Overture – Open-source Tools for Formal Modelling TR-2009-02
January 2010

User Guide for the Overture VDM Tool Support

by

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Contents

ABSTRACT

This document is a user manual for the Overture Integrated Development Environment (IDE) open source tool for VDM. It can serve as a reference for anybody wishing to make use of this tool with one of the VDM dialects (VDM-SL, VDM++ and VDM-RT). This tool support is build of top of the Eclipse platform. The objective of the Overture open source initiative is to enable a platform that both can be used for experimentation of new subsets or supersets of VDM dialects as well as new features analysing such VDM models in different ways. The tool is entirely open source so anybody can join the development team and influenece the future developments. The long term target is also to ensure that stable versions of the tool suite can be used for large scale industrial applications of the VDM technology.

1 Introduction

The Vienna Development Method (VDM) is one of the longest established model-oriented formal methods for the development of computer-based systems and software [Bjørner&78a, Jones90, Fitzgerald&08a]. It consists of a group of mathematically well-founded languages for expressing system models during early design stages, before expensive implementation commitments are made. The construction and analysis of the model using Overture help to identify areas of incompleteness or ambiguity in informal system specifications, and provide some level of confidence that a valid implementation will have key properties, especially those of safety or security. VDM has a strong record of industrial application, in many cases by practitioners who are not specialists in the underlying formalism or logic [Larsen&95, Clement&99, Kurita&09]. Experience with the method suggests that the effort expended on formal modeling and analysis can be recovered in reduced rework costs arising from design errors.

VDM models are expressed in a specification language (VDM-SL) that supports the description of data and functionality [ISOVDM96, Fitzgerald&98, Fitzgerald&09]. Data are defined by means of types built using constructors that define structured data and collections such as sets, sequences and mappings from basic values such as Booleans and numbers. These types are very abstract, allowing the user to add any relevant constraints as data type invariants. Functionality is defined in terms of operations over these data types. Operations can be defined implicitly by preconditions and postconditions that characterize their behavior, or explicitly by means of specific algorithms. An extension of VDM-SL, called VDM++, supports object-oriented structuring of models and permits direct modeling of concurrency [Fitzgerald&05]. An additional extension to VDM++ is called VDM Real Time (VDM-RT) (formerly called VDM In a Constrained Environment (VICE)) [Mukherjee&00, Verhoef&06]. All these different dialects are supported by the unified tool called Overture.

Since the VDM modeling languages have a formal mathematical semantics, a wide range of analyses can be performed on models, both to check internal consistency and to confirm that models have emergent properties. Analyses may be performed by inspection, static analysis, testing or mathematical proof. To assist in this process, Overture supply tool support for building models in collaboration with other modeling tools, to execute and test models and to carry out different forms of static analysis [Larsen&10]. It can be seen as an open source version of the commercial tool called VDMTools [Elmstrøm&94, Larsen01, Fitzgerald&08b] although that also have features to generate executable code in high-level programming languages which are not yet available in Overture.

This guide explains how to use the Overture IDE for developing models for different VDM dialects. This user manual starts with explanantion about how to get hold of the software in Section 2. This is followed in Section 3 with an introduction to the concepts used in the different Overture perspectives based on Eclipse terminology. In Section 4 it is explained how projects are managed in the Overture IDE. In Section 5 the features supported when editing VDM models are explained. This is followed in Section 6 with an explainantion of the interpretation and debugging capabilities in the Overture IDE. Section 7 then illustates how test coverage information can be gathered when models are interpreted. Afterwards Section 8 shows how models with and without test coverage

information can be generated to the text processing system LaTeX and automatically converted to `pdf` format if one have `pdflatex` installed on the computer. Afterwards from Section 9 to Section 13 different VDM specfic features are explained. In Section 9 the use of the notion for proof obligations and its support in Overture is explained. In Section 10 a notion of combinatorial testing and the automation support for that in Overture is presented. In Section 11 support for mapping between object-oriented VDM models to and from UML models is presented. In Section 12 it is illustrated how one can move from a VDM++ project to a new VDM-RT project. In Section 13 it is shown how support to analysing and displaying logs from executing such VDM-RT models. After these sections the main part of the user manual is completed in Section 14 with an explanantion of the features from Overture that also is available from a command-line interface. From Appendix A to F complete lists of different kinds of errors, warnings and proof obligations are provided and further explanation are provided where it is judged necessary. Finally in Appendix G an index of significant terms used in this user manual can be found.

2 Getting Hold of the Software

Overture is an open source tool, developed by a community of volunteers and built on the Eclipse platform. The project to develop the tools is managed using SourceForge. The best way to run Overture is to download a special version of Eclipse with the Overture functionality already pre-installed. If you go to:

```
http://sourceforge.net/projects/overture
```

you can use the *Download Now* button to automatically download a pre-installed versions of Overture for your operating system. Supported systems are: Windows, Linux and Mac[1]. Note that when you have extracted all files from the zip file with the Overture executable for your selected operating system you will find the first time you start it up it will ask you for selecting a workspace. Here we simply recommend you to chose the default one it is selecting and tick off the box for "use this as the default and do not ask again". A welcome screen will also only the first time introduce you to the overall mission of the Overture open source initiative.

Large libraries of sample VDM-SL, VDM++ and VDM-RT models is available and can be downloaded from SourceForge under the `files/Examples` section using the URL[2]:

```
https://sf.net/projects/overture/files/Examples/
```

Such existing projects can be imported as described in subsection 4.1.

[1] It is planned to develop an update facility, allowing updates to be applied directly from within the generic Eclipse platform without requiring a reinstallation. However, this can be a risky process because of the dependencies on non-Overture components and so is not yet supported.

[2] The library files are created to be used with Eclipse, but can be opened with file compression programs like `Winrar` on Windows

3 Using the Overture Perspective

3.1 Getting into the Eclipse Terminology

Eclipse is an open source platform based around a *workbench* that provides a common look and feel to a large collection of extension products. Thus if a user is familiar with one Eclipse product, it will generally be easy to start using a different product on the same workbench. The Eclipse workbench consists of several panels known as *views*, such as the Script Explorer view at the top left of Figure 1. A collection of panels is called a *perspective*, for example Figure 1 shows the standard Overture perspective. This consists of a set of views for managing Overture projects and viewing and editing files in a project. Different perspectives are available in Overture as will be described later, but for the moment think about a perspective as a useful composition of views for conducting a particular task.

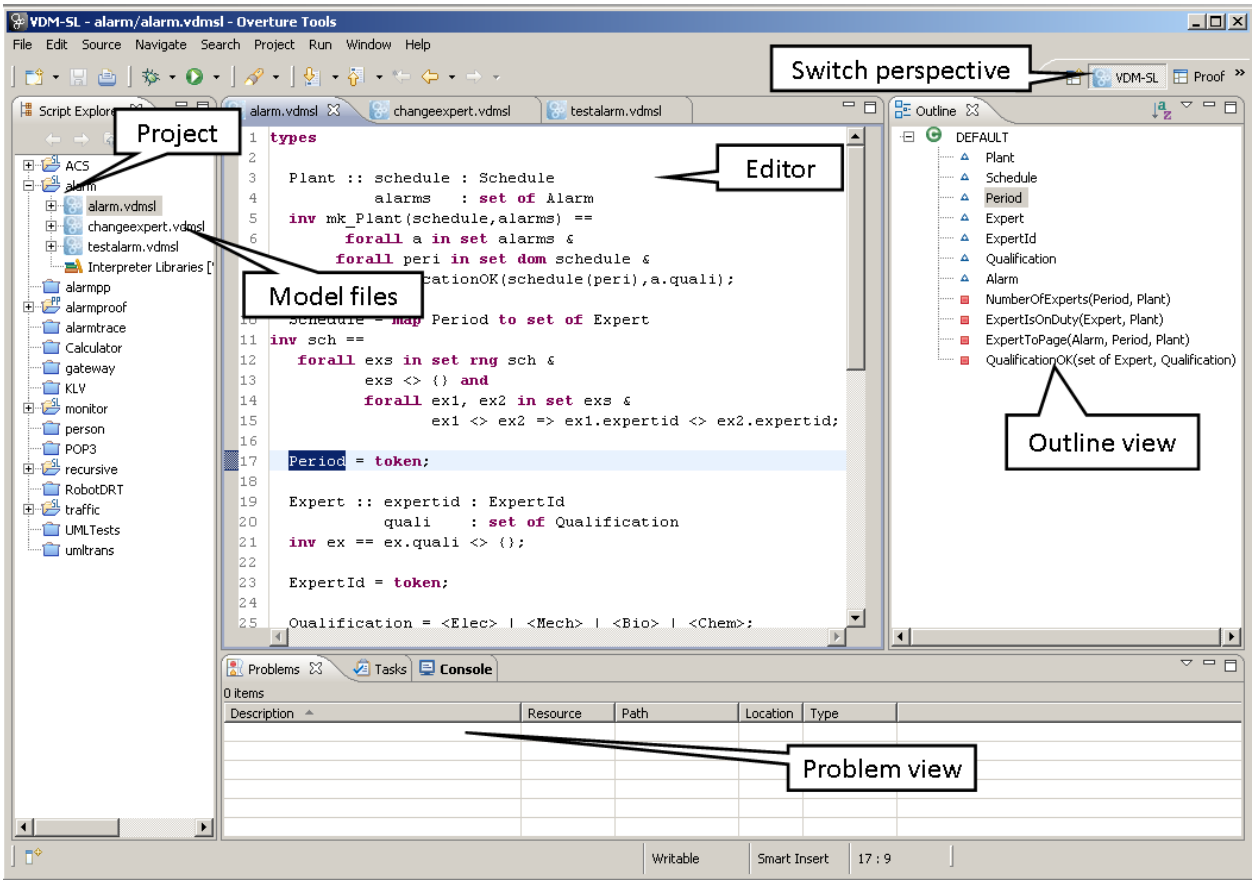
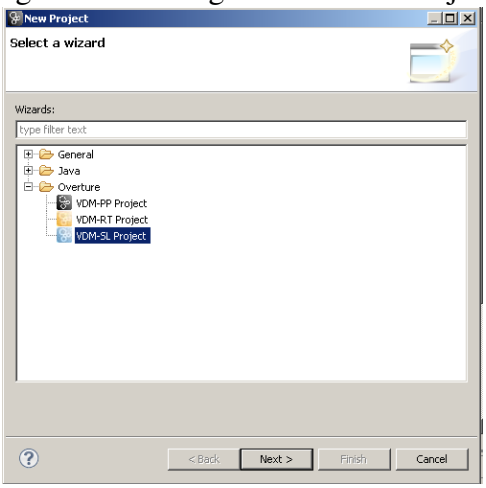


Figure 1: The Overture Perspective

The *Script Explorer view* lets you create, select, and delete Overture projects and navigate between the files in these projects.

Depending upon the dialect of VDM used in a given project, a corresponding Overture editor will be available here. A new VDM project is created choosing the *File* → *New* → *Project*. Then Figure 2 will appear and here the desired VDM dialect can be selected and *Next* can be used and finally a name needs to be given to the project and then simply select `Finish`.

Figure 2: Creating a New VDM Project



The *Outline view*, to the right of the editor (see Figure 3), presents an outline of the file selected in the editor. The outline displays any declared VDM definitions such as their state components, values, types, functions and operations. In case of a flat VDM-SL model the module is called `DEFAULT`. Figure 1 shows the outline view on the right hand side. Clicking on an operation or function will move the cursor in the editor to the definition of the operation. At the top of the outline view there is a button to optionally sort what is displayed in the outline view, for instance it is possible to hide variables.

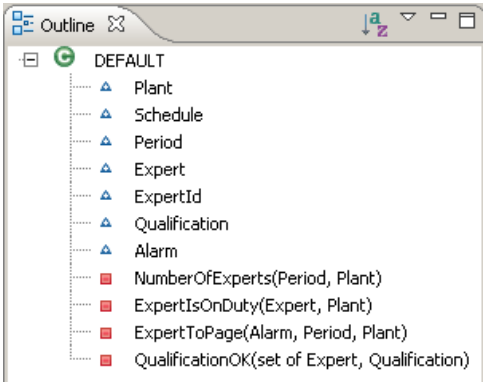


Figure 3: The Outline View

The *Problems view* gathers information messages about the projects you are working on. This

includes information generated by Overture, such as warnings and errors. Note also that the suggestions made in the error messages may not always be entirely the action you may wish to take when correcting the source since the tool cannot guess what you intended to write.

Most of the other features of the workbench, such as the menus and toolbars, are similar to other Eclipse applications, though note that there is a special menu with Overture specific functionality. One convenient feature is a toolbar of shortcuts to switch between different perspectives that appears on the right side of the screen; these vary dynamically according to context and history.

3.2 Additional Eclipse Features Applicable in Overture

3.2.1 Opening and Closing Projects

In order not to take up too much space and computing power it may be advantageously to close projects that are not used currently. That can be done by right clicking such projects and then selecting the *Close Project* entry in the menu as shown in Figure 4. For such closed projects it is possible to open them again in the same fashion using the *Open project* entry in the menu.

3.2.2 Adding Additional VDM File Extensions

If one would like to use additional file types to be associated with a particular VDM editor instead of the standard `vdmsl`, `vdmpp` and `vdmrt` file types this is possible in Overture. This is done using the *Window* → *Preferences* menu point. Here one can start typing `contents types` and then one will get a menu similar to Figure 5. Here one can press the `Add` button for the appropriate contents type that one wishes to add additional types of file extensions.

