick navigation to model elements. Thus it helps to get an overview on the current state in the editor at a glance. To make the appearance of the outline more appealing it is very easy possible to provide customization for the label and the image that is used for an element. Actually this customization will be used at various places in your IDE, for example in the window that displays completion proposals when content assist was invoked. (Customizing the structure of the outline is described in a separate chapter).

The LabelProvider is the service which is used to compute the image for model elements and – as its name suggests – the label that represents an element. What you basically have to do is to provide an implementation for two methods which read `Image getImage(Object)` and `String getText(Object)` respectively. As this tends to be cumbersome due to `instanceof` and cast orgies, Xtext ships with a reasonable and convenient default implementation.

7.1.1. DefaultLabelProvider

The default implementation of the `LabelProvider` interface utilizes the polymorphic dispatcher idiom to implement an external visitor as the requirements of the LabelProvider are kind of a best match for this pattern. It comes down to the fact that the only thing you need to do is to implement a method that matches a specific signature. It either provides a image filename or the text to be used to represent your model element. Have a look at following example to get a more detailed idea about the `DefaultLabelProvider`.

```
public class SampleLabelProvider extends DefaultLabelProvider {

  String text(RuleA rule) {
  return "Rule: " + rule.getName();
 }

 String image(RuleA rule) {
  return "ruleA.gif";
 }

 String image(RuleB rule) {
  return "ruleB.gif";
 }

}
```

The declarative implementation of the label itself is pretty straightforward. The image in turn is expected to be found in a file named `icons/<result of image-method>` in your plugin. This path is actually configurable by google guice. Have a look at the PluginImageHelper to learn about the customizing possibilities.

What is especially nice about the default implementation is the actual reason for its class name: It provides very reasonable defaults. To compute the label for a certain model element, it will at first have a look for an EAttribute that is called `name` and try to use this one. If it cannot find a feature like this, it will try to use the first feature, that can be used best as a label. At worst it will return the class name of the model element, which is kind of unlikely to happen.

More advanced usage patterns of the `DefaultLabelProvider` include a dispatching to an error handler called `String error_text(Object, Exception)` and `String error_image(Object, Exception)` respectively.

7.2. Content Assist

The Xtext generator, amongst other things, generates the following two content assist (CA) related artifacts:

- an abstract proposal provider class named `'Abstract[Language]ProposalProvider'` generated into the `src-gen` folder within the `ui` project
- a concrete descendent in the `src`-folder of the `ui` project `ProposalProvider`

First we will investigate the generated `Abstract[Language]ProposalProvider` with methods that look like this:

7.2.1. ProposalProvider

```
public void complete[TypeName]_[FeatureName](
  EObject model,
  Assignment assignment,
  ContentAssistContext context,
  ICompletionProposalAcceptor acceptor) {
  // clients may override
}

public void complete_[RuleName](
  EObject model,
  RuleCall ruleCall,
  ContentAssistContext context,
  ICompletionProposalAcceptor acceptor) {
  // clients may override
}
```

The snippet above indicates that the generated ProposalProvider class contains a `complete*`-method for each assigned feature in the grammar and for each rule. The brackets are place-holders that should give a clue about the naming scheme used to create the various entry points for clients. The generated proposal provider falls back to some default behavior for cross references. Furthermore it inherits the logic that was introduced in reused grammars.

Clients who want to customize the behavior may override the methods from the `AbstractProposalProvider` or introduce new methods with specialized parameters. The framework dispatches method calls according to the current context to the most concrete implementation, that can be found.

It is important to know, that for a given offset in a model file, many possible grammar elements exist. The framework dispatches to the method declarations for any valid element. That means, that a bunch of '‘complete.*’' methods may be called.

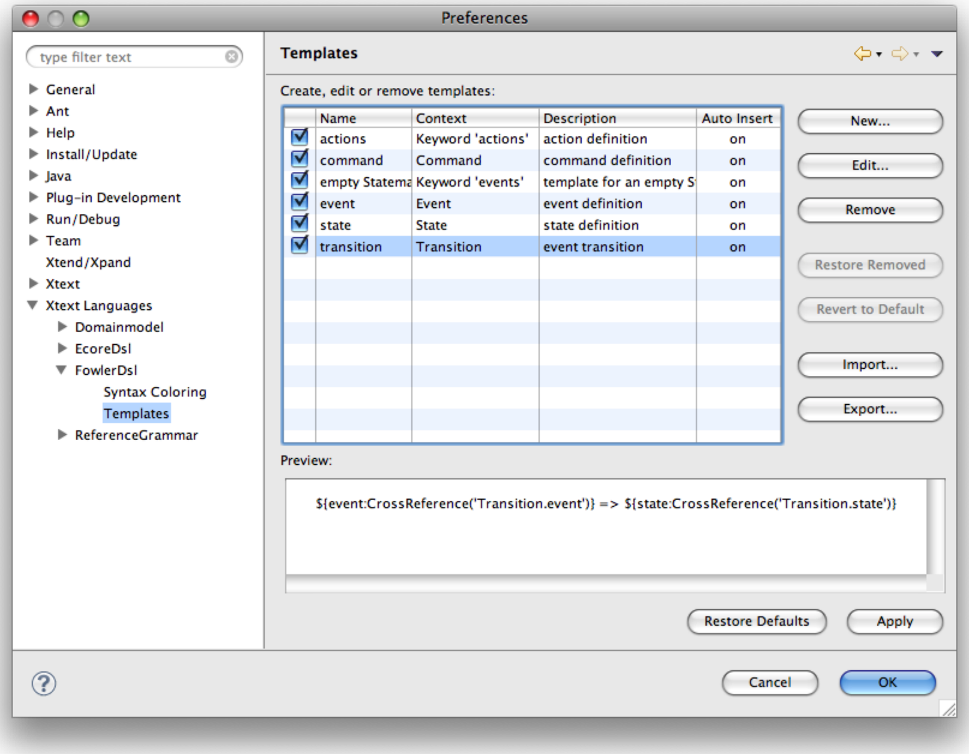
7.2.2. Sample Implementation

To provide a dummy proposal for the description of a model object, you may introduce a specialization of the generated method and implement it as follows. This will give ‘Description for model #7’ for a model with the intAttribute '7'

```
public void completeModel_StringDescription (
  Model model,
  Assignment assignment,
  ContentAssistContext context,
  ICompletionProposalAcceptor acceptor) {
  // call implementation in superclass
  super.completeModel_StringDescription(
    model,
    assignment,
    context,
    acceptor);

  // compute the plain proposal
  String proposal = "Description for model #" + model.getIntAttribute();

  // convert it to a valid STRING-terminal
  proposal = getValueConverter().toString(proposal, "STRING");

  // create the completion proposal
  // the result may be null as the createCompletionProposal(..) methods
  // check for valid prefixes
  // and terminal token conflicts
  ICompletionProposal completionProposal =
    createCompletionProposal(proposal, context);

  // register the proposal, the acceptor handles null-values gracefully
  acceptor.accept(completionProposal);
}
```

7.3. Template Proposals

Xtext-based editors automatically support code templates. That means that you get the corresponding preference page where users can add and change template proposals. If you want to ship a couple of default templates, you have to put a file named `templates.xml` inside the `templates` directory of the generated ui-plugin. This file contains templates in a format as described in the Eclipse online help .



By default Xtext registers ContextTypes for each Rule (`.[RuleName]`) and for each keyword (`.kw_[keyword]`), as long as the keywords are valid identifiers. If you don't like these defaults you'll have to subclass XtextTemplateContextTypeRegistry and configure it via Guice.

In addition to the standard template proposal extension mechanism, Xtext ships with a predefined set of TemplateVariableResolvers to resolve special variable types inside a given template (i.e. TemplateContext). Besides the standard template variables available in `org.eclipse.jface.text.templates.GlobalTemplateVariables` like ${user}, ${date}, ${time}, ${cursor}, etc., these TemplateVariableResolver support the automatic resolving of CrossReferences (type `CrossReferences`) and Enumerations (type `Enum`) like it is explained in the following sections.

