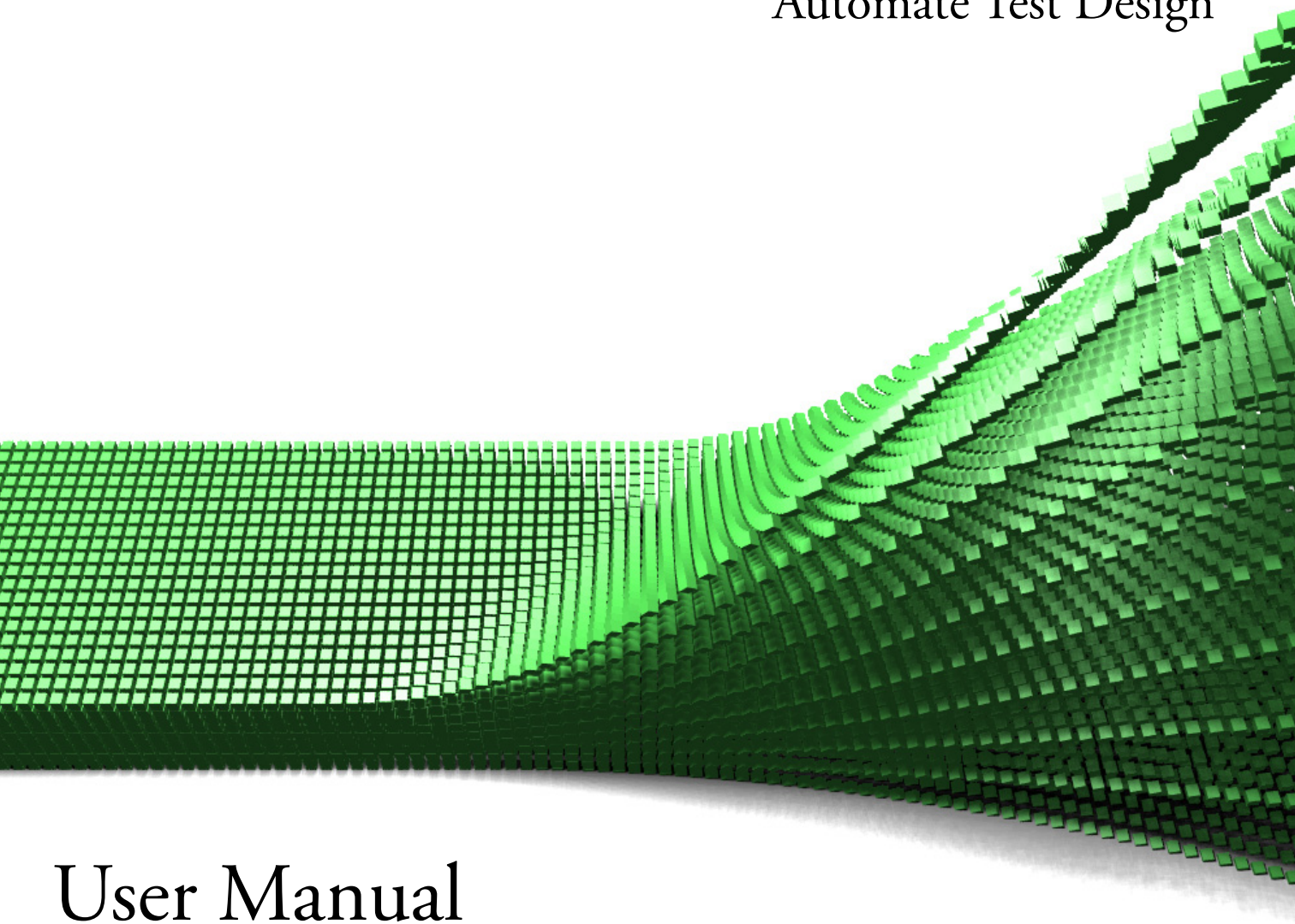
CONFORMIQ

QTRONIC™

Automate Test Design™



User Manual

Conformiq Qtronic2 Manual

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Table of Contents

1 Introduction 8
1.1 The Design-Validation Cycle 9
1.2 Costs of Testing 10
1.3 Conformiq Qtronic in Software Process 12
1.4 Benefits of Conformiq Qtronic 14

2 Installing Conformiq Qtronic2 16
2.1 System Requirements 17
2.1.1 Qtronic Eclipse Client Requirements 17
2.1.2 Qtronic Computation Server Requirements 17
2.1.3 Other Requirements 18
2.2 Preparations 18
2.3 Installing Qtronic 2 on Windows 19
2.3.1 How to Install Qtronic 2 on Windows 19
2.3.2 How to Uninstall Qtronic 2 on Windows 20
2.4 Installing Qtronic 2 on Linux 21
2.4.1 How to Install Qtronic 2 on Linux 21
2.4.2 How to Uninstall Qtronic 2 on Linux 22
2.5 Checking the QEC Installation 23
2.6 License Management in Qtronic2 25
2.6.1 Configuring Qtronic Feature Set 26
2.6.2 Qtronic Evaluation 27
2.6.3 Node-Locked Licensing 29
2.6.4 Floating Licensing 29
2.6.5 Obtaining Node Identifiers 30
2.7 License Server Management 31
2.7.1 Viewing Licensing Status 32
2.7.2 Adding Licenses 33

3 Testing with Conformiq Qtronic2 34
3.1 Quick Start of Using Qtronic 2 36
3.2 How to Switch to Qtronic Perspective 37
3.3 How to Configure Qtronic2 Client 38
3.4 How to Work with Qtronic2 Projects 39
3.5 How to Select Models 42
3.6 How to Create Test Design Configurations 44
3.7 How to Configure Test Generation 46
3.7.1 How to Configure Global Testing Parameters 46
3.7.2 How to Configure Design Configuration Specific Testing Parameters 49
3.8 How to Generate Tests 55
3.9 How to Analyze Test Generation Results 57
3.9.1 Coverage Editor 58
3.9.2 Test Case List 59
3.9.3 Traceability Matrix View 61
3.9.4 Test Case View 62
3.9.5 Test Step View 64
3.9.6 Execution Trace View 66
3.9.7 Analyzing Model Defects 66
3.10 How to Export Test Cases 68
3.10.1 How to Use Script Backends Shipped with Qtronic2 71
3.11 Test Case Management 76
3.12 Managing Qtronic Projects 79

4 Creating Models in QML 81
4.1 Textual Notation of QML 82
4.2 Basic Language Features 84
4.2.1 Keywords 84
4.2.2 Comments 88
4.2.3 Literals 88
4.2.4 Operators 88

4.2.5 Data Types 90
4.2.6 Access Modifiers 99
4.2.7 Type Aliases 100
4.2.8 Control structures 100
4.2.9 Input and Output 102
4.2.10 System Block 104
4.2.11 Main Entry Point 104
4.2.12 Globals and Functions 105
4.2.13 Modifiers 105
4.2.14 Regions with No Coverage Goals 105
4.3 Object Orientation 106
4.3.1 Inheritance 106
4.3.2 Interfaces 107
4.3.3 Operator Overloading 107
4.3.4 Templates 108
4.3.5 Nullable Types 110
4.3.6 Implicitly Typed Local Variables 111
4.4 Modeling Use Cases with QML 113
4.4.1 An Example 114
4.5 Predefined Data Types 116
4.5.1 Class and Record Super Types 116
4.5.2 Threads and Communication 117
4.5.3 Exceptions 120
4.5.4 Synchronization 121
4.5.5 Containers 122
4.6 Predefined Functions 126
4.6.1 Assertion Like Functions 126
4.6.2 Requirements 128
4.6.3 Random Number Generators 129
4.6.4 Mathematical Functions 130
4.6.5 Use Cases 130

4.6.6 Probabilities and Priorities 131
4.6.7 End Conditions for Test Generation 134
4.6.8 Miscellaneous Functions 135
4.7 Backward Compatibility with Conformiq Test Generator 136
4.7.1 Optional Fields in Records 136
4.7.2 Type Copies 137
4.8 Graphical Notation of QML 138
4.8.1 State Machines 138
4.8.2 Transition Strings 139
4.8.3 Internal Transitions of a State 143
4.9 Importing QML Models Into Qtronic 144
4.10 Examples 145
4.10.1 A Simple Echo Model 145
4.10.2 Another Echo Model 146
4.10.3 Yet Another Echo Model 147

5 Using Conformiq Modeler 150
5.1 Opening a model 153
5.2 Saving a model 153
5.3 State machines 153
5.4 Drawing 153
5.4.1 Zooming 154
5.4.2 Scrolling 154
5.4.3 States 154
5.4.4 Transitions 155
5.4.5 Notes and note connectors 155
5.5 Undo and Redo 156

6 Importing Models from Third Party Tools 157
6.1 Enterprise Architect 158
6.1.1 Imported Components 158

6.1.2 A Simple Example 159

7 Creating Qtronic2 Scripting Backends 163
7.1 Communicating Using QML Datum Interface 164
7.2 Creating Scripting Backends in Java 165
7.3 Exposing Scripting Backend Configuration 169
7.4 Preparing Eclipse Workbench 172
7.5 Creating Java Project for Scripting Backends 172
7.6 Creating Scripting Backend JAR 174
7.7 Debugging Scripting Backends 174

8 Support and Troubleshooting 176
8.1 Troubleshooting Guidelines 177
8.1.1 Troubleshooting QEC 177
8.1.2 Performance Problems 178
8.2 Reporting Problems with Qtronic 178

A Qtronic 2 Release Notes 180
A.1 Download and Install 181
A.2 Qtronic 2.0.3 182
A.3 Qtronic 2.0.2 183
A.4 Qtronic 2.0.1 183
A.5 Qtronic 2.0.0 183

B Plugin API Reference Manual 186

CONFORMIQ

QTRONIC

I Introduction

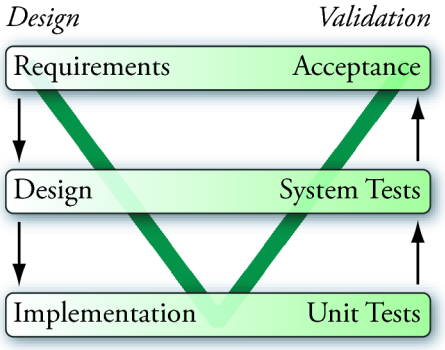
Welcome to use Conformiq Qtronic, the world's leading solution for automatic model driven test case design!

Conformiq Qtronic is the result of more than five years of continuous programming and development. It is based on advanced discrete mathematics and theory of computer science, yet it is a very pragmatic tool. The benefits that Conformiq Qtronic brings into day-to-day software development are tangible and pervasive. It reduces risks caused by accidentally missing tests or defective tests and increases test design productivity and target system quality.

In this introduction we go through the value proposition for Conformiq Qtronic: what it is, why it exists, and how it can help you.

1.1 The Design-Validation Cycle

On high level, software development can be seen to consist of interleaved cycles of *design* and *validation*. Design is about creating business requirements and architectural plans, writing running code, producing implementations. Validation is about checking what has already been designed with respect to other explicit artifacts as well as implicit requirements in the process.



Overview of the traditional V model

For example, in the traditional "V model" there is first a design phase, process beginning with business requirements and ending at implementation, and this is followed by a validation phase which begins with unit testing and proceeds until post-deployment monitoring. In more recent process models, such as those under the umbrella of "agile processes", design and validation are more intertwined. Still, design and validation are always two fundamental parts of the process. The underlying reason lies in the psychology of man: the human brain has a tendency to make mistakes, and hence everything people create must be cross-checked to ensure its quality. This is true also in the sphere of software engineering. The design-validation cycle is a fundamental characteristic of all software processes.

Some of the best known methods for *validation* include testing, inspections and reviews, and static analysis. Conformiq Qtronic is a tool for optimizing test design as well as the whole design-validation cycle in large. But it is not a tool for source code reviewing or static analysis.

1.2 Costs of Testing

Software testing is a broad domain of concepts and processes. Today it is probably the most important way to validate software. Testing consumes significant amounts of time and

money, estimated from 30 to 90 percentages out of total development budgets.

The division of testing costs depends on how testing is organized. Typical ways to organize testing include:

- Manual testing
- Record and replay
- Development and execution of custom testing software

Manual testing means that a testing engineer or tester interacts with the system under test personally, often following a plan written down in a human tongue, creating reports of his or her experiences with the system as well as of any defects spotted. The dominating costs are personnel costs caused directly by the testing activity on hour to hour basis.

Record and replay is a widely deployed paradigm for testing software with graphical user interfaces. First, a tester interacts manually with the system under test through the user interface. The interaction is recorded in a suitable way. Later the interaction can be replayed many times and the workings of the system compared to the expected, "golden" outcomes that come either from the original execution or from an otherwise prepared data table. In record and replay the costs are attributed to the production of the scripts in the first place, the maintenance and modification of them later when the product or its requirements change during the life cycle, the examination of those cases where tests fail for diagnosis, and the total cost of the ownership of the record and replay tool itself.

Record and replay excels in a process where progressive versions of the same software must be tested many times (regression testing). Record and replay achieves relative economics of scale over manual testing when the number of regression test runs grows.

The same is true for using *custom testing software*. This is a typical way to organize regression tests for small units, but it is used also for larger systems. In this approach, a testing engineer creates and maintains custom software whose raison d'être is to, when executed, test some other software. The initial development costs for custom testing software can be higher than for record and replay — at least a different skill set is required — but in the long run it can be more efficient. Typically, a custom testing program can generate millions of different test

inputs to a system, and can analyze the outcome from the system in a much more detailed way than a usual record and replay solution.

Because testing is eventually cross-checking an implementation against requirements, all forms of testing create costs related to understanding and analyzing requirements. In the context of manual testing these costs show up as working time spent by testers during the testing activity itself. For custom testing software, both test design as well as analysis of flagged defects incur costs (all automatically spotted defects must be analyzed because it could be that the testing software itself, being just another computer program written by a human, could be incorrect in itself).

For our purposes, a coarse but sufficient way to categorize the cost drivers of a testing process is:

1. Understanding and analyzing requirements
2. Creating and maintaining test artifacts (recorded interactions, custom testing software)
3. Executing tests (either manually or by running automation tools)
4. Analyzing test results
5. Reporting

1.3 Conformiq Qtronic in Software Process

Conformiq Qtronic is a tool for automatic test case design that is driven by "design models". This means that Conformiq Qtronic designs tests for a system automatically when it is given a "design model" of the system as an input. The tests are "black box tests", meaning that they evaluate the system under test based only on its external behavior, not on monitoring its internal workings directly (this kind of testing would is called "white box testing").

This "design model" is a description of the intended behavior of the system on some level of abstraction. It is also correct to see it as a golden reference implementation of the system, albeit usually an abstracted and simplified one. This design model can be expressed as a

collection of

1. Textual source files in Java-compatible but extended notation that describe data types, constants, classes and their methods (the extensions include support for value-type records, true static polymorphism, etc.).
2. Statechart diagrams with methods and procedures in Java syntax representing the behavioral logic of active classes, i.e. classes whose instances can “execute on their own” as an alternative to representing the logic textually.
3. Class diagrams as a graphical alternative to declare classes and their relationships.

Design models can also be seen as operational requirements or behavioral requirements. They describe the intended external operational characteristics of the system, in essence how the system should work from the perspective of a user. Design models do not need to reflect the real implementation structurally as long as they describe the intended outwardly observable characteristics.

Conformiq Qtronic selects and optionally executes tests automatically based on the design model, and calculates expected answers from the system under test automatically. With Conformiq Qtronic, there is no need to create test scripts manually or to record them. Test design, optional execution and analysis are all automatic. These benefits directly reduce costs and risks. But behind this level of "obvious" benefits, Conformiq Qtronic brings in a pervasive change to the software process: it links design with validation in a revolutionary way.

Without Conformiq Qtronic, testing involves manual translation of requirements into tests and test verdicts. This task is carried out either by a manual tester, a test designer, or an engineer writing testing software — in the last case the costs are the most directly visible. Basically, a custom testing program is just a new expression of the requirements for the system, this time in the form of an executable that checks that the system the executable is run against fulfills the requirements in some, selected cases ("test cases"). This results in having to maintain two artifacts in parallel: the requirements and the testing software.

This source of costs and risks can be eliminated with the use of Conformiq Qtronic because

the tool generates tests directly from the requirements themselves (when they are expressed as functional models). This brings in double benefits: test artifacts do not need to be maintained, and the quality of the requirement documents increases drastically. After all the tests generated by Conformiq Qtronic from a design model pass, there is strong evidence that the system and the requirements are mutually coherent. This increases the value of the behavioral requirements as technical documentation for the system.

1.4 Benefits of Conformiq Qtronic

The main benefit of using Conformiq Qtronic is an increased product quality that is achieved by using the design model as the golden reference implementation of the system. Unlike with other testing tools tests can be automatically generated from the design model.

When using the online testing mode, Qtronic generates a multitude of distinct test cases from the given design model. It can use the model to directly test a running system or to generate test scripts that can be independently executed afterwards. Generated test scripts can be stored in version control system allowing tests to be sent to collegues or to execute them independently.

As with online testing, also automatic test case generation from system models reduces risks and costs: It eliminates the risk of defective test cases and reduces costs by cutting the amount of manual test case maintenance work.

One of the most obvious benefits of using Conformiq Qtronic is that automatic testing based on design models saves effort as there is no need to maintain separate tests and requirement designs. Test execution and analysis are automatic so continuous involvement from engineers is not required.

Since Qtronic creates test cases by analysing the design model it is able to infer test cases that could be otherwise overlooked. It also reduces the risk of defective tests as the tests are inferred directly from the design models. For special and important tests test engineers can write separate use case tests describing certain specific behaviour that has to be explicitly tested.

Using design models as artifacts for testing has a positive impact to the quality of design models as the model works also as a documentation for the system. Whenever an error is found between the model and the implementation either of them is updated. This implies that the system documentation is always up to date and conforms with the system.

Because the design model has such an important role, Qtronic has to offer a *model debugging* feature — While the design model is being constructed, Qtronic can be used to determine that there are no execution paths that would lead to internal computation errors, such as division by zero. If Qtronic finds such an execution, it provides a counter-example with the corresponding execution trace and data values enabling the user to correct the model. This automatic model validation feature of Qtronic is reliable and speeds up development.

Thorough reports provide all the required information. In addition, Qtronic provides the means to generate custom reports.

2 Installing Conformiq Qtronic2

Conformiq Qtronic is a professional software tool that installs on the supported platforms. Should you, however, experience problems in installing the software after following the guidelines in this chapter, please contact your supplier for advice.

2.1 System Requirements

Conformiq Qtronic employs client-server architecture where the client user interface is implemented as an Eclipse plugin. The server component - Qtronic Computation Server - can be installed on the same computer as the Qtronic Eclipse Client or on another node in the local area network.

2.1.1 Qtronic Eclipse Client Requirements

- Qtronic is provided as an Eclipse plugin for *Eclipse 3.3 (Europa)* or newer. The recommended package is *Eclipse Classic*.
- The required Java environment for running Qtronic Eclipse Client (QEC) is Sun Java 6 or higher.
- The system on which Qtronic Eclipse Client is installed should have at least 1024 MB memory.
- A relatively powerful CPU, a multiprocessor or multi-core processor computer is recommended.

2.1.2 Qtronic Computation Server Requirements

- Windows XP/Vista and most Linux distributions are supported by the Qtronic Computation Server (QCS).
- The system on which Qtronic Computation Server is installed must have at least 1024 MB of memory but 2048 MB is recommended.
- We highly recommend a powerful CPU with multiprocessor or multi-core processor that is Intel 586 (Pentium) compatible due to the large amount of

calculations the software must do during automatic test generation.

- A 64 bit version is available for Linux.

2.1.3 Other Requirements

In addition, these software requirements are needed for a Linux installations:

- The GNU C Library (**libc** that defines "system calls" and other basic functionality) must be 2.4 or newer.

If QEC and QCS are both run on a same computer, this computer must have at least 2048 MB of memory (but 4096 MB is recommended) and a powerful multiprocessor or multi-core processor computer.

2.2 Preparations

Before starting the actual installation, make sure that the system meets those requirements described in Section System Requirements.

Preparations When Installing Qtronic Eclipse Client

When installing Qtronic Eclipse client, make sure that you have a working Eclipse installation in your system. The Eclipse must be 3.3 or newer. Also make sure that you have necessary permissions to write Qtronic plugin information to the Eclipse installation directory.

Preparations When Installing Qtronic Computation Server

When installing Qtronic Computation Server, make sure that there is no PostgreSQL database service running on port TCP 5432 (or any other service for that matter). In Linux you can do this by executing `netstat` command:

```
netstat -ant | grep 5432
```

and in Windows, you do this by executing `netstat` command:

```
netstat -a
```

If there is a service that listens port 5432, close this service before you start the installation.

2.3 Installing Qtronic 2 on Windows

Conformiq Qtronic can be installed on Windows Vista/XP/2000. The software is provided as a 32-bit compilation. It can be used also on 64-bit machines as any other 32-bit application can.

2.3.1 How to Install Qtronic 2 on Windows

Qtronic2 for Windows is provided as a NullSoft installer.

The installer can be used to install the Qtronic Eclipse client or Qtronic Computation Server or both. The installer will also allow the installation of **Conformiq Modeler**, a light-weight modeling tool for drawing UML statemachine diagrams, example models, and more.