3.2.3 Remove Directories without Source Files

3.2.4 Including line numbers in the Editor

In case line numbers are desired in the Overture editor it is possible to to right click in the left-hand-side margin of the editor and then select `show line numbers` as shown in Figure 6.

4 Managing Overture Projects

4.1 Importing Overture VDM Projects

It is possible to import Overture VDM projects by right-clicking the explorer view and selecting *Import*, followed by *General* → *Existing Projects into Workspace*. In this way the projects from `.zip` files mentioned in Section 2 can be imported very easily.

4.2 Creating a New Overture Project

1. Create a new project by choosing *File* → *New* → *Project* → *Overture*;

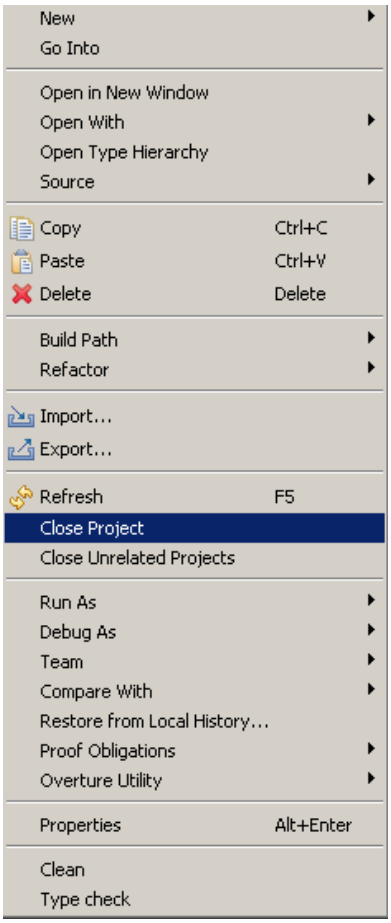


Figure 4: Closing a Project

2. Select the VDM dialect you wish to use (VDM-SL, VDM-PP or VDM-RT);
3. Type in a project name
4. Chose whether you would like the contents of the new project to be in your workspace or outside from existing source files (browse to the appropriate directory) and
5. click the finish button (see Figure 7).

4.3 Creating Files

Switching to the Overture perspective will change the layout of the user interface to focus on the VDM development. To change perspective go to the menu window → open perspective → other...and choose the Overture perspective. When the developer is in the Overture Perspective the user can create files using one of the following methods:

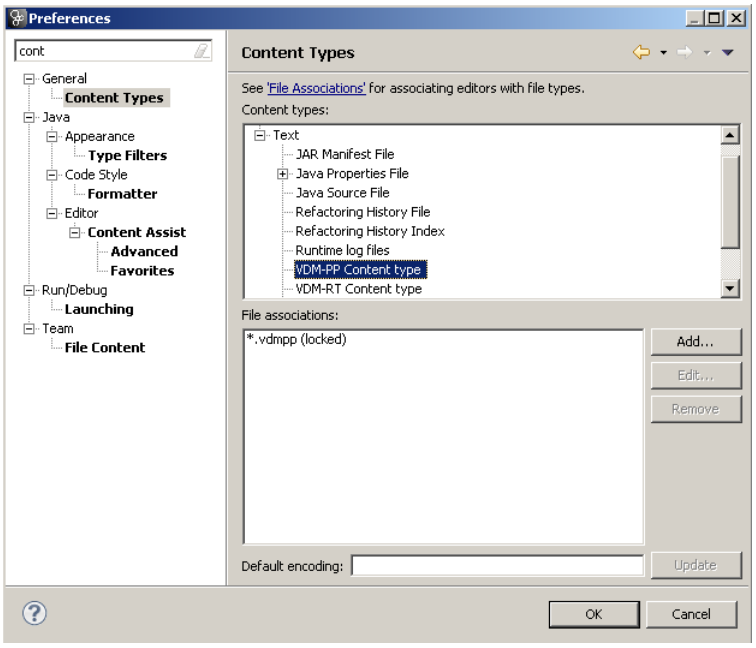


Figure 5: Adding Additional Contents Types

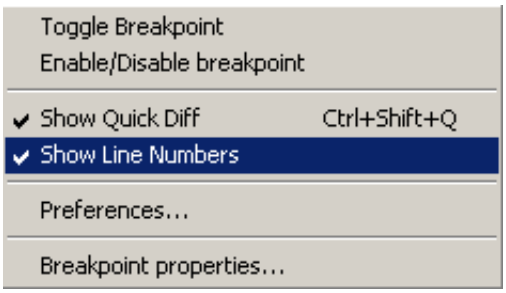


Figure 6: Adding Line Numbers in Editor

1. Choose *File* → *New* → *VDM-SL Module* or *VDM-PP Class* or *VDM-RT Class* or
2. Right click on the Overture project where you would like to add a new file and then choose *New* → *VDM-SL Module* or *VDM-PP Class* or *VDM-RT Class*.

In both cases one needs to choose a file name and optionally choose a directory if one does not want to place the file in the directory for the chosen Overture project. Then a new file with the appropriate file extension according to the chosen dialect (`vdmsl`, `vdmpp` or `vdmrt`) can be created in the selected directory. This file will use the appropriate module/class template to get the user started with defining the module/class meant to be placed in this new file. Naturally keywords for kinds of definitions that will not be used can be deleted.

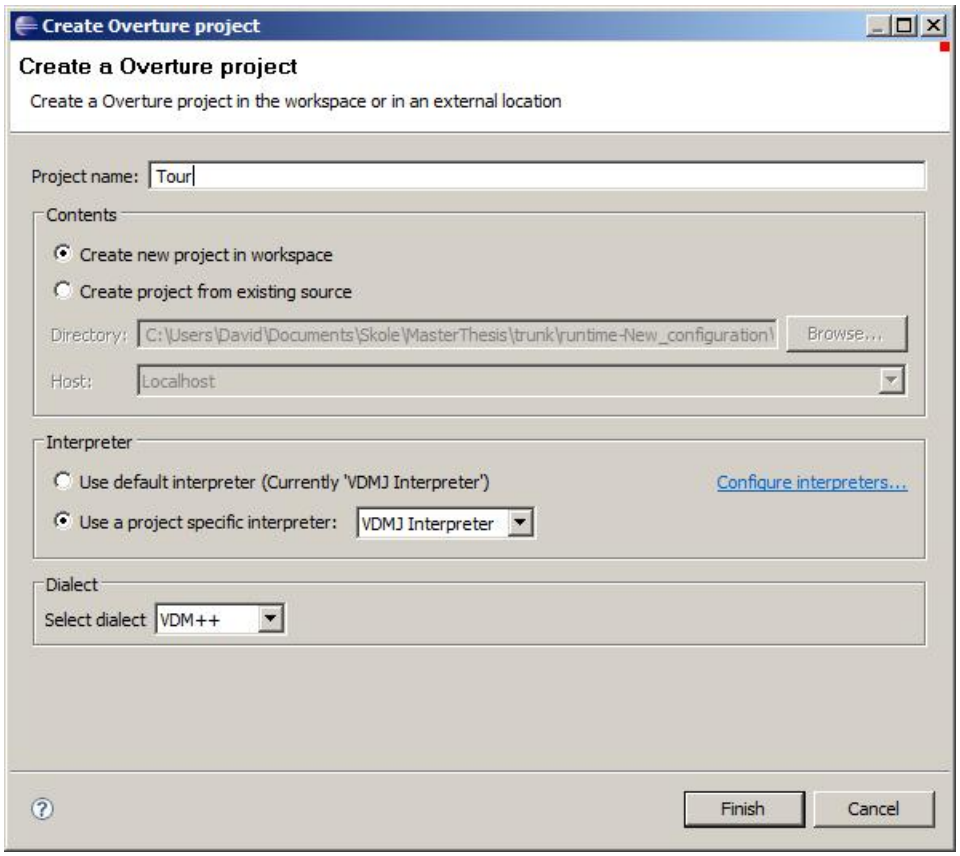


Figure 7: Create Project Wizard

4.4 Setting Project Options

For each Overture VDM project it is possible to set various VDM specific settings. One can get access to these by selecting a project in the *Explorer view* and then right clicking and selecting *properties*. Here there is a VDM specific settings property that looks like in Figure 8. The options that can be set for each VDM project are:

Language version: Here the standard is to use the *classic* version that is similar to what is used in the similar VDMTools version. Alternatively one can select VDM-10 which is a new improved (but not necessarily backwards compatible) version of different VDM dialects developed by the Overture Language Board.

Suppress type checking warnings: This flag is per default not set but if one would like to swich off such warning the flag can be set here.

Dynamic type checks: This is an option to the interpreter which per default is switched on for continuously type checking the values during interpretation of a VDM model. It is possible to swich off this checking here.

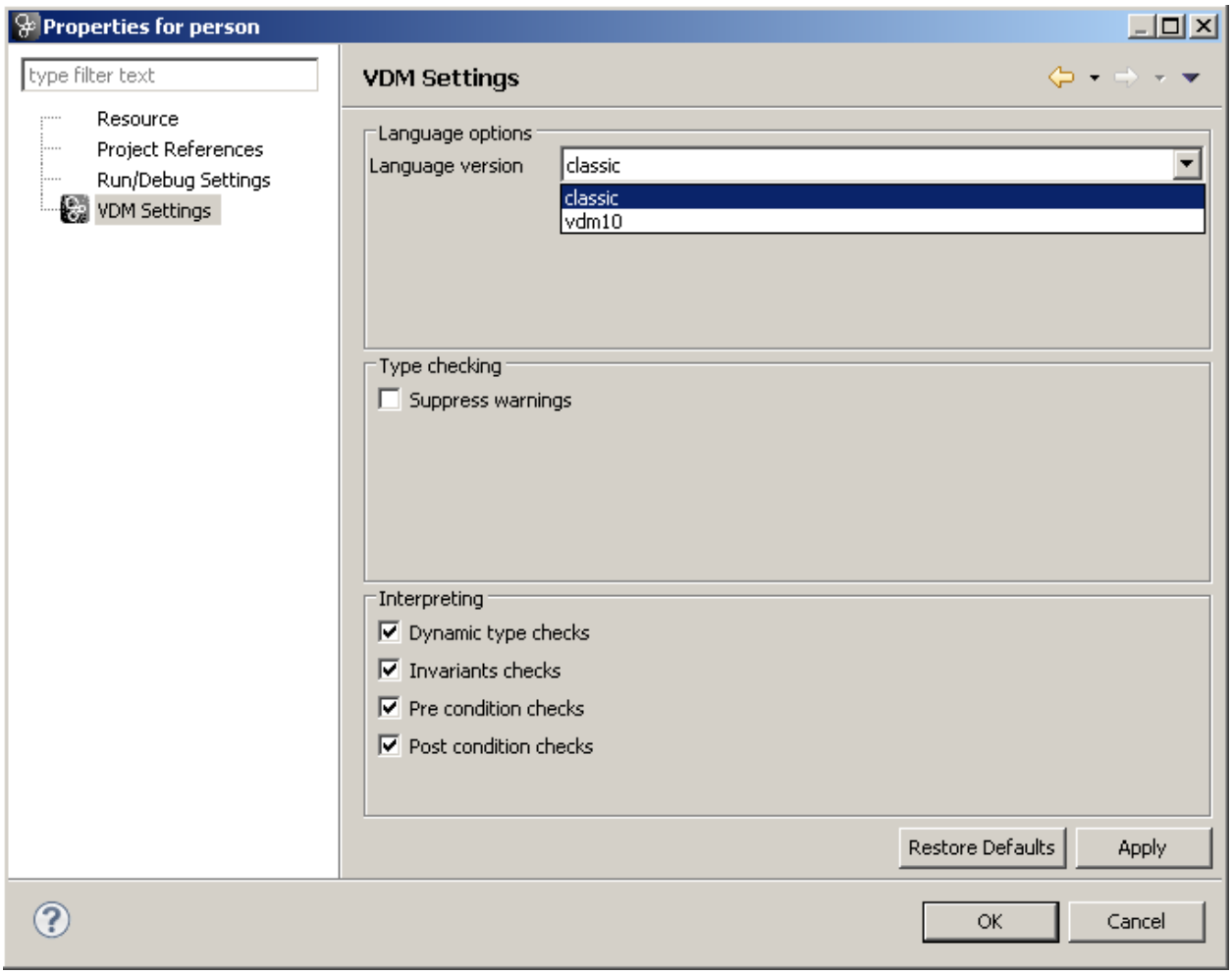


Figure 8: Overture Project Settings

Invariant checks: This is an option to the interpreter which per default is switched on for continuously also checking both state and type invariants of the values during interpretation of a VDM model. It is possible to swich off this checking here but note that option requires dynamic type checking also to be swiched on.

Pre condition checks: This is an option to the interpreter which per default is switched on for continuously checking pre-conditions for all functions and operations during interpretation of a VDM model. It is possible to swich off this checking here.

Post condition checks: This is an option to the interpreter which per default is switched on for continuously checking post-conditions for all functions and operations during interpretation of a VDM model. It is possible to swich off this checking here.

5 Editing VDM models

5.1 VDM Dialect Perspectives

Whenever one wish to edit parts of a VDM model it can be done in the editor view. In general it is recommended to make use of the VDM dialect perspective when one wish to carry out the editing, since browsing in the VDM model is supported both by the editor view as well as by the Outline view. Whenever editing is carried out in the edit view syntax checking is carried out continuously (even before the files are saved). Once files are saved the syntax checking is acompanied by type checking of the entire VDM model if no syntax errors are found. As a result new problems (errors and/or warnings) can be found. These will be displayed both in the problems view as well as with small icons in the editor view at the lines where the problems have been identified.