It is best practice to edit the templates in the preferences page, export them into the `templates.xml`-file and put this one into the `templates` folder of your ui-plugin. However, these templates will not be visible by default. To fix it, you have to manually edit the xml-file and insert an ID attribute for each template element.

7.3.1. CrossReference TemplateVariableResolver

Xtext comes with a specific template variable resolver `org.eclipse.jface.text.templates.TemplateVariableResolver)` called `CrossReferenceResolver`, which can be used to place cross references within a template.

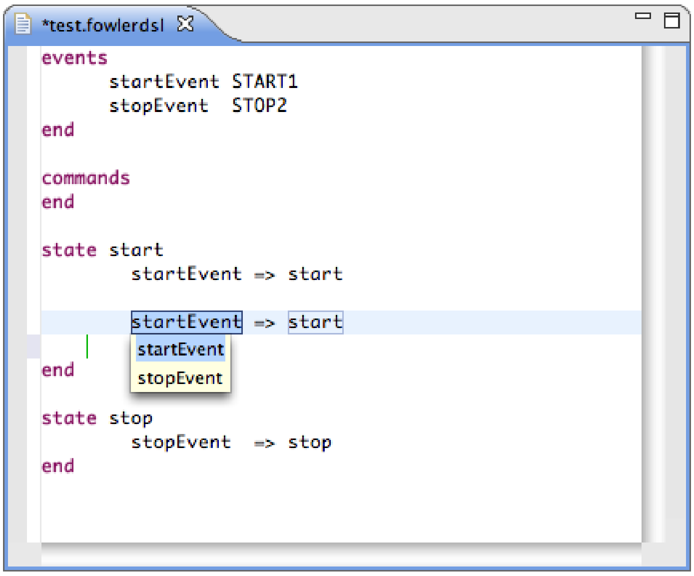
The syntax is as follows:

```
${displayText:CrossReference('MyType.myRef')}
```

For example the following template:

```
<template name="transition" description="event transition" id="transition"
    context="org.eclipse.xtext.example.FowlerDsl.Transition" enabled="true">
    ${event:CrossReference('Transition.event')} =>
     ${state:CrossReference('Transition.state')
</template>
```

yields the text `event => state` and allows selecting any events and states using a drop down.



7.3.2. Enumeration TemplateVariableResolver

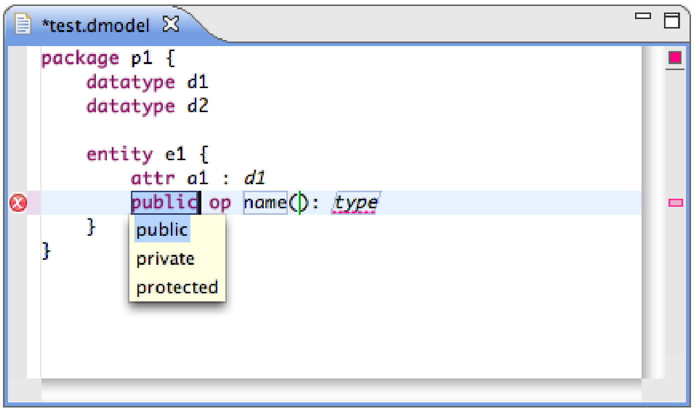
The EnumTemplateVariableResolver resolves a template variable to `EEnumLiteral` literals which are assignment-compatible to the enumeration type declared as the first parameter of the the `Enum TemplateVariable`.
The syntax is as follows:

```
${displayText:Enum('Visibility')
```

For example the following template (taken from the domainmodel example):

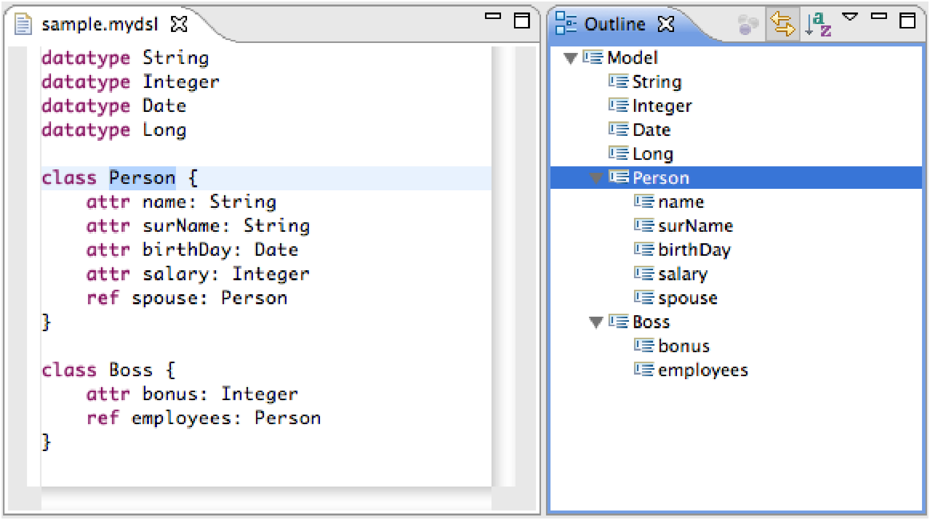
```
<template name="Operation" description="template for an Operation"
        id="org.eclipse.xtext.example.Domainmodel.Operation"
        context="org.eclipse.xtext.example.Domainmodel.Operation"
         enabled="true">
        ${visibility:Enum('Visibility')} op ${name}(${cursor}):
           ${type:CrossReference('Operation.type')}
</template>
```

yields the text `public op name(): type` where the display text ‘public’ is replaced with a drop down filled with the literal values as defined in the Visibility `EENumeration`. Also, ‘name’ and ‘type’ are placeholders.



7.4. Outline View

Xtext provides an outline view to help you navigate your models. By default, it provides a hierarchical view on your model and allows you to sort tree elements alphabetically. Selecting an element in the outline will highlight the corresponding element in the text editor. Users can choose to synchronize the outline with the editor selection by clicking the *Link with Editor* button.



You can customize various aspects of the outline by providing implementation for its various interfaces. The following sections show how to do this.

7.4.1. Influencing the outline structure

In its default implementation, the outline view shows the containment hierarchy of your model. This should be sufficient in most cases. If you want to adjust the structure of the outline, i.e., by omitting a certain kind of node or by introducing additional even virtual nodes, you customize the outline by implementing ISemanticModelTransformer.

The Xtext wizard creates an empty transformer class (`MyDslTransformer`) for your convenience. To transform the semantic model delivered by the Xtext parser, you need to provide transformation methods for each of the EClasses that are of interest:

```
public class MyDslTransformer extends
    AbstractDeclarativeSemanticModelTransformer {
  /**
   * This method will be called by naming convention:
   * - method name must be createNode
   * - first param: subclass of EObject
   * - second param: ContentOutlineNode
   */
  public ContentOutlineNode createNode(
      Attribute semanticNode, ContentOutlineNode parentNode) {
    ContentOutlineNode node = super.newOutlineNode(semanticNode, parentNode);
    node.setLabel("special " + node.getLabel());
    return node;
  }

  public ContentOutlineNode createNode(
      Property semanticNode, ContentOutlineNode parentNode) {
    ContentOutlineNode node = super.newOutlineNode(semanticNode, parentNode);
    node.setLabel("pimped " + node.getLabel());
    return node;
  }

  /**
   * This method will be called by naming convention:
   * - method name must be getChildren
   * - first param: subclass of EObject
   */
  public List<EObject> getChildren(Attribute attribute) {
    return attribute.eContents();
  }

  public List<EObject> getChildren(Property property) {
    return NO_CHILDREN;
  }
}
```

To make sure Xtext picks up your new outline transformer, you have to register your implementation with your UI module:

```
public class MyDslUiModule extends AbstractMyDslUiModule {

  @Override
  public Class<? extends ISemanticModelTransformer>
    bindISemanticModelTransformer() {
    return MyDslTransformer.class;
  }
  ...
}
```

7.4.2. Filtering

Often, you want to allow users to filter the contents of the outline to make it easier to concentrate on the relevant aspects of the model. To add filtering capabilities to your outline, you need to add AbstractFilterActions to the outline. Actions can be contributed by implementing and registering a DeclarativeActionBarContributor.