The following list detail the process of installing Qtronic to your computer:

1. Double-click on the 'Conformiq Qtronic <version>.exe' installer file in Windows Explorer. This will start the installer.
2. Select destination folder for the installation. The default is **C:\Program Files\Conformiq Software\Conformiq Qtronic2**. If the installation directory does not exist, the installer will create one.
3. Choose the installed components. There are four different installation groups:

1 **Full**: select all the components

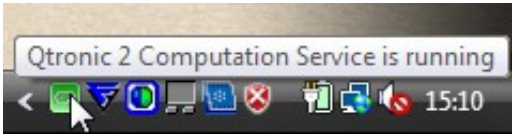
2 **Server**: select server components, namely Qtronic Computation Server and PostgreSQL database

3 **Client**: select client components, namely Qtronic Eclipse Client, Conformiq Modeler, and example models

4 **Custom**: lets user to select only those components that are needed

4. If Qtronic Eclipse Client was selected, the next thing is to specify the directory where Eclipse has been installed.
5. If PostgreSQL database was selected, the next thing is to specify the data directory for the Qtronic database. It is recommended that the location is outside the Qtronic installation directory.
6. Specify the menu items i.e. should the installer create Start Menu items and Desktop shortcuts.
7. Click **Install**. This will install the selected set of components to your computer.

The Qtronic Computation Server can be started by double clicking the "Qtronic 2 Computation Service" icon in desktop (or directly executing *qtronic2manager.exe* in the installation directory). Once started, QCS will minimize itself to Windows system tray that you can see on the lower right hand side of the Windows desktop.



QCS minimized to Windows system tray

2.3.2 How to Uninstall Qtronic 2 on Windows

Qtronic for Windows can be removed from your computer by using a built in feature of

Windows for uninstalling programs. In order to uninstall Qtronic, choose Qtronic from the list of installed programs found from *Add or Remove Programs* from *Control Panel* of Windows.

2.4 Installing Qtronic 2 on Linux

Conformiq Qtronic can be installed on most modern Linux distributions with Intel 586 (Pentium) compatible processors. For support for other processors, please contact your supplier.

2.4.1 How to Install Qtronic 2 on Linux

Linux installer is provided as a **bash** script.

The installer can be used to install the Qtronic Eclipse client or Qtronic Computation Server or both. The installer will also allow the installation of Conformiq Modeler, a light-weight modeling tool for drawing UML statemachine diagrams, example models, and more.

Unpack the installer package before continuing to the installation:

- Unpack the installer file using `tar` command

```
tar xvfz qtronic-<version>-linux-libc-2.4.tgz
```

* Change to the installation directory

```
cd qtronic-<version>-linux-libc-2.4
```

* Execute the **install.sh** bash script in the installation directory. This will start the Linux installer.

```
./install.sh
```

The following list detail the process of installing Qtronic to your computer:

1. Specify destination directory for the installation. The default is **$HOME/qtronic**. If the installation directory does not exist, the installer will create one. Make sure that you have permissions to write to the destination directory.
2. Specify whether you want to install Qtronic Computation Server. The default is **yes**. If you select server installation, the installer will install the server and database components to the destination directory, and initialize the database appropriately.
3. Specify whether you want to install Qtronic Eclipse client. The default is **yes**.

1 If you select the client installation, the installer will prompt you to specify the location of Eclipse installation. The default location that the installer looks is **$HOME/eclipse**.

4. Installer will install the selected set of components to your computer.
5. At your own discretion, you may want to add the directory where Qtronic resides to your $PATH, or create a symbolic link from '/usr/local/bin' or '/usr/bin' to the individual executables.

The Qtronic Computation Server can be started by executing command `qcs` in the installation directory. For example installing QCS to default location, QCS is started as follows:

```
$HOME/qtronic/qcs
```

2.4.2 How to Uninstall Qtronic 2 on Linux

- Remove the directory that you originally selected as the destination directory for the installation. For example, if this directory is **$HOME/qtronic**, execute

```
rm -rf $HOME/qtronic
```

* If you created any symbolic links to the executables, remove the symbolic links.

- Remove the Qtronic Eclipse Client "link file" from the Eclipse installation directory. For example, if the Eclipse installation directory is **$HOME/eclipse**, execute

```
rm $HOME/eclipse/links/com.conformiq.qtronic.client.link
```

2.5 Checking the QEC Installation

After Qtronic Eclipse Client has been installed, the next step is to check that the plugin has been properly activated by Eclipse. The most straightforward way is to start Eclipse and select **Window > Open Perspective ...** and check that **Qtronic** is listed there. If not, the most likely reason is that the Java version that Eclipse is using is not recent enough or similar. See Section How to Switch to Qtronic Perspective for more information about Qtronic perspective.

Troubleshooting QEC Installation

If the **Qtronic** is not listed in the list of available perspectives explained in previous section, it is recommended that you start troubleshooting by following the steps detailed below:

1. Select **Window > Show View** and select **Other**. This will open **Show view** wizard.
2. From **Show view** wizard, select **PDE Runtime > Plug-in Registry**. This will open **Plug-in Registry** wizard.
3. Locate **com.conformiq.qtronic.client** from the list of installed Eclipse plug-ins. If the plug-in is not listed here, the installation has failed and you need to reinstall the QEC again. Make sure that you have the permission to write to Eclipse installation

directory.

4. If the **com.conformiq.qtronic.client** plug-in is listed in **Plug-in Registry**, check that the version of Java compiler that Eclipse is using is 1.6 or higher. In case you have multiple different versions of Java installed on your computer, you may need to set your **PATH** environment variable so that it lists Java version 1.6 first before older versions and to restart Eclipse.

If after taking the steps above, Qtronic is still not registered in Eclipse, please contact software provider.

Note that plug-in registry is not available in all the Eclipse packages. It is recommended to use *Eclipse Classic*.

Checking the Version of QEC

The version of QEC plugin can be checked by selecting **Help > About Eclipse SDK**. This will open **About Eclipse SDK** view where you select **Plug-in Details** which opens **About Eclipse SDK Plug-ins** view. This view will list all the plugins that are installed to the Eclipse with version numbers. The QEC plugin is provided by *Conformiq Software* and the plug-in name is *com.conformiq.qtronic.client*.

Customizing the Qtronic Perspective

The Qtronic perspective in Eclipse user interface can be customized in number of ways. You can for example, disable and enable some of the command groups in the tool bar.

In order to add or remove command groups from the tool bar, follow the steps detailed below

1. Switch to Qtronic perspective, for example by selecting **Window > Open Perspective > Qtronic**.
2. Select **Window > Customize Perspective...**. This will open **Customize Perspective** wizard.

3. Select the **Commands** tab.
4. Select the command groups that you want to have in the tool bar from the **Available command groups**

Use the steps above if for some reason the Qtronic specific commands are not visible in the tool bar in Qtronic perspective.

2.6 License Management in Qtronic2

Conformiq Qtronic is license managed software. This means that every time you run Qtronic it checks for an electronic certification of your right to use it. (This does not mean that Qtronic would contact any service outside your company, for instance, a service provided by Conformiq Software at its own domain.)

The purpose of the license management features is not to define what your use rights are in the first place, because this is done in the licensing agreements between you or your company, and the copyright holders of Conformiq Qtronic. Rather, the license management features help you to abide within the terms of these agreements.

Keeping this in mind, there are three different mechanisms that Qtronic uses to verify your right to use the software:

- Qtronic evaluation version makes use of evaluation keys, which are short character sequences looking like APO39-JK119-NCQOL-011LX-ZMNNM. When Qtronic is running as the evaluation version it will ask for an evaluation key. Evaluation keys have a limited validity time.
- Other versions of Qtronic, like Qtronic SG, check for a right to use the software at startup and then regularly until the software is closed.

In the last case, what Qtronic needs is a license grant, which is a small electronic document (actually, a block of a few lines), that certifies that Qtronic can be used in its present configuration at your local computer node. Qtronic can get access to this license grant in two ways:

- You can manually cut-and-paste the block into a text edit box in Qtronic via the GUI's license management features. The license grants fed in by this method are usually long-term, node-locked grants. This is known as node-locked licensing.
- Qtronic can automatically check out the grants as short-term, renewable grants from a license server. Qtronic uses web-based license server (but the license server usually resides at your intranet server rather than in the public Internet). This is known as floating licensing.

As already implied, there exist different configurations of Conformiq Qtronic. These configurations are not shipped or installed separately. Instead, Conformiq Qtronic can be configured dynamically to run in any of these configurations. However, because different configurations have different licensing requirements, probably not all of them are actually usable for you. If you select a configuration that you do not have a license for, Qtronic will not work properly but will prompt you about a missing license and guide you to reconfigure the product.

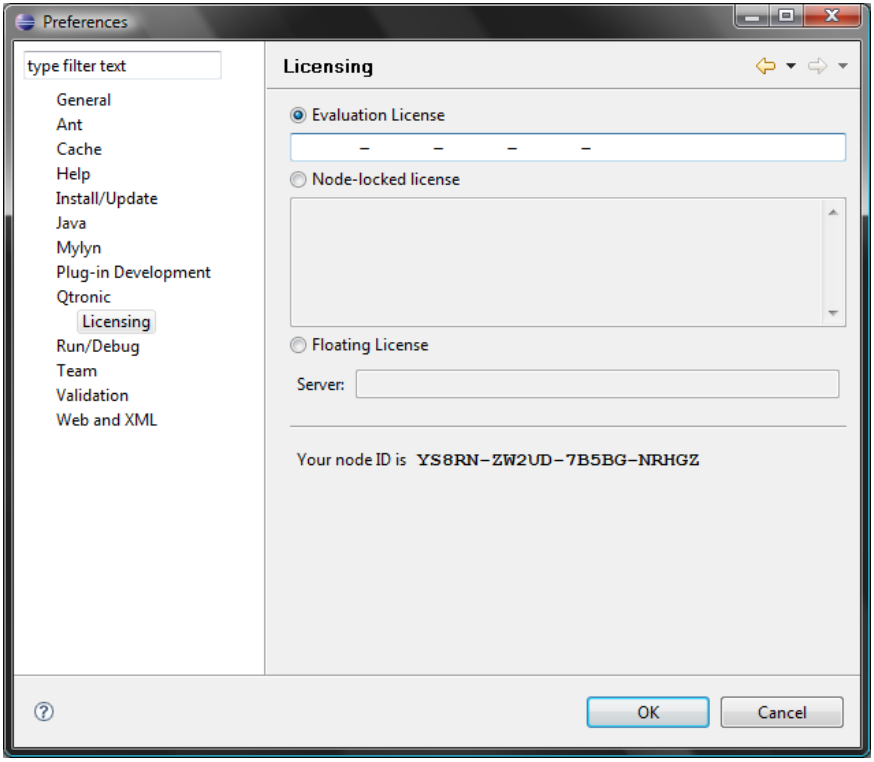
2.6.1 Configuring Qtronic Feature Set

When you start Conformiq Qtronic for the first time, the tool will immediately ask you for the product configuration.

If you are conducting an evaluation of Conformiq Qtronic, choose Qtronic Evaluation. In other cases, choose the Qtronic version that matches your node-locked or floating licenses. When in doubt here, contact your system administrator.

Qtronic will remember your choice and will not prompt you again for it. However, you can reconfigure Qtronic at your will by

1. selecting **Window > Preferences...** in the main menu. This will open Preferences wizard
2. selecting **Qtronic > Licensing** from the Preferences wizard. This will open the Qtronic License Management view shown in the figure.



Qtronic License Management view

2.6.2 Qtronic Evaluation

Conformiq provides a limited time evaluation licenses for the prospective customers who are interested to find out the suitability of Conformiq Qtronic to their specific needs and test environments. Prospects can download an evaluation copy of Conformiq Qtronic from Conformiq website and request the license online.

The evaluation licenses are node specific: two nodes cannot use the same evaluation license, but instead a separate evaluation license must be provided for each distinct node. The evaluation versions of Qtronic can only be run on computers that can connect to the external internet using the port 80 (HTTP) because Qtronic Computation Server will check that the given evaluation license is not already registered to some other node.

If you need to use HTTP proxy in order to get access to external network, you can configure Qtronic Computation Server to use HTTP proxy by setting **http_proxy** environment variable before running QCS. In Linux you can do this by running **export http_proxy=http://proxy.mycompany.com** in sh/bash/ksh shells and **setenv http_proxy http://proxy.mycompany.com** in csh/tcsh shells. In Windows, the environment variable can be set for example by using the **set http_proxy=http://proxy.mycompany.com** command. If your proxy uses login then the proxy address needs to be written in the format **http://user:password@proxy.ip.address:port** in the above commands.

If you are conducting evaluation of Conformiq Qtronic, make sure you have selected the "Qtronic Evaluation" configuration (see above). If you do not have a valid evaluation license already installed, Qtronic will ask you for one. Enter the evaluation key you have received when prompted. Qtronic will notify you about the remaining evaluation time every time you establish connection to QCS.

If you want to change the evaluation key even while the current key is still valid, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open Preferences wizard
2. Select **Qtronic > Licensing** from the Preferences wizard.
3. Check **Evaluation License** check box and enter the license text block.

Most features of Qtronic are available in the evaluation version.

2.6.3 Node-Locked Licensing

If you have a node-locked license for your configuration and your node, you can provide the license to Qtronic in the license management dialog.

To configure a node-locked license, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open Preferences wizard
2. Select **Qtronic > Licensing** from the Preferences wizard.
3. Check **Node-Locked License** check box and enter the license text block.

Node-locked licenses are text blocks that start with "#### BEGIN CONFORMIQ LICENSE GRANT ####" and end with "#### END CONFORMIQ LICENSE GRANT ####". Typically you receive this kind of a license via e-mail. Cut-and-paste the block to the text box and accept the dialog. Qtronic notifies you whether the license was successfully added or not.

Qtronic remembers the node-locked licenses you have installed so you do not need to store the block separately in the file system.

2.6.4 Floating Licensing

To employ floating licensing you must have an installed web-based license server for Conformiq Qtronic. The administration of the server is described elsewhere; this section focuses on the use of Conformiq Qtronic given that a license server is running.

To configure the license server into use, follow the steps detailed below:

1. Select **Window > Preferences...** in the main menu. This will open Preferences wizard
2. Select **Qtronic > Licensing** from the Preferences wizard.

3. Check **Floating License** check box and enter the base URL for the server. This base URL you will receive from your system administration, as it depends on where the license server has been installed.

The URL to the license server binary is the "base URL" that Qtronic users must configure into their Qtronic installations; for example, "http://server.company.com/cgi-bin/cgiserver.exe". See Section License Server Management for more information.

Usually the license server resides at an intranet web server, so if you have an access to the web server from the external Internet, it can be possible that you can check out Qtronic licenses also from outside your local network. How this actually works depends on how your company has organized external intranet access. Please note that Qtronic does not use https (secure HTTP) for accessing the license server and therefore cannot log in on a secure web server, so you may need to have a VPN solution or a local web proxy.

The floating license mechanism works also when the license server and licensing client do not agree on the current (wall-clock) time, but if the time difference is more than 24 hours in either way licensing will stop working properly. Also, if you adjust the clock at the licensing client while there are active grants for the client you may find out that refreshed grants will not work properly. In this case you must wait until your local license grants have expired and continue using Qtronic only afterwards.

2.6.5 Obtaining Node Identifiers

Some times you need to be able to obtain the node identifier for your local node manually. The two cases are:

- You are ordering a node-locked license and your supplier must receive the node identifier in order to bind the license to it.
- You are administrating the license server and you are ordering floating licenses to it.

In order to get the node identifier, open the **Preferences** wizard and select **Qtronic > Licensing**. The node identifier is shown on the bottom of the opened page. You can also retrieve the node identifier by running the "Conformiq Node Identification" program (**cq-node-id** in Linux and **cq-node-id.exe** in Windows). This will show a popup window that contains your node identifier. When the popup is shown, the node identifier has been copied on your system's clipboard, so you can immediately paste it in any other application.

The purpose of the node identifier is to reliably distinguish between different machines where Qtronic might be used or a Qtronic license server might be installed. The node identifier is aggregated from some details of the node's hardware devices. It is possible, although not usual, that the hardware devices change in a way that cause the node identifier to change. This may also happen if you enable / disable for example wireless network devices from BIOS. If you are running floating licensing this is not a huge problem because the grants for the old node will expire whenever they were going to expire anyway, after which you can check out grants for the new node. In the case of node-locked licensing you must contact your supplier who will help you to transfer you node-locked license to the new node.

2.7 License Server Management

If you want to provide floating licensing to your users you must install the license server. This is a CGI (Common Gateway Interface) binary thay you install (usually, copy in the filesystem) into your web server in a location where it can be accessed via an URL.

For example, if you are using the Apache web server you must copy the binary to a directory that has the ExecCGI option set, or that has been set as a general location for CGI scripts by the ScriptAlias directive.

The server CGI binary will establish a license management database when it is run for the first time. The location for this database cannot be changed in order to prevent accidentally

running multiple license server copies. On Windows the location is C:\WINDOWS\Conformiq\licserv.db and on Linux /etc/conformiq/licserv.db. On both operating systems the database file is a regular file.

The web server must have write access to the directory and the database file when it is executing the CGI binary.

The license database is actually an SQL database that resides inside the file. If you try to modify the contents of the database by hand you will end up in a situation where the server says that the integrity checks for the database fail. At this point the database has been rendered unusable and the license server ceases to work. Do not modify the database by hand.

Once you have installed the CGI binary (cgiserver.exe) to the correct location, you can validate that the installation has been succesful by opening the CGI binary via a web browser.

For example, if you installed the binary on an Apache server in its default configuration on server "server.company.com", try to access it via "http://server.company.com/cgi-bin/cgiserver.exe". If the installation has been succesful and the database created correctly you will receive a page showing an empty list of licenses and a text box where you can edit text (this box is used for adding permanent licenses to the server).

The URL to the binary (as above) is the "base URL" that Qtronic users must configure into their Qtronic installations; for example, "http://server.company.com/cgi-bin/cgiserver.exe".

2.7.1 Viewing Licensing Status

To view the licensing status, just open the CGI binary via a web browser. You will receive a list of licenses with their corresponding active grants (if any).

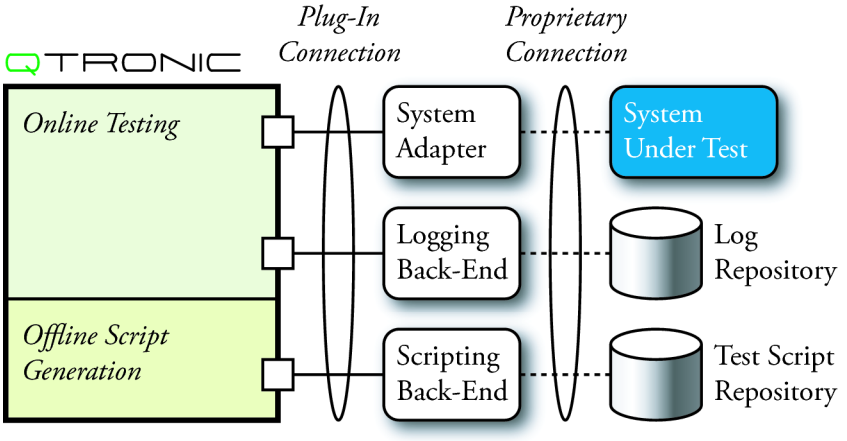
2.7.2 Adding Licenses

To add licenses to the server, cut-and-paste the license block you have received from your vendor in the text box that is shown on the status page below the list of licenses and active grants.

3 Testing with Conformiq Qtronic2

Conformiq Qtronic2 is a tool for offline generation of test scripts (the particular features available depend on your licensing options). Conformiq Qtronic creates and executes tests driven by design models. It is not in itself, however, a tool for creating these design models. The reason for this is that Conformiq Qtronic supports multiple types of design models, and the different types are created and modified using different tools:

- Java/UML models can be created using text editors and Conformiq Modeler, a separate tool that is shipped with Qtronic GP.
- Conformiq Qtronic Ecosystem Packages (QEPs) are created using special software used to manage ecosystem licensing.
- Models created using some of the leading 3rd-party modeling tools.



Overview of the Qtronic architecture

To start testing with Conformiq Qtronic one needs first a *design model* (see Secion Conformiq Qtronic in Software Process). One also needs further *scripting back-end*.

For more information about creating UML/Java models, see Creating Models in QML. Scripting backends are discussed in Creating Qtronic2 Scripting

Backends.

3.1 Quick Start of Using Qtronic 2

The following list summarizes the steps when working with Qtronic 2.

1. Switch to Qtronic perspective by selecting **Window > Open Perspective...** and then **Qtronic**.
2. Select **Window > Preferences...** to configure license and the QCS server location.
3. Create a new Qtronic project by selecting **New > Qtronic Project**. This will also create a *Test Design Configuration* which 'owns' the coverage settings and scripter plugins.
4. Select model files to project by either importing or linking them to project.
5. Import model files to QCS by clicking **Load model files to Computation Server**.
6. Select coverage goals from the test design configuration that was automatically created when Qtronic project was created.
7. Select Qtronic project and click **Properties** to configure Qtronic algorithmic options.
8. Generate test case by clicking **Generate Test Cases from Model**.
9. Analyze the test generation results in the QEC user interface after the test generation finishes.
10. Select a scripter plugin by selecting the test design configuration and clicking **New > Scripting Backend**.
11. Render the test cases in the format specified by the scripter plugin by clicking **Render All Test Cases**.

As discussed in Section How to Work with Qtronic2 Projects it is highly recommended to

store project data locally to prevent any data loss due to network outages or other problems by selecting *Qtronic* > *Save Project* after project has been updated, after changing and reloading the model, and after generating test cases.