5.2 Using Templates

Templates can be particularly useful when modifying VDM-SL models. If you hit the key combination *CTRL+space* after the initial characters of the template needed, Overture triggers a proposal. For example, if you type ”fun” followed by *CTRL+space*, the Overture IDE will propose the use of an implicit or explicit function template as shown in Figure 9. The Overture IDE supports several types of template: cases, quantifications, functions (explicit/implicit), operations (explicit/implicit) and many more. Additional templates can easily be added in the future. The use of templates makes it much easier for users lacking deep familiarity with VDM syntax to nevertheless construct models.

It is possible to adjust and add to the templates enabled inside the Overture editor. This can be done by selecting the menu called *Window* → *Preferences*. By starting to type *template* the Overture specific preferences for templates will become visible. In Figure 10 it can be seen how the template for cases expressions is defined in Overture. Note that new templates can be added and the already defined ones can be adjusted by selecting the *Edit* button. It is also possible to remove templates using the *Remove* button.

6 Interpretation and Debugging in Overture

This section describes how to debug a model using the Overture IDE.

6.1 Debug configuration

Debugging the model under development is done by creating a debug configuration from the menu *Run* → *Debug configuration* . . . The debug configuration dialog requires the following information as input to start the debugger: the project name, the class and the starting operation/function. Figure 11 shows a debug configuration, clicking one of the browse buttons will open a dialog which give the user a list of choices. The class and operation/function are chosen from the dialog with the list of expandable classes, if the operation or function have arguments these must be typed

```
30 functions
31
32   NumberOfExperts: Period * Plant -> nat
33   NumberOfExperts(peri,plant) ==
34     card plant.schedule(peri)
35   pre peri in set dom plant.schedule;
36
37   ExpertIsOnDuty: Expert * Plant -> set of Period
38   ExpertIsOnDuty(ex,mk_Plant(sch,-)) ==
39     {peri| peri in set dom sch & ex in set sch(peri)};
40
41   ExpertToPage(a:Alarm,peri:Period,plant:Plant) r: Expert
42   pre peri in set dom plant.schedule and
43       a in set plant.alarms
44   post r in set plant.schedule(peri) and
45        a.quali in set r.quali;
46
47   QualificationOK: set of Expert * Qualification -> bool
48   QualificationOK(exs,reqquali) ==
49     exists ex in set exs & reqquali in set ex.quali
50
51   functionName :  parameterTypes -> resultType
52   functionName (parameterNames) == expression
53   pre preCondition
54   post postCondition
55
```

Figure 9: Explicit function template

in manually. Alternatively one can get to the *Debug Configuration* by right clicking on a project in the Explorer view and then selecting the *Debug As* → *debug Configuration*. Finally it is also possible to get to the *Debug Configuration* by using the small downwards pointing arrow next to the debug icon () at the top of the Overture tool.

6.2 Debug Perspective

The Debug Perspective contains the views needed for debugging in VDM. Breakpoints can easily be set at desired places in the model, by double clicking in left margin. When the debugger reaches the location of the breakpoint, the user can inspect the values of different identifiers and step through the VDM model line by line.

The debug perspective shows the VDM model in an editor as the one used in the Overture Perspective, but in this perspective there are also views useful during debugging. The features provided in the debug perspective are described below. The Debug Perspective is illustrated on Figure 12

The *Debug view* is located in the upper left corner in the Debug perspective. The Debug view shows all running models and the call stacks belonging to them. It also shows whether a given model is stopped, suspended or running. All threads are also shown, along with their running status. It is possible to switch between threads from the Debug view.

At the top of the view are buttons for controlling debugging such as; stop, step into, step over

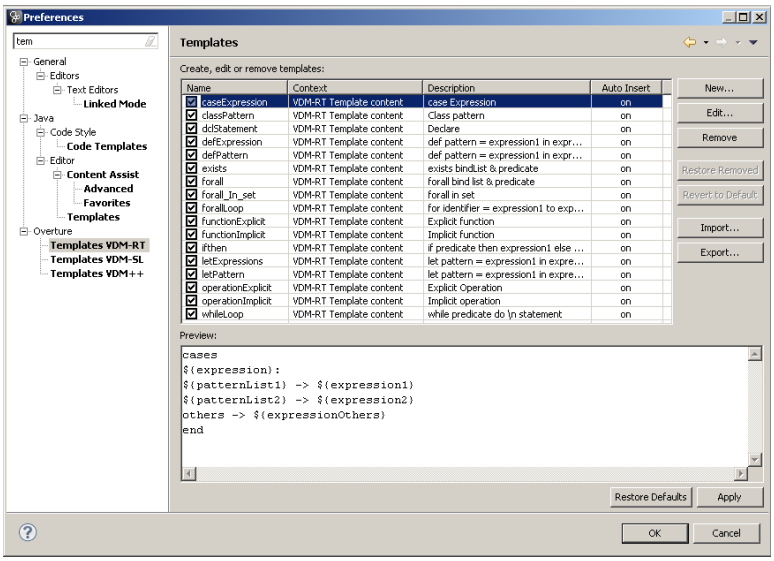


Figure 10: Adjusting templates for Overture

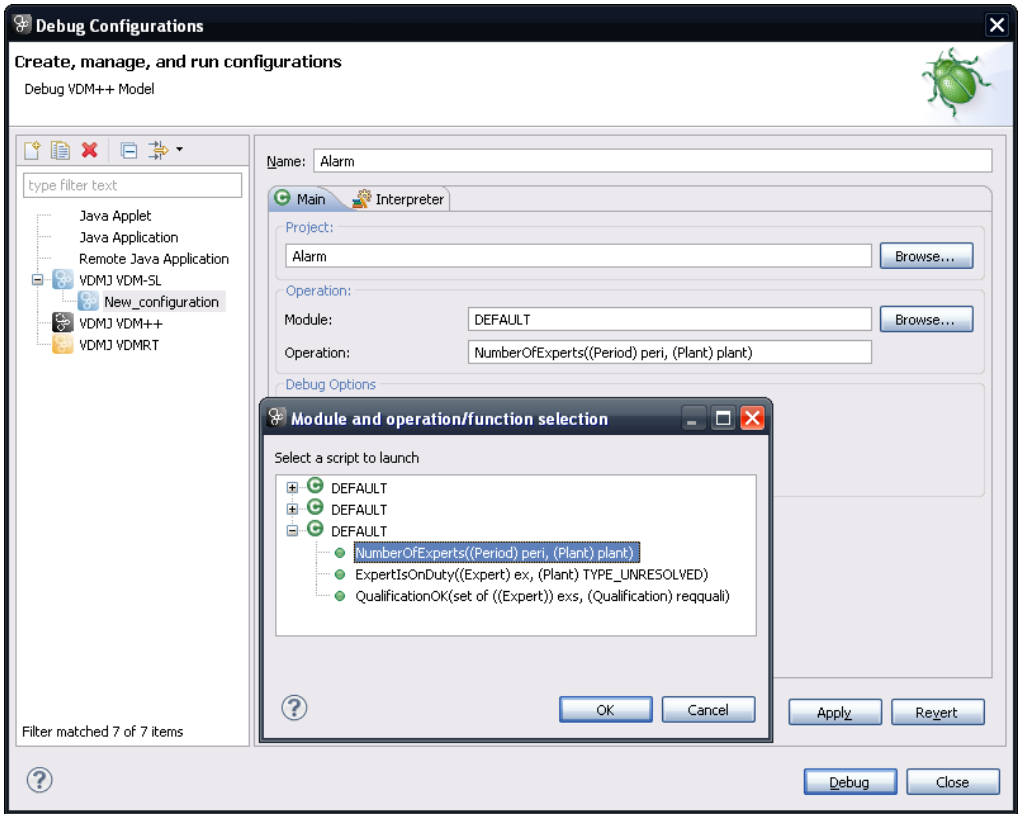


Figure 11: The debug configuration dialog

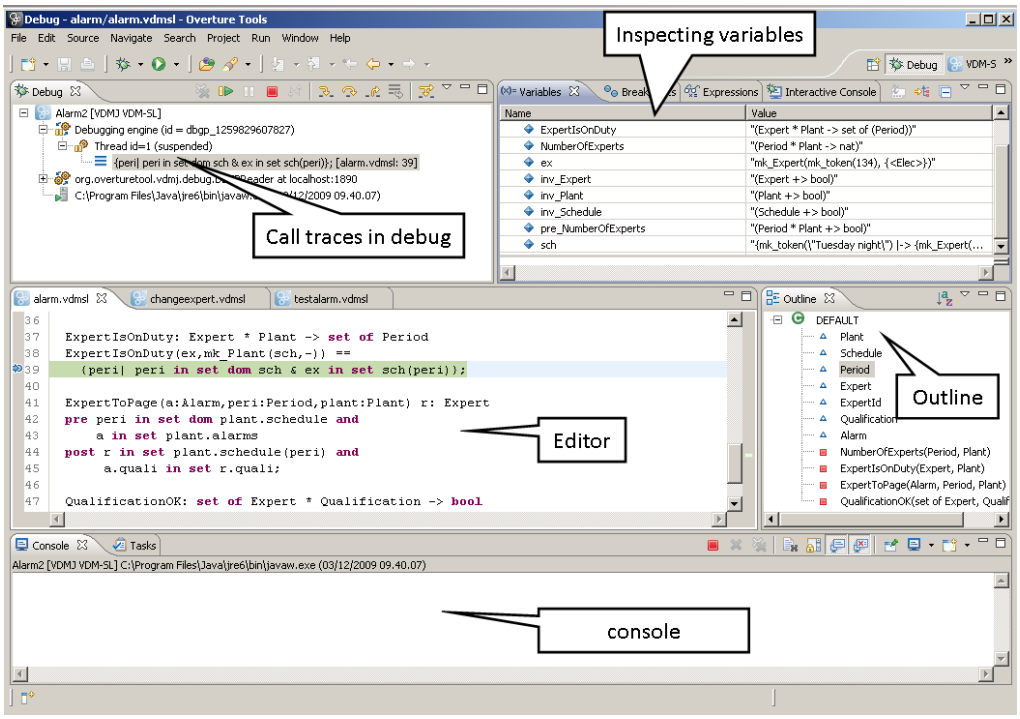


Figure 12: Debugging perspective

Table 1: Overture debugging buttons

Button	Explanation
	Resume debugging
	Suspend debugging
	Terminate debugging
	Step into
	Step over
	Step return
	Use step filters

and resume. These are standard Eclipse debugging buttons (see Table 1).

6.2.1 Debug View

The debug View is located in the upper left corner in the Debug Perspective - see Figure 12. The debug view shows all running models and the call stack belonging to them. It also displays whether a given model is stopped, suspended or running. In the top of the view buttons for debugging such as; stop, step into, step over, resume, etc. are located. All threads are also shown, along with their running status. It is possible to switch between threads from the Debug View.

6.2.2 Variables View

This view shows all the variables in a given context, when a breakpoint is reached. The variables and their values displayed are automatically updated when stepping through a model. The variables view is by default located in the upper right hand corner in the Debug Perspective. It is also possible to inspect complex variables, expanding nested structures and so forth.

6.2.3 Breakpoints View

Breakpoints can be added both from the edit perspective and the debug perspective from the editor view. In the debug perspective however, there is a breakpoints view that shows all breakpoints. From the breakpoints view the user can easily navigate to the location of a given breakpoint, disable, delete or set the hit count or a break condition. In Figure 12 the Breakpoints View is hidden behind the Variables View in the upper right hand corner in a tabbed notebook. Section 6.2.6 explains how to use conditional breakpoints.

6.2.4 Expressions View

The expressions view allows the user to write expressions, as for the variables view, the expressions are automatically updated when stepping. Watch expressions can be added manually or created by selecting 'create watch expression' from the variables view. It is of course possible to edit existing expressions. Like the Breakpoints View this view is hidden in the upper right hand corner.

6.2.5 Interactive Console View

While the Expressions View allows to easily inspect values, the functionality is somewhat limited compared with the functionality provided by VDMTools. For more thorough inspections the Interactive Console View is more suited. Here commands can be executed on the given context, i.e. where the debugger is at a breakpoint. The Interactive console keeps a command history, so that already executed commands can be run again without actually typing in the command all over. Figure 13 shows the interactive console.

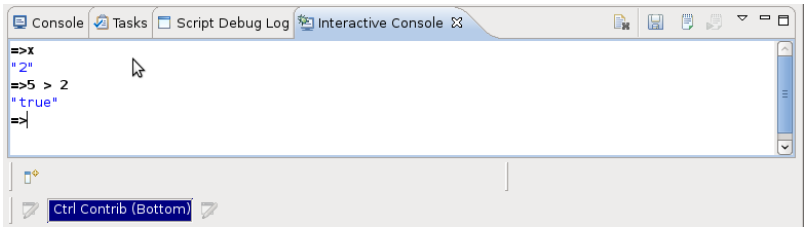


Figure 13: The interactive console

6.2.6 Conditional breakpoints

Conditional breakpoints can also be defined. These are a powerful tool for the developer since it allows specifying a condition for one or more variables which has to be true in order for the debugger to stop at the given breakpoint. Apart from specifying a break condition depending on variables, a hit count can also be defined. A conditional breakpoint with a hit count lets the user specify a given number of calls to a particular place at which the debugger should break.