To register a `DeclarativeActionBarContributor`, add the following lines to your `MyDslUiModule` class:

```
public class MyDslUiModule extends AbstractMyDslUiModule {

  @Override
  public Class<? extends IActionBarContributor> bindIActionBarContributor() {
    return MyDslActionBarContributor.class;
  }
  ...
}
```

The action bar contributor will look like this:

```
public class MyDslActionBarContributor extends
    DeclarativeActionBarContributor {
  public Action addFilterParserRulesToolbarAction(
      XtextContentOutlinePage page) {
    return new FilterFooAction(page);
  }
}
```

Filter actions must extend `AbstractFilterAction` (this ensures that the action toggle state is handled correctly):

```
public class FilterFooAction extends AbstractFilterAction {

  public FilterFooAction(XtextContentOutlinePage outlinePage) {
    super("Filter Foo", outlinePage);
    setToolTipText("Show / hide foo");
    setDescription("Show / hide foo");
    setImageDescriptor(Activator.getImageDescriptor("icons/foo.gif"));
    setDisabledImageDescriptor(
     Activator.getImageDescriptor("icons/foo.gif"));
  }

  @Override
  protected String getToggleId() {
    return "FilterFooAction.isChecked";
  }

  @Override
  protected ViewerFilter createFilter() {
    return new FooOutlineFilter();
  }

}
```

The filtering itself will be performed by `FooOutlineFilter`:

```
public class FooOutlineFilter extends ViewerFilter {

  @Override
  public boolean select(
      Viewer viewer, Object parentElement, Object element) {
    if ((parentElement != null)
        && (parentElement instanceof ContentOutlineNode)) {
      ContentOutlineNode parentNode = (ContentOutlineNode) parentElement;
      EClass clazz = parentNode.getClazz();
      if (clazz.equals(MyDslPackage.Literals.ATTRIBUTE)) {
        return false;
      }
    }
    return true;
  }

}
```

7.4.3. Context menus

You might want to register context menu actions for specific elements in the outline, e.g. to allow users of your DSL to invoke a generator or to validate the selected element. As all elements in the outline are ContentOutlineNodes, you cannot easily register an Object contribution. (Besides, using the extension point `org.eclipse.ui.popupMenus` is regarded somewhat old school – you should rather use the new command and expression framework, as depicted below).

To register context menus for specific node types of your Ecore model, we need to:

- implement IContentOutlineNodeAdapterFactory which will translate ContentOutlineNodes to their underlying node type
- register a menu contribution to add a command / handler pair to the context menu for the specific node types you're interested in.

7.4.3.1. Registering an `IContentOutlineNodeAdapterFactory`

The Xtext code generator creates a subclass of DefaultContentOutlineNodeAdapterFactory. All we need to do is specify a list of types that we later want to bind context menu contributions to.

```
public class MyDslContentOutlineNodeAdapterFactory extends
    DefaultContentOutlineNodeAdapterFactory {
  @SuppressWarnings("unchecked")
  private static final Class[] types = { Attribute.class };

  @SuppressWarnings("unchecked")
  public Class[] getAdapterList() {
    return types;
  }
}
```

If you want to bind context menu actions to nodes representing `Attribute` and `Entity`, you need to change the declaration of `type` as follows:

```
private static final Class[] types = { Attribute.class, Entity.class };
```

7.4.3.2. Registering a menu contribution

You can now add command / handler pairs to the context menu.

First, you need to define a command – it will serve as a handle to glue together the handler and the menu contribution:

```
<extension
  point="org.eclipse.ui.commands">
  <command
    id="org.example.mydsl.ui.editor.outline.SampleOutlineCommand"
    name="Sample Command"
    description="Just a sample command">
  </command>
</extension>
```

Next, you need to define a handler which will eventually execute the code to operate on the selected node. Please pay special attention to the attribute `commandId` - it must match the `id` attribute of your command.

```
<extension
  point="org.eclipse.ui.handlers">
  <handler
    class="org.example.mydsl.ui.editor.outline.SampleOutlineNodeHandler"
    commandId="org.example.mydsl.ui.editor.outline.SampleOutlineCommand">
  </handler>
</extension>
```

Finally, define a `menuContribution` to add the command to the context menu:

```
<extension
  point="org.eclipse.ui.menus">
  <menuContribution
    locationURI="popup:org.eclipse.xtext.ui.common.outline?after=additions">
    <command
      commandId="org.example.mydsl.ui.editor.outline.SampleOutlineCommand"
      label="Sample action registered for Attributes">
      <visibleWhen checkEnabled="false">
        <iterate>
          <adapt type="org.example.mydsl.Attribute" />
        </iterate>
      </visibleWhen>
    </command>
  </menuContribution>
</extension>
```

Again, pay attention to the `commandId` attribute. The connection between your node type(s) and the menu contribution is made by the part `<adapt type="org.example.mydsl.Attribute" />`.

7.5. Hyperlinking

The Xtext editor provides hyperlinking support for any tokens corresponding to cross references in your grammar definition. This means that you can either control-click on any of these tokens or hit F3 while the cursor position is at the token in question and this will take you to the referenced model element. As you'd expect this works for references to elements in the same resource as well as for references to elements in other resources. In the latter case the referenced resource will first be opened using the corresponding editor.

7.5.1. Location Provider

When navigating a hyperlink Xtext will also select the text region corresponding to the referenced model element. Determining this text region is the responsibility of the ILocationInFileProvider. The default implementation (DefaultLocationInFileProvider) implements a best effort strategy which can be summarized as:

1. If the model element's type (i.e. EClass) declares a feature *name* then return the region of the corresponding token(s). As a fallback also check for a feature *id*.
2. If the model element's parse tree contains any top-level tokens corresponding to *ID* rule calls in the grammar then return a region spanning all those tokens.
3. As a last resort return the region corresponding to the first keyword token of the referenced model element.

7.5.1.1. Customized Location Provider

As the default strategy is a best effort it may not always result in the selection you want. If that's the case you can override the `ILocationInFileProvider` binding in the UI module as in the following example:

```
public class MyDslUiModule extends AbstractMyDslUiModule {

  @Override
  public Class<? extends ILocationInFileProvider>
    bindILocationInFileProvider() {
    return MyDslLocationInFileProvider.class;
  }
  ...
}
```

Often the default strategy only needs some guidance (e.g. selecting the text corresponding to another feature than *name*). In that case you can simply subclass `DefaultLocationInFileProvider` and override the methods `getIdentifierFeature` and / or `useKeyword` to guide the first and last steps of the strategy as described above (see XtextLocationInFileProvider for an example).

7.6. Formatting (Pretty Printing)

A formatter can be implemented via the IFormatter service. Technically speaking, a formatter is a Token Stream which inserts/removes/modifies hidden tokens (whitespace, line-breaks, comments).

The formatter is invoked during the serialization phase and when the user triggers formatting in the editor (for example, using the CTRL+SHIFT+F shortcut).

Xtext ships with two formatters:

- The OneWhitespaceFormatter simply writes one whitespace between all tokens.
- The AbstractDeclarativeFormatter allows advanced configuration using a FormattingConfig. Both are explained in the next chapter.