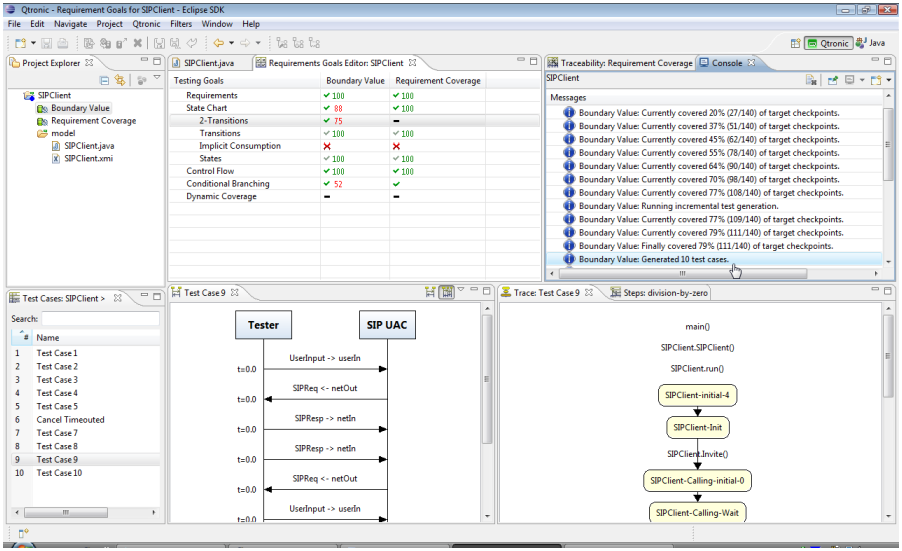
The usual flow in testing with Conformiq Qtronic is very simple as shown in the next few how-tos.

3.2 How to Switch to Qtronic Perspective

Qtronic perspective in Eclipse is a group of views and editors in the Workbench window. Qtronic perspective can exist in a single Workbench window with other perspectives.

Switching to Qtronic perspective is carried out by selecting **Window > Open Perspective > Qtronic**. If the Qtronic perspective is not visible after selecting **Window > Open Perspective**, select **Other...** from the drop down menu where **Qtronic** is shown.

The Qtronic perspective looks as shown in the Figure. The different views and editors are covered in detail in the following sections.



Qtronic Eclipse Client

3.3 How to Configure Qtronic2 Client

Before loading models or generating any test cases, Qtronic2 Eclipse client must be configured with the Qtronic computation server address and port number. The server address can be either a hostname or IP-address. By default, the port number that Qtronic computation server uses is 2727.

1. Open preferences by selecting **Window > Preferences...**.
2. From *Preferences*, select *Qtronic*
3. Enter the address and the port number of the Qtronic computation server


The location of QCS is *Eclipse workspace* specific setting, therefore each Qtronic project in a Eclipse workspace share the same QCS location. See Section Managing Qtronic Projects for more information about Eclipse workspaces.

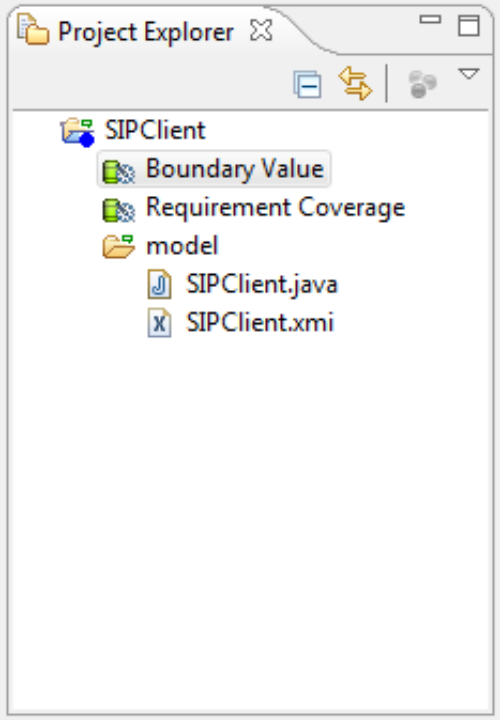
3.4 How to Work with Qtronic2 Projects

Testing setups are managed as projects in Conformiq Qtronic2. They are structural units that can be opened and closed. Qtronic projects contain the following information:

- Model files
- Test design configurations
- Test generation options

In order to create a new Qtronic project, follow the steps below:

1. On the main menu bar, select **File > New Qtronic Project**. The New Project wizard opens.
2. In the **Project name** field, enter the name of the new Qtronic project.
3. Click **Finish**. This will create a new Qtronic project which will be visible in the Project Explorer. Note that this operation will also create a single *Test Design Configuration*. More information about Test Design Configuration is given in Section How to Create Test Design Configurations.



An example Qtronic project in Eclipse Project Explorer

In order to prevent any possible data loss due to network connection problems with Qtronic Eclipse Client and Qtronic Computation Server, it is *highly* recommended that the project data is saved by the user by selecting **Qtronic > Save Project Data** after project has been updated, after changing and reloading the model, and after generating test cases. This will take a snapshot of the server database which can be restored by the client if server for some reason becomes unavailable and is restarted.

In order to close a Qtronic project, follow the steps below:

1. Select the Qtronic project in the Project Explorer view.
2. Click **Close Project** in the pop-up menu.

It is recommended that you close Qtronic projects when you are not working with them, because closing of a Qtronic project will free some resources from the Qtronic Computation Server.

To re-open the Qtronic project:

1. Select the Qtronic project in the Project Explorer view.
2. Click **Open Project** in the pop-up menu.

To delete a project and remove its contents from the file system:

1. Select the Qtronic project to be removed in Project Explorer view.
2. Click **Delete** on the pop-up menu.
3. In the dialog that opens select **Also delete the contents under ...**
4. Click **Yes**

If you do not wish to delete the contents as well, simply select **Do not delete contents** from the opened dialog.

If the model files and scripter plugins are imported to the project (the process of adding model files and scripter plugins to the project is explained later), the original files are left intact even if you choose **Also delete the contents under ...** in the dialog window.

See Section Managing Qtronic Projects for more information about Qtronic projects.

3.5 How to Select Models

Each Qtronic project contains a folder called **model**. This is where the model from which the tests will be generated will reside.

The manifest file concept used in Qtronic 1.X is no longer used and the model files are individually selected to the project instead of a single manifest file.

The first step in importing the model to Qtronic is to add model files to **model** folder. There are couple of ways to do this:

This first option is to actually copy the model files to the Qtronic project. This means that the original model files and imported model files are totally distinct thus changes and not reflected automatically between these physical resources. The steps to import model files to a Qtronic project are detailed below:

1. Select **model** folder under a Qtronic project in Project Explorer
2. Select **Import** from the pop-up menu. This will open Import wizard.
3. Select **General > File System** and click **Next**.
4. Click the **Browse** button on the opened page to select the directories from which the model files will be added. Click **OK** once the directory has been selected.
5. From the pane on the right hand side select those files that are part of the model and click **Finish**.

The second option is to create a link to model files in the file system. This means that the Qtronic project does not contain the model files, but just file links to them. The steps to create file links to the actual model files are detailed below:

1. Select **model** folder under a Qtronic project in Project Explorer
2. Select **New > File** from the pop-up menu. This will open New File wizard.
3. Click **Advanced** and check **Link to file in the file system**.

4. Select **Browse...** which will open a file selector.
5. Navigate to the model file and select **OK**.
6. Finally click **Finish** in the New File wizard.
7. Repeat the steps above for each file that is part of the model.

A very convenient way to work with linked resources is to use *path variables* which are used to specify locations on the file system. The location of linked resources may be specified relative to these path variables. By using a path variable, you can share projects containing linked resources with team members without requiring the exact same directory structure as on your file system.

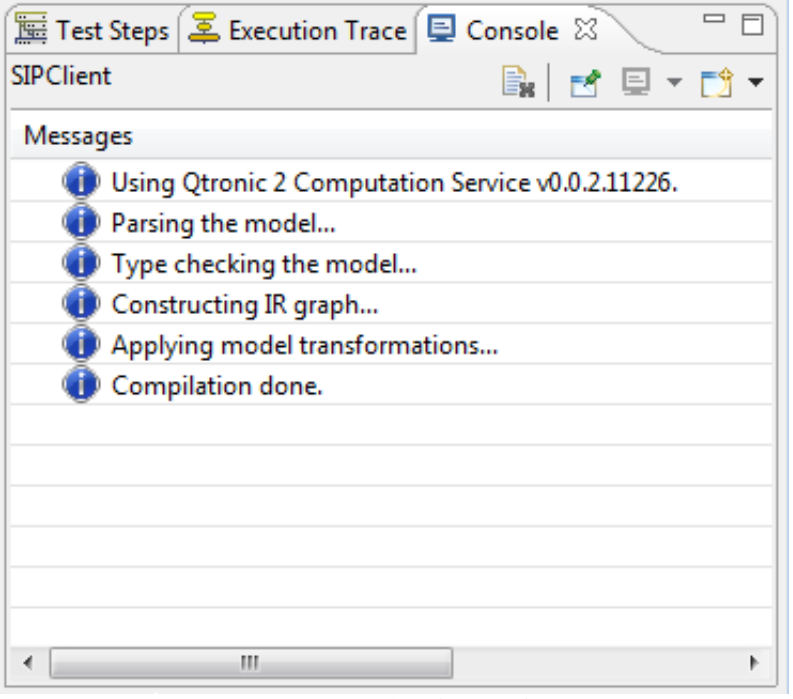
Path variables are created as follows

1. Select **Window > Preferences...**. This will open **Preferences** wizard.
2. Select **General > Workspace > Linked Resources**.
3. Select **New...** and enter the name of the new path variable and the location.

Now when you link a model file to your Qtronic project, you can do it by using this path variable. Now instead of defining the absolute path to the model file, you select path to the model file that is relative to the path variable. This way when another member of your team uses the same Qtronic project, she can redefine the path variable to point to a proper location in her file system.

See Section Managing Qtronic Projects for more information about Qtronic projects.

Once the model files have been imported from the file system to the Qtronic project, the model can be loaded to Qtronic computation server by selecting **Load Model** in the tool bar. This will send the model files to the Qtronic computation server, which then imports the model. The status information in addition to warning and error messages is shown in the Eclipse Console.



Eclipse console showing results of successful model import

Model files are always inserted to **model** folder. This is where Qtronic will look for model files, nowhere else. Under model folder, you can have directory hierarchy so that logically distinct model parts (such as server components and client components) can be placed into different subdirectories. Note however that all the files under model directory are treated as part of the model, therefore you cannot place for example documentation files under model directory.

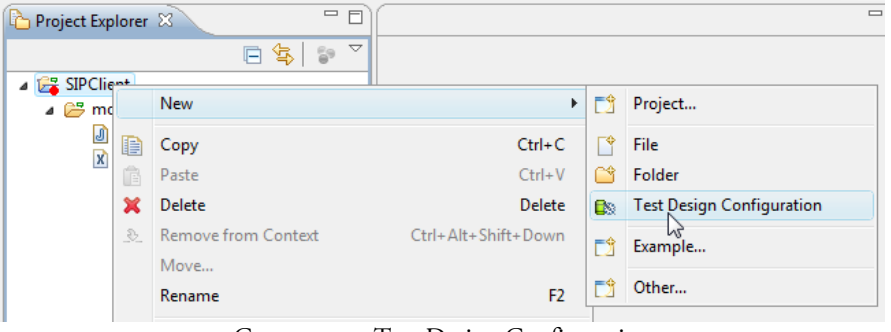
3.6 How to Create Test Design Configurations

A feature introduced in Qtronic 2.0 is the test design configurations. The test design config-

urations allow user to create different profiles with different coverage settings and scripter plugins for different testing purposes. For example, user may wish to have a test suite for verifying very basic requirements of the system and another test suite for verifying very detailed corner cases such as boundary values of integral comparisons and such. In this particular case, user can define two distinct test design configurations to a single Qtronic project: one for verifying the very basic requirements and another for verifying more detailed corner cases.

Test design configurations contain a set of coverage settings and a set of (possibly an empty set) of scripter plugins. In order to create a new test design configuration to a Qtronic project, follow the steps below:

1. Select the Qtronic project in the Project Explorer view.
2. Select **New > Test Design Configuration** from the pop-up menu. This will open **New Test Design Configuration** wizard.
3. Enter the name of the new test design configuration to **Test Design Configuration name** field and click **Finish**.



Create a new Test Design Configuration

Note that when Qtronic project is created, a single Test Design Configuration is created by default. For more information about creating and working with Qtronic projects, refer to Section How to Work with Qtronic2 Projects.

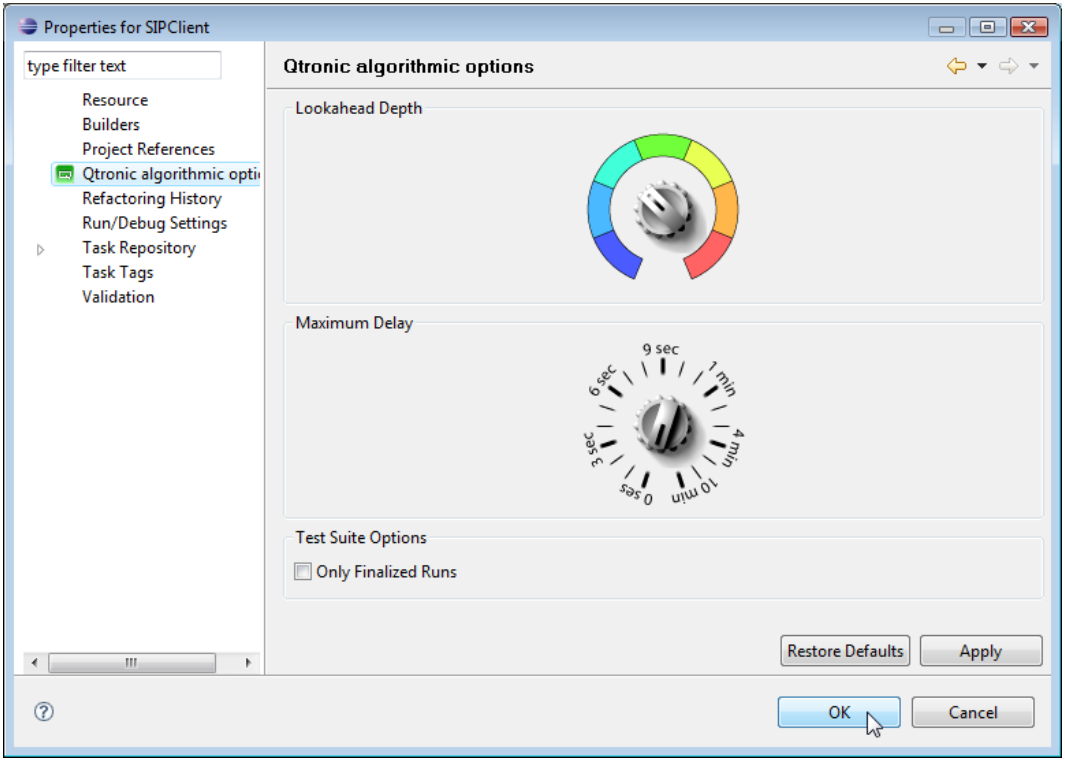
3.7 How to Configure Test Generation

There are two different "types" of test generation parameters in Conformiq Qtronic: those that are general and global across different test design configurations, and those that are bound to specific test design configurations. For example, the concepts of *lookahead depth* and *only finalized runs* are generic as they are properties that evolves from the model.

3.7.1 How to Configure Global Testing Parameters

To modify the project wide testing parameters, follow the steps shown below:

1. Select Qtronic project in the Project Explorer
2. Select **Properties** from the pop-up menu. This will open **Properties** wizard.
3. Select **Qtronic** from the left hand side of the view.



Configuration view for Qtronic algorithmic options

The properties shown in the view are the following:

Lookahead Depth

Controls the amount of lookahead for planning the test scripts. The value of the lookahead corresponds to the number of external input events to the system or timeouts. Selecting values from the left correspond to lower lookahead values. When Qtronic plans the tests, it intellectually selects interesting values for data based on the logic in the design model. If the logic that manipulates the data is after certain number of external events, the lookahead value must be increased, because Qtronic must be able to "see" this in order to make decisions on the data

values. If you set this value to a too low value you can miss some tests (of course, you will see this from the coverage reporting). On the other hand, having too high a value can cause very high test generation times. Therefore, reasonable values for lookahead depth are recommended and you should always start with the lowest possible value. Practically most often the third level (color cyan) is the highest that you need to go and if this is not sufficient, it is likely that there is some problem in the model.

Maximum Delay

Defines the communication slack i.e. the time interval in which it is OK to deliver a message. Recommended values are from 3 to 10 seconds, but this depends on your application. As a rule of thumb, the latency value should be at most 1/2 of the granularity of timeouts in your system if any. For example, if your system has a timer that expires in ten seconds, you should not use latency value higher than 5 seconds.

Test Suite Options

When 'Only Finalized Runs' is selected, Qtronic will only generate test cases that end the system in a “clean” state. When this setting is activated, only such test cases are accepted to the generated test suite that would cause all threads in the model to terminate. In practice, this usually means that a main statechart has entered one of its final states.

When 'Stop at 100% Requirement Coverage' is selected, the test generation is automatically stopped upon reaching 100% requirement coverage, which obviously can mean that test generatation is topped before reaching 100% final overall coverage.

'Test Case Name Prefix' is used to define the default name prefix that is given to new test cases. By default this value is 'Test Case ' which means that when a new test case is generated, they are given names such as 'Test Case 1', 'Test Case 2' and so on. For more information about naming / renaming test cases, please refer to Section Naming Test Cases.

Generic offline test generation parameters may not be changed during offline script generation so these options are all disabled while generating tests.

3.7.2 How to Configure Design Configuration Specific Testing Parameters

Each test design configuration have their own set of *model driven coverage criteria* that is used by Qtronic to select a set of test cases to form a good test suite. The *coverage goals* are used to guide Qtronic to look for certain behaviors from models or to enable certain behaviors i.e. to generate test cases that "cover" the coverage goals in the model whether they are related to the constructs in state machines (such as states and transitions) or to the constructs in the action language (such as conditional branching or statements). In Qtronic it is defined that a test case covers a certain coverage goal if execution of the test against the model itself would cause the goal to be exercised.

Coverage options are organized into a hierarchy where atomic coverage options are contained inside groups. The coverage groups are a way to organize and present atomic coverage options to the user. Each coverage option can have the following setting:

Denotes a *target* goal. Guides Qtronic to look for behaviors that cover each target goal.

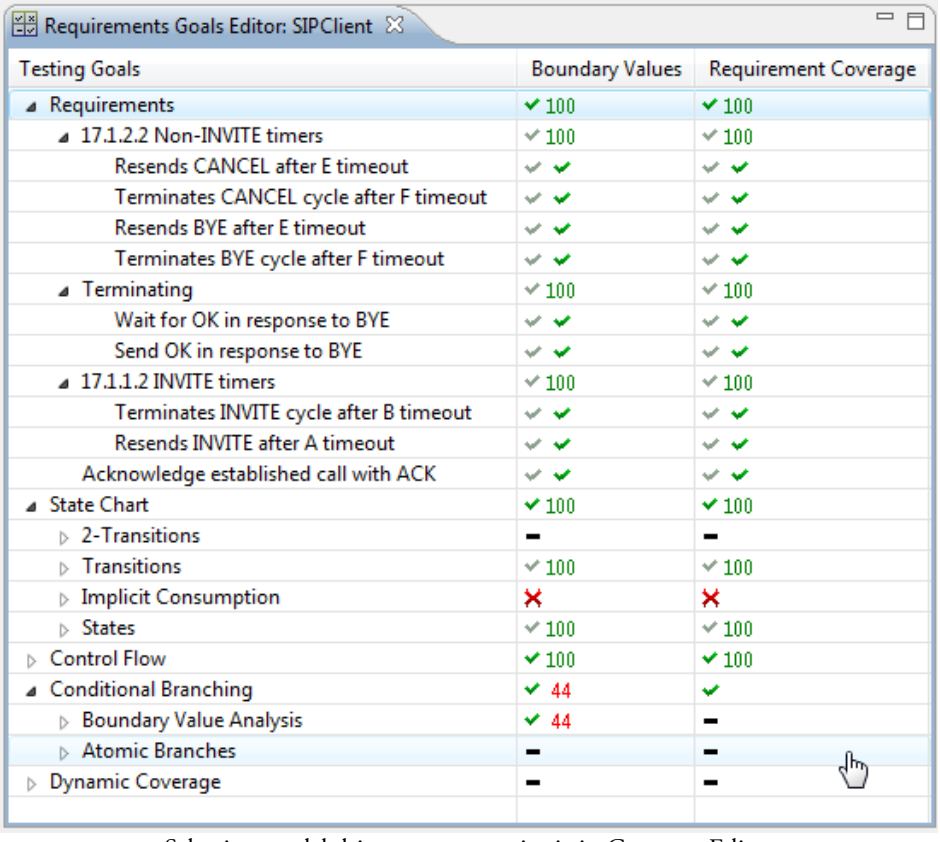
Denotes an ignored goal ("do not care"). Qtronic will ignore these goals while generating the tests.

Denotes a blocked goal. Guides Qtronic to omit all the scenarios where the given coverage option is covered. Thus the distinction with **Do not care** and **Block** is that goals marked as **Do not care** can still be covered in the generated tests, they are simply not goals for the tool. Qtronic will not generate such a test that would exercise a blocked coverage option, therefore with blocked coverage options user can prevent Qtronic from generating

such test cases that realize certain unwanted test scenarios.