Making a breakpoint conditional is done by right clicking on the breakpoint mark in the left margin and select the option Breakpoint properties... This opens a dialog like the one shown in Figure 14. It is possible to choose between two different conditional breakpoints, a hit count condition and one based on an expression defined by the user.

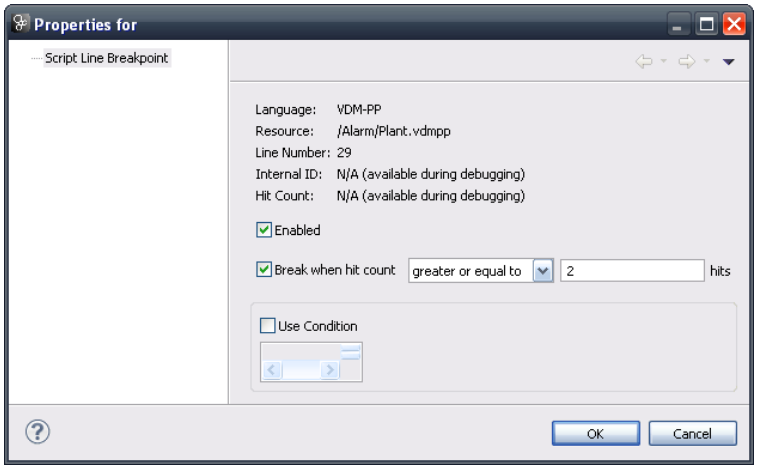


Figure 14: Conditional breakpoint options

7 Collecting Test Coverage Information

When a VDM model is being interpreted it is possible to automatically collect test coverage information. Test coverage measurement helps you to see how well a given test suite covers the VDM

model. This is done by collecting information in a special test coverage file about which statements and expressions are evaluated during the execution of the test suite.

More

8 Pretty Printing to LaTeX

Include `overture.tex` which among other things makes use of the `times.cls` and `listings.cls` style classes. This emables the use of the standard `lstlisting` environment for type setting source text and display it in a tele-type proportional font where all VDM keyword are typeset in a bold font. Per default the listings will be inserted into boxes but it is easy to adjust (using the parameters to the `lstlisting` environment) if no boxes are desired.

It is possible to use literate programming/specification [Johnson96] just as inside VDMTools. Then one needs to use the LaTeX text processing system with plain VDM models mixed with textual documentation. The VDM model parts must be enclosed within "`\begin{vdm_al}`" and "`\end{vdm_al}`". The text-parts outside the specification blocks are ignored by the parser (but used by the pretty-printer).

9 Managing Proof Obligations

In the different VDM dialects it is possible to identify places where run-time errors potentially could occur if the model was to be executed. In essence these can be considered as additional to the existing type checking performed. Just like almost all other computer based languages it is not possible to automatically statically check if such places indeed could result in a run-time error or not. Thus Overture provides socalled "proof obligations" for all places where such run-time errors "could" occur. Each *Proof Obligation* (PO) is formulated as a predicate that must hold on a particular place of the VDM model and thus it may have particular context information associated with it. These POs can be considered as constraints that will gurantee the internal integrity of the VDM models if they are all correct. In the long term it will be possible to prove these constraints by a proof component in Overture but this is not yet working as well as we wish.

It takes a little time for newcommers to VDM to get used to the form of these so it may be worthwhile to elaborate a bit on the form of the proof obligations. Theses can be divided into different categories depending upon their nature. These can be found in Appendix F along with a small explanation for each of them.

The proof obligation generator is invoked either on a VDM project (and then POs for all the VDM model files will be generated) or for a selected VDM file one can right click in the *Explorer* view and then select the *Proof Obligations* → *Generate Proof Obligations* menu item. Overture will then change into a special *Proof Obligations Perspective* as shown in Figure 15.

Note that in the *Proof Obligation Explorer* view each proof obligation have a number of components:

- A unique number in the list shown;

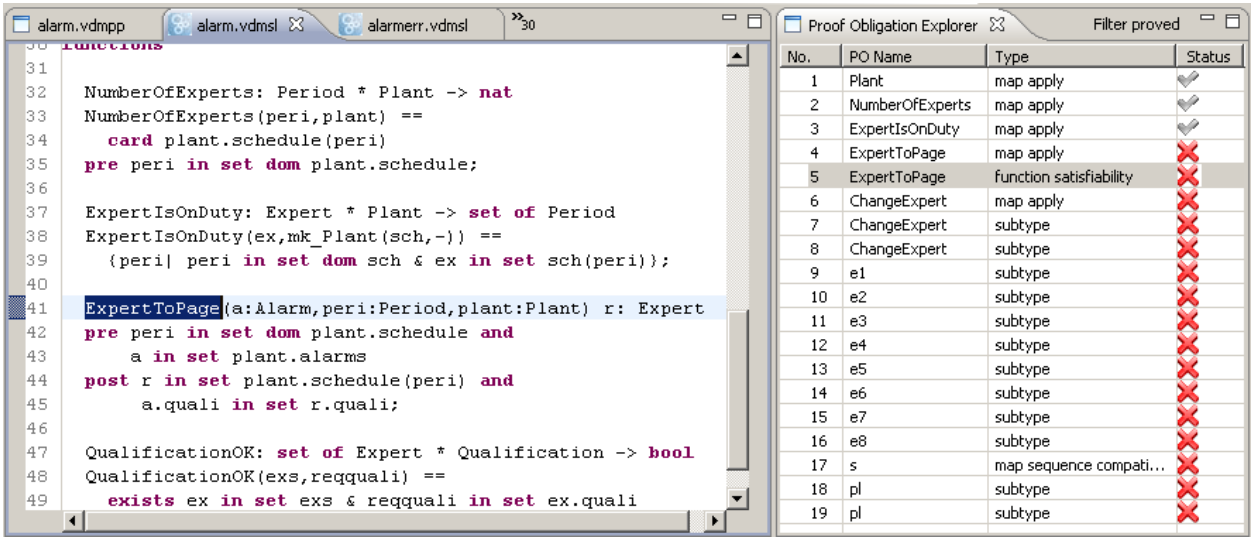


Figure 15: The Proof Obligation perspective

- The name of the definition in which the proof obligation is generated from;
- The proof obligation category (type) and finally
- A status field indicating whether the proof obligation is trivially correct or would have to be proved by a normal proof engine.

Note that at the top of the *Proof Obligation Explorer* it is possible to filter away all the proof obligations that are trivially correct pressing the *Filter proved* button at the top of this view.

10 Combinatorial Testing

In order to automate parts of the testing process a notion of *traces* have been introduced into VDM++ (note that this is only available for VDM-SL models if VDM-10 have been selected). Such traces conceptually correspond to regular expressions that can be expanded to a collection of test cases. Each such test case is then composed as a sequence of operation calls. If a user defines such traces it is possible to make use of a special combinatorial testing perspective that enables the automatic unfolding of the traces and automatic execution of each of the test cases. Subsequently the results of running all these can be inspected and test cases that have detected errors in the VDM++ model can easily be found and the user can then fix the problem and reuse the same traces definitions.

10.1 The Use of the Trace Definition Syntax

The syntax for trace definitions are defined as:

traces definitions = 'traces', { named trace } ;

named trace = identifier, { '/', identifier }, ':', trace definition list ;

The naming of trace definitions (with the "/" separator) is used for indicating the paths that are used for generated argument files for test cases (`.arg`) and the corresponding result files (`.res`)[3].

trace definition list = trace definition term, { ';', trace definition term } ;

So the "**;**" operator is used for indicating a sequencing relationship between its *trace definition term*'s.

trace definition term = trace definition
| trace definition term, '|', trace definition ;

So the "|" operator is used for indicating alternative choices between trace definitions.

trace definition = trace core definition
| trace bindings, trace core definition
| trace core definition, trace repeat pattern
| trace bindings, trace core definition, trace repeat pattern ;

Trace definitions can have different forms and combinations:

- Core definitions which includes application of operations and bracketed trace expressions.
- Trace bindings where identifiers can be bound to values and in case of looseness (**`let`** *bind* **`in set`** *setexpr* **`in`** *expr*) this will give raise to multiple test cases generated.
- Trace repeat patterns which are used whenever repetition is desired.

trace core definition = trace apply expression
| trace bracketed expression ;

trace apply expression = identifier, '.', identifier, '(', expression list, ')' ;

Trace apply expressions are the most basic element in trace definitions. The identifier before the "**.**" indicate an object for with the operation (listed after the "**.**") is to be applied with a list of arguments (the expression list inside the brackets). Note that with the current syntax for trace definitions apply expressions are limited to this form `instid.opid(args)` so it is for example not at the moment possible to call an operation in the same class directly as `opid(args)`. Nor is it possible with the current syntax to make use of a particular operation in a superclass in case of multiple possible ones which in VDM++ is would be written as `instid.clid`opid(args)`. In the current version it is also not allowed to call functions here directly, although that may be changed at some stage in the future.

[3]Currently the full path names are however not supported in an Overture context but this is envisaged in the future.

```
trace repeat pattern = '*'
                     | '+'
                     | '?'
                     | '{', numeric literal, '}'
                     | '{', numeric literal, ',' numeric literal, '}' ;
```

The different kinds of repeat patterns have the following meanings:

- '*' means 0 to n occurrences (n is tool specific).
- '+' means 1 to n occurrences (n is tool specific).
- '?' means 0 or 1 occurrences.
- '{', n, '}' means n occurrences.
- '{', n, ',' m '}' means between n and m occurrences.

```
trace bracketed expression = '(', trace definition list, ')' ;

trace bindings = trace binding, { trace binding } ;

trace binding = 'let', local definitions, { ',', local definition }, 'in'
              | 'let', bind, 'in'
              | 'let', bind, 'be', 'st', expression, 'in' ;
```

10.2 Using the Combinatorial Testing GUI

If one have used the **`traces`** syntax described above it is possible to go to the *Combinatorial testing* perspective. An example of using that perspective can be seen in Figure 16.

Different icons are used to illustrate the verdict in a test case. These are:

 : This icon is used to indicate that the test case has not yet been executed.

 : This icon is used to indicate that the test case has a pass verdict.

 : This icon is used to indicate that the test case has an inconclusive verdict.

 : This icon is used to indicate that the test case has a fail verdict.

 : If test cases result in a run-time error other test cases with the same prefix will be filtered away and thereby skipped by in the test execution. The number of skipped test cases is indicated after number of test cases for the trace definition name.

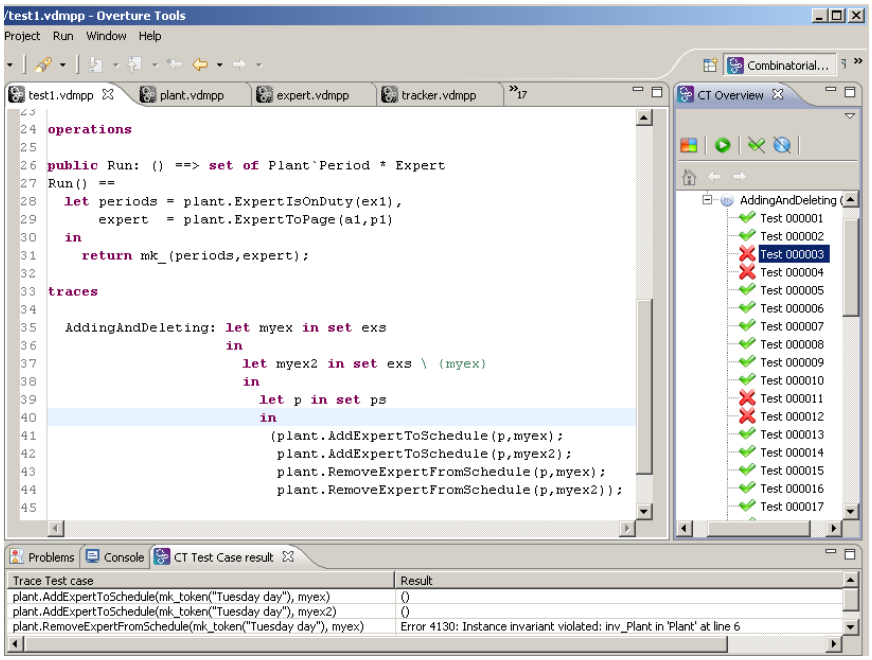


Figure 16: Using Combinatorial Testing

11 Mapping VDM++ back and forth to UML

For VDM++ projects (and later on also for VDM-RT projects) it is possible automatically to move back and forth between a VDM++ model and its corresponding UML model. Essentially these can be considered as different views of the same model. The UML model is typically used as a graphical overview of the model using class diagrams and the sequence diagrams can be used to indicate the desired test scenarios that a user would like to perform. The VDM++ model is typically used as the model where the details for each definition can be found and used for detailed semantic analysis. The exchange between VDM++ and UML is done using the XML formal called XMI. At the moment only the UML tool Enterprise Architect is supported. Export from EA is done by selcted the *Project* menu and selecting *Import/Export → Export Package to XMI*. This is illustrated in Figure 17.

Mapping back and forth between a VDM++ model and a UML model is in practice done from the *Explorer* view where right-clicking on the project will result in a menu popping up. In this menu there is an entry for *UML transformation*. If this is selected it is either possible to *Import XMI* if one wish to import UML definitions from UML or to *Export XMI* if one wish to go from VDM++ to UML.