7.6.1. Declarative Formatter

A declarative formatter can be implemented by sub-classing {org.eclipse.xtext/src/org.eclipse.xtext.formatting.impl.AbstractDeclarativeFormatter}, as shown in the following example:

```
public class ExampleFormatter extends AbstractDeclarativeFormatter {

  @Override
  protected void configureFormatting(FormattingConfig c) {
    ExampleLanguageGrammarAccess f = getGrammarAccess();

    c.setAutoLinewrap(120);

    // Line
    c.setLinewrap(2).after(f.getLineAccess().getSemicolonKeyword_1());
    c.setNoSpace().before(f.getLineAccess().getSemicolonKeyword_1());

    // TestIndentation
    c.setIndentation(
      f.getTestIndentationAccess().getLeftCurlyBracketKeyword_1(),
        f.getTestIndentationAccess().getRightCurlyBracketKeyword_3());
    c.setLinewrap().after(
      f.getTestIndentationAccess().getLeftCurlyBracketKeyword_1());
    c.setLinewrap().after(
      f.getTestIndentationAccess().getRightCurlyBracketKeyword_3());

    // Param
    c.setNoLinewrap().around(f.getParamAccess().getColonKeyword_1());
    c.setNoSpace().around(f.getParamAccess().getColonKeyword_1());

    // comments
    c.setNoLinewrap().before(f.getSL_COMMENTRule());
  }
}
```

The formatter has to implement the method `configureFormatting(...)` which is supposed to declaratively set up a FormattingConfig.

The FormattingConfig consist general settings and a set of rules:

7.6.1.1. General FormattingConfig Settings

- `setAutoLinewrap(int)` defines the amount of characters after which a line-break should be dynamically inserted between two tokens. The rule `setNoLinewrap()` can be used to suppress this behavior locally. The default is 80.
- `setIndentationSpace(String)` defines the string which is used for a single degree of indentation. The default is two whitespace.
- `setWhitespaceRule(AbstractRule)` defines the grammar rule which is used to match whitespace. This is needed by the formatter to identify whitespace and to insert whitespace. The default is the rule named `WS`.

- `setIndentation(start, end)` increases the level of indentation when the element `start` is matched and decreases the level when element `end` is matched. The matching of elements happens in the same way as it does for formatting rules.

7.6.1.2. FormattingConfig Rules

Per default, the Declarative Formatter inserts one whitespace between two tokens. Rules can be used to specify a different behavior. They consist of two parts: *When* to apply the rule and *what* to do.

To understand *when* a rule is applied think of a stream of tokens whereas each token is associated with the corresponding grammar element. The rules are matched against these grammar elements. The following matching criteria exist.

- `after(ele)`: The rule is executed after the grammar element `ele` has been matched. For example, if your grammar uses the keyword “;” to end lines, this can instruct the formatter to insert a line-break after the semicolon.
- `before(ele)`: The rule is executed before the matched element. For example, if your grammar contains lists which separate its values with keyword “,”, you can instruct the formatter to suppress the whitespace before the comma.
- `around(ele)`: This is the same as `before(ele)` combined with `after(ele)`.
- `between(ele1, ele2)`: This matches if `ele2` directly follows `ele1`. There may be no other elements in between.
- `bounds(ele1, ele2)`: This is the same as `before(ele1)` combined with `after(ele2)`.
- `range(ele1, ele2)`: The rule is enabled when `ele1` is matched, and disabled when `ele2` is matched. Thereby, the rule is active for the complete region which is surrounded by `ele1` and `ele2`.

The parameter `ele` can be a grammar’s `AbstractElement` or a grammar’s `AbstractRule`. However, only elements which represent a token in the textual representation can be matched. This are:

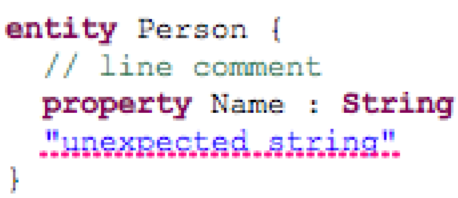
- terminal rules for comments.
- keywords, assignments, call to terminal or data-type rules.

After having explained how rules can be activated, this is what they can do:

- `setLinewrap()`: Inserts a line-break at this position.
- `setLinewrap(int)`: Inserts the specified number of line-breaks at this position.
- `setNoLinewrap()`: Suppresses automatic line wrap, which may occur when the line’s length exceeds the defined limit.
- `setNoSpace()`: Suppresses the whitespace between tokens at this position. Be aware that between some tokens a whitespace is required to maintain a valid concrete syntax.

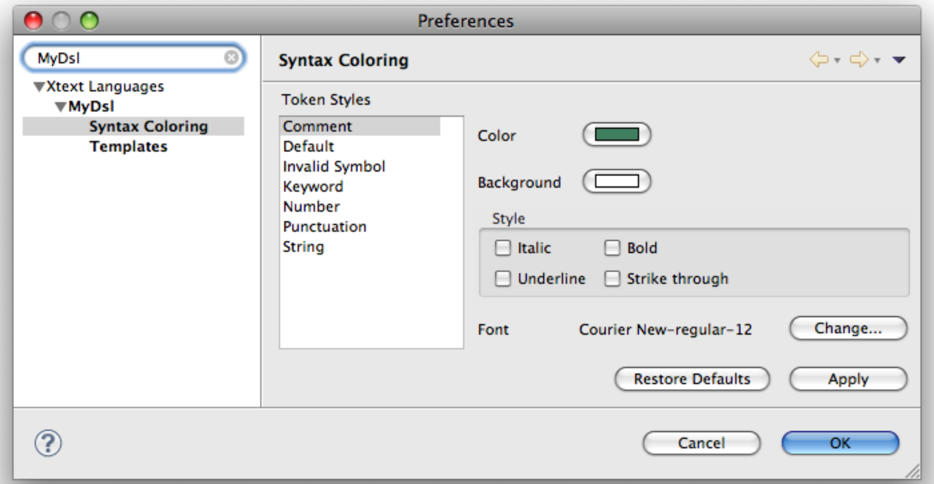
7.7. Syntax Coloring

Besides the already mentioned advanced features like content assist and code formatting the powerful editor for your DSL is capable to mark-up your model-code to improve the overall readability. It is possible to use different colors and fonts according to the meaning of the different parts of your input file. One may want to use some decent colors for large blocks of comment while identifiers, keywords and strings should be colored differently to make it easier to distinguish between them. This kind of text decorating mark-up does not influence the semantics of the various sections but helps to understand the meaning and to find errors in the source code.



The highlighting is done in two stages. This allows for sophisticated algorithms that are executed asynchronously to provide advanced coloring while simple pattern matching may be used to highlight parts of the text instantaneously. The latter is called lexical highlighting while the first is based on the meaning of your different model elements and therefore called semantic highlighting.

When you introduce new highlighting styles, the preference page for your DSL is automatically configured and allows the customization of any registered highlighting setting. They are automatically persisted and reloaded on startup.



7.7.1. Lexical Highlighting

The lexical highlighting can be customized by providing implementations of the interface ILexicalHighlightingConfiguration and the abstract class AbstractTokenScanner. The latter fulfills the interface `ITokenScanner` from the underlying JFace Framework, which may be implemented by clients directly.