The fourth option is **Inherit** i.e., coverage option inherits the setting from the coverage group containing the coverage option.

The **Coverage Editor** is used to set coverage settings. In order to open the view double click test design configuration under a Qtronic project in Project Explorer. This will open the view as shown in the Figure. Note that the view only contains relevant information once the model has been loaded to the Qtronic computation server. In this view, there are two columns for each test design configuration: the left hand side corresponds to the coverage setting (intention) and the right hand side column corresponds to the current coverage status (result). When the cell is edited (left hand side column), the coverage status will be kept as it is, but the test design configuration name in the column header is appended with * -character. When test generation is finished (completed), this * -character is cleared.



Selecting model driven coverage criteria in Coverage Editor

See Section Coverage Editor for more information about analyzing coverage status information.

With enhanced coverage goal setting features introduced in Qtronic 2.0 users have finer grained control over selected structural features enabling users to set coverage setting to individual structural features: now users can select only an interesting

subset of the structural features instead of having to set all the coverage goals related to a given structural feature or none of them.

The following coverage settings are related to state machines and they are not visible if there are no state machines in the model.

State Coverage

Guides Qtronic to look for behaviors that cover every UML level state at least once (not visible if there are no states in the model).

Transition Coverage

Guides Qtronic to look for behaviors that cover every UML level transition at least once (not visible if there are no transitions in the model).

2-Transition Coverage

Guides Qtronic to look for behaviors that cover every pair of two subsequent UML level transitions at least once (not visible if there are no transitions in the model).

Implicit Consumption

Guides Qtronic to test that the system correctly ignores messages that are not handled on any transitions going out from a UML state. A word of warning, though. Enabling implicit consumption may not be what you really want. Without implicit consumption selected, Qtronic focuses testing on the explicitly modeled message handlers. With implicit consumption, Qtronic may send to the system also messages that are not handled in your UML diagrams.

The following configuration options are related to conditional branching. These options are not visible if there are no such a conditional branching in the model.

Boundary Value Analysis

Guides Qtronic to look for behaviors that cover the boundary value cases for all the arithmetic comparisons. Boundary value analysis is a technique to determine tests

covering known areas of frequent problems at the boundaries of input ranges.

In boundary value analysis the boundaries partition the input domain and we assume that the system partitions the input into a set of domains in which the systems behavior is similar. Due to this, we assume that if an input from a domain causes an error then all the inputs of that domain will cases a similar error and if an input from a domain does not cases an error then all the inputs of that domain will fail to produce an error.

Based on these assumptions, Qtronic attempts to cover the structure of the input as follows:

- For every arithmetic comparison 'x = y' and 'x != y' cover cases 'x < y', 'x = y', and 'x > y'
- For every arithmetic comparison 'x < y' cover cases 'x < y - 1', 'x = y - 1', 'x = y', and 'x > y'
- For every arithmetic comparison 'x <= y' cover cases 'x <= y - 1', 'x = y', 'x = y + 1', and 'x > y + 1'

Branch Coverage

Guides Qtronic to look for behaviors that cover every QML level branch (such as *then* and *else* branches of *if* statements) at least once.

Atomic Condition Coverage

Guides Qtronic to look for behaviors that cover every QML level atomic condition branch (such as left and right hand sides of a Boolean *and*) at least once. Note that because the modeling language uses short-circuit evaluation for Boolean connectives, there are value combinations that cannot be meaningfully tested in general. For example, in the case of `x && y`, Qtronic will not attempt to generate a test case where 'x' would be false and 'y' would be true. The reason is that the short-circuit evaluation rule will cause the evaluation of the condition to cease after it has been found out that 'x' evaluates to false, which makes it possible that the value of 'y' may depend on the assumption that 'x' evaluates to true. (Note that 'x' and 'y' can be both e.g. method calls).

The following configuration options are related to general control flow.

Method Coverage

Guides Qtronic to look for behaviors that cover every QML level method at least once. Note that this coverage option essentially has no effect on the values passed to methods.

Statement Coverage

Guides Qtronic to look for behaviors that cover every QML level statement at least once.

The following coverage options belong to "dynamic coverage goals" group i.e. these coverage goals are calculated by Qtronic on-the-fly as it analyses the model. Because of this on-the-fly calculation, Qtronic will not give coverage percentage for these goals and these coverage goals do not have effect to the final coverage figures.

Parallel transition coverage

Parallel transition option is used to guide Qtronic to look for behaviors that cover every parallel transition configuration. The major new benefit of this feature is that Qtronic can generate tests for parallel configurations of components that are modeled as independent components that can interact maliciously in the real implementation. As parallel transition coverage goals are calculated on-the-fly, also multiple instances of a state machine are taken into account.

The following configurations options are related to *all paths coverage*.

All Paths - States

Guides Qtronic to look for behaviors that cover every *sequence* of UML level states at least once. For example:

1. initial - state1 - state2 - state3 - state4
2. initial - state1 - state3 - state6 - ... - stateN ...

All Paths - Transitions

Guides Qtronic to look for behaviors that cover every *sequence* of UML level transitions at least once. For example:

1. initial->state1 - state1->state2 - ...
2. initial->state1 - state1->state3 - ... ...

All Paths - Control Flow

Guides Qtronic to look for behaviors that cover every *sequence* of conditional branches (f.ex. then and else branches of `if` statements) at least once.

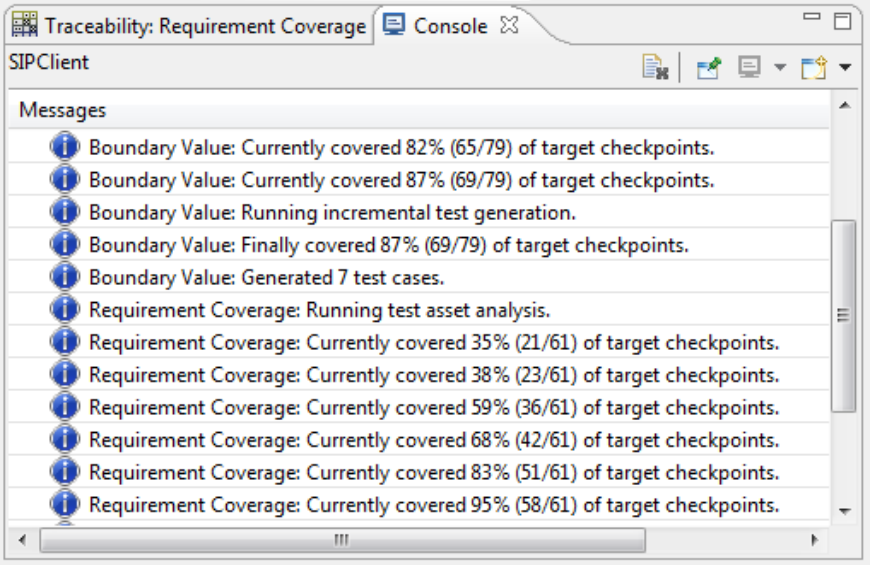
If you have multiple "all paths" coverage options selected, you get combinations of the above sequences as result.

In addition to the different coverage criteria based on the structure of the model described above, the user has the option to use *requirements traceability links* to establish additional test goals driven by functional requirements and testing goals (The requirement links are marked in to the model using `requirement` statement that is an extension to standard Java provided by the QML language. See Section Requirements for more information.). Requirements provide a way to drive test generation by coverage of external functional requirements.

3.8 How to Generate Tests

Once the model files have been selected, the model has been imported to the Qtronic computation server, and the coverage settings have been properly set for the test design configurations, the test generation can be triggered by selecting **Update Test Set**. This will trigger the test generation on the Qtronic computation server.

As the test generation progresses, the Eclipse console window will show the status of the test generation. In addition the *coverage editor* will show the coverage status real-time i.e. what are the so far covered aspects and what is still left to cover for Qtronic.



Status of test generation shown in Eclipse console

Once the test generation finishes, the final coverage will be shown in the Eclipse console as well as the final coverage of each requirement and structural feature in the coverage editor. In addition, the test generation results will be shown in various views in the Eclipse user interface, a subject of the next section.

Test generation can be stopped manually also before the test generation finishes. This can be done by opening the **Progress** wizard for example by double clicking the status text on the lower right hand side of the Eclipse user interface and by clicking the red box with **Cancel Operation** label. When the test generation is manually stopped, QEC will present you two possibilities:

- **Merge** the test generation results, meaning that all the generated test cases generated up till the moment the test generation was stopped are merged to existing set of test cases.
- **Discard** the test generation results, meaning that all the generated test cases

generated up till the moment the test generation was stopped are discarded and existing set of test cases will stay the same as before.

3.9 How to Analyze Test Generation Results

When generating test cases, Conformiq Qtronic maps the test cases to the different test goals induced by the coverage settings as explained in Section How to Configure Design Configuration Specific Testing Parameters. It then selects from the test cases it has constructed a sub set that covers all the found test goals using a minimal cost test suite, where the cost of an individual test case is the number of messages in it squared. This ensures that the suite is reasonably small and compact but at the same time the individual test cases remain relatively short, which eases test execution and debugging. In addition to this, Conformiq Qtronic also prefers to cover all test goals as early as possible, i.e. after as few messages as possible, providing better separation of concerns between test cases.

Once the test generation finishes, the Eclipse user interface shows a number of different views that can be used to analyze the test generation results: in Qtronic 2.X the generated tests are visible in the user interface allowing user to do detailed analysis of the generated tests. The views that are available for test generation result analysis are the following:

- **Coverage Editor** shows the final status of black-box coverage figures.
- **Test Case List** shows all the generated test cases with the generation date and the name of the test case where user can also rename the test cases.
- **Traceability Matrix View** correlates the coverage options to the test cases that "covers" them.
- **Test Case View** shows the interaction between the tester and the system under test.
- **Test Step View** shows detailed information about the messages that are transfered between the tester and system under test in the given test case.
- **Execution Trace View** links back the test case back to the model from which it was generated on a rudimentary way.

3.9.1 Coverage Editor

In addition to selecting the target coverage goals (as explained in Section How to Configure Design Configuration Specific Testing Parameters) **Coverage Editor** can also be used to analyze the status of black-box coverage figures.

While the test generation is running, this view is updated in real-time providing user the means of analyzing the status of the test generation. Once test generation finishes, this view will show the final coverage figures. Coverage status cells can be empty (indicating that the goal was uncovered because it was not targeted), it can contain icon (indicating that the goal has been covered or uncovered although it was targeted), or it can contain a coverage percentage value in case the status corresponds to a coverage goal group. This percentage value is calculated by the user interface from the intentions (targets) and results (covered targets).

The meaning of different icons in the coverage status cells are given below:

 Denotes a covered target goal.

 Denotes a target goal that Qtronic failed to cover. Note that while Qtronic is generating the test cases, there is no status icon for the given atomic goal. However, if the target goal is still uncovered when the test generation stops, this icon will be shown in the QEC user interface.


Note that when the tests are generated, the coverage setting cells cannot be edited.

If the test generation is aborted by the user, the following happens

- If user decides to merge the changes, the Coverage Editor is left to the state that it is (as it was already updated in real-time).
- If user decides to unroll the changes, the Coverage Editor is reverted to a state

before the test generation.

User has several possibilities to filter information in the Coverage Editor using the filtering buttons in the Eclipse menu bar:

 Denotes a filter for unaffected settings i.e. when this filter is enabled the view will only show those cells that have been edited since last test generation or that have never been used in test generation (thus each cell is in "edited state" initially, until tests are generated according to its initial setting).

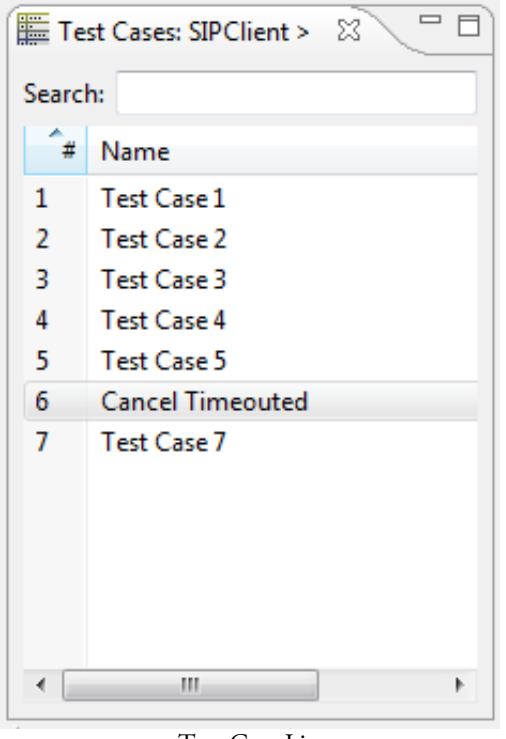
 Denotes a filter for "overridden" settings i.e. when this filter is enabled the view will only show those cells that are not "inherited".

 Denotes a filter for uncovered target goals i.e. when this filter is enabled the view will only show those cells that show a target goal (intension) that Qtronic failed to cover.

3.9.2 Test Case List

The **Test Case List** will show the list of generated test case once Qtronic computation engine has finished with the test generation with the names and creation dates as shown in the Figure.

The Test Case View can be opened by selecting **Window > Show View > Test Case List**.



Test Case List

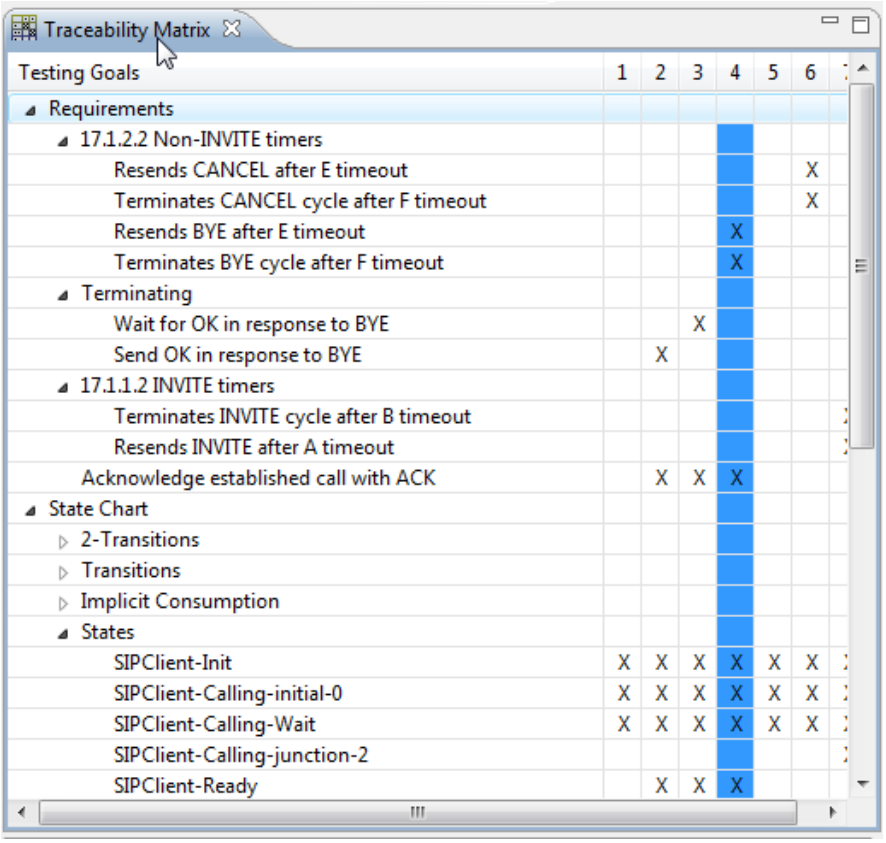
In the Test Case View the test cases can be named and renamed by double clicking a test case in the view. The test case names stay persistent over consecutive test generations.

The test cases can be sorted in the view by any of the visible columns. User can also search for test cases by name by writing a substring of a test case name in to text field above the view.

3.9.3 Traceability Matrix View

A **Traceability Matrix** is a table that correlates the coverage goals (structural features and high-level testing requirements) to the matching parts of test cases in many-to-many relationship. The column on the left in the traceability matrix shows the coverage goals and the number of the test cases are placed across the top row. There is a marking cross in the intersecting cell when the coverage goal in the left column is covered in the test case in the top row.

The Traceability Matrix View can be opened by selecting **Window > Show View > Traceability Matrix**.



Traceability Matrix

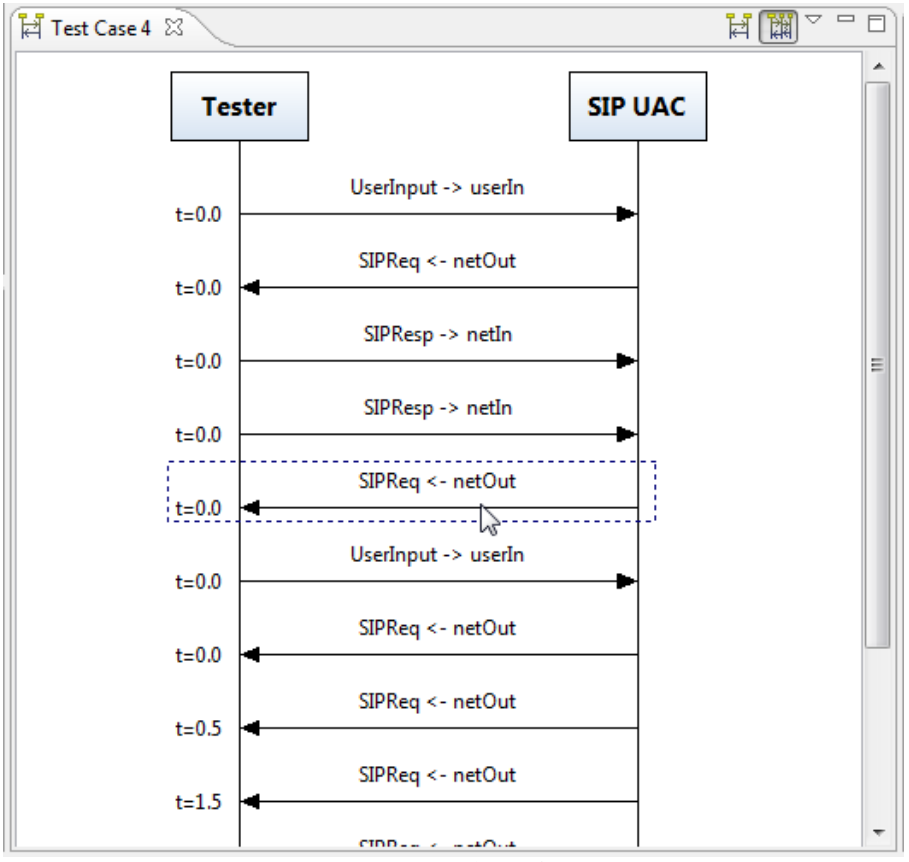
The coverage goal groups can be expanded and collapsed by the user. If a particular test case is active and shown in the matrix, the corresponding column is highlighted.

3.9.4 Test Case View

The **Test Case View** shows the flow of logic within the test case i.e. the interaction between the tester and the system under test (Tester and SUT in the view). The tester and the system

under test are represented as parallel vertical lines ("lifelines") representing the life span of the object during the test scenario. The message take-overs between them is represented with horizontal arrows augmented with the name of the message being transfered, the name of the port, and the exact time stamp at which the message is transfered.

The Test Case View can be opened by selecting **Window > Show View > Test Case View**.



Message Sequence Chart of a test case

In order to also see how internal model threads interact, you can open extended Test Case

View by clicking **Show all messages** on top of the view. Extended view will show the tester as the left most lifeline and each named internal thread as a separate lifeline on right from the tester lifeline. The extended view will also show all the internal message take-overs between the internal threads.

To get back to the basic view i.e. to see only the interaction between the tester and the SUT, click **Show external messages only** on top of the view.

There are also two filters in the top of the view for showing and hiding coverage goals that are covered by the test case:


Show/hide covered requirements is used to filter the covered requirements.

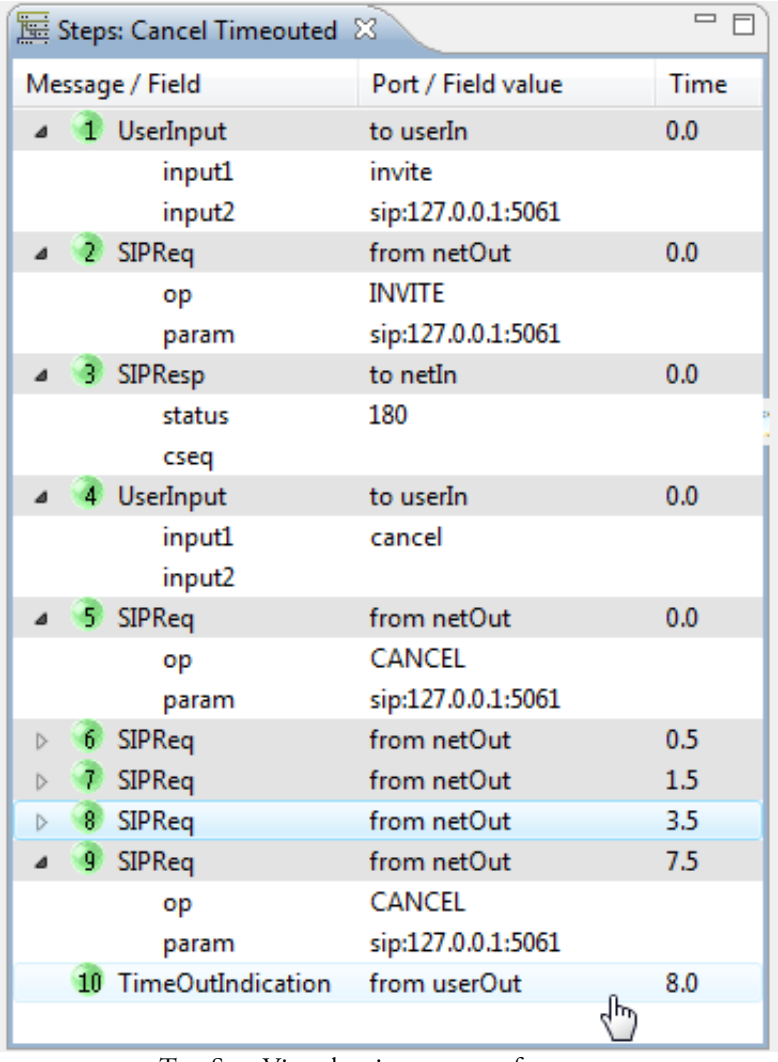

Show/hide covered structural features is used to filter the covered structural features.