At the class diagram at the UML level additional classes will be generated for standard VDM++ basic types. When such UML models are mapped back to VDM++ such additional classes are ignored.

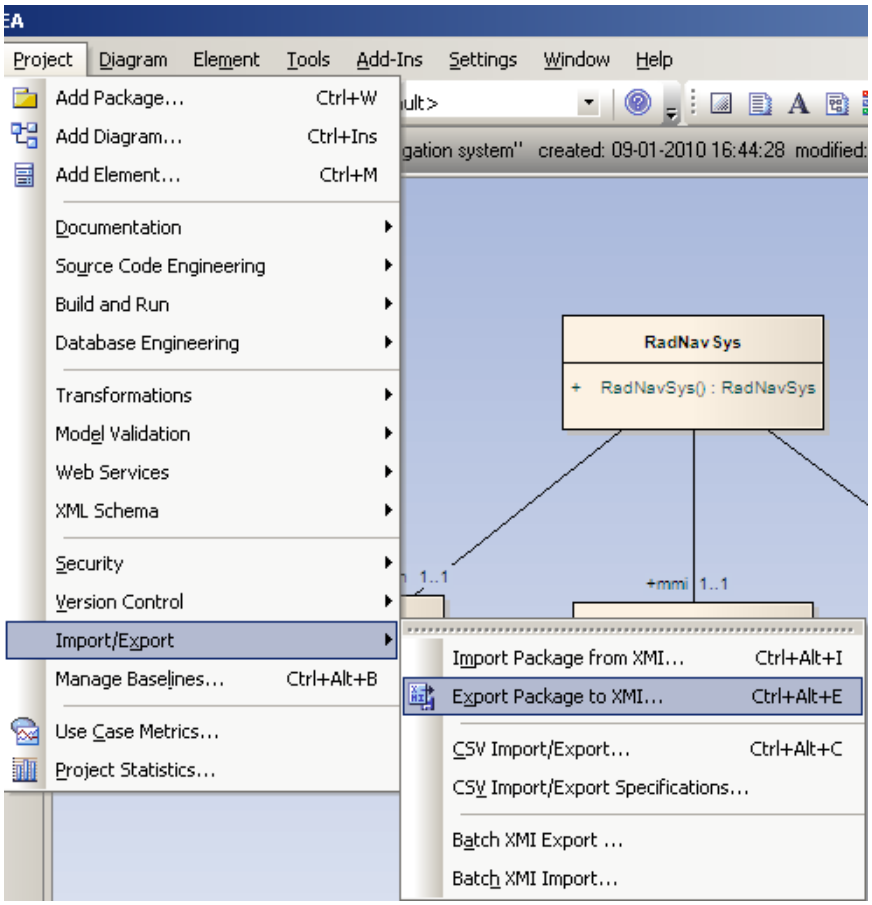


Figure 17: Exporting UML definitions from EA

12 Moving from VDM++ to VDM-RT

In the methodology for the development of distributed real-time embedded systems using the VDM techniology there is a step where one moves from a VDM++ model to a VDM-RT model [Larsen&09]. This step is supported by the Overture tool suite where it is possible to copy a VDM++ project into the starting point for a VDM-RT project. This is done by right clicking on the VDM++ project to be converted in this fashion in the Project Explorer view. In the menu that comes up one then need to select the *Overture Utility → Create Real Time Project*. As a consequence a new VDM-RT project is created. It will be called exactly the same as the VDM++ project with `RT` appended to the project name. Inside the project all the `vdmpp` files will instead have the `vdmrt` extension. The original VDM++ project is not changed at all. Thus this is simply an easy way to fast get the starting point for a VDM-RT model developed. One then manually need to create a **system** with appropriate declarations of `CPU`s and `BUS`ses.

13 Analysing and Displaying Logs from VDM-RT Executions

When a VDM-RT model is being executed a textual logfile is created in a "`logs/debugconfig`" folder with the *.logrt* extension. The file name for the logfile indicates the time at which it has been written so it is possible to store multiple of these. This logfile can be viewed in the build-in Real-Time Log Viewer, by double-clicking the file in the project view. The viewer enables the user to explore system execution in various perspectives. In Figure 18 the architectural overview of the system is given, describing the distributed nature of the model.

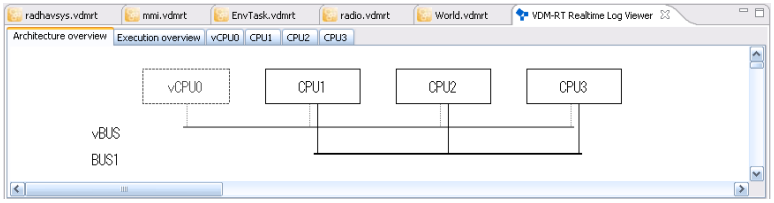


Figure 18: Architectural overview

The RealTime Log Viewer also enables the user to get an overview of the model execution on a system level – this can be seen in Figure 19. This view shows how the different CPUs communicate via the BUSes of the system.

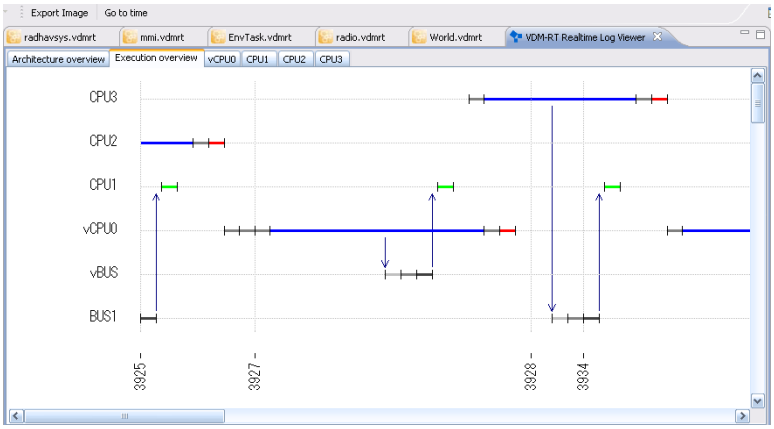


Figure 19: Execution overview

Since the complete execution of the model cannot be shown in a normal sized window, the user has the option of jumping the a certain time using the *Go to time* button. It is also possible to export all the generated views to *JPG* format using the *Export Image* button. All the generated pictures will be placed in the "`logs`" folder.

In addition to the execution overview, the RealTime Log Viewer can also give an overview of all executions on a single CPU. This view gives a detailed description of all operations and

functions invoked on the CPU as well as the scheduling of concurrent processes. This can be seen in Figure 20.

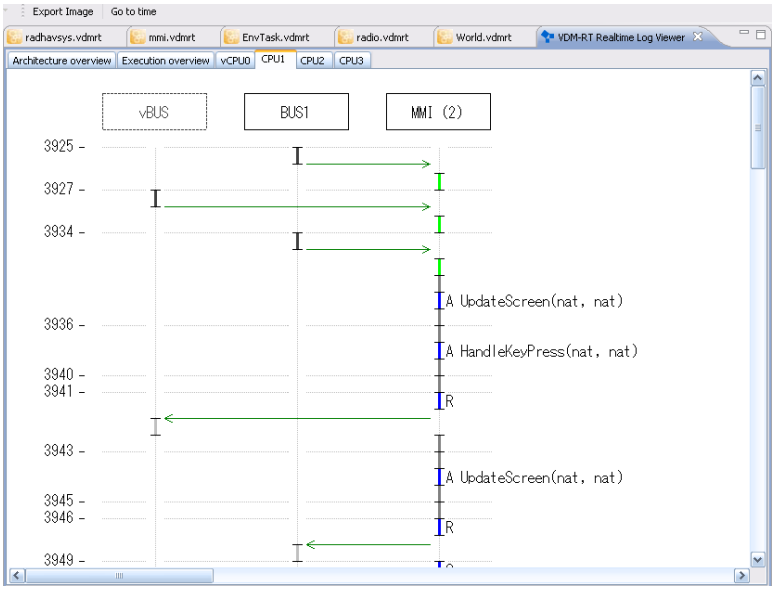


Figure 20: Execution on single CPU

14 A Command-Line Interface to VDMJ

A central part of the Overture tool is a Java application called VDMJ that provides a command-line interface that may be valuable for users outside the Eclipse interface of Overture.

14.1 Starting VDMJ

VDMJ is contained entirely within one jar file. The jar file contains a MANIFEST that identifies the main class to start the tool, so the minimum command line invocation is as follows:

```
$ java -jar vdmj-2.0.0.jar
VDMJ: You must specify either -vdmsl, -vdmpp or -vdmrt
Usage: VDMJ <-vdmsl | -vdmpp | -vdmrt> [<options>] [<files>]
```

So the first parameter indicates the VDM dialect used and then various extra options can be used. These are:

-w: This will suppress all warning messages.

-q: This will suppress all information messages, such as the number of source files processed etc.

-i: This will start the interpreter if the VDM model is successfully parsed and type checked, otherwise the errors discovered will be listed.

-p: This will generate all proof obligations for the VDM model (if it is syntax and type correct) and then stop.

-e <exp>: This will evaluate the <exp> print the result and stop.

-c <charset>: This will select a file character set. This is to allow a specification written in languages other than the default for your system to be used (see section **??**).

-t <charset>: This will select a console character set. The output terminal can use a different character set to the specification files.

-o <filename>: This will save the internal representation of a parsed and type checked specification. Such files are effectively libraries, and can be can be re-loaded without the parsing/checking overhead. If files are sufficiently large, this may be faster.

-pre: This will disable all pre-condition checks.

-post: This will disable all post-condition checks.

-inv: This will disable type/state invariant checks.

-dtc: this will disable all dynamic type checking.

-log: This will enable VDM-RT real-time event logging. These are useful with the Overture Eclipse GUI, which has a plugin to display timing diagrams (see Section 13).

Normally, a VDM model will be loaded by identifying all of the VDM source files to include. At least one source file must be specified unless the -i option is used, in which case the interpreter can be started with no specification. If a directory is specified rather than a file, then VDMJ will load all files in that directory with a suffix that matches the dialect (eg. *.vdmpp files for VDM++). Files and directory arguments can be mixed.

If no `-i` option is given, the tool will only parse and type check the VDM model files, giving any errors and warnings on standard output, then stop.

The `-p` option will run the proof obligation generator and then stop, assuming the specification has no type checking errors.

For batch execution, the `-e` option can be used to identify a single expression to evaluate in the context of the loaded specification, assuming the specification has no type checking errors.

14.2 Parsing, Type Checking, and Proof Obligations

All specification files loaded by VDMJ are parsed and type checked automatically. There are no type checking options; the type checker always uses "possible" semantics. If a specification does not parse and type check cleanly, the interpreter cannot be started and proof obligations cannot be generated (though warnings are allowed).

All warnings and error messages are printed on standard output, even with the `-q` option. A source file may contain VDM embedded in a LaTeX file using `vdm_al` environments (see Section 8); the markup is ignored by the parser, though reported line numbers will be correct.

The Java process will return with an exit code of zero if the specification is clean (ignoring warnings). Parser or type checking errors result in an exit code of 1. The interpreter and PO generator always exit with a code of zero.

14.3 The Interpreter with Debugging Fuctionality

Assuming a specification does not contain any parse or type checking errors, the interpreter can be started by using the `-i` command line option. The interpreter is an interactive command line tool that allows expressions to be evaluated in the context of the specification loaded. For example, to load and interpret a VDM-SL specification from a single file called `shmem.vdmsl`, the following options would be used:

```
$ java -jar vdmj-2.0.0.jar -vdmsl -i shmem.vdmsl
Parsed 1 module in 0.266 secs. No syntax errors
Type checked in 0.047 secs. No type errors
Interpreter started
```

The interpreter prompt is ">". The interactive interpreter commands are as follows (abbreviated forms are permitted for some, shown in square brackets):

modules: This command lists the loaded module names in a VDM-SL specification. In case of a flat VDM-SL model the name `DEFAULT` is used. The default module will be indicated in the list displayed.

classes: This command lists the loaded class names in both VDM++ and VDM-RT specifications. The default class will be indicated in the list displayed.

default <module/class>: This command sets the default module/class name as the prime scope for which the lookup of identifiers appear (i.e. names in the default module do not need to be qualified, so you can say "`print xyz`" rather than "`print M`xyz`").

create <id> := <exp>: This command is only available for the VDM++ and VDM-RT dialects. It creates a global variable that can be used subsequently in the interpreter. It is mostly used for creating global instances of classes.

log [<file> | off]: This command can only be used in VDM-RT models. It starts to log real-time events to the file indicated. By default, event logging is turned off, but logging can be enabled to the console by using log with no arguments, or to a file using textttlog ¡filename¿. Logging can subsequently be turned off again by using textttlog off. The events logged include requests, activations and completions of all functions and operations, as well as all creation of instances of classes, creation of CPUs and BUSses, deployment of objects to specific CPUs and the swapping in an out of threads.

threads: This command can only be used for the VDM++ and VDM-RT dialects. It lists the active threads with status information for each thread.

state: This command can only be used for the VDM-SL dialect and shows the default module state. The value of the state can be changed by operations called.