The `ILexicalHighlightingConfiguration` is used to register any default style without a specific binding to a pattern in the model file. It is used to populate the preferences page and to initialize the `ITextAttributeProvider`, which in turn is the component that is used to obtain the actual settings for a style's id. An implementation will usually be very similar to the DefaultLexicalHighlightingConfiguration and read like this:

```
public class DefaultLexicalHighlightingConfiguration
    implements ILexicalHighlightingConfiguration {

 public static final String KEYWORD_ID = "keyword";
 public static final String COMMENT_ID = "comment";

 public void configure(IHighlightingConfigurationAcceptor acceptor) {
  acceptor.acceptDefaultHighlighting(KEYWORD_ID, "Keyword",
    keywordTextStyle());
  acceptor.acceptDefaultHighlighting(COMMENT_ID, "Comment", // ...
  // ...
 }

 public TextStyle keywordTextStyle() {
  TextStyle textStyle = new TextStyle();
  textStyle.setColor(new RGB(127, 0, 85));
  textStyle.setStyle(SWT.BOLD);
  return textStyle;
 }

 // ...
}
```

Implementations of the `ITokenScanner` are responsible for splitting the content of a document into various parts, the so called tokens, and return the highlighting information for each identified range. It is critical that this is done very efficiently because this component is used on each keystroke. Xtext ships with a default implementation that is based on the lexer that is generated by ANTLR which is very lightweight and fast. This default implementation can be customized by clients easily. They simply have to bind another implementation of the AbstractAntlrTokenToAttributeIdMapper. To get an idea about it, have a look at the DefaultAntlrTokenToAttributeIdMapper.

7.7.2. Semantic Highlighting

The semantic highlighting stage is executed asynchronously in the background and can be used to calculated highlighting states based on the meaning of the different model elements. Users of the editor will notice a very short delay after they have edited the text until the styles are actually applied to the document. This keeps the editor responsive while providing aid when reading and writing your model.

As for the lexical highlighting there exist two interfaces whose implementations work closely together and allow the customization of the semantic highlighting. Namely these are the ISemanticHighlightingConfiguration and ISemanticHighlightingCalculator. While the configuration for the semantic highlighting works the same way as the `ILexicalHighlightingConfiguration`, the `ISemanticHighlightingCalculator` is the primary hook to implement the logic that will compute to-be-highlighted ranges based on the model elements.

The framework will pass the XtextResource and an IHighlightedPositionAcceptor to the calculator. It is ensured, that the resource will not be altered externally until the called method `provideHighlightingsFor` returns. The task is to navigate your semantic model and compute various ranges based on the node information and associate styles with them. This may read similar to the following snippet:

```
public void provideHighlightingFor(XtextResource resource,
    IHighlightedPositionAcceptor acceptor) {
 if (resource == null)
  return;

 Iterable<AbstractNode> allNodes = NodeUtil.getAllContents(
   resource.getParseResult().getRootNode());
 for (AbstractNode abstractNode : allNodes) {
  if (abstractNode.getGrammarElement() instanceof CrossReference) {
    acceptor.addPosition(node.getOffset(), node.getLength(),
      SemanticHighlightingConfiguration.CROSS_REF);
  }
 }
}
```

This example refers to an implementation of the `ISemanticHighlightingConfiguration` that registers a style for a cross reference. It is pretty much the same implementation as for the previously mentioned sample of an `ILexicalHighlightingConfiguration`.

```
public class SemanticHighlightingConfiguration
    implements ISemanticHighlightingConfiguration {

 public final static String CROSS_REF = "CrossReference";

 public void configure(IHighlightingConfigurationAcceptor acceptor) {
  acceptor.acceptDefaultHighlighting(CROSS_REF,
    "Cross References", crossReferenceTextStyle());
 }

 public TextStyle crossReferenceTextStyle() {
  TextStyle textStyle = new TextStyle();
  textStyle.setStyle(SWT.ITALIC);
  return textStyle;
 }
}
```

The implementor of an `ISemanticHighlightingCalculator` should be aware of performance to ensure a good user experience. It is probably not a good idea to traverse everything of your model when you will only register a few highlighted ranges that can be found easier with some typed method calls. It is strongly advised to use purposeful ways to navigate your model. The parts of Xtext's core that are responsible for the semantic highlighting are pretty optimized in this regard as well. The framework will only update the ranges that actually have been altered, for example. This optimizes the redraw process. It will even move, shrink or enlarge previously announced regions based on a best guess before the next semantic highlighting pass has been triggered after the user has changed the document.

7.8. Project Wizard

Optionally Xtext can also generate a project wizard for your DSL. Using this wizard a user can then with only a few clicks create a new project containing a sample model file and workflow. You enable the project wizard generation by adding the `SimpleProjectWizardFragment` fragment to the workflow:

```
<!-- project wizard fragment -->
<fragment class="org.eclipse.xtext.ui.generator.projectWizard.SimpleProjectWizardFragment"
 generatorProjectName="${projectName}.generator"
 modelFileExtension="mydsl"/>
```

Here:

- the `generatorProjectName` attribute is used to specify the generator project containing the workflows and templates used to generate artifacts from your DSL. The generated project wizard uses this to add a corresponding dependency to the created project.
- and the `modelFileExtension` specifies the default file extension associated with your DSL. When the user clicks the *Finish* button the project wizard will look for a file with the given extension in the created project and open it in the DSL editor.

After running the Xtext generator the DSL's UI project will contain a new Xpand template `MyDslNewProject.xpt` inside the `src` folder (under the package `<base-package>.ui.wizard`). This workflow will be run by the project wizard when the user clicks the *Finish* button and it is responsible for initializing the project with some sample content. The default Xpand template generated by the fragment will when executed by the wizard create a sample model file and a simple workflow to run the model through the generator project's `MyDslGenerator.mwe` workflow. As the Xpand template is in the `src` source folder you may of course modify it to generate whatever files you want. Just make sure to leave the top-level `main` definition in place, as that is the interface for the project wizard.

Note: To edit the generated Xpand template you shoud check that the JavaBeans meta model contributor is enabled under *Preferences* > *Xtend/Xpand*. Further you should also configure the UI project with the Xpand/Xtend nature using *Configure* > *Add Xpand/Xtend Nature* in the context menu.

7.8.1. Customizing the project wizard

To further customize the creation of the project (e.g. add a nature and a builder or some additional dependencies) you can implement your own *project creator*. The default project creator is represented by the generated class `MyDslProjectCreator` (suitable for subclassing) and will simply create a new project with Java and plug-in natures and execute the `main` definition of the Xpand template as described above.

To add more pages or input fields to the project wizard you should subclass the class `MyDslNewProjectWizard` as appropriate. Don't forget to register the subclass in the UI project's `plugin.xml`. You may also want to make this additional project info available to the Xpand template, in which case you should create a subclass for `MyDslProjectInfo` to hold that information, as this is the context object which gets passed to the template when it's executed.

Chapter 8. From oAW to TMF

TMF Xtext is a complete rewrite of the Xtext framework previously released with openArchitectureWare 4.3.1 (oAW). We refer to the version from oAW as oAW Xtext whereas the current Xtext version that is hosted at Eclipse.org will be called TMF Xtext to avoid confusion. oAW Xtext has been around for about 2 years before TMF Xtext was released in June 2009 and has been used by many people to develop little languages and corresponding Eclipse-based IDE support.

TMF Xtext has been improved in many aspects compared to the former version. While it integrates far better into EMF, it offers new fundamental features as well. The overhauled architecture leads to better performance when working with large models and since the whole framework is wired via dependency injection it is highly customizable. Last not least a test coverage of more than 2.000 unit tests provide confidence in the overall quality of TMF Xtext. We have been using the framework in production environments since one of the earlier milestones.

In this document we want to share the experience we made when migrating existing Xtext projects. The document describes the differences between oAW Xtext and TMF Xtext and is intended to be used as a guide to migrate from oAW Xtext to TMF Xtext. For people already familiar with the concepts of oAW Xtext it should also serve as a shortcut to learn TMF Xtext.

8.1. Why a rewrite?

The first thing you might wonder about is why we decided to reimplement the framework from scratch as opposed to use the existing code base and enhance it further on. We decided so because we had learned a lot of lessons from oAW Xtext. Although we wanted to stick with many proven concepts we found the implementation was lacking a solid foundation (the author of these lines is the original author of that non-solid code btw. :-)). The first version of oAW Xtext was basically a proof of concept which was so well received that it had been extended with all kinds of features (some were good, some were bad). Unfortunately code quality, clean and orthogonal concepts and test coverage did not receive the necessary focus.