3.9.5 Test Step View

The **Test Case View** shows the interaction between the tester and the SUT with name of the messages that are transfered. The **Test Step View** shows more detailed information about the message content. The following information can be obtained from this view:

- The number of the test step. The first test step in the test case is always 1.
- The name of the type of the message being transfered between objects.
- The name of the port to which the message was sent to.
- The time stamp of the test step i.e. at what time was the message transfered.
- The content of the structural message with the field name and field value. See Section Record Types for more information about structural messages.

The Test Step View can be opened by selecting **Window > Show View > Test Step View**.



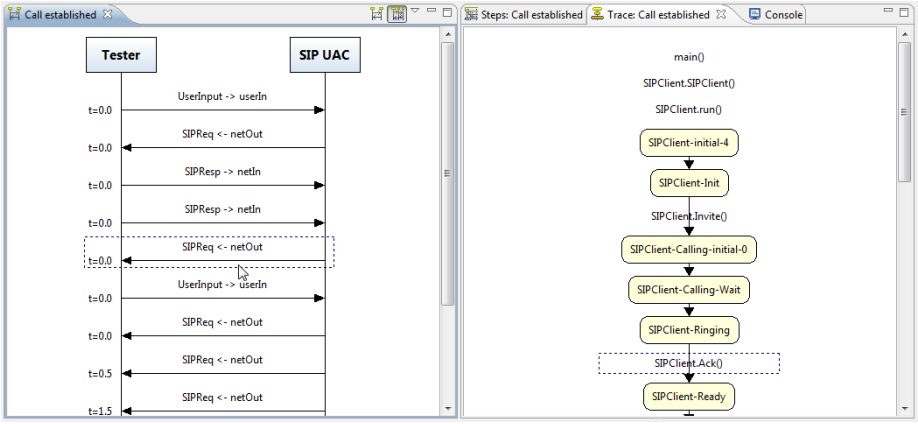
Test Step View showing content of test steps

3.9.6 Execution Trace View

The **Execution Trace View** shows the execution trace of the test case in the model i.e. the execution path in the model that would be seen if the test case would be executed against the model itself. The information in the view is shown graphically so that each state machine level state is represented as a rounded box with the name of the state inside it, the state machine level transitions (i.e. the transfer of control from one state machine level state to another) are represented as arrows between the states, and action language level method invocation are represented as text.

In essence, the Execution Trace View provides a rudimentary way to link back the generated tests to the model from which the tests were generated by showing the execution flow in the model.

The Execution Trace View can be opened by selecting **Window > Show View > Execution Trace View**.



Execution Trace View

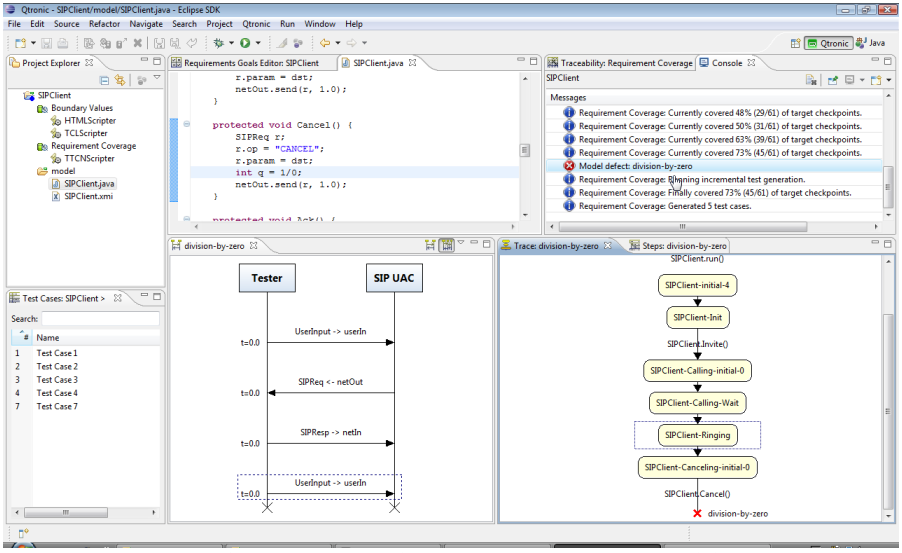
3.9.7 Analyzing Model Defects

System models document the desired functionality of the system; model driven testing turns

these functional requirements into valuable testing assets. It is correct to see a system model as a golden reference implementation of the system. However, since system models are human made, they may contain errors.

While performing the test generation, Qtronic also verifies that the model is internally consistent i.e. the tool will check the absence of internal computation errors (such as division by zero) while it analyzed the model. If the model contains internal computation errors, Qtronic reports these defects by showing the call stack trace and the IO trace that leads to the particular error.

The figure shows an example of such an internal computation error where the model contains a division by zero.



Analyzing an internal computation error in a model

Note that information about encountered model defects are reset in the tool when tests are regenerated: there will be no useful information about model

crashes that have happened in previous test generation runs available in the tool.

3.10 How to Export Test Cases

There are software processes wherein it is beneficial to generate separate test scripts that can be stored in version control systems, maybe sent around, and executed independently afterwards. To meet this need, Qtronic provides the means for generating test scripts from system models where test cases are derived automatically from a functional design model and can be executed against a real system.

Simply, a scripting back-end is a scripting backend that is connected to Conformiq Qtronic using a well-defined API. These scripters can be created by the organization that employs Conformiq Qtronic for testing, or they can be outsourced or, in some cases, bought as off-the-self software components.

In 2.X the scripting backends are Java archives and Java is the programming language used to implement scripting backends.

Conformiq Qtronic2 is shipped with a number of scripting back-ends.

- An HTML script backend for generating browsable HTML documents.
- A TTCN-3 script backend for generating test script in TTCN-3 which enables employment of model driven testing in a TTCN-3 environment.
- A TCL script backend for generating test scripts in TCL.

Each test design configuration can contain more than one scripting backends.

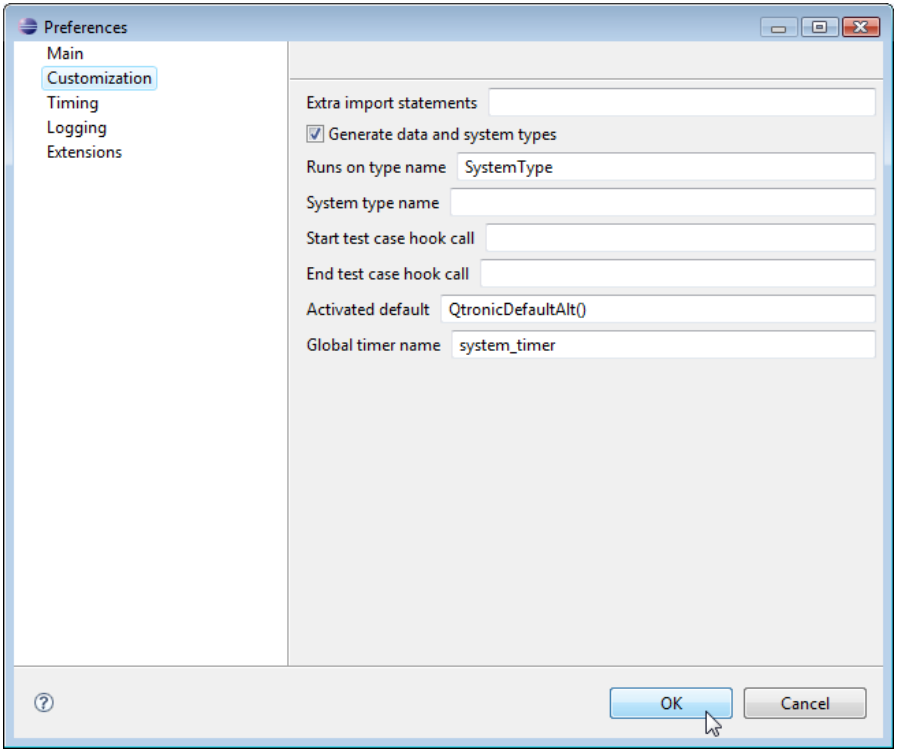
The scripting backends are added to test design configurations as follows:

1. Select a test design configuration from the Project Explorer to which the scripter is added.

2. Select **New > Scripting Backend** from the pop-up menu. This will open **New Scripting Backend Configuration** wizard.
3. Enter the path to the scripting backend or locate the scripting backend by clicking **Browse**.
4. Once the scripting backend has been specified, click **Finish**.

The next step is to configure the selected scripting backend. This is carried out as follows:

1. Select the scripting backend from the Project Explorer you wish to configure.
2. Select **Properties** from the pop-up menu. This will open **Properties** wizard where you see all the scripter specific configuration options.
3. Configure the scripter.
4. Once the scripter has been properly configured, click **OK**.



Configuration for TCL scripter

Note that the configuration is scripting backend specific. Section How to Use Script Backends Shipped with Qtronic2 details how to configure scripting backends shipped with Qtronic 2.

The Qtronic generated test cases can then be exported by clicking **Render Test Cases**.

Note that selected scripting backends can be enabled and disabled. By default, all the scripting backends are enabled. In order to disable a scripting backend, select

the scripting backend from the Project Explorer view, and select **Disable** from the pop-up menu. The scripter can be re-enabled similarly.

3.10.1 How to Use Script Backends Shipped with Qtronic2

This section describes how to configure script backends that are shipped with Qtronic.

How to Use HTML Script Backend

The HTML script back-end saves the log as an HTML file. A generated HTML file can be viewed with any modern web browser that supports JavaScripts and Cascading Style Sheets. The HTML script backend is configured using the following configuration options:

Main / Generated HTML file

Selects the output file. The output file name should have the format <DIRECTORY>/<INDEX PAGE>.html, for example /tmp/testcases.html or C:\testcases.html.

Customizations / Multi page output

set to "yes" or "no". If set to "yes", each test case is generated to a separate file. In addition, an index page is generated that contains hyper links to the test case files.

Customizations / Separate lifelines for ports

Show separate lifelines also for ports in tester side. The default value is "no" in which case only lifelines for tester and for all the threads active in the given test case will be visible.

Customizations / Input port suffix

Omit port suffix from an input port. With this option it is possible to combine lifelines of unidirectional input and output ports to a single lifeline that represents a single bidirectional port. This option is only applicable when "Separate lifelines

for ports" is set to "yes". The default value is "_in". For example, if the model contains input port "X_in", and output port "X_out", and both "Input port suffix" and "Output port suffix" have been left to default values, the plugin generates a separate lifeline named "X", which contains both input of "X_in" and outputs of "X_out".

Customizations / Output port suffix

Omit port suffix from an output port. With this option it is possible to combine lifelines of unidirectional input and output ports to a single lifeline that represents a single bidirectional port. This option is only applicable when "Separate lifelines for ports" is set to "yes". The default value is "_out".

How to Use TTCN-3 Script Backend

A TTCN-3 script backend for generating test script in TTCN-3 which enables employment of model driven testing in a TTCN-3 environment. With TTCN-3 script back-end, TTCN-3 test cases can be derived automatically from a functional design model and be executed against a real system.

The TTCN-3 script backend is configured using the following configuration options:

Main / Generated TTCN-3 file

Selects the output file. The output file name should have the format <DIRECTORY>/<MODULE>.ttcn3, for example /tmp/out.ttcn3 or C:\out.ttcn3. The <MODULE> part is used automatically as the name of the generated TTCN-3 module so it should be an acceptable TTCN-3 literal.

Customization / Extra import statements

TTCN-3 code that is included in verbatim at the beginning of the generated module. Add semicolon if not empty, e.g. "import from MyModule all;".

Customization / Generate data and system types

set to "yes" or "no". If set to "yes", Qtronic generates TTCN-3 records and default

templates based on the types in the model, and also generates system type for the system type defined in the "System type name" option field. If "no", record and port types, default templates and system type must be provided by importing.

Customization / System type name

the type name of the system / MTC the test cases run on.

Customization / Start test case hook call

a function call that will be embedded in every test case just before the (optional) activation of default. If not empty, semicolon is added automatically so you can have e.g. "start_case()".

Customization / End test case hook call

a function call that will be embedded in every test case just after the deactivation of the optionally activated default, and also in the Qtronic-generated default in the case of an unexpected event that causes test case to fail.

Customization / Activated default

default to activate for test cases. Have the complete call (with parameters if needed) but without semicolon here. If empty, no default is activated (but you can still activate and deactivate defaults in the hooks).

Customization / Global timer name

name of the timer Qtronic uses to follow-up with wall clock to make sure tests time correctly. If Qtronic generated system type is used, this timer is embedded in it, but if you import a system type, a timer with this name must be declared therein.

Timing / Communications slack limit

allowance for delay in expected input messages before a failure is triggered. For example, if model predicts a message M at time 5.0 and slack limit is 10.0, failure to receive M is indicated at time 5.0 + 10.0 = 15.0.

Logging / Log checkpoints

if true, add log statements for coverage goals.

Logging / Name of the 'log' command

call used to make log statements. "log" comes from TTCN-3 standard, but you can have a customized routine, import it via the extra imports feature, and then use the customized routine instead here.

Qtronic assumes that for every record type *RecordType* there exists a template with the name *DefaultRecordTypeTemplate*, which is then modified in the test data declarations.

How to Use TCL Script Backend

A TCL script backend for generating test script in TCL which enables employment of model driven testing in a TCL environment. With TCL script back-end, TCL test cases can be derived automatically from a functional design model and be executed against a real system.

The TCL script backend is configured using the following configuration options:

Main / Generated TCL file

Selects the output file. The output file name should have the format <DIRECTORY>/<SCRIPT>.tcl, for example /tmp/out.tcl or C:\out.tcl.

Test case template / Template TCL file

the location of test case template used. This file contains extra code that can be inserted before and after Qtronic generated test cases, such as initialization and de-initialization of a test harness.

Test case template / Generate stub template

generate a stub test case template file if one does not exists.

Library / Library TCL file

the location of the TCL library file, i.e. the library file which contains the

implementation of the routines that the scripter generates

Library / Library include method (source|embed)

source / embed the generated library to the script

Library / Generate stub library

generate a stub library file if one does not exist that contains the default implementation of the routines that the scripter generates

Customizations / Array member separator

the separator of QML level array members in TCL

Customizations / Omit port prefixes (port_in -> in)

omit QML port prefixes, i.e. convert port names such as "some_port_in" to "in"

Customizations / RSD-RT Model

Enable conventions of RSD-RT to be used in the generated script. Disabled by default but can be disabled by setting this option to "yes".

Customizations / Dump Qtronic configuration

Dump the configuration of Qtronic to the beginning of script file. This configuration information includes for example the name of the Qtronic project from which the script has been generated, all the algorithmic options, and all the coverage settings. Enabled by default but can be disabled by setting this option to "no".

Customizations / Highlight actions in code

Surround test steps in the script with comment blocks so that they because "highlighted" in the generated script. Disabled by default but can be disabled by setting this option to "yes".

Customizations / Add indexes to variable names

Append an index number to generated variable names. Enabling this option

prevents variable name clashes, but can be disabled by setting the option to "no".

3.11 Test Case Management

The generated test cases in Conformiq Qtronic 2 can be managed and analyzed in the Qtronic Eclipse user interface. The different views that can be used in test generation result analysis were covered in Section How to Analyze Test Generation Results. *Test Case Management* is another very important new feature in Qtronic 2.X series: the results of test generation runs are stored to a persistent data storage that can be managed using the Qtronic UI.

Persistent Storage for Test Cases

Conformiq Qtronic 2 stores the results of test generation to a persistent data storage every time the test cases are updated. This means that the results from the past test generation runs are not lost if the model is updated and the test cases are regenerated. However, when the model is updated, the updates may render some of the existing test cases invalid as they do not reflect the external behavior of the model anymore. Also, all those test cases become invalid that cover features in the model that were previously targets (or "do not cares") but are now blocked (See Section How to Configure Design Configuration Specific Testing Parameters for more information about coverage options and settings).

The previously generated test results are also used as an incremental input for future test generations: When generating test cases, Qtronic first analyzes existing test cases to see which of them are still valid with respect to the external behavior of the model. Once the incremental analysis is over, Qtronic runs incremental algorithm to augment the existing test set with additional test cases only if this is required. When tests are regenerated due to a change in the model etc. there is no need to regenerate tests from the parts of the model that are not changed. Thus, if the existing test set covers all the target coverage goals (See Section How to Configure Design Configuration Specific Testing Parameters for more information about coverage goals), there is no need to

generate more test cases, and Qtronic will stop before running the incremental test generation algorithm.

When analyzing the test generation results, the following rules apply to representation of the generated test cases, whether valid or invalid:

- When you click a Qtronic project in the Project Explorer of Qtronic Eclipse user interface, the Test Case List view will show *all* the generated test cases for that project: you see all the test cases from all the test design configurations that are part of the particular Qtronic project. This set of test cases also includes those test cases that are no longer valid i.e. test cases that do not represent the updated external behavior that the model exhibits. These invalid test cases are presented in red font to differentiate them from the valid test cases that properly represents the behavior.
- When you click a test design configuration in the Project Explorer of Qtronic UI, the Test Case List view will show *only* those test cases that were generated using the test design configuration specific coverage settings. In addition, this view always shows only valid test cases, never invalid.


A test case can "belong" to multiple test design configurations at the same time because it can be valid over multiple test design configurations i.e. a test case can be shared by more than one test design configuration.


Note that because scripter plugins are always part of test design configurations, when test cases are rendered, only those test cases that belong to the given test design configuration are rendered using the particular scripter plugin. There is no way to render invalid test cases.

If the update to the model that caused invalidation of some test case is reverted, the invalidated test case becomes valid once again so it is "moved" back to the test design config-

urations where the test case was valid in the beginning. In addition, this test case is once again marked as valid in the project wide test case list (i.e. it is not rendered in red font).

Naming Test Cases

As mentioned in Section Test Case List, the generated test cases have names so they can be identified and differentiated from one another. As the test cases are persistent, also the names of the test cases are persistent, and they remain the same even if the test cases are regenerated. By default, the test cases are named with 'Test Case ' prefix meaning that the names given to new test cases by default are 'Test Case 1', 'Test Case 2', and so on. In addition to renaming test cases one by one, you can also set the default test case name prefix in Qtronic Algorithmic Options -property page explained in Section How to Configure Global Testing Parameters.

The test cases can be named in the Test Case List view by double clicking the test case shown in the view.

Deleting Test Cases

The generated test cases are stored in to a persistent data storage and they remain "live" across model reloads and test generations. However, if you wish to delete one or more test case for a reason or another, this can be done in the Qtronic Eclipse user interface as follows:

In order to delete a single test case:

1. Select the test case in the **Test Case List** view.
2. Press **Delete** button

The following rules apply when deleting single test case at a time.

- When a particular test design configuration is selected and a test case is deleted, the test case is only deleted from the given test design configuration and will remain in other test design configurations and in the Qtronic project to which the test design configuration belongs to.

- When Qtronic project is selected a deletion of a test case will delete the given test case also from all the test design configurations that belong to the project.

In order to delete all the test cases owned by the Qtronic project

1. Select the Qtronic project in the Project Explorer view.
2. Select **Qtronic > Delete Test Cases** from the pop-up menu. This will delete all the test cases owned by the project.

Note also that when test cases are deleted from the project, there are no incremental test assets for future test generation runs: Instead, Qtronic needs to start the test generation all over again.

WARNING There is no way to undo test case deletion from a project: deleted test cases are immediately deleted from the persistent data storage.

3.12 Managing Qtronic Projects

The central hub for data files in Eclipse is called a *workspace*. Each of these workspace houses a collection of projects that were already discussed in Section How to Work with Qtronic2 Projects. Each project is stored in to the file system under the workspace location. Each project folder stored in to the file system contains information related to the given Qtronic project, namely model files, coverage settings, generated results, and so on.

It is recommended to generate a distinct workspace for Qtronic related projects. This makes it more convenient to work with different Eclipse based applications: whenever you start a new Eclipse based application, you give them their own workspace. Switching between different projects is flexible this way, because instead of opening and closing different projects and trying to find the right project to work with, you just

switch workspaces entirely. The current workspace for Eclipse can be switched by selecting **File > Switch Workspace** from the Eclipse menu bar.

As the workspace is the central hub for the user data files and project folders it contains all the information for each Qtronic project, it is the Qtronic project folder that is stored into version control system or sent around to another computer. The structure below represents an example Eclipse workspace containing a Qtronic project name *SIPClient*:

```
workspace
  Qtronic
    SIPClient
    .dbdump
    .project
    .qtronic
    model
      SIPClient.cqa
      SIPClient.xmi
```

As mentioned in Section How to Select Models, model files can be either imported (copied) to the project folder or we can establish file links to model files. In the former case, also the actual model files are stored to version control while in the latter one, only the file link to actual model file is stored, not the model file itself.