[p]rint <expression>: This command evaluates the expression provided in the current context. Note that if combinatorial traces are defined in the model using the syntax from Section 10.1 then the `print` command can also be used to evaluate a named trace. This will carry out the combinatorial test by expanding all the regular expressions and executing the resulting operation sequences.

assert <file>: This command runs assertions from the file provided. The assertions in the file must be Boolean expressions, one per line. This command evaluates each assertion in turn, raising an error for any which is false.

init: This command re-initializes the global environment. Thus all state components will be initialised to their initial value again, created variables are lost and code coverage is reset.

env: This command lists the value of all global symbols in the default environment. This will show the signatures for all functions and operations as well as the values assigned to identifiers from value definitions and global state definitions (in VDM++ terminology, public static instance variables). Note that this includes invariant, initialization and pre/postcondition functions. In the VDM++ and VDM-RT dialects the identifiers created using the `create` command will also be included.

pog: This command generates a list of all proof obligations for the VDM model that is loaded.

break [<file>:]<line#> [<condition>]: This command create a breakpoint at a specific file and line and optionally makes it a conditional breakpoint.

break <function/operation> [<condition>]: This command creates a breakpoint at the start of a function or an operation and optionally makes it a conditional breakpoint.

trace [<file>:]<line#> [<exp>]: This command creates a tracepoint for a specific line inside one of the source files. A tracepoint is similar to a breakpoint but with an implcit continue after it. This creates a trace of the expression given whenever the tracepoint is reached.

trace <function/operation> [<exp>]: This command create a tracepoint at the start of a function or operation. See `trace` above for an explanation of tracepoints.

remove <breakpoint#>: This command removes a trace/breakpoint by referring to its number (given by the `list` command).

list: This command provides a list of all current trace/breakpoints by number.

coverage [<file>|clear]: This command displays/clears file line test coverage. The coverage command displays the source code of the loaded VDM model (by default, all source files are listed), with "+" and "-" signs in the left hand column indicating lines which have been executed or not, respectively. Finally, the percentage coverage of each source file is displayed.

latex|latexdoc [<files>]: This command generates LaTeX line coverage files. These are LaTeX versions of the source files with parts of the specification highlighted where they have not been executed. The LaTeX output also contains a table of percentage cover by module/class and the number of times functions and operations were hit during the execution. The `latexdoc` command is the same, except that output files are wrapped in LaTeX document headers. The output files are written to the same directory as the source files, one per source file, with the extension `.tex`. Coverage information is reset when a specification is loaded, when an `init` command is given, or when the command
texttttcoverage clear is executed, otherwise coverage is cumulative. If several files are loaded, the coverage for just one source file can be listed with `coverage <file>` or `latex <file>`.

files: This command list all source files loaded.

reload: This command will re-parse and type check the VDM model files currently loaded. Note that if there are any errors in the parse or type check of the files, the interpreter will exit after reload.

load <files>: This command replace current loaded VDM model files. Note that if there are any errors in the parse or type check of the files, the interpreter will exit after load.

[q]uit: This command leave the interpreter.

When the interpretation of a VDM model is stopped at a breakpoint, there are additional commands that can be used. These are:

[s]tep: This command steps forward until the current expression/statement is on a new line.

[n]ext: This command is similar to
texttttstep except function and operation calls are stepped over.

[o]ut: This command runs to the return of the current function or operation.

[c]ontinue: This command resumes execution and continues until the next breakpoint or completion of the thread that is being debugged.

stack: This command displays the current stack frame context (i.e. the call stack).

up: This command moves the stack frame context up one frame to allow variables to be seen.

down: This command moves the stack frame context down one frame.

source: This command lists VDM source around the current breakpoint.

stop: This command terminate the execution immediately.

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A Internal Errors

This appendix provides a list of the internal errors used in Overture and an explanantion, for each of them, the circumstances under which the internal error can be expected. Most of these errors should never be seen by an ordinary user, so if they appear please report it to the SourceForge bug reporting utility (`https://sourceforge.net/tracker/?group_id=141350&atid=749152`).

0000: File IO errors, e.g. `File not found`. This typically occurs if a specification file is no longer present.

0001: `Mark/reset not supported - use push/pop`

0002: `Cannot change type qualifier: <name><qualifiers> to <qualifiers>`

0003: `PatternBind passed <class name>`

0004: `Cannot get bind values for type <type>`

0005: `Illegal clone`

0006: `Constructor for <class> can't find <member>`

0007: `Cannot write to IO file <name>`

0009: `Too many syntax errors`. This error typically occurs if one have included a file that is in a non VDM format and by mistake have given it a vdm file extension (`vdmsl`, `vdmpp` or `vdmrt`).

0010: `Too many type checking errors`

0011: `CPU or BUS creation failure`

0012: `Document has no specifications?`

0013: `Document has no expression?`

0014: `Unexpected type in definition block`

0015: `Unexpected type definition shape: <type>`

0016: `Typeless functions not supported`

0017: `Unexpected function shape: <shape>`

0018: `Unknown function body type`

0019: `Unexpected operation shape: <shape>`

0020: `Unknown operation body type`

0021: `Unknown instance variable type`

0022: `Unknown sync predicate type`

0023: `Expecting integer periodic argument`

0024: `Sporadic threads not implemented`. In the PhD thesis from Marcel Verhoef a notion of sporatic threads are included. However these are not (yet) incorporated into Overture.

0025: `Unknown thread specification type`

0026: `Let binding expects value definition`

0027: `Bare Dcl statement encountered`

0028: `Unknown trace specification type`

0029: `DBGP: <reason>`. This error is related to the protocol used between the GUI part of the debugger inside Eclipse and the underlying interpreter implementation inside VDMJ.

0030: `Statement type unsupported: <type>`

0031: `Expected object state designator type`

0032: `Expected object state designator type`

0033: `Expected state designator type`

0034: `Native library error`

0035: `Expression type unsupported: <type>`

0036: `Unexpected pattern/bind type`

0037: `Unexpected pattern/bind type`

0038: `Unexpected pattern/bind type`

0039: `Unexpected bind type`

0040: `Unexpected bind type`

0041: `Expected set bind type`

0042: `Expected set bind type`

0043: `Operator type unsupported: <type>`

0044: `Tuple field select is not a number`

0045: Unexpected expression type: <type>

0046: Unexpected literal expression

0047: Class instantiation not supported

0048: Unexpected type expression

0049: Unexpected literal pattern type

0050: Unexpected pattern type

0051: Unexpected scope value

0052: Cannot set default name at breakpoint

B Lexical Errors

When a VDM model is parsed, the first phase is to gather the single characters into tokens that can be used in the further processing. This is called a lexical analysis and errors in this area can be as follows:

1000: `Malformed quoted character`

1001: `Invalid char <ch> in base <n> number`

1002: `Expecting '|->'`

1003: `Expecting '...'`

1004: `Expecting '<-:'`

1005: `Expecting close double quote`

1006: `Expecting close quote after character`

1007: `Unexpected tag after '#'`

1008: `Malformed module‘name`

1009: `Unexpected character '<c>'`

1010: `Expecting <digits>[.<digits>][e<+-><digits>]`

1011: `Unterminated block comment`

C Syntatic Errors

If the syntax of the file you have provided does not live up to the syntax rules for the VDM dialect you wish to use, syntax errors will be reported. These can be as follows:

2000: `Expecting 'in set' after pattern in set binding`

2001: `Expecting 'in set' in set bind`

2002: `Expecting ':'  in type bind`

2003: `Expecting 'in set' after pattern in binding`

2004: `Expecting 'in set' or ':'  after patterns`

2005: `Expecting list of 'class' or 'system' definitions`

2006: `Found tokens after class definitions`

2007: `Expecting 'end <class>'`

2008: `Class does not start with 'class'`

2009: `Can't have instance variables in VDM-SL`

2010: `Can't have a thread clause in VDM-SL`

2011: `Only one thread clause permitted per class`

2012: `Can't have a sync clause in VDM-SL`

2013: `Expected 'operations', 'state', 'functions', 'types' or 'values'`

2014: `Recursive type declaration`. This is reported in type definitions such as `T = T`.

2015: `Expecting =<type> or ::<field list>`

2016: `Function name cannot start with 'mk_'`

2017: `Expecting ':'  or '(' after name in function definition`

2018: `Function type is not a -> or +> function`

2019: `Expecting identifier <name> after type in definition`

2020: `Expecting '(' after function name`

2021: `Expecting ':'  or '(' after name in operation definition`

2022: `Expecting name <name> after type in definition`

2023: Expecting '(' after operation name

2024: Expecting external declarations after 'ext'

2025: Expecting <name>: exp->exp in errs clause

2026: Expecting 'rd' or 'wr' after 'ext'

2027: Expecting +ive number in periodic statement

2028: Expecting 'per' or 'mutex'

2029: Expecting <set bind> = <expression>

2030: Expecting simple field identifier

2031: Expecting field number after .#

2032: Expecting field name

2033: Expected 'is not specified' or 'is subclass responsibility'

2034: Unexpected token in expression

2035: Tuple must have >1 argument

2036: Expecting mk_<type>

2037: Malformed mk_<type> name <name>

2038: Expecting is_<type>

2039: Expecting maplet in map enumeration

2040: Expecting 'else' in 'if' expression

2041: Expecting two arguments for 'isofbase'

2042: Expecting (<class>,<exp>) arguments for 'isofbase'

2043: Expecting two arguments for 'isofclass'

2044: Expecting (<class>,<exp>) arguments for 'isofclass'

2045: Expecting two expressions in 'samebaseclass'

2046: Expecting two expressions in 'sameclass'

2047: Can't use history expression here

2048: Expecting #act, #active, #fin, #req or #waiting

2049: Expecting 'end <module>'

2050: Expecting library name after 'uselib'

2051: Expecting 'end <module>'

2052: Expecting 'all', 'types', 'values', 'functions' or 'operations'

2053: Exported function is not a function type

2054: Expecting types, values, functions or operations

2055: Imported function is not a function type

2056: Cannot use module'id name in patterns

2057: Unexpected token in pattern

2058: Expecting identifier

2059: Expecting a name

2060: Found qualified name <name>. Expecting an identifier

2061: Expecting a name

2062: Expected 'is not specified' or 'is subclass responsibility'

2063: Unexpected token in statement

2064: Expecting <object>.identifier(args) or name(args)

2065: Expecting <object>.name(args) or name(args)

2066: Expecting object field name

2067: Expecting 'self', 'new' or name in object designator

2068: Expecting field identifier

2069: Expecting <identifier>:<type> := <expression>

2070: Function type cannot return void type

2071: Expecting field identifier before ':'

2072: Expecting field name before ':-'

2073: Duplicate field names in record type

2074: Unexpected token in type expression

2075: Expecting 'is subclass of'

2076: Expecting 'is subclass of'

2077: Expecting 'end' after class members

2078: Missing ';' after type definition

2079: Missing ';' after function definition

2080: Missing ';' after state definition

2081: Missing ';' after value definition

2082: Missing ';' after operation definition

2083: Expecting 'instance variables'

2084: Missing ';' after instance variable definition

2085: Missing ';' after thread definition

2086: Missing ';' after sync definition

2087: Expecting '==' after pattern in invariant

2088: Expecting '@' before type parameter

2089: Expecting '@' before type parameter

2090: Expecting ']' after type parameters

2091: Expecting ')' after function parameters

2092: Expecting '==' after parameters

2093: Missing colon after pattern/type parameter

2094: Missing colon in identifier/type return value

2095: Implicit function must have post condition

2096: Expecting <pattern>[:<type>]=<exp>

2097: Expecting 'of' after state name

2098: Expecting '==' after pattern in invariant

2099: Expecting '==' after pattern in initializer

2100: Expecting 'end' after state definition

2101: Expecting ')' after operation parameters

2102: Expecting '==' after parameters

2103: Missing colon after pattern/type parameter

2104: Missing colon in identifier/type return value

2105: Implicit operation must define a post condition

2106: Expecting ':' after name in errs clause

2107: Expecting '->' in errs clause

2108: Expecting <pattern>=<exp>

2109: Expecting <type bind>=<exp>

2110: Expecting <pattern> in set <set exp>

2111: Expecting <pattern> in set <set exp>

2112: Expecting '(' after periodic

2113: Expecting ')' after period arguments

2114: Expecting '(' after periodic(...)

2115: Expecting (name) after periodic(...)