In addition to this aspects of quality, oAW Xtext suffers from some severe performance problems. The extensive and naive use of Xtend (see next section) prevented many users to use oAW Xtext for growing real-world models.

8.2. Migration overview

Although a couple of things have changed we tried to keep good ideas and left many things unchanged. At the same time we wanted to clean up poor concepts and solve the main problems we and you had with oAW Xtext. From a bird's eye view if you want to migrate an existing oAW Xtext project to TMF Xtext, you mainly just need to rename the old grammar from *.xtxt to *.xtext and add two lines to the beginning of that document (see below for details). You might also have to change a few keywords, but all in all this is pretty easy and we've migrated a couple of oAW Xtext projects this way without problems. The other aspect where lots of code might have been written for is validation. In oAW Xtext we used Xpand's Check language to define constraints on the Ecore model. Even though this has been one major reason for the lack of scalability in Xtext we decided to keep the Check language as an option for compatibility reasons. Therefore, you do not need to translate your existing checks to a different language. Even better, you can overcome some performance issues by leveraging the newly introduced hooks to control the time of validation (while you type, on save, or on triggering an explicit action). Anyway, if you want to provide a slick user experience validation should run fast while you type. Therefore, we strongly encourage you to implement validation using our declarative Java approach.

We've developed and reviewed a lot of oAW Xtext projects and saw that most of the work was done in the grammar and in the validation view point. Other aspects such as outline view, label provider or content assist have been customized too, but they usually do not contain complicated Xtend code. In some projects the exception was linking and content assist which in oAW Xtext usually forces one to write a lot of duplicated code. While working on this we came up with a new concept called "scopes" that not only streamlines implementation in terms of redundancy. Scopes also increase the overall performance of Xtext. But since the concept of scopes was not carved out in oAW Xtext one usually implemented a cluttered and duplicated poor copy through linking and content assist. For obvious reasons, we didn't manage to come up with a good compatibility layer. So this is where most of the migration effort will go into if implemented customized linking. But we think the notion of scopes is such a valuable addition that it is worth the refactoring. Also, when looking at existing oAW Xtext projects we found that most projects either didn't change the default linking that much or they came up with their own linking framework anyway.

However, if we have completely misunderstood the situation and your oAW Xtext project cannot be migrated in a reasonable amount of time, please tell us. We want to help you!

8.3. Where are the Xtend-based APIs?

One of the nice things with oAW Xtext was the use of Xtend to allow customizing different aspects of the generated language infrastructure. Xtend is a part of the template language Xpand, which is shipped with oAW (and now is included in M2T Xpand). It provides a nicer expression syntax than Java. Especially the existence of higher-order functions for collections is extremely handy when working with models. In addition to the nice syntax, it provides dynamic polymorphic dispatch, which means that declaring e.g. label computation for an Ecore model is very convenient and type safe at the same time. In Java one usually has to write instanceof and cast orgies.

8.3.1. Xtend is hard to debug

While the aforementioned features allow the convenient specification of label and icon providers, outline views, content assist and linking, Xtend is interpreted and therefore hard to debug. Because of that Xpand is shipped with a special debugger facility. Unfortunately, this debugger cannot be used in the context of Xtext since it implies that the Xtend functions have to be called from a workflow. This is not and cannot be the case for Xtext Editors. As a result one has to debug his way through the interpreter, which is hard and inconvenient (even for us, who have written that interpreter).

8.3.2. Xtend is slow

But the problematic debugging in the context of Xtext was not the main reason why there are no Xtend-based APIs beside Check in TMF Xtext. The main reason is that Xtend is too slow to be evaluated “inside” the editor again and again while you type. While Xtend's performance is sufficient when run in a code generator, it is just too slow to be executed on keystroke (or 500ms after the last keystroke, which is when the reconciler reparses, links and validates the model). Xtend is relatively slow, because it supports polymorphic dispatch (the cool feature mentioned above), which means that for each invocation it matches at runtime which function is the best match and it has to do so on each call. Also Xtend supports a pluggable typesystem, where you can adapt to other existing type systems such as JavaBeans or Ecore. This is very powerful and flexible but introduces another indirection layer. Last but not least the code is interpreted and not compiled. The price we pay for all these nice features is reduced performance.

In addition to these scalability problems we have designed some core APIs (e.g. scopes) around the idea of Iterables, which allows for lazy resolution of elements. As Xtend does not know the concept of Iterators you would have to work with lists all the time. Copying collections over and over again is far more expensive than chaining Iterables through filters and transformers like we do with Google Collections in TMF Xtext.

8.3.3. Convenient Java

To summarize the dilemma we had to find a way to allow for convenient, scalable and debuggable APIs. Ultimately we wanted to provide neat DSLs for every view point, which provide all these things. However, we had to prioritize our efforts with the available resources in mind. As a result we found ways and means to tweak Java as good as possible to allow for relatively convenient, high performing implementations.

Java is fast and can easily be debugged but ranks behind Xtend regarding convenience. We address this with different approaches to make Java development in the context of Xtext as comfortable as possible.

Most of the APIs in TMF Xtext use polymorphic dispatching, which mimics the behavior known from Xtend. Another valuable feature of Xtend while working with oAW Xtext is static type checking while working with the inferred Ecore model whereas in Java the work with dynamic Ecore classes was rather cumbersome. Since TMF Xtext generates static Ecore classes per default you get static typing in Java as well. Additionally, the use of [Google Collections] reduces the pain when navigating over your model to extract information.

With these techniques an ILabelProvider that handles your own EClasses `Property` and `Entity` can be written like this:

```
public class DomainModelLabelProvider extends DefaultLabelProvider {

  String label(Entity e) {
    return e.getName();
  }

  String image(Property p) {
    return p.isMultiValue() ? "complexProperty.gif": "simpleProperty.gif";
  }

  String image(Entity e) {
    return "entity.gif";
  }

}
```

As you can see this is very similar to the way one describes labels and icons in oAW Xtext, but has the advantage that it is easier to test and to debug, faster and can be used everywhere an ILabelProvider is expected in Eclipse.

8.3.4. Conclusion

Just to get it right, Xtend is a very powerful language and we still use it for its main purpose: code generation and model transformation. The whole generator in TMF Xtext is written in Xpand and Xtend and its performance is at least in our experience sufficient for that use case. Actually we were able to increase the runtime performance of Xpand by about 60% for the Galileo release of M2T Xpand. But still, live execution in the IDE and on typing is very critical and one has to think about every millisecond in this area.

As an alternative to the Java APIs we also considered other JVM languages. We like static typing and think it is especially important when processing typed models (which evolve heavily). That's why Groovy or JRuby were no alternatives. Using Scala would have been a very good match, but we didn't want to require knowledge of Scala so we didn't use it and stuck to Java.

8.4. Differences

In this section differences between oAW Xtext and TMF Xtext are outlined and explained. We'll start from the APIs such as the grammar language and the validation and finish with the different hooks for customizing linking and several UI aspects, such as outline view and content assist. We'll also try to map some of the oAW Xtext concepts to their counterparts in TMF Xtext.

8.4.1. Differences in the grammar language

When looking at a TMF Xtext grammar the first time it looks like one has to provide additional information which was not necessary in oAW Xtext. In oAW Xtext *.xtxt files started with the first production rule where in TMF Xtext one has to declare the name of the language followed by declaration of one or more used/generated Ecore models:

TMF Xtext heading information

```
  grammar my.namespace.Language with org.eclipse.xtext.common.Terminals
  generate myDsl "http://www.namespace.my/2009/MyDSL"

  FirstRule : ...
```

In oAW Xtext this information was provided through the generator (actually it is contained in the *.properties file) but we found that these things are very important for a complete description of a grammar. Therefore we made that information becoming a part of the grammar language in order to have self-describing grammars and allow for sophisticated static analysis, etc..