In addition of being storage location for example for model files and several configuration settings, Qtonic project also contains all the information about the test generation results. Therefore, by sharing the Qtronic project with other users (via version control, for example) enables them to get access to the test generation results as well.

4 Creating Models in QML

One of the formalisms that can be used to express design models is **Qtronic Modelling Language** (QML). In QML, design models can be expressed entirely using the textual notation, which is essentially a superset of Java with some ideas from C#, or with the graphical notation, where models are described using UML state machines with the QML textual notation as an action language.

Note that while design models can be expressed in QML (amongst others), Qtronic internally uses CQλ (which is a variant of LISP, more exactly a variant of the Scheme programming language) and QML models are compiled into CQλ before Qtronic testing engine is started.

4.1 Textual Notation of QML

QML is an object-oriented language that can be used to describe design models. The textual notation is essentially a superset of Java with some variations. In this document we only describe those features of QML textual notation that are different from "standard Java".

At a glance, compared to standard Java, the QML language is restricted or enhanced in a few ways, including but not limited to the following:

- There can be global variables and global methods. Globals have public visibility.
- The main entry point is not a static member method like in Java, but rather a global function that takes no parameters and returns nothing. The name of the main entry point is `main` just like in C and C++.
- Generics in QML are not implemented as in Java 5.0 by using type erasure, but rather as templates like in C++. In this regard, Java generics are very different from QML templates: QML produces different types for each distinct template instantiation, which means that also primitive types and methods can be used as template arguments. Because of type erasure in Java, Java does not support arrays of parameterized types, while QML does.
- The Syntax for invoking template methods is different from Java. In QML, type parameters are placed after the method name like in C++, rather than before.

- There is no boxing/unboxing of types, because it is not required. QML has nullable types (like in C#) which address the scenario where you want to be able to have a primitive type with a `null` value.
- In addition to reference types (classes and arrays), QML has also support for structured value type *record*s.
- The inner classes in QML are semantically closer to the nested classes of C++ rather than the inner classes of Java. The inner classes in QML are roughly equivalent to the static inner classes of Java.
- There are no anonymous inner classes or records in QML.
- Communication with the environment is carried out by using *ports* that are declared inside a *system* block.
- QML supports operator overloading.
- QML supports type aliases through `typedef` keyword like in C and C++.
- QML supports implicit types for local variables: once an implicit type has been inferred during compilation it does not change.
- Currently there is no support for packages.
- Currently there are no enumerators.
- Annotations are not supported.
- `goto` and labeled `break` and `continue` are not supported in QML.
- All the user defined types have global visibility.
- The standard library of QML is very limited compared to the standard library of Java.

The convention is to name the QML textual notation files with the *.cqa* suffix.

4.2 Basic Language Features

The following topics introduce and discuss the essential components of the QML textual notation, a language for defining design models.

4.2.1 Keywords

The keywords of the QML textual notation are listed in the table below.

Keyword	*Meaning*
`abstract`	An abstract class or method.
`after`	An after event (from UML).
`and`	A logical AND (an alias to &&).
`assert`	An assert that a condition holds.
`boolean`	A boolean type.
`break`	Break out from a loop or `switch case` statement.
`byte`	An 8-bit integer type.
`case`	A case of a `switch case`.
`catch`	A clause of a `try` block catching an exception.
`char`	A character type.
`class`	A class type definition (classes are reference types).
`complete`	Indicates end of an incomplete region of model. See Section End Conditions for Test Generation for details.
`const`	A constant.
`continue`	Continues to the end of a loop.
`default`	The default clause of a `switch case`.
`do`	The top of a `do while` loop.
`double`	An arbitrary precision floating point number

	(an alias to `float`).
`else`	The else clause of an `if` statement,
`enum`	An enumerated type (*currently not supported*).
`extends`	A super class definition (parent) of a class or a super record of a record.
`final`	A constant or a class, a record, or a method that cannot be reimplemented.
`finally`	A clause of a `try` statement that is always executed after exiting `try` block.
`float`	An arbitrary precision floating point number.
`for`	A `for` loop.
`goto`	*QML does not support gotos*.
`if`	A conditional statement.
`implements`	Defines the list of interfaces that the class or record implements.
`import`	Import a library. All the libraries in QML are in the *conformiq* namespace.
`Inbound`	Defines an external inbound port in the system block.
`incomplete`	Indicates beginning of an incomplete region of model. See Section End Conditions for Test Generation for details.
`instanceof`	Tests if a variable is an instance of a type (this is not restricted to reference types as in Java).
`int`	An arbitrary precision integer.
`interface`	An abstract type with methods that the class or record must implement.
`long`	An arbitrary precision integer (an alias to

	`int`).
`native`	*Not supported.*
`new`	Allocates a new object or an array. Note that records are *not* created with `new`.
`nocoverage`	Marks a region with no coverage goals attached. See Section Regions with No Coverage Goals for more details.
`null`	The nil reference.
`Outbound`	Defines an external outbound port in the system block.
`omit`	The `omit` keyword specifies that the record field is omitted from the record instance. Provided for backward compatibility with Conformiq Test Generator adapters.
`operator`	Overloads an operator.
`or`	A logical OR (an alias to `||`).
`package`	*Not supported.*
`priority`	Adds a priority to model. See Section Probabilities and Priorities for details.
`private`	A private modifier — a feature that is accessible only by the methods of *this* class or record.
`probability`	Adds a probability to model. See Section Probabilities and Priorities for details.
`protected`	A protected modifier — a feature that is accessible by the methods of *this* class or record and in all the subtypes.
`public`	A public modifier — a feature that is accessible by all.
`record`	Defines a record type (a value type). Records are **the only** types that can be used to

	communicate with an environment.
`require`	Require that the boolean argument supplied is true.
`requirement`	Inserts a new requirement into the model.
`return`	Returns from a method or a function.
`short`	A 16-bit integer.
`static`	A feature that is unique to its class or record, not to an instance of the class or record.
`strictfp`	*Not supported.*
`super`	The direct super class of an instance of a class or record, or a constructor.
`switch`	A selection statement.
`synchronized`	*Not supported.*
`system`	Defines the system block which contains the declarations of the external ports used to communicate with an environment.
`this`	The implicit argument of a method, or a constructor of the *this* class.
`throw`	Throws an exception.
`throws`	*Currently not supported.*
`transient`	*Not supported.*
`try`	A block of code that traps exceptions.
`typedef`	Create a type alias (`typedef` of QML is similar to `typedef` of C and C++).
`var`	An automatic variable type — the type of a variable is inferred by the QML compiler.
`void`	Denotes a method that returns nothing.
`volatile`	*Not supported.*
`while`	The `while` loop.

4.2.2 Comments

Comments in the QML textual notation are just like in Java except that block comments are recursive. For example:

```
// This is a one line comment.
/* This is a block comment. */
/* This is a /* recursive */ block comment. */
```

4.2.3 Literals

A literal is the source code representation of a value of a primitive type, the String type, or the null type. Literals in the QML textual notation are as in Java.

- Integer literals are either decimals (base 10), hexadecimals (base 16), or octals (base 8).
- Floating point literals have a whole-number part, a point (represented by an ASCII period character), a fractional part, an exponent, and a type suffix.
- Boolean literals true and false.
- A character literal is expressed as a character or an escape sequence, enclosed in ASCII single quotes. Lines are terminated by the ASCII characters LF or CR LF.
- A string literal consists of zero or more characters enclosed in double quotes.
- The nil reference, represented as the literal `null`.

4.2.4 Operators

Syntax	*Meaning*
	Arithmetic binary operators
+	Addition.

`-`	Subtraction.
`*`	Multiplication.
`/`	Division.
`%`	Modulus (returns the integer remainder).
	Arithmetic unary operators
`-`	Unary negation.
`++`	Increment (prefix and postfix).
`--`	Decrement (prefix and postfix).
	Comparisons
`==`	Equals.
`!=`	Not equal.
`>`	Greater than (applicable to numeric types only).
`>=`	Greater than or equal to (applicable to numeric types only).
`<`	Less than (applicable to numeric types only).
`<=`	Less than or equal to (applicable to numeric types only).
	Assignment operators
`=`	Assign.
`+=`	Add and assign.
`-=`	Subtract and assign.
`*=`	Multiply and assign.
`/=`	Divide and assign.
`%=`	Modulus and assign.
	Boolean operators
`&& and`	Logical AND.
`|| or`	Logical OR.
`! not`	Logical NOT (negation).
	Conditional expressions
`?:`	Conditional expressions use the compound operator `condition ? true-clause : false-clause`.
	String operators
`+`	Concatenation.

`+=` Concatenation and assignment.

Note that bitwise operators (`~ & | ^ &= |= ^= << >> >>> <<= >>= >>>=`) are **not supported**.

As in Java, Boolean operators are short-circuited meaning that operators are evaluated from left to right until the result is determined. Operator precedences are given in the table below.

Operator precedences

Operator	*Associativity*
`[] . ()` (method call)	Left
`! ++ -- +` (unary) `-` (unary) `()` (cast) `new`	Right
`* / %`	Left
`+ -`	Left
`< > <= >=` `instanceof`	Left
`== !=`	Left
`&&`	Left
`||`	Left
`?:`	Right
`= += -= *= /= %=`	Left

4.2.5 Data Types

Just like Java, QML is a strongly typed language meaning that type of each variable and each expression is known at the compile time.

Types in QML are divided into 3 groups: primitive types, reference types, and value types.

Opposed to standard Java, type comparison operator `instanceof` is not restricted to comparing only reference types — `instanceof` in QML can be used to compare types of any kind.

Primitive Types

Primitive types are Boolean type (`boolean`) and numeric types. Integral types are `byte`, `short`, `int`, and `long`. Floating point types are `float`, and `double`.

Type	*Inclusive range*
Integer types	
`byte`	-128 to 127
`short`	-32768 to 32767
`int`	Arbitrary precision
`long`	Arbitrary precision
Floating point types	
`float`	Arbitrary precision
`double`	Arbitrary precision
Boolean types	
`boolean`	Boolean `true` and `false`
Character types	
`char`	0 to 65536

Note that `int` and `long` may hold arbitrary precision integer values. Therefore, there is no need for `BigInteger` of Java (actually `BigInteger` of QML is an alias to `long` which on the other hand is an alias to `int`). Similarly, `float` and `double` may hold arbitrary precision floating point values. Therefore, there is no need for `BigDecimal` of Java (actually `BigDecimal` of Conformiq Java is an alias to `double` which on the other hand is an alias to `float`).

Array Types and Strings

Just like Java, QML has an array type for each type. Arrays are homogeneous types, meaning

that each array member must have the same type (or they have to be sub-types of the array member types). Arrays have a read-only `length` attribute that contains the number of elements in the array. There are two ways to allocate arrays at run-time:

- Using the operator `new` which may also take expressions whose values are not known at compile time.
- Using array initializers which are shorthands for allocating an array object and supplying initial values at the same time (`new` is not used with array initializers).

```
// Create an int array with 10 items using new.
int[] array1 = new int[10];
```

```
// Create an int array and supply the initial values.
int[] array2 = {1, 2, 3, 4, 5};
```

Arrays may be multi-dimensional — multi-dimensional arrays are actually just arrays of arrays.

```
// Create a two-dimensional array of Foos.
Foo[][] foos = new Foo[10][10];
for (int i = 0; i < foos.length; i++)
    for (int j = 0; j < foos[i].length; j++)
        foos[i][j] = new Foo();
```

Multi-dimensional arrays may also be constructed using array initializers.

```
int[][] array3 = { {1, 2}, {3, 4}, {5}, {6, 7, 8} };
```

Just like in Java, arrays are always reference types in QML.

In Qtronic versions 1.0.X when an array containing objects was allocated using the operator `new`, each array member was also allocated using the default constructor, i.e. a constructor that does not take arguments. For this reason, QML always provided this constructor that takes no arguments if there were no such a constructor. Since Qtronic 1.1.0 this has been changed so that array allocation is done just like in Java; when we allocate an array containing objects using the operator `new`, each array member is assigned a *null* value.

Note that the default value for an unallocated array is always *null*.

```
int[] array; // array == null
```

The `String` class represents constant character strings. All string literals, such as "foobar", are implemented as instances of `String` class. Just like in standard Java, the QML language provides special support for the string concatenation operator `+`.

```
class String {
    /** Returns a new string that is a substring of this string. */
    public String substring(int begin);
    /** Returns a new string that is a substring of this string. */
    public String substring(int begin, int end);
}
```

In Qtronic versions 1.0.X an instance of `String` in the QML textual notation was actually just an array of `char`s. However, since Qtronic 1.1.0 `String`s are objects just like in Java. Note that you can still use brackets to reference an item of a `String`.

Reference Types

As in Java, classes are reference types in QML. Class types are always created with `new`.

Classes may contain fields, methods, operators, type aliases, and nested (inner) types.

Classes may be

- *Abstract* (defined with the `abstract` modifier) — they cannot be instantiated. Abstract classes may (in addition to concrete classes) contain abstract methods which must be overridden in concrete subclasses that extend the abstract class. Abstract classes may not be final.
- *Final* (defined with the `final` modifier) — they cannot be sub-classed. Obviously, final classes may not be abstract.

Classes are always public regardless of whether they are on the top-level or nested.

QML supports single inheritance with a monolithic class hierarchy, just like Java does, and the super type of all the classes is `Object` just as in Java. Inheritance is further discussed in Section Inheritance. `Object` in QML is defined as follows:

```
class Object {
    /** Creates and returns a copy of this object. */
    public Object clone();
    /** Returns a String representation of the object. */
    public String toString();
}
```

Reference types may be parameterized with type arguments. A parameterized type consists of a class, interface, or record (see Section Templates) name and an actual type argument list. It is a compile time error if the type name is not the name of a template class, interface, or record, or if the number of type arguments in the actual type argument list differs from the number of declared type parameters. Template types are further discussed in Section Templates.

The syntax for declaring classes is as follows:

```
[modifiers] class identifier [type-parameters]
            [extends type] [implements type-list]
{
    [members]
}
```

`this` and `super` may be used inside classes just like in Java.

As mentioned above, a class may hold inner classes — classes that are defined inside another classes. The syntax for instantiating inner classes (or inner records, for that matter) in QML is not the same as in Java. While in Java inner classes are instantiated as follows

```
Outer outer = new Outer();
Outer.Inner inner = outer.new Inner();
```

in QML inner classes are instantiated as follows

```
Outer.Inner inner = new Outer.Inner();
```

QML does not require an instance of the outer class to exist in order to create an instance of the inner class. Thus inner classes in QML are similar to the nested classes in C++ rather than the inner classes of Java, and they are roughly equivalent to the static inner classes of Java. In QML, inner classes can directly use type names and the names of static members from the enclosing class: unlike in Java, the instances of inner classes do not get access to both its own data fields and those of the outer object because there is no outer object.

Recall that the arrays of reference types (see Array Types and Strings) are reference types themselves.

As in standard Java, at run-time, the result of the operator == (`!=`) is Boolean `true` (`false`) if the operand values are both `null` or both refer to the same object or array; otherwise, the result is Boolean `false` (`true`). For example

```
class C { public int value; }

void main()
{
    C c1 = new C();
    C c2 = new C();
    c1.value = c2.value = 1;
    assert c1 != c2;
    c1 = c2;
    assert c1 == c2;
    c1 = null;
    assert c1 == null;
}
```

Record Types

A record is a user-defined type similar to a class in the sense that they may contain fields, methods, operators, and nested types. They may inherit other records and they may implement interfaces, just like classes. Also, just like a class type, a record type may be parameterized with type arguments.

The differences between the two kind of types are as follows:

- While classes are reference types, records are value types. Records are never created with `new`.
- Records may not mutate themselves through `this` pointer. This means that records may not have constructors or member methods that mutate the members of `this`.
- Records may not have member variables that are nullables (see Section Nullable Types) or class types: records may hold fields of all the primitive types, `String` type, other record types, and arrays.
- Records may contain nested types, but they all must be records. Type aliases may also be declared inside a record.

- Records are the only data types that may be used to communicate with an environment using `receive()`, `send()`, and `sync()` of `CQPort` (see Section Input and Output).

Just like `Object` is the super type of all the class types, `AnyRecord` is the super type of all the record types. `AnyRecord` is a record that has no fields or members:

```
record AnyRecord { }
```

`this` and `super` may be used inside records just like inside classes.

The syntax for declaring records is almost identical to that of a class:

```
[modifiers] record identifier [type-parameters]
            [extends type] [implements type-list]
{
    [members]
}
```

Example

```
record MyRecord {
    record MyInnerRecord {
        public int i = 1;
    }
    MyInnerRecord inner;
    public MyInnerRecord CopyInner()
    {
        MyInnerRecord r;
        r.i = inner.i;
        // Illegal:
        // inner.i = 10;
        return r;
    }
}

...

MyRecord r;
r.inner.i = 10;
MyRecord.MyInnerRecord inner = r.CopyInner();
```

Recall that the arrays of records (see Array Types and Strings) are reference types. Also recall that the default value of an unallocated array is always *null*, therefore an unallocated array inside a record gets *null* as its default value. This means that whenever we reference an array field of a dynamic record value (a value that we have received from environment. See Input and Output) we must first verify whether the field has null value, otherwise we do null pointer reference:

```
record X { int[] field; }
...
AnyRecord a = port.receive();
require a instanceof X;
X x = (X) a;
// Require that the integer array is not null
require x.field != null;
// Now that we know that integer array is not null so we can safely
// reference it.
require x.field.length == 2;
```

At run-time, the result of the operator == (!=) is Boolean `true` (`false`) if the operand values are of the same type and have recursively equal contents. For example

```
record R { public int value; }

void main()
{
    R r1, r2;
    r1.value = r2.value = 1;
    assert r1 == r2;
}
```

Issues concerning backward compatibility with Conformiq Test Generator are discussed in Backward Compatibility with Conformiq Test Generator.

4.2.6 Access Modifiers

The access to classes, records, , constructors, methods and fields are regulated using access modifiers i.e. classes and records can control what information or data can be accessible by other classes and records.

public

Members declared **public** are visible to any class / record

private

Members declared **private** are strictly controlled, meaning that they cannot be accesses by anywhere outside the enclosing class / record.

protected

Members declared **protected** in a super type can be accessed only by sub types. Protected members cannot be accesses by anywhere outside the enclosing class / record.

By default, the members of classes are private and the members of records are public.

4.2.7 Type Aliases

Type aliases may be declared using the keyword `typedef`; it aliases an existing type whereas a variable declaration creates a new memory location. Since `typedef` is a declaration, it can be intermingled with a variable declaration. For example

```
typedef int Integer;
Integer x = 100;
```

```
typedef SomeTemplateType<Integer> MyType;
MyType y = new MyType();
```

Issues concerning backward compatibility with Conformiq Test Generator are discussed in Backward Compatibility with Conformiq Test Generator.

4.2.8 Control structures

Conditional statements

A conditional statement in the QML textual notation has the form

```
if (condition) statement
```

where the condition must be surrounded by parenthesis. A more general form of the conditional statement is

```
if (condition)
    true-clause
else
    false-clause
```

The `if-else` construct may become cumbersome when there are multiple selections with many alternatives. Here it is better to use the `switch` statement which has the form

```
switch (expr)
{
    case value:
        statements;
        break; // Break or else fall through to the next case label.
    ...
    default:
        statements;
        break;
}
```

Loops

The `while` loop executes a statement while the condition is satisfied. It has the form

```
while (condition)
    statement
```

If you want to make sure that the loop is executed at least once, use the `do while` loop instead. It has the form

```
do
    statement
while (condition);
```

Determinate Loops

The `for` loop is a construct that supports iteration that is controlled by a counter or similar that is updated at each iteration. The general form is

```
for (initialization-clause; condition-clause; update-clause)
    statement
```

Note that currently the QML textual notation does not support the `for-each` construct of Java 5.0.

4.2.9 Input and Output

Communication with an environment is carried out using ports. A port is a point of communication. There are three types of ports in QML:

1. Input ports
2. Output ports
3. Internal ports

An input port is a part of the external interface of the system specified in QML. It is a one-directional channel for messages that arrive from the outside world to the system (inbound data).

An output port is similar, but it is for messages that leave from the system to the outside world (outbound data).

Internal ports are used for communication between threads inside the system and they are

bidirectional. They are not visible and cannot be observed from the outside world. As opposed to input and output ports, internal ports can be also created dynamically during execution. Input and output ports cannot be created dynamically because that would mean that the external, "physical" interface of the system would change unpredictably on the fly.

Note that records are the only types that can be sent to and received from ports.

An internal port is defined by instantiating `CQPort`. `CQPort` has the following definition

```
class CQPort {
    /** Build a new internal port. External ports are defined in the
        system block. */
    public CQPort();
    /** Give a descriptive name to the port. */
    public final void setPortName(String name);
    /** Send a message to an external output port or to an internal
        port.*/
    public final boolean send(AnyRecord r, float timeout);
    /** Send a message to an external output port or to an internal
        port without timeout. */
    public final boolean send(AnyRecord r);
    /** Receive a message from an external input port or from an
        internal port. */
    public final AnyRecord receive(float timeout);
    /** Receive a message from an external input port or from an
        internal port without timeout. */
    public final AnyRecord receive();
    /** A synchronous call: send and receive without a timeout. */
    public final AnyRecord sync(AnyRecord r);
}
```

If the above operations of `CQPort` do a timeout, `CQTimeoutException` is thrown. The definition of `CQTimeoutException` is as follows:

```
class CQTimeoutException extends Exception { }
```

External ports are, however, defined statically inside the system block discussed next. The type of an external port is also CQPort. It is a run-time error to send message to an external

input or, and to trying to receive message from an external output port.