2116: Expecting <name> => <exp>

2117: Expecting '(' after mutex

2118: Expecting ')' after 'all'

2119: Expecting ')'

2120: Expecting 'e1,...,e2' in subsequence

2121: Expecting ')' after subsequence

2122: Expecting ')' after function args

2123: Expecting ’]’ after function instantiation

2124: Expecting ’)’

2125: Expecting ’is not yet specified

2126: Expecting ’is not yet specified

2127: Expecting ’is subclass responsibility’

2128: Expecting comma separated record modifiers

2129: Expecting <identifier> |-> <expression>

2130: Expecting ’)’ after mu maplets

2131: Expecting ’)’ after mk_ tuple

2132: Expecting is_(expression, type)

2133: Expecting ’)’ after is_ expression

2134: Expecting pre_(function [,args])

2135: Expecting ’}’ in empty map

2136: Expecting ’}’ after set comprehension

2137: Expecting ’e1,...,e2’ in set range

2138: Expecting ’}’ after set range

2139: Expecting ’}’ after set enumeration

2140: Expecting ’}’ after map comprehension

2141: Expecting ’}’ after map enumeration

2142: Expecting ’]’ after list comprehension

2143: Expecting ’]’ after list enumeration

2144: Missing ’then’

2145: Missing ’then’ after ’elseif’

2146: Expecting ’:’ after cases expression

2147: Expecting ’->’ after others

2148: Expecting 'end' after cases

2149: Expecting '->' after case pattern list

2150: Expecting 'in' after local definitions

2151: Expecting 'st' after 'be' in let expression

2152: Expecting 'in' after bind in let expression

2153: Expecting '&' after bind list in forall

2154: Expecting '&' after bind list in exists

2155: Expecting '&' after single bind in exists1

2156: Expecting '&' after single bind in iota

2157: Expecting '&' after bind list in lambda

2158: Expecting 'in' after equals definitions

2159: Expecting '(' after new class name

2160: Expecting '(' after 'isofbase'

2161: Expecting ')' after 'isofbase' args

2162: Expecting '(' after 'isofclass'

2163: Expecting ')' after 'isofclass' args

2164: Expecting '(' after 'samebaseclass'

2165: Expecting ')' after 'samebaseclass' args

2166: Expecting '(' after 'sameclass'

2167: Expecting ')' after 'sameclass' args

2168: Expecting <#op>(name(s))

2169: Expecting <#op>(name(s))

2170: Expecting 'module' at module start

2171: Expecting 'end' after module definitions

2172: Expecting 'dlmodule' at module start

2173: Expecting 'end' after dlmodule definitions

2174: Malformed imports? Expecting 'exports' section

2175: Expecting ':' after export name

2176: Expecting ':' after export name

2177: Expecting ':' after export name

2178: Expecting 'imports'

2179: Expecting 'from' in import definition

2180: Mismatched brackets in pattern

2181: Mismatched braces in pattern

2182: Mismatched square brackets in pattern

2183: Expecting '(' after mk_ tuple

2184: Expecting ')' after mk_ tuple

2185: Expecting '(' after <type> record

2186: Expecting ')' after <type> record

2187: Expecting 'is not yet specified

2188: Expecting 'is not yet specified

2189: Expecting 'is subclass responsibility'

2190: Expecting 'exit'

2191: Expecting 'tixe'

2192: Expecting '{' after 'tixe'

2193: Expecting '|->' after pattern bind

2194: Expecting 'in' after tixe traps

2195: Expecting 'trap'

2196: Expecting 'with' in trap statement

2197: Expecting 'in' in trap statement

2198: Expecting 'always'

2199: Expecting 'in' after 'always' statement

2200: Expecting '||'

2201: Expecting '(' after '||'

2202: Expecting ')' at end of '||' block

2203: Expecting 'atomic'

2204: Expecting '(' after 'atomic'

2205: Expecting ')' after atomic assignments

2206: Expecting '(' after call operation name

2207: Expecting '(' after new class name

2208: Expecting 'while'

2209: Expecting 'do' after while expression

2210: Expecting 'for'

2211: Expecting 'in set' after 'for all'

2212: Expecting 'in set' after 'for all'

2213: Expecting 'do' after for all expression

2214: Expecting 'in' after pattern bind

2215: Expecting 'do' before loop statement

2216: Expecting '=' after for variable

2217: Expecting 'to' after from expression

2218: Expecting 'do' before loop statement

2219: Missing 'then'

2220: Missing 'then' after 'elseif' expression

2221: Expecting ':=' in object assignment statement

2222: Expecting ':=' in state assignment statement

2223: Expecting ')' after map/seq reference

2224: Expecting statement block

2225: Expecting ';' after statement

2226: Expecting ')' at end of statement block

2227: Expecting ';' after declarations

2228: Expecting name:type in declaration

2229: Expecting 'return'

2230: Expecting 'let'

2231: Expecting 'in' after local definitions

2232: Expecting 'st' after 'be' in let statement

2233: Expecting 'in' after bind in let statement

2234: Expecting 'cases'

2235: Expecting ':' after cases expression

2236: Expecting '->' after case pattern list

2237: Expecting '->' after others

2238: Expecting 'end' after cases

2239: Expecting 'def'

2240: Expecting 'in' after equals definitions

2241: Expecting '['

2242: Expecting ']' after specification statement

2243: Expecting 'start'

2244: Expecting 'start('

2245: Expecting ')' after start object

2246: Expecting 'startlist'

2247: Expecting 'startlist('

2248: Expecting ')' after startlist objects

2249: Missing 'of' in compose type

2250: Missing 'end' in compose type

2251: Expecting 'to' in map type

2252: Expecting 'to' in inmap type

2253: Expecting 'of' after set

2254: Expecting 'of' after seq

2255: Expecting 'of' after seq1

2256: Bracket mismatch

2257: Missing close bracket after optional type

2258: Expecting '==>' in explicit operation type

2259: Operations cannot have [@T] type parameters

2260: Module starts with 'class' instead of 'module'

2261: Missing comma between return types?

2262: Can't have traces in VDM-SL

2263: Missing ';' after named trace definition

2264: Expecting ':' after trace name

2265: Expecting '{n1, n2}' after trace definition

2266: Expecting '{n}' or '{n1, n2}' after trace definition

2267: Expecting 'id.id(args)' or '(trace definitions)'

2268: Expecting 'id.id(args)'

2269: Expecting '(trace definitions)'

2270: Only value definitions allowed in traces

2271: Expecting 'duration'

2272: Expecting 'duration('

2273: Expecting ')' after duration

2274: Expecting 'cycles'

2275: Expecting 'cycles('

2276: Expecting ')' after cycles 2277,-

2278: Async only permitted for operations

2279: Invalid breakpoint hit condition

2280: System class cannot be a subclass

2290: System class can only define instance variables and a constructor

2291: 'reverse' not available in VDM classic

D Type Errors and Warnings

If the syntax rules are satisfied, it is still possible to get type errors from additional type checking. The errors here can be as follows:

3000: `Expression does not match declared type`

3001: `Class inherits thread definition from multiple supertypes`

3002: `Circular class hierarchy detected: <name>`

3003: `Undefined superclass: <supername>`

3004: `Superclass name is not a class: <supername>`

3005: `Overriding a superclass member of a different kind: <member>`

3006: `Overriding definition reduces visibility` This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3007: `Overriding member incompatible type: <member>`

3008: `Overloaded members indistinguishable: <member>`

3009: `Circular class hierarchy detected: <class>`

3010: `Name <name> is ambiguous`

3011: `Name <name> is multiply defined in class`

3012: `Type <name> is multiply defined in class`

3013: `Class invariant is not a boolean expression`

3014: `Expression is not compatible with type bind`

3015: `Set bind is not a set type?`

3016: `Expression is not compatible with set bind`

3017: `Duplicate definitions for <name>`

3018: `Function returns unexpected type`

3019: `Function parameter visibility less than function definition` This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3020: `Too many parameter patterns`

3021: `Too few parameter patterns`

3022: `Too many curried parameters`

3023: `Too many parameter patterns`

3024: `Too few parameter patterns`

3025: `Constructor operation must have return type <class>`

3026: `Constructor operation must have return type <class>`

3027: `Operation returns unexpected type`

3028: `Operation parameter visibility less than operation definition` This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3029: `Function returns unexpected type`

3030: `Function parameter visibility less than function definition` This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3031: `Unknown state variable <name>`

3032: `State variable <name> is not this type`

3035: `Operation returns unexpected type`

3036: `Operation parameter visibility less than operation definition` This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3037: `Static instance variable is not initialized: <name>`

3038: `<name> is not an explicit operation`

3039: `<name> is not in scope`

3040: `Cannot put mutex on a constructor`

3041: `Duplicate mutex name`

3042: `<name> is not an explicit operation`

3043: `<name> is not in scope`

3044: Duplicate permission guard found for <name>

3045: Cannot put guard on a constructor

3046: Guard is not a boolean expression

3047: Only one state definition allowed per module

3049: Thread statement/operation must not return a value

3050: Type <name> is infinite

3051: Expression does not match declared type

3052: Value type visibility less than value definition This error message typically are caused by using a more restrictive access modifier (or none which is interpreted as private) at this place compared to for example an inherited definition.

3053: Argument of 'abs' is not numeric

3054: Type <name> cannot be applied

3055: Sequence selector must have one argument

3056: Sequence application argument must be numeric

3057: Map application must have one argument

3058: Map application argument is incompatible type

3059: Too many arguments

3060: Too few arguments

3061: Inappropriate type for argument <n>

3062: Too many arguments

3063: Too few arguments

3064: Inappropriate type for argument <n>

3065: Left hand of <operator> is not <type>

3066: Right hand of <operator> is not <type>

3067: Argument of 'card' is not a set

3068: Right hand of map 'comp' is not a map

3069: Domain of left should equal range of right in map 'comp'

3070: Right hand of function 'comp' is not a function

3071: Left hand function must have a single parameter

3072: Right hand function must have a single parameter

3073: Parameter of left should equal result of right in function 'comp'

3074: Left hand of 'comp' is neither a map nor a function

3075: Argument of 'conc' is not a seq of seq

3076: Argument of 'dinter' is not a set of sets

3077: Merge argument is not a set of maps

3078: dunion argument is not a set of sets

3079: Left of '<-:' is not a set

3080: Right of '<-:' is not a map

3081: Restriction of map should be set of <type>

3082: Left of '<:' is not a set

3083: Right of '<:' is not a map

3084: Restriction of map should be set of <type>

3085: Argument of 'elems' is not a sequence

3086: Else clause is not a boolean

3087: Left and right of '=' are incompatible types

3088: Predicate is not boolean

3089: Predicate is not boolean

3090: Unknown field <name> in record <type>

3091: Unknown member <member> of class <class>

3092: Inaccessible member <member> of class <class>

3093: Field <name> applied to non-aggregate type

3094: Field #<n> applied to non-tuple type

3095: Field number does not match tuple size

3096: Argument to floor is not numeric

3097: Predicate is not boolean

3098: Function value is not polymorphic

3099: Polymorphic function is not in scope

3100: Function has no type parameters

3101: Expecting <n> type parameters

3102: Parameter name <name> not defined

3103: Function instantiation does not yield a function

3104: Argument to 'hd' is not a sequence

3105: <operation> is not an explicit operation

3106: <operation> is not in scope

3107: Cannot use history of a constructor

3108: If expression is not a boolean

3109: Argument to 'inds' is not a sequence

3110: Argument of 'in set' is not a set

3111: Argument to 'inverse' is not a map

3112: Iota set bind is not a set

3113: Unknown type name <name>

3114: Undefined base class type: <class>

3115: Undefined class type: <class>

3116: Argument to 'len' is not a sequence

3117: Such that clause is not boolean

3118: Predicate is not boolean

3119: Map composition is not a maplet

3120: Argument to 'dom' is not a map

3121: Element is not of maplet type

3122: Argument to 'rng' is not a map

3123: Left hand of 'munion' is not a map

3124: Right hand of 'munion' is not a map

3125: Argument of mk_<type> is the wrong type

3126: Unknown type <type> in constructor

3127: Type <type> is not a record type

3128: Record and constructor do not have same number of fields

3129: Constructor field <n> is of wrong type

3130: Modifier for <tag> should be <type>

3131: Modifier <tag> not found in record

3132: mu operation on non-record type

3133: Class name <name> not in scope

3134: Class has no constructor with these parameter types

3135: Class has no constructor with these parameter types

3136: Left and right of '<>' different types

3137: Not expression is not a boolean

3138: Argument of 'not in set' is not a set

3139: Left hand of <operator> is not numeric

3140: Right hand of <operator> is not numeric

3141: Right hand of '++' is not a map

3142: Right hand of '++' is not a map

3143: Domain of right hand of '++' must be nat1

3144: Left of '++' is neither a map nor a sequence

3145: Argument to 'power' is not a set

3146: Left hand of <operator> is not a set

3147: Right hand of <operator> is not a set

3148: Left of ':->' is not a map

3149: Right of ':->' is not a set

3150: Restriction of map should be set of <type>

3151: Left of ':>' is not a map

3152: Right of ':>' is not a set

3153: Restriction of map should be set of <type>

3154: <name> not in scope

3155: List comprehension must define one numeric bind variable

3156: Predicate is not boolean

3157: Left hand of '^' is not a sequence

3158: Right hand of '^' is not a sequence

3159: Predicate is not boolean

3160: Left hand of '\' is not a set

3161: Right hand of '\' is not a set

3162: Left and right of '\' are different types

3163: Left hand of <operator> is not a set

3164: Right hand of <operator> is not a set

3165: Left and right of intersect are different types

3166: Set range type must be an number

3167: Set range type must be an number

3168: Left hand of <operator> is not a set

3169: Right hand of <operator> is not a set

3170: Map iterator expects nat as right hand arg

3171: Function iterator expects nat as right hand arg

3172: '**' expects number as right hand arg

3173: First arg of '**' must be a map, function or number

3174: Subsequence is not of a sequence type

3175: Subsequence range start is not a number

3176: Subsequence range end is not a number

3177: Left hand of <operator> is not a set

3178: Right hand of <operator> is not a set

3179: Argument to 'tl' is not a sequence

3180: Inaccessible member <name> of class <name>

3181: Cannot access <name> from a static context

3182: Name <name> is not in scope

3183: Exported function <name> not defined in module

3184: Exported <name> function type incorrect

3185: Exported operation <name> not defined in module

3186: Exported operation type does not match actual type

3187: Exported type <type> not defined in module

3188: Exported value <name> not defined in module

3189: Exported type does not match actual type

3190: Import all from module with no exports?