Apart from the first two lines the grammar languages of both versions are more or less compatible. The syntax for all the different EBNF concepts (alternatives, groups, cardinalities) is similar. Also assignments are syntactically and semantically identical in both versions. However in TMF Xtext some concepts have been generalized and improved:

8.4.1.1. String rules become Datatype rules

The very handy String rules are still present in TMF Xtext but we generalized them so that you don't need to write the 'String' keyword in front of them and at the same time these rules can not only produce EStrings but (as the name suggests) any kind of EDataType. Every parser rule that neither includes assignments nor calls any other that does, returns an EDataType containing the consumed data. Per default this is an EString but you can now simply create a parser rule returning other EDataTypes as well (see Datatype rules).

```
Float returns ecore::EDouble : INT ('.' INT)?;
```

8.4.1.2. Enum rules

Enum rules have not changed significantly. The keyword has changed to be all lower case ('enum' instead of 'Enum'). Also the right-hand side of the assignment is now optional. That is in oAW Xtext:

```
Enum MyEnum : foo='foo' | bar='bar';
```

becomes

```
enum MyEnum : foo='foo' | bar='bar';
```

and because the name of the literal equals the literal value one can omit the right-hand side in this case and write:

```
enum MyEnum : foo | bar;
```

8.4.1.3. Native rules

Another improvement is that we could replace the blackbox native rules with full-blown EBNF syntax. That is native rules become terminal rules and are no longer written as a string literal containing ANTLR syntax.

Example :

```
Native FOO : "'f' 'o' 'o'";
```

becomes

```
terminal FOO : 'f' 'o' 'o';
```

See the reference documentation for all the different expressions possible in terminal rules.

8.4.1.4. No URI terminal rule anymore

We decided to remove the URI terminal. The only reason for the existence was to mark the model somehow so that the framework knows what information to use in order to load referenced models. Instead we decided to solve this similar to how we imply other defaults: by convention.

So instead of using a special token which is syntactically a STRING token, the default import mechanism now looks for EAttributes of type EString with the name 'importURI'. That is if you've used the URI token like this:

```
Import : 'import' myReference=URI;
```

you'll have to rewrite it that way

```
Import : 'import' importURI=STRING;
```

Although this changes your Ecore model, one usually never used this reference explicitly as it was only there to be used by the default import mechanism. So we assume and hope that changing the reference is not a big deal for you.

8.4.1.5. Return types

The syntax to explicitly declare the return type of a rule has changed. In oAW Xtext (where this was marked as 'experimental') the syntax was:

```
MyRule [MyType] : foo=ID;
```

in TMF Xtext we have a keyword for this :

```
MyRule returns MyType : foo=ID;
```

This is a bit more verbose, but at the same time more readable. And as you don't have to write the return type in most situations, it's good to have a more explicit, readable syntax.

8.4.2. Differences in Linking

The linking has been completely redesigned. In oAW Xtext linking was done in a very naive way: To find an element one queries a list of all 'visible' EObjects, then filters out what is not needed and tries to find a match by comparing the text written for the crosslink with the value returned by the `id()` extension. As a side-effect of `link_feature()` the reference is set.

The code about selecting and filtering `allElements()` usually has been duplicated in the corresponding content assist function, so that linking and content assist are semantically in sync. If you're good (we usually were not) you externalized that piece of code and reused the same extension in content assist and linking.

To put it bluntly this approach could be summarized in two steps:

1. Give me the whole universe including every unregarded object in the uncharted backwaters of the unfashionable end of the western spiral arm of the galaxy and squeeze it into an Arraylist
2. From this, select the one I need

This was not only very expensive but also lacks an important abstraction: the notion of scopes.

8.4.2.1. The idea of scopes

In TMF Xtext we've introduced scopes and scope providers that are responsible for creating scopes. A scope is basically a set of name->value pairs. Scopes are implemented upon Iterables and are nested to build a hierarchy. With scopes we declare "visible" objects in a lazy and cost-saving way where the linker only navigates as far as necessary to find matching objects. The content assist reuses this set of visible objects to offer only reachable objects.

When the linking has to be customized scoping is where most of the semantics typically goes into. By implementing an IScopeProvider for your language linking and content assist will automatically be kept in sync since both use the scope provider.

The provided default implementation is semantically mostly identical to how the default linking worked in oAW Xtext:

1. Elements which have an attribute 'name' will be made visible by their name
2. Referenced resources will be put on the (outer) scope by using the 'importURI'- naming convention and will only be loaded if necessary
3. The available elements are filtered by the expected type (i.e. the type of the reference to be linked)

8.4.2.2. Migration

We expect the migration of linking to be very simple if you've not changed the default semantics that much. We've already migrated a couple of projects and it wasn't too hard to do so. If you have changed linking (and also content assist) a lot, you'll have to translate the semantics to the IScopeProvider concept. This might be a bit of work, but it is worth the effort as this will clean up your code base and better separate concerns.

8.4.3. Differences in UI customizing

In oAW Xtext several UI services such as content assist, outline view or the label provider have been customized using Xtend. In TMF Xtext there is no Xtend API for these aspects. Extensive model computations for the content assist is most probably not necessary anymore- it reuses scopes. And since we provide a declarative Java API that mimics the polymorphic dispatch and relies on static Ecore classes you will gain nearly the same expressiveness as before while increasing maintainability and performance.

Beside the API change in favor of Java we have to mention that in TMF Xtext the outline view does not support multiple view points so far. This is just because we didn't manage to get this included. We don't think that view points are a bad idea in general, but we decided that other things were more important.

8.5. New Features

This section provides an overview of new possibilities with TMF Xtext compared to oAW Xtext. Please note that this list is neither complete nor does it explain every aspect in detail to keep this document tight.

8.5.1. Dependency Injection with Google Guice

Beyond the mentioned architectural overhaul that carve out separate concerns in a meaningful way these different classes of TMF Xtext are wired using Google Guice and can easily be replaced by or combined with your own implementation. We could have foreseen some common needs for adaption but with this mechanism you can virtually change every aspect of Xtext without duplicating an unmanageable amount of code.

8.5.2. Improvements on Grammar Level

The Xtext grammar language introduces some new features, too. Read the chapter grammar language to understand the details about all the improvements that have been implemented.

Grammar mixins allow you to extend existing languages and change their concrete and abstract syntax. However the abstract syntax (i.e. the Ecore model) can only be extended. This allows you to reuse existing validations, code generators, interpreters or other code which has been written against those types.

In oAW Xtext common terminals like ID, INT, STRING, ML_COMMENT, SL_COMMENT and WS (whitespace) were hard coded into the grammar language and couldn't be removed and hardly overridden. In TMF Xtext these terminals are imported through the newly introduced grammar mixin mechanism from the shipped grammar `org.eclipse.xtext.common.Terminals` per default. This means that they are still there but reside in a library now. You don't have to use them and you can come up with your own set of reusable rules.

Reusing existing Ecore models in oAW Xtext didn't work well and we communicated this by flagging this feature as 'experimental'. In TMF Xtext importing existing Ecore models is fully supported. Moreover, it is possible to import a couple of different EPackages and generate some at the same time, so that the generated Ecore models extend or refer to the existing Ecore models.

The grammar language gained one new concept that is of great value when writing left-factored grammars (e.g. expressions). With actions one can do minor AST rewritings within a rule to overcome degenerated ASTs. You will find an in-depth explanation of actions in the dedicated chapter in the reference documentation.

8.5.3. Fine-grained control for validation

In order to make more expensive validations possible without slowing down the editor, TMF Xtext supports three different validation hooks.

1. FAST constraints are triggered by the reconciler (i.e. 500 ms after the last keystroke) and on save.
2. NORMAL constraints are executed on save only.
3. EXPENSIVE constraints are executed through an action which is available through the context menu.

Please note that when using Xtext models for code generation the checks of all three categories will be performed.