4.2.10 System Block

The system block begins with the keyword `system`, and it is used to define external ports that are used to communicate with an environment. Inside the system block the names, directions, and types that can be sent or received, are given for each port. There can be only one system block in a model.

For example:

```
system {
    Inbound in : MyRecord, AnotherRecord;
    Outbound out : AnyRecord;
}
```

The system block above defines two ports: an input port `in` for receiving messages from an environment and an output port `out` for sending messages to an environment. The record type names after the colon (`:`) define upper bounds for the types that can be send or received from a particular port. Therefore, in the example above, we may receive only instances of record type `MyRecord`, `AnotherRecord`, and their sub-types from `in`, while we may send records of any kind to port `out`, as all the user-defined record types are sub-types of `AnyRecord`.

4.2.11 Main Entry Point

In "standard Java", all the functions are methods of some class, thus a shell class for the main entry point is required. The main entry point is defined as a static method of this shell class. QML, on the other hand, has global variables and functions. In QML, the main entry point is a global method that takes no arguments and returns no value, i.e. it has the following signature

```
main: () -> void
```

For example

```
void main()
{
    ...
}
```

4.2.12 Globals and Functions

As mentioned earlier, QML supports global functions and variables, similarly as in C and C++. You may also define type aliases in the global scope. All the globals are public.

For example

```
int global = 1;
typedef int MyAlias;
MyAlias max(MyAlias a, MyAlias b) { return a > b ? a : b; }
```

4.2.13 Modifiers

Access modifiers in QML are essentially the same as in Java with following variations:

- There is no support for `volatile`, `transient`, `strictfp`, and `native` modifiers.
- All the user-defined types are always `public`.

4.2.14 Regions with No Coverage Goals

QML provides construct for marking areas in the model that have no coverage goals attached to them. These regions are marked using `nocoverage` keyword.

For example:

```
nocoverage
{
    // There will be no coverage goals for constructs in this block.
    if (x == 10)
    {
        foo();
    }
}
```

In the above example, there will be no conditional branching or statement coverage goals for the *if* statement and no statement coverage goals for the method invocation.

However, if *nocoverage* block contains a *requirement* statement, the given requirement will be treated as a coverage goal and Qtronic strives to find executions that covers that given requirement.

4.3 Object Orientation

QML is an object-oriented programming language just like Java. However, while Java is "totally" object-oriented, i.e. it is impossible to program it in the procedural style, this is not the case with QML as mentioned previously.

4.3.1 Inheritance

QML, just like Java, supports single inheritance: a structured type may only extend a single parent. Each class type is a sub-type of `Object` and each record type is a sub-type of `AnyRecord`.

For example

```
class ParentClass { ... }
class ChildClass extends ParentClass { ... }
```

```
record ParentRecord { ... }
record ChildRecord extends ParentRecord { ... }
```

4.3.2 Interfaces

An interface is an abstract type with no implementation details. Its purpose is to define how a set of classes and records will be used. Types that implement a common interface can be used interchangeably within the context of the interface type.

Essentially interfaces in QML are just like interfaces in Java: they may only contain abstract methods and static final fields. All the members of an interface are always public as opposed to Java where members are only public by default.

Note that records may not implement interfaces.

For example

```
interface MyInterface {
    public void fun();
}

class C implements MyInterface {
    public void fun() { ... }
}
```

4.3.3 Operator Overloading

Often it is a design goal of an object-oriented language that user-defined types can have all the functionality of built-in types and QML is no exception. Therefore, as opposed to Java, QML supports operator overloading which allows more intuitive and consistent way of

operating with user-defined types.

In QML, operators are implemented as non-static methods whose return value represents the result of an operation and whose parameters are operands. The operator is thus overloaded for the particular type.

A binary operator is defined as a non-static member method taking one argument. A unary operator is defined as a non-static member method that takes no argument, respectively. Operators are overloaded using the keyword `operator`.

For example, to overload the subtraction (`-`) operator (binary operator) in type `MyType`

```
public MyType operator - (MyType operand) { ... }
```

and to overload negation (`-`) operator (unary operator)

```
public MyType operator - () { ... }
```

The following binary operators may be overloaded in QML.

```
== != > << <= >= + - * / % += -= *= /= %=
```

The following unary operators may be overloaded in QML.

```
- ++ (prefix and postfix) -- (prefix and postfix) ~
```

4.3.4 Templates

Generics (or more accurately, templates) in QML are not implemented as in Java 5.0 by using type erasure, but rather as templates like in C++. In this regard, Java generics are very different from QML templates: QML produces different types for each distinct template

instantiation, which means that also primitive types and methods may be used as template arguments.

As QML supports global functions, it also supports function templates. Function templates provide a functional behavior that can be called for different types — in essence, a function template represents a family of functions. The following example shows a function template that returns a maximum of two values:

```
<T> T max(T a, T b) { return a > b ? a : b; }
```

Note that in Java (as well as in QML) syntax the type arguments are placed before the return type in function declaration.

Similarly to functions, classes and records can also be parameterized with types. For example

```
class MyClass<T> {
    public MyClass(T variable) { this.variable = variable; }
    public T Get() { return variable; }
    private T variable;
}

record MyRecord<T> {
    public T Get() { return variable; }
    public T variable;
}

...

// Instantiate MyClass with a primitive int.
MyClass<int> instance = new MyClass<int>(10);
assert instance.Get() == 10;

// Instantiate MyRecord with a predefined String.
MyRecord<String> record;
record.variable = "Qtronic";
```

As mentioned before, Qtronic produces different types for each distinct template instantiation, which means that also methods may be used as template arguments. For example

```
class MyClass { ... }
void function(MyClass r) { ... }

<T> void generic(MyClass r)
{
    T fun;
    fun(r);
}
void main()
{
    generic<function>(new MyClass());
}
```

In addition, QML supports arrays of parameterized types, which Java does not due to type erasure. Therefore it is perfectly legal to write the following code in QML while in standard Java this causes a compiler error.

```
class MyClass<T> { ... }

...

MyClass<int> array = new MyClass<int>[10];
```

4.3.5 Nullable Types

QML supports nullable types in a similar fashion to C#.

Nullable types address the scenario where you want to be able to have a value type with a null value — a nullable type can represent the normal range of values for its underlying value type, plus an additional null value. For example "nullable of Boolean" may have values `true`, `false`, or `null`.

Nullable types in QML have the following characteristics:

- Nullable types represent primitive type variables that can be assigned the value of null. A nullable type value cannot be created based on a reference type (classes and

arrays) or a record type.

- Nullable types are created using syntax *T?*, where *T* is a primitive type.
- A value is assigned to a nullable value in the same way as for an ordinary primitive type.
- Checking for null values is carried by comparing a nullable value against `null`.

For example

```
int? a = null;
int? b = 2;
assert a == null;
assert b != null;
a = 1;
assert a != null;
assert a == 1;
```

4.3.6 Implicitly Typed Local Variables

QML supports implicitly typed local variables, which permit the type of local variables to be inferred from the expressions used to initialize them. When an identifier is unbound in the local scope, the type of the variable is determined at compile time based on the expression to the right of the assignment. Implicitly typed local variables are declared with the keyword `var`.

For example

```
// x, y, z, and a are unbound here.
var x = new MyClass();
var y = 10;
var z = "string";
var a = new MyClass[10];
// x is bound to instance of MyClass here.
// y is bound to an integer.
// z is bound to a String.
// a is bound to MyClass[].
```

The above implicit typed local variable declaration is equivalent to the following.

```
MyClass x = new MyClass();
int y = 10;
String z = "string";
MyClass[] a = new MyClass[10];
```

Note that when using `var` for arrays, no brackets on the left hand side of the assignment are provided. Therefore the examples below are invalid.

```
var[] a = new MyClass[10]; // Illegal.
var a[] = new MyClass[10]; // Illegal.
```

There are a few restrictions that a implicitly typed local variables are subjected to.

- The declarator must include an initializer, i.e. the following is illegal

```
var x; // No initializer to infer type from.
```

- Implicitly typed local variables may not be used for array initializers, i.e. the following is illegal

```
var x = {1, 2, 3}; // Illegal.
```

- The compile-time type of the initializer expression cannot be the `null` type.

```
var x = null; // Cannot infer type of x from null.
```

- `var` can be used for local variables only.

As with any other variable declaration, the keyword `var` may be used to hide an existing binding of the given identifier

```
int x = 100;
// x is bound to integer here.
{
    var x = "string";
    // x is bound to String here.
}
// x is bound to integer here.
```

4.4 Modeling Use Cases with QML

As mentioned in Chapter Testing with Conformiq Qtronic, a use case is a technique for capturing functional requirements of systems. Each use case provides one or more scenarios that convey how the system should interact to achieve a specific goal or function.

Most often, when use cases are used to control testing, there is a system model and a use case model that are distinct. As explained earlier in this manual, the design model is used to capture the desired functionality of the system. The use case model, on the other hand, is used to guide the testing by instructing Qtronic to look for certain behaviors inferred from the design model.

A use case model written in QML language has the following characteristics:

- A use case model must have `main()` entry point, just like the design model.

- A use case model must *mirror* the ports defined in the design model, i.e. if the design model has an input port named *myport*, the use case model must have an output port named *myport*.
- A single use case can be guarded using predefined `usecase()` function. Once a use case is defined in the model, this use case may be enabled/disabled from the Qtronic user interface as shown in Chapter Testing with Conformiq Qtronic.

```
if (usecase("my first use case"))
{
    // This use case can be enabled/disabled from Qtronic GUI.
}
```

Use case contracts is not supported by Conformiq Qtronic 2.X.

4.4.1 An Example

Let's assume that we have the following very simple design model.

```
system { Inbound portA: X, Err; Outbound portB: X, Err; }

record X { int x; }
record Err { }

void main()
{
    AnyRecord a = portA.receive();
    require a instanceof X;
    X x = (X) a;
    if (x.x == 1)
    {
        portB.send(x);
    }
    else
    {
        Err e;
        portB.send(e);
    }
}
```

The execution of this model can be guided with a very simple use case model shown below.

```
// Note that the ports are mirrored here.
system { Outbound portA: X, Err; Inbound portB: X, Err; }

record X { int x; }
record Err { }

// We must have main() entry point in use case model as well.
void main()
{
    X x;
    if (usecase("my simple use case"))
    {
        x.x = 1;
        portA.send(x);
        assert portB.receive() instanceof X;
    }
    else
    {
        x.x = 2;
        portA.send(x);
        assert portB.receive() instanceof Err;
    }
}
```

4.5 Predefined Data Types

QML includes a number of predefined data types that can be used in models.

4.5.1 Class and Record Super Types

`Object` is the super type of all the class types.

```
abstract class Object {
    /** Return the string representation of the object. */
    public String toString();
    /** Creates and returns a copy of this object. */
    public Object clone();
}
```

`AnyRecord` is the super type of all the record types.

```
record AnyRecord { }
```

4.5.2 Threads and Communication

`CQPort` is the class that can be used to communicate with an environment and between multiple threads. An operation which takes a timeout argument throws `CQTimeoutException` if a timeout occurs. If the timeout argument is set below 0, then the particular operation never does a timeout.

```
class CQPort {
    /** Build a new internal port. External ports are defined in the
        system block. */
    public CQPort();
    /** Give a descriptive name to the port. */
    public final void setPortName(String name);
    /** Send a message to an external output port or to an internal
        port.*/
    public final boolean send(AnyRecord r, float timeout);
    /** Send a message to an external output port or to an internal
        port without timeout. */
    public final boolean send(AnyRecord r);
    /** Receive a message from an external input port or from an
        internal port. */
    public final AnyRecord receive(float timeout);
    /** Receive a message from an external input port or from an
        internal port without timeout. */
    public final AnyRecord receive();
    /** A synchronous call: send and receive without a timeout. */
    public final AnyRecord sync(AnyRecord r);
}
```

`Runnable` is an interface that each class whose instances are intended to be executed as threads must implement. The class must define a method of no arguments called run. This interface is designed to provide a common protocol for objects that wish to execute code while they are active.

```
interface Runnable {
    public void run();
}
```

`Thread` is a thread of execution in a program. Qtronic allows to have multiple threads of execution running concurrently.

```
class Thread {
    public Thread(Runnable runnable);
    /** Set a descriptive name to the thread. Note that this
        routine must be called inside run(). */
    protected final void setThreadName(String name);
    /** Causes this thread to begin execution and the run()
        method of this thread is called. */
    public final void start();
    /** Starting the thread causes the object's run() method
        to be called in that separately executing thread. */
    public void run();
}
```

Like in Java, there are two ways to create a new thread of execution in QML. One is to declare a class to be a subclass of `Thread`. This subclass should override the `run` method of `Thread`. An instance of the subclass can then be allocated and started. For example

```
class MyThread extends Thread {
    public void run() { ... }
}
...
MyThread t = new MyThread();
t.start();
```

The other way is to declare a class that implements the `Runnable` interface described above. That particular class must implement the `run` method. An instance of the class can then be allocated, passed as an argument when creating `Thread`, and started. For example

```
class MyThread implements Runnable {
    public void run() { ... }
}
...
Thread t = new Thread(new MyThread());
t.start();
```

`StateMachine` provides the means to construct a "state machine" — a state machine has

its own execution thread, and it supports communication with it using ports (see Section Input and Output).

```
abstract class StateMachine extends CQPort implements Runnable {
    /** Set a descriptive name to the state machine. Note that this
        routine must be called inside run(). */
    public final void setThreadName(String name);
    /** Causes this state machine to begin execution and initial state of the
        corresponding state machine is called (or the run() method
        if there is no such a state machine diagram). */
    public final void start();
}
```

There are two ways to create state machines. One is to declare a class that extends `StateMachine` and implement `run` in this class using the QML textual notation. For example

```
class MyStateMachine extends StateMachine {
    public void run() { /* State machine execution logic here. */ }
}
```

Once defined, instances of the state machine may be started.

The other way to create a state machine is to declare a class that extends `StateMachine` and define a state machine diagram using **Qtronic Modeler** with the same name as the declared class. This state machine diagram defines the run method using the QML graphical notation. This is further discussed in Section Graphical Notation of QML.

4.5.3 Exceptions

`Throwable` class is the superclass of errors and exceptions. As opposed to Java, QML does not require that only objects that are instances of this class (or one of its subclasses) can be thrown.

```
class Throwable { }
class Exception extends Throwable { }
```

`CQTimeoutException` is the exception that the operations on `CQPort` throw when a timeout occurs.

```
class CQTimeoutException extends Exception { }
```

4.5.4 Synchronization

`Lock` enables controlling access to a shared resource by multiple threads: only one thread at a time can acquire the lock, and the resource cannot be accessed without the lock.

```
class Lock {
    public Lock();
    /** Acquire the lock. */
    public void lock();
    /** Release the lock. */
    public void unlock();
}
```

`Semaphore` is a lock which can be acquired for certain number of times before blocking. The value of the semaphore is initialized to the number of equivalent shared resources it is implemented to control. Each acquire blocks if necessary until a resource is available, and then takes it. Each release adds to the number of shared resources, potentially releasing a blocking acquirer.

```
class Semaphore {
     /** Initialize to the number of shared resources. */
     public Semaphore(int value);
     /** Acquires the semaphore, blocking until it is available. */
     public void acquire();
     /** Release the semaphore. */
     public void release();
}
```

`Barrier` can be utilized in synchronizing threads. A thread executing an "episode" of a barrier waits for all other threads before proceeding to the next. When a barrier is reached, all threads are forced to wait for the last thread to arrive.

```
class Barrier {
      /** Initialize to the number of waiting threads. */
      public Barrier(int value);
      /** Wait until a number of threads have reached the barrier. */
      public void await();
}
```

4.5.5 Containers

The `Comparable<T>` interface imposes a total ordering on the objects of each class that implements it.

```
interface Comparable<T> {
    public boolean comp(T value);
}
```

The `Pair` as used in Lisp-like languages is used to keep pairs of values.

```
class Pair<First, Second> {
    public Pair();
    public Pair(First first, Second second);
    public First first;
    public Second second;
}
```

The `Enumeration<T>` is an interface for generating a series of elements, one at a time. Successive calls to the `nextElement` method return successive elements of the series. In order to use `Enumeration`, you must include the line `import conformiq.Enumeration;`.

```
interface Enumeration<T> {
    /** Tests if this enumeration contains more elements. */
    public boolean hasMoreElements();
    /** Returns the next element of this enumeration if this enumeration
        object has at least one more element to provide. */
    public T nextElement();
}
```

The `Vector<T>` is a dynamic array of objects. In order to use `Vector`, you must include the line `import conformiq.Vector;`.

```
class Vector<T> {
     /** Create an empty vector. */
     public Vector();
     /** Appends the specified element to the end of this vector. */
     public void add(T value);
     /** Tests if the specified object is a component in this
         vector. */
     public boolean contains(T value);
     /** Returns the component at the specified index. */
     public T elementAt(int index);
     /** Returns an enumeration of the components of this vector. */
     public Enumeration<T> elements()
     /** Returns the component at the specified index. */
     public T get(int index);
     /** Replaces the element at the specified position in this
         Vector with the specified element. */
     public T set(int index, T value);
     /** Removes the element at the specified position in this Vector. */
     public void remove(int index);
     /** Is this an empty vector. */
     public boolean isEmpty();
     /** Returns the number of elements in the vector. */
     public int size();
     /** Removes all of the elements from this vector. */
     public void clear();
}
```

The `Stack` class represents a last-in-first-out (LIFO) stack of objects. `Stack` in QML, as opposed to `Stack` in standard Java, does extend `Vector`, which means that stack in QML is strictly LIFO. In order to use `Stack`, you must include the line `import conformiq.Stack;`.

```
class Stack<T> {
    /** Create an empty stack. */
    public Stack();
    /** Tests if this stack is empty. */
    public boolean empty();
    /** Looks at the object at the top of this stack without removing it from
        the stack. */
    public T peek();
    /** Removes the object at the top of this stack and returns that object as
        the value of this function. */
    public T pop();
    /** Pushes an item onto the top of this stack. */
    public T push(T item);
    /** Returns the 1-based position where an object is on this stack. */
    public int search(T value);
}
```

The `Hashtable<Key, Value>` maps keys to values. Note that *Value* must be a nullable type (i.e. a type that can be assigned `null` value. See Sections Reference Types and Nullable Types for details). In order to use `Hashtable`, you must include the line `import conformiq.Hashtable;`.

```
class Hashtable<Key, Value> {
    /** Creates an empty hashtable. */
    public Hashtable();
    /** Clears this hashtable so that it contains no keys. */
    public void clear();
    /** Tests if some key maps into the specified value in this hashtable. */
    public boolean contains(Value value);
    /** Tests if the specified object is a key in this hashtable. */
    public boolean containsKey(Key key);
    /** Returns true if this Hashtable maps one or more keys to this value. */
    public boolean containsValue(Value value);
    /** Returns an enumeration of the values in this hashtable. */
    public Enumeration<Value> elements();
    /** Returns the value to which the specified key is mapped in this
        hashtable. */
    public Value get(Key key);
    /** Tests if this hashtable maps no keys to values. */
    public boolean isEmpty();
    /** Returns an enumeration of the keys in this hashtable. */
    public Enumeration<Key> keys();
    /** Maps the specified key to the specified value in this hashtable. */
    public void put(Key key, Value value);
    /** Removes the key (and its corresponding value) from this hashtable. */
    public void remove(Key key);
    /** Returns the number of keys in this hashtable. */
    public int size();
}
```

4.6 Predefined Functions

QML includes a number of predefined functions that can be used in models.

4.6.1 Assertion Like Functions

`assert` checks that the boolean argument supplied is `true`. An assertion is a predicate placed in the model to indicate that the predicate is expected to be always true at that point. If `assert` is called with a `false` argument, a run-time error is signaled.

```
assert <expression>;
```

`require` checks that the boolean argument supplied is `true`. In Qtronic, it is guaranteed that `require` is never called with a `false` argument — an attempt to call require with a `false` argument triggers a backtracking point.

```
require <expression>;
```

It is important to note the semantic difference between `assert` and `require`. `assert` is used to assert that expression provided is true. Assertions should be used to document logically "impossible" situations and discover modeling errors. Failed assertion means that the (calling) program is fundamentally wrong thus *internally inconsistent*. With `require`, on the other hand, is used to require that the expression provided is true. Failed requirement means that a series of nondeterministic choices and environment inputs as a whole have lead to a situation that is beyond the scope of the program, especially when the program is considered to be a description or a specification of system. In brief, `assert`s are used to make sure that the program is internally consistent while `require`s are used to *restrict* nondeterministic choices and environment inputs that are inferred by Qtronic.

`notreached` marks a code block that is never reached. In Qtronic, it is guaranteed that `notreached` is never called — an attempt to call `notreached` triggers a backtracking point in a similar way as does an attempt to call `require` with a `false` argument. `notreached()` is equivalent to `require(false)`.

```
void notreached();
```

4.6.2 Requirements

In addition to the different coverage criteria based on the structure of the model, the user has the option to use requirements traceability links to establish new test goals driven by *functional requirements*. The requirement links are marked in the model by the `requirement` statement. As described in Testing with Conformiq Qtronic chapter, functional requirements inserted using `requirement` statement are used as coverage criteria that can be enabled and disabled independently in the Qtronic user interface. Every selected requirement becomes a test goal and they are used to guide Qtronic to look for behaviors that cover the particular requirement. A test case covers a selected requirement if executing the test case against the model causes a requirement statement that has the selected requirement as the argument to be executed.

```
requirement <constant string>
```

The argument to the `requirement` statement defines the requirement identifier and must be globally unique constant string. Qtronic model import gives an error if model contains more than one requirements that share the same identifier.