3191: No export declared for import of type <type> from <module>

3192: Type import of <name> does not match export from <module>

3193: No export declared for import of value <name> from <module>

3194: Type of value import <name> does not match export from <module>

3195: Cannot import from self

3196: No such module as <module>

3197: Expression matching set bind is not a set

3198: Type bind not compatible with expression

3199: Set bind not compatible with expression

3200: Mk_ expression is not a record type

3201: Matching expression is not a compatible record type

3202: Record pattern argument/field count mismatch

3203: Sequence pattern is matched against <type>

3204: Set pattern is not matched against set type

3205: Matching expression is not a product of cardinality <n>

3206: Matching expression is not a set type

3207: Object designator is not an object type

3208: Object designator is not an object type

3209: Member <field> is not in scope

3210: Object member is neither a function nor an operation

3211: Expecting <n> arguments

3212: Unexpected type for argument <n>

3213: Operation <name> is not in scope

3214: Cannot call <name> from static context

3215: <name> is not an operation

3216: Expecting <n> arguments

3217: Unexpected type for argument <n>

3218: Expression is not boolean

3219: For all statement does not contain a set type

3220: From type is not numeric

3221: To type is not numeric

3222: By type is not numeric

3223: Expecting sequence type after 'in'

3224: If expression is not boolean

3225: Such that clause is not boolean

3226: Incompatible types in object assignment

3228: <name> is not in scope

3229: <name> should have no parameters or return type

3230: <name> is implicit

3231: <name> should have no parameters or return type

3232: <name> is not an operation name

3233: Precondition is not a boolean expression

3234: Postcondition is not a boolean expression

3235: Expression is not a set of object references

3236: Class does not define a thread

3237: Class does not define a thread

3238: Expression is not an object reference or set of object references

3239: Incompatible types in assignment

3241: Body of trap statement does not throw exceptions

3242: Map element assignment of wrong type

3243: Seq element assignment is not numeric

3244: Expecting a map or a sequence

3245: Field assignment is not of a record type

3246: Unknown field name, <name>

3247: Unknown state variable <name> in assignment

3248: Cannot assign to 'ext rd' state <name>

3249: Object designator is not a map, sequence, function or operation

3250: Map application must have one argument

3251: Map application argument is incompatible type

3252: Sequence application must have one argument

3253: Sequence argument is not numeric

3254: Too many arguments

3255: Too few arguments

3256: Inappropriate type for argument <n>

3257: Too many arguments

3258: Too few arguments

3259: Inappropriate type for argument <n>

3260: Unknown class member name, <name>

3261: Unknown field name, <name>

3262: Field assignment is not of a class or record type

3263: Cannot reference 'self' from here

3264: At least one bind cannot match set

3265: At least one bind cannot match this type

3266: Argument is not an object

3267: Empty map cannot be applied

3268: Empty sequence cannot be applied

3269: Ambiguous function/operation name: <name>

3270: Measure <name> is not in scope

3271: Measure <name> is not an explicit function

3272: Measure result type is not a nat, or a nat tuple

3273: Measure not allowed for an implicit function

3274: External variable is not in scope: <name>

3275: Error clause must be a boolean

3276: Ambiguous names inherited by <name>

3277: Trace repeat illegal values

3278: Cannot inherit from system class <name>

3279: Cannot instantiate system class <name>

3280: Argument to deploy must be an object

3281: Arguments to duration must be integer >= 0

3282: Arguments to cycles must be integer >= 0

3283: System class constructor cannot be implicit

3284: System class can only define instance variables and a constructor

3285: System class can only define a default constructor

3286: Constructor cannot be 'async'

3287: Periodic thread must have <n> argument(s)

3288: Period argument must be non-zero

3289: Delay argument must be less than the period

3290: Argument to setPriority must be an operation

3291: Argument to setPriority cannot be a constructor

3292: Constructor is not accessible

3293: Asynchronous operation <name> cannot return a value

3294: Only one system class permitted

3295: Argument to 'reverse' is not a sequence

3296: `Cannot use <typename> outside system class`

3297: `Cannot use default constructor for this class`

3298: `Cannot inherit from CPU`

3299: `Cannot inherit from BUS`

3300: `Operation <type> cannot be called from a function`

3301: `Variable <name> in scope is not updatable`

3302: `Variable <name> cannot be accessed from this context`

Warnings from the type checker include:

5000: `Definition <name> not used`

5001: `Instance variable is not initialized:  <name>`

5002: `Mutex of overloaded operation`

5003: `Permission guard of overloaded operation`

5004: `History expression of overloaded operation`

5005: `Should access member <member> from a static context`

5006: `Statement will not be reached`

5007: `Duplicate definition:  <name>`

5008: `<name/location> hides <name/location>`

5009: `Empty set used in bind`

5010: `State init expression cannot be executed` 5011, -

5012: `Recursive function has no measure` 5013, -

5014: `Uninitialized BUS ignored`. This warning appears if one has defined a `BUS` that is not used.

5015: `LaTeX source should start with %comment, \document, \section or \subsection`

E Run-Time Errors

When using the interpreter/debugger it is possible to get run-time errors indicating that a problem with the VDM model analysed have been detected. This includes the following kinds of errors:

4000: Cannot instantiate abstract class <class>

4002: Expression value is not in set bind

4003: Value <value> cannot be applied

4004: No cases apply for <value>

4005: Duplicate map keys have different values

4006: Type <type> has no field <field>

4007: No such field in tuple: #<n>

4008: No such type parameter @<name> in scope

4009: Type parameter/local variable name clash, @<name>

4010: Cannot take head of empty sequence

4011: Illegal history operator: <#op>

4012: Cannot invert non-injective map

4013: Iota selects more than one result

4014: Iota does not select a result

4015: Let be st found no applicable bindings

4016: Duplicate map keys have different values: <domain>

4017: Duplicate map keys have different values: <domain>

4018: Maplet cannot be evaluated

4019: Sequence cannot extend to key: <index>

4020: State value is neither a <type> nor a <type>

4021: Duplicate map keys have different values: <key>

4022: mk_ type argument is not <type>

4023: Mu type conflict? No field tag <tag>

4024: 'not yet specified' expression reached

4025: Map key not within sequence index range: <key>

4026: Cannot create post_op environment

4027: Cannot create pre_op environment

4028: Sequence comprehension pattern has multiple variables

4029: Sequence comprehension bindings must be numeric

4030: Duplicate map keys have different values: <key>

4031: First arg of '**' must be a map, function or number

4032: 'is subclass responsibility' expression reached

4033: Tail sequence is empty

4034: Name <name> not in scope

4035: Object has no field: <name>

4036: ERROR statement reached

4037: No such field: <name>

4038: Loop, from <value> to <value> by <value> will never terminate

4039: Set bind does not contain value <value>

4040: Let be st found no applicable bindings

4041: 'is not yet specified' statement reached

4042: Sequence does not contain key: <key>

4043: Object designator is not a map, sequence, operation or function

4045: Object does not contain value for field: <name>

4046: No such field: <name>

4047: Cannot execute specification statement

4048: 'is subclass responsibility' statement reached

4049: Value <value> is not in set bind

4050: Value <value> is not in set bind

4051: Cannot apply implicit function: <name>

4052: Wrong number of arguments passed to <name>

4053: Parameter patterns do not match arguments

4055: Precondition failure: <pre_name>

4056: Postcondition failure: <post_name>

4057: Curried function return type is not a function

4058: Value <value> is not a nat1

4059: Value <value> is not a nat

4060: Type invariant violated for <type>

4061: No such key value in map: <key>

4062: Cannot convert non-injective map to an inmap

4063: Duplicate map keys have different values: <domain>

4064: Value <value> is not a nat1 number

4065: Value <value> is not a nat

4066: Cannot call implicit operation: <name>

4067: Deadlock detected

4068: Wrong number of arguments passed to <name>

4069: Parameter patterns do not match arguments

4071: Precondition failure: <pre_name>

4072: Postcondition failure: <post_name>

4073: Cannot convert type parameter value to <type>

4074: Cannot convert <value> to <type>

4075: Value <value> is not an integer

4076: Value <value> is not a nat1

4077: Value <value> is not a nat

4078: Wrong number of fields for <type>

4079: Type invariant violated by mk_ arguments

4080: Wrong number of fields for <type>

4081: Field not defined: <tag>

4082: Type invariant violated by mk_ arguments

4083: Sequence index out of range: <index>

4084: Cannot convert empty sequence to seq1

4085: Cannot convert tuple to <type>

4086: Value of type parameter is not a type

4087: Cannot convert <value> (<kind>) to <type>

4088: Set not permitted for <kind>

4089: Can't get real value of <kind>

4090: Can't get rat value of <kind>

4091: Can't get int value of <kind>

4092: Can't get nat value of <kind>

4093: Can't get nat1 value of <kind>

4094: Can't get bool value of <kind>

4095: Can't get char value of <kind>

4096: Can't get tuple value of <kind>

4097: Can't get record value of <kind>

4098: Can't get quote value of <kind>

4099: Can't get sequence value of <kind>

4100: Can't get set value of <kind>

4101: Can't get string value of <kind>

4102: Can’t get map value of <kind>

4103: Can’t get function value of <kind>

4104: Can’t get operation value of <kind>

4105: Can’t get object value of <kind>

4106: Boolean pattern match failed

4107: Character pattern match failed

4108: Sequence concatenation pattern does not match expression

4109: Values do not match concatenation pattern

4110: Expression pattern match failed

4111: Integer pattern match failed

4112: Quote pattern match failed

4113: Real pattern match failed

4114: Record type does not match pattern

4115: Record expression does not match pattern

4116: Values do not match record pattern

4117: Wrong number of elements for sequence pattern

4118: Values do not match sequence pattern

4119: Wrong number of elements for set pattern

4120: Values do not match set pattern

4121: Cannot match set pattern

4122: String pattern match failed

4123: Tuple expression does not match pattern

4124: Values do not match tuple pattern

4125: Set union pattern does not match expression

4126: Values do not match union pattern

4127: Cannot match set pattern

4129: Exit <value>

4130: Instance invariant violated: <inv_op>

4131: State invariant violated: <inv_op>

4132: Using undefined value

4133: Map range is not a subset of its domain: <key>

4134: Infinite or NaN trouble

4135: Cannot instantiate a system class

4136: Cannot deploy to CPU

4137: Cannot set operation priority on CPU

4138: Cannot set CPU priority for operation

4139: Multiple BUS routes between CPUs <name> and <name>

4140: No BUS between CPUs <name> and <name>

4141: CPU policy does not allow priorities

4142: Value already updated by thread <n>

4143: No such test number: <n>

4144: State init expression cannot be executed

4145: Time: <n> is not a nat1

F Categores of Proof Obligations

This appendix provide a list of the different proof obligation categories used in Overture and an explanantion for each of them the circumstances under which the PO category can be expected.

map apply: Whenever a map application is used it needs to be ensured that the argument is indeed in the domain of the mapping.

function apply: Whenever a function application is used it needs to be ensured that the list of arguments to the function are all of the types expected by the function signature as well as satisfy the pre-condition of the function in case such a predicate is present.

sequence apply: Whenever a sequence application is used it needs to be ensured that the argument is indeed in the indices of the sequence.

post condition:

function satisfiability: For all implicit function definitions this proof obligation will be generated to ensure that it will be possible to find a result satisfying the post-condition for all arguments of the function input types satisfying the pre-conditions.

function parameter patterns:

let be st existence: Whenever a let-be-such-that expression/statement is used it needs to be guranteed that the set to selecte from is non-empty.

unique existence binding: The `iota` expression requires a unique binding to be present and that is guranteed by proof obligations from this category.

function iteration:

map iteration:

function compose:

map compose:

non-empty set: This kind of proof obligations are used whenever non-empty sets are required.

non-empty sequence: This kind of proof obligations are used whenever non-empty sequences are required.

non-zero: This kind of proof obligations are used whenever zero cannot be used (e.g. in division).

finite map: If a type binding to a type that potentially have infinitely many elements is used inside a map comprehension this proof obligation will be generated because all mappings in VDM are finite.

finite set: If a type binding to a type that potentially have infinitely many elements is used inside a set comprehension this proof obligation will be generated because all sets in VDM are finite.

map compatible:

map sequence compatible:

map set compatible:

sequence modification:

tuple selection: This proof obligation category is used whenever a tuple selection expression is used and it must be guranteed that the length of the tuple at least is as long as the selector used.

value binding:

subtype: This proof obligation category is used whenever it is not possible to statically detect that the given expression indeed falls into the subtype required in the actual use of it.

cases exhaustive: If a cases expression does not have an **`others`** clause it is necessary to ensure that the different case alternatives are exhaustive over the type of the expression used in the case choice.

type invariant: Proof obligations from this category are used to ensure that invariants for elements of a particular type are satisfied.

recursive function: This proof obligation makes use of the **`measure`** construct to ensure that a recursive function will terminate.

state invariant: If a state (including instance variables in VDM++) have an invariant this proof obligation will be generated whenever assignment is made to a part of the state all the places where the invariant shall be satisfied.

while loop termination: This kind of proof obligation is a reminder to ensure that a while loop is terminating. However, for embedded systems that is typically not desirable and thus in those cases there is no need to satisfy this proof obligation.

operation post condition:

operation parameter patterns:

operation satifiability: For all implicit operation definitions this proof obligation will be generated to ensure that it will be possible to find a result satisfying the post-condition for all arguments of the operation input types satisfying the pre-conditions.

G Index

Index