Beside this it is now possible to add information about the feature which is validated.

```
context Entity#name ERROR "Name should start with a capital "+this.name+"." :
  this.name.toFirstUpper() == this.name;
```

If you add the name of a feature prepended by a hash ('#') in Check, the editor will only mark the value of the feature (name), not the whole object (Entity). Both concepts, control over validation time as well as pointing to a specific feature, complement one another in Check and Java based validation.

8.6. Migration Support

In this document we tried to explain why we decided to change some aspects of Xtext's architecture. We consider most changes as minor but when it comes to scopes you will face a conceptual enhancement that did not exist in oAW Xtext. We tried to explain why it is not easily possible to come up with an adapter for scoping.

That said you might not have the time to do the migration and wished to have advice for migrating, especially from oAW linking to TMF linking. You're welcome to ask any questions in the newsgroup and we'll try to help you as much as possible in order to get your projects migrated. Also, if you don't want to do the migration yourself we (itemis AG) can do the work for you or help you with that.

Chapter 9. Migrating from TMF Xtext 0.7.x

9.1. Take the shortcut?

If you haven't made too many customizations to the generated defaults and if you're not referencing many classes of your Xtext language from the outside, you might consider starting with a new Xtext project, copying your grammar and then manually restoring your changes step by step. If that does not work for you, go on reading!

9.2. Go the hard way...

9.2.1. Changes in the grammar

The grammar language is fully backward compatible. You should not have to apply any changes here.

9.2.2. Changes in the workflow

Xtext 1.0 introduces MWE2 to describe the workflow to build the Xtext infrastructure. MWE2 is a domain-specific language developed with Xtext that completely replaces the original XML based MWE and offers far better tooling. MWE workflows will still work but are considered legacy. For a more detailed description see the section on MWE2.

The following generator fragments have changed:

- The packrat parser has been abandoned. Please use the AntLR parser now. With that change, the generator fragments `AntlrDelegatingFragment`, `DelegatingGeneratorFragment`, and `PackratParserFragment` have vanished and should be replaced by `de.itemis.xtext.antlr.XtextAntlrGeneratorFragment`.
- The `JavaScopingFragment` should be replaced by `ImportURIScopingFragment`.

9.2.3. Changes in the generated code

After adapting your workflow, you must rerun the code generator. Note that it will delete all existing code in `src-gen` folders, so make sure you haven't got any manual changes there.

We have appended `.ui` to the name of the base package in the generated UI plug-in to comply with Eclipse naming conventions. The initial package's content in the `src` folder will therefore coexist with the newer version. Even though that was not the primary purpose, this can help you copying your manual customizations one by one. Don't forget to delete the old packages when you're finished. This package renaming has consequences in the UI plug-ins `MANIFEST.MF` and `plugin.xml`, too.

9.2.4. Changes in the MANIFEST.MF and plugin.xml

- In the generated UI plug-in's `MANIFEST.MF`, remove the package exports of no longer existing packages and make sure the bundle activator points to the newly generated one (with `.ui.` in its package name).
- The plug-ins `org.eclipse.xtext.ui.core` and `org.eclipse.xtext.ui.common` have been merged into a new single plug-in `org.eclipse.xtext.ui`. The same happened to the respective Java packages. Change the dependencies in all manifests.
- The plug-in `org.eclipse.xtext.log4j` no longer exists. We use a package import of `org.apache.log4j` instead. Also remove the buddy registration.
- To run MWE2 workflows, you must change the plug-in dependencies from `org.eclipse.emf.mwe.core` to `org.eclipse.emf.mwe2.launch`. Optional resolution is fine.
- Due package renamings, you have to fix all references to classes therein in the `plugin.xml`. A diff with `plugin.xml_gen` will be a great help. If you haven't added a lot manually, consider

merging these into the generated version instead of going the other way around. Note that warnings in `plugin.xml` can be considered real errors most of the time. Make sure

- the `XExecutableExtensionFactory` has the `.ui.` package prefix
- classes from `org.eclipse.xtext.ui.common` and `org.eclipse.xtext.ui.core` are now usually somewhere in `org.eclipse.xtext.ui`. The are also referenced by the `XExecutableExtensionFactory` and thus not covered by the editor's validation.

- A number of new features are being registered in the `plugin.xml`, e.g. *Find references*, *Quick Outline*, and *Quickfixes*. You can enable them by manually copying the respective entries from `plugin.xml_gen` to `plugin.xml`.

9.2.5. Changes in the src folders

The `src` folders are generated once, so existing code will not be overwritten.

- After re-generation, there will now be a `XStandaloneSetup` inheriting form the generated `AbstractXStandaloneSetup` to allow customization. Make sure to call the super constructor.

You will face a couple of compilation problems due to changes in the API. Here's a list of the most prominent changes:

- The method `IScopeProvider.getScope(EObject,EClass)` has been deleted. Use `IScopeProvider.getScope(EObject,EReference)` instead.
- Renamed `DefaultScopeProvider` to `SimpleNameScopeProvider`. There have been further significant changes in the scoping API. Consult the section on scoping for details.
- The return type of `AbstractInjectableValidator.getEPackages()` has changed form `List<? extends EPackage>` to `List<EPackage>`.
- The parser interfaces now use `java.io.Reader` instead of `java.io.InputStream` to explicitly address encoding.
- The handling of `ILabelProvider` in various contexts has been refactored. The former base class `DefaultLabelProvider` no longer exists. See the section on label providers for details.
- We have introduced a couple of new packages to better separate concerns. Most classes should be easy to relocate.
- The runtime and UI modules have separate base classes `DefaultRuntimeModule` and `DefaultUiModule` now. We use Guice's module overrides to combine them and the new `SharedModule`.
- The interfaces `ILexicalHighlightigConfiguration` and `ISemanticHighlightingConfiguration` have been merged into `IHighlightingConfiguration`.
- Some more interfaces have changed, e.g. `IFragmentProvider`, `ITransientValueService`... Their JavaDocs will point you into the right direction.

9.3. Now go for the new features

After migrating, some of the new features in Xtext 1.0 will be automatically available. Others require further configuration. We recommend reading the sections about

- qualified names and namespace imports
- the builder infrastructure
- quick fixes
- unordered groups
- quick outline
- MWE2
- referencing Java elements

For an overview over the new features consult our New and Noteworthy online.

Chapter 10. The ANTLR IP issue (or which parser to use?)

In order to be able to parse models written in your language, Xtext needs to provide a special parser for it. The parser is generated from the language grammar.

Currently it is recommended to use the ANTLR-based parser. ANTLR is a very sophisticated parser generator framework based on a so called LL(*) algorithm. It is fast, simple and at the same time has some very nice and sophisticated features. Especially its support for error recovery is much better than what other parser generators provide.

ANTLR comes in two parts: the runtime and the generator. Both are shipped under the BSD license and have a clean intellectual property history. However the generator is still implemented in an older version of ANTLR (v 2.x), where it was not possible for the Eclipse Foundation to be sure where exactly every line of code originated. Therefore ANTLR v 2.x didn't get the required approval. Eclipse has a strict IP policy, which makes sure that everything provided by Eclipse can be consumed under the terms of the Eclipse Public License. The details are described in this document.

Unfortunately as the generator of ANTLR V3 needs ANTLR V2 it is as well not yet IP approved. That is why we are not allowed to ship Xtext with the ANTLR generator (the runtime is IP approved), but have to provide it separately via update-site at:

- http://download.itemis.com/updates/

IMPORTANT : *Although if you use the non-IP approved ANTLR generator, you can still ship any languages and the IDEs you've developed with Xtext without any worrying, because the* ***ANTLR runtime is IP approved***

10.1. What if I do not want to use non IP-approved code

If you, against all recommendations, need to stick to a fully IP approved generator, you can use the parser generator we've developed. But be warned, although it's fully functional and equally fast, it does not have any error recovery. This makes the editing experience in the editor more or less unacceptable.