For example:

```
requirement "Here we have fulfilled a functional requirement X";
```

Functional requirements are hierarchical and the `/` character is used to separate hierarchical requirements. For example

```
requirement "Top level/Here we have fulfilled a functional requirement Y";
```

Often functional requirements contain a unique name or an identifier and a brief summary with maybe some rationale for the requirement. This information is used to help to understand why the requirement is needed and to track the requirement through the development process. In order to accommodate this, a summary or a description can be given as an argument to `requirement` statement using the following syntax

```
requirement <constant string> : <constant string>
```

The first argument to the `requirement` statement defines the globally unique identifier as before. The second argument gives the summary or more detailed description of the functional requirement. The summary part does not need to be globally unique like the identifier part. For example

```
requirement "This is an identifier" : "This is a summary of the functional
requirement";
```

4.6.3 Random Number Generators

`random` and `qrandom` generate pseudo random numbers. `random` returns an integer number that is at least zero and strictly less than `x`, while `qrandom` returns a floating point number that is at least zero and strictly less than `x`.

```
int random(int x);
double qrandom(double x);
```

Note that `random` and `qrandom` in QML are not "a real random generators" in a sense: they just return an interesting value from behavioral point of view which is at least zero and strictly less than the given argument. If from the behavioral point of view the actual value

here is irrelevant, these functions will always return zero. However, if the behavior depends on this value, then these function will give "different random values".

Also note that when you are generating test scripts, i.e. running Qtronic in offline script generation mode, then it is most often a misconception to have `random` or `qrandom` in the model as this is a source of non-determinism and models in script generation must be deterministic.

4.6.4 Mathematical Functions

`ceiling` returns the smallest integer greater than or equal to the specified value.

```
int ceiling(double value);
```

`floor` returns the largest integer less than or equal to the specified value.

```
int floor(double value);
```

`abs` returns the absolute value of a specified value.

```
double abs(double value);
int abs(int value);
```

4.6.5 Use Cases

`usecase` provides the means to branch based on the selected set of use cases. A use case is a technique for capturing functional requirements of systems. Each use case provides one or more scenarios that convey how the system should interact to achieve a specific goal or function.

```
boolean usecase(String uc)
```

Once a use case is defined in the model, this use case may be enabled/disabled from the Qtronic user interface as shown in Chapter Testing with Conformiq Qtronic. For example.

```
if (usecase("my use case"))
{
    // This branch is only entered if the given use case has been enabled.
}
```

As functional requirements described above, also use cases are hierarchical and the `/` character is used to separate parent and child use cases. For example

```
if (usecase("parent uc"))
{
    // This branch is entered if any of the child use cases of 'parent uc'
    // has been enabled
}
if (usecase("parent uc/child uc"))
{
    // This branch is only entered if 'child uc' of 'parent uc' has been
    // enabled
}
```

Refer Section Modeling Use Cases with QML for more information about use cases.

> iUse case construct is not supported by Conformiq Qtronic 2.X.

4.6.6 Probabilities and Priorities

Keywords `probability` and `priority` makes it possible to experiment with adding probabilities and/or priorities to models. This mechanism can be used to simulate in a robust fashion both use case probability modeling and general priority schemes.

```
probability <expression>
priority <expression>
```

The <expression> must always be positive. For `probability` the most sensible values are between 0 and 1. For `priority` any positive number can be used.

Qtronic calculates for every generated "path" in the model a "priority value" in the following fashion: at the beginning of the model the "priority value" is set to 1. Every "probability N" changes the priority number from *x* to *x*N*, and every "priority N" changes it from *x* to *x+N*. Thus, the "priority value" after executing

```
probability 0.5
priority 2
probability 0.5
```

is *((1 * 0.5) + 2) * 0.5 = 1.25*.

When Qtronic has finished enumerating test cases, it calculates probability for each of them by dividing the priority value of the test case with the sum of all the priority values. Qtronic reports the test cases in the order of decreasing probability if these construct are applied in the model.

To emulate use case probability modeling, use only `probability` and whenever you add a probability on one branch in the model, add probability statements on others also and make sure they sum to one. E.g.:

```
if (msg.x < 100)
{
    probability 0.6;
    ...
}
else
{
     probability 0.4;
    ...
}
```

You can of course use `probability` on transitions also.

To use a more ad hoc priority scheme, you can emphasize different parts or functions or options in your model by adding priority bonuses to them, for example:

```
if (msg.x == 0)
{
    // important case
    priority 100;
    ...
}
```

which would make the control flows with *msg.x == 0* 100 times more probable than the others if there were no other `priority` or `probability` statements in the model.

Finally, you can combine these two mechanisms e.g. by using `probability` statement between state transitions and `priority` to fine-tune priorities inside transitions. Note that for this mechanism to work well, you should use small priority values (< 1).

Being able to order test cases by their "importance" or "probability" can be very useful, but for larger models it may become very difficult to "optimize" or "tune" the model correctly. Eventually the reason to use Qtronic is to improve your testing and the quality of your system under test, not to construct a test suite that looks completely perfect to the human eye.

For the best results, combine this feature with "all paths" generation. This will provide you

with an extensive test suite with test cases in their priority order.

Even through Qtronic generates the whole test suite, you can in order to speed up test execution only execute the "most probable" test cases, for example until the cumulative probability has reached 75% or 90%.

4.6.7 End Conditions for Test Generation

In some cases it is convenient to generate only test cases that end the system in a "clean" state meaning that Qtronic will only accept such test cases to the generated test suite that cause all threads in the model to be in "clean" state or outside of "incomplete regions".

The QML language provides constructs that you can use to mark incomplete regions of model where test generation is not allowed to end, even thought that Qtronic would have already generated another test that covers the given continuation, but instead test generation will extend tests so that they reach all the way to the end of given region.

These incomplete regions in the model can be marked using `incomplete` and `complete` expressions that takes no parameters:

```
incomplete
complete
```

With these constructs, Qtronic maintains a counter for a set of incomplete regions, rather than an "incomplete" flag of a single region and in this way the usage somewhat resembles the usage of counting semaphores.

These constructs are complementary to 'Only Finalized Runs' test generation parameter (see Chapter Testing with Conformiq Qtronic for more information) and provide more control and flexibility to test generation.

For example:

```
// An incomplete regions starts here.
incomplete;

// Test generation is not allowed to stop here,
// because we are inside an incomplete region.

while (some condition)
{
    // Do some external I/O here, for example.
}

// The incomplete region ends here.
complete;

// Test generation is allowed to stop here,
// because we are not inside an incomplete region.
```

4.6.8 Miscellaneous Functions

`trace` is used to display messages in the log window of Qtronic while testing. Qtronic also invokes *Trace()* function of each connected script and logger plugin once this expression is executed by the Qtronic engine.

```
void trace(String msg);
```

`time` returns the time that has been elapsed since the testing started.

```
double time();
```

`sleep` puts the current thread into sleep for the specified seconds.

```
void sleep(double timeout);
```

4.7 Backward Compatibility with Conformiq Test Generator

QML has number of features provided for backward compatibility with Conformiq Test Generator adapters.

4.7.1 Optional Fields in Records

In Conformiq Test Generator Action Language elements of a record may be optional, therefore omitted. In CTG Action Language these optional fields are specified using the keyword `optional`. QML language provides also the means to create optional record fields by using predefined special `Optional<T>` type.

For example.

```
record X {
    Optional<int> optint;
    Optional<X> optx;
}
```

If a record field is optional, the variables of that type can, but need not, have that field in them. You can assign a new value with such a field to a variable with no such field and vice versa.

The `omit` keyword is used to specify that the field is omitted from the record instance. Optional fields are omitted by default.

The predefined function `ispresent<T>(T)` can be used to check if an optional field is present in a record variable. Note that it is a run-time error to reference an omitted record field. The signature of this function is given below.

```
boolean ispresent<T>(T field);
```

For example.

```
void main()
{
    X x;
    // Optional fields are omitted by default, therefore it is a
    // run-time error to reference optional fields here.
    assert !ispresent(x.optint);
    x.optint = 1;
    assert ispresent(x.optint);
    assert x.optint == 1;
    x.optint = omit;
    assert !ispresent(x.optint);
}
```

4.7.2 Type Copies

For backward compatibility with the Conformiq Test Generator adapters, QML language provides the means to create not only type aliases (see Type Aliases) but also *type copies*. A type copy introduces a new distinct type, not a type alias.

Type copies may be declared using the keyword `typecopy`. Whereas `typedef` aliases an existing type, `typecopy` introduces a new type which is a copy of the original type. While `typedef` can be intermingled with a variable declaration, type copies may only be declared in the global scope.

For example

```
record X { int i; }
typecopy X Y;

void main()
{
    X x;
    Y y;
    x.i = 10;
    y.i = 10;
}
```

Type copies in QML are semantically equivalent to the type aliases in CTG Action Language.

4.8 Graphical Notation of QML

In addition to a pure textual notation, QML also has a graphical notation that can be used to create design models. The graphical notation is always used with the textual notation.

4.8.1 State Machines

Recall from the earlier sections that predefined abstract base class `StateMachine` provides the means to construct a "state machine". A state machine has its own execution thread and it supports communication with it using ports.

There are two ways to create state machines. One is to declare a class that extends `StateMachine` and implement the `run` method in this class using the QML textual notation. For example

```
class MyStateMachine extends StateMachine {
    public void run() { /* State machine execution logic here. */ }
}
```

Once defined, instances of the state machine may be started. State machine threads are created like any other thread in QML, i.e. a state machine is instantiated and it is started by

invoking the `start` method. (Alternatively, you can create a new instance of `Thread` by passing the state machine as an argument and call `start`.)

```
MyStateMachine sm = new MyStateMachine();
sm.start();
```

The other way is to extend the predefined `StateMachine` super class of QML as usual and provide no implementation of the `run` method in the QML textual notation. Instead, a state machine given as a UML state diagram with a same name as the user-defined state machine class is defined, which defines the implementation of the `run` method.

For example, assume the following

```
class MyStateMachine extends StateMachine {
    /* No run() defined here. It will be defined in a state machine
       called 'MyStateMachine'. */
}
```

Once the state machine in the QML graphical notation with the name `MyStateMachine` is provided, the state machine is taken as the `run` method.

Note that if the state machine `run` is defined using state machine diagrams, the state machine type may not be parameterized with type arguments. This would mean that the compiler would have to instantiate the whole state machine diagram for each distinct type argument, and this is currently not supported. Therefore, the following causes a compilation error.

```
/* Erroneous state machine declaration. */
class MyStateMachine<T> extends StateMachine { }
```

4.8.2 Transition Strings

Transition strings are used in state machine diagrams to attribute transitions. They may have

the following three parts:

- trigger,
- guard, and
- action.

The parts are not obligatory, that is, an empty transition string is also valid. If a transition string contains any combination of a trigger, a guard, and an action, they have to be in the above order.

A trigger specifies the pattern of data to match and receive incoming data, while a guard specifies a condition for the transition to fire. An action, in turn, specifies the action statements to perform if the transition fires.

```
<trigger>? ('[' <guard> ']')? ('/' <action>)?
```

Trigger

A *signal trigger* is used to model the reception of an event.

An event name specifies the event that triggers a transition. The message received may be exactly of the same type as we are expecting or any of its sub-types. Recall, that the type of the message must be one of the user-defined record types or `AnyRecord`. Even though state machines may not be parameterized with type arguments (see Section State Machines), the message type may be a template record. In this case the message signature must contain a proper instantiation of the template type. There is an example of this at the end of this Section.

The event signature is as follows:

```
<message type>
```

When a trigger is defined as above, all the input ports defined in the model are listened in addition to the internal port of the state machine containing the transition.

Signal triggers may also specify a singleton port which is being listened to. In this case, the trigger is composed of two parts separated by a colon (`:`). The first part defines the name of the port from which we expect a message to arrive, and the second part defines the type of the message that we expect. The port name in a trigger must be defined inside the system block as an input port, or it may be `this` in which case the internal port associated with the state machine holding the transition is used.

```
<port name>:<message type>
```

```
this:<message type>
```

If more than one thread is waiting for input to arrive from a certain port, it is unspecified which thread consumes the message.

Note that the implicit consumption of events may be turned on and off from "QML Model Coverage Settings" in Qtronic GUI.

The received message is automatically bound to a local variable `msg` which is visible inside the guard and the action parts. Note that the local variable `msg` is constant in the guard, but mutable in the action part.

Timers can be specified with the help of an `after` trigger. If none of the other triggers fire in the current state within the specified timeout interval, `after` will. A timer is initialized only when a state with a leaving transition having an after is entered. If such a state contains a hierarchy, none of the firings of the transitions that take place within the hierarchy reset the timer.

```
after(float timeout)
```

where `timeout` is the time specifier in seconds.

Guard

Guard expressions are simply enclosed in square brackets: `[...]`. The order in which guards are evaluated is non-deterministic in case a trigger enables more than one transition. The `else` guard can be used for a single outgoing transition to indicate that it should be fired if all the other guards fail.

```
[else]
```

Action

When an event is received and a guard yields true, the transition fires and the action is executed. An action contains a block of QML code. Action always starts with the `/` character, which separates it from the other elements of the transition string. An empty action string denoted by `/` is valid.

An Example

For example, assume that we have the following QML textual notation definitions.

```
system {
    Inbound MyInput : MyRecord;
    Outbound MyOutput : MyRecord;
}
record MyRecord {
    public int x;
}
record TemplateRecord<T> {
    public T x;
}
```

Now assume that we are expecting a message of type `MyRecord` from input port `MyInput` with the member variable `x` assigned to 3.

```
MyPort:MyRecord [msg.x == 3]
/
/* Echo 'msg' back to the environment. */
MyOutput.send(msg, -1);
```

A proper template instantiation in the transition string for `TemplateRecord` would for example be

```
MyPort:TemplateRecord<String> [msg.x == "a message"]
```

4.8.3 Internal Transitions of a State

A UML level basic state may contain a set of *internal transitions*.

An internal transition is a transition that remains within a single state rather than a transition that involves two states. It represents the occurrence of an event that does not cause a change of state.

Note that an internal transition is not equivalent to a *self-transition* from a state back to the same state. If there is a sub state machine in a basic state, the self-transition causes the initial

state to be entered, whereas the internal transition does not cause a change of state (including a sub state).

Internal transitions are written into the basic state as transition strings with a mandatory trigger, i.e.

```
<trigger>{1} ('[' <guard> ']')? ('/' <action>)?
```

For example:

```
input:EventX [msg.param == 1] / { output.send(msg); }
input:EventY [msg.param == 2] / { output.send(msg); }
```

4.9 Importing QML Models Into Qtronic

Once the model has been described using QML, all the files that must be compiled and imported into Qtronic are placed in a manifest file. This file simply contains a list of files separated by new lines. The convention is to name the manifest file with a *.qml* suffix.

In Conformiq Qtronic 2.X the manifest file concept is deprecated and model files are individually selected in the Qtronic Eclipse Client user interface.

For example, assume that we have *source_1.cqa* and *source_2.cqa* that contain the textual part of the model, and *model.xmi* that contains the graphical part of the model. The manifest file is now as follows:

```
source_1.cqa
source_2.cqa
model.xmi
```

The order of the files in the manifest file is irrelevant.

As mentioned earlier, Qtronic compiles QML models into CQλ and always uses CQλ internally.

4.10 Examples

4.10.1 A Simple Echo Model

This example uses only the QML textual notation. The echo model (*echo.cqa*) is given below:

```
system
{
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg
{
    public String msg;
}
void main()
{
    int idx = 0;
    while (true)
    {
        String str = "message" + ++idx;
        AnyRecord recv = input.receive();
        // Require that the received message is of the type 'Msg'.
        require recv instanceof Msg;
        Msg echoed = (Msg) recv;
        // Require that the 'msg' field is what we expect.
        require echoed.msg == str;
        output.send(recv, -1);
    }
}
```

The manifest file must now include this file:

```
echo.cqa
```

4.10.2 Another Echo Model

Here is another simple echo model. Here we use the QML textual notation to define "an echo state machine".

We start by defining the set of external ports that we require in the system block and extend the abstract base class `StateMachine` and define `EchoMachine`. The `run` method is used to define the state machine behavior in the QML textual notation.

We also define the main entry point in which we create an instance of `EchoMachine` and we start it as a new thread.

```
system {
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg {
    public String msg;
}
class EchoMachine extends StateMachine {
    public void run()
    {
        // Set name to this thread.
        setThreadName("echo machine");
        int idx = 0;
        while (true)
        {
            String str = "message" + ++idx;
            var recv = input.receive();
            require recv instanceof Msg;
            Msg echoed = (Msg) recv;
            require echoed.msg == str;
            output.send(recv, -1);
        }
    }
}
void main()
{
    EchoMachine echoer = new EchoMachine();
    echoer.start();
}
```

The manifest file must now include the file containing the code above:

```
echo.cqa
```

4.10.3 Yet Another Echo Model

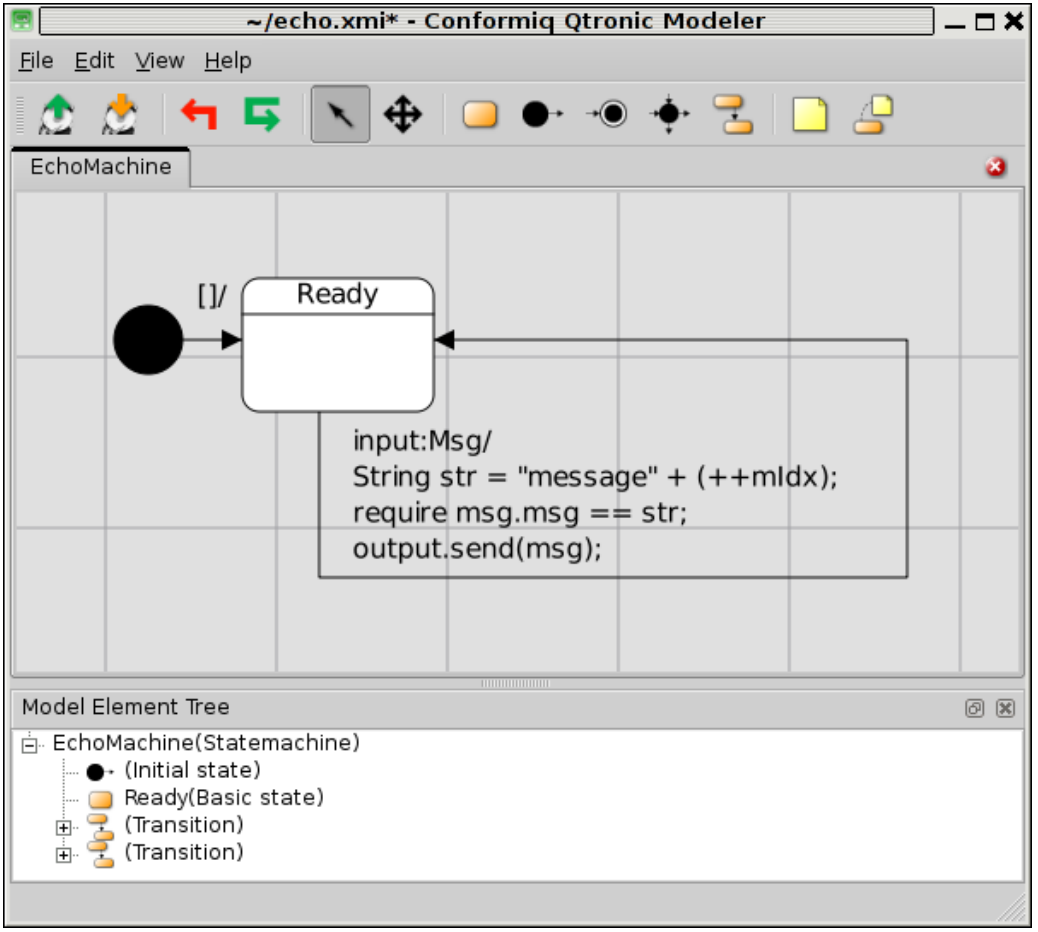
Here is yet another simple echo model. Here we use the QML graphical notation in addition to the purely textual notation and define the echo behavior in a UML state machine.

First we define the set of external ports that we require in the system block and extend the abstract base class `StateMachine` and define `EchoEngine` with a single member variable `mIdx`. We also define the main entry point in which we create an instance of `EchoMachine`, and we start it as a new thread. Note that we do not define the `run` method in `EchoMachine` using the textual notation as we are going to use the graphical notation for that.

The QML textual notation part of the echo model is shown below.

```
system {
    Outbound output : Msg;
    Inbound input : Msg;
}
record Msg {
    public String msg;
}
class EchoMachine extends StateMachine {
    private int mIdx = 0;
}
void main()
{
    EchoMachine echoer = new EchoMachine();
    Thread thread = new Thread(echoer);
    thread.start();
}
```

The behavior of the state machine is defined using **Qtronic Modeler** as shown in the figure below.



Definition of the `run` method of EchoMachine as a UML state diagram

Assume that the textual notation part is in the file *echo.cqa* and the state machine is defined in *echo.xmi*. The manifest file must now include these files:

```
echo.cqa
echo.xmi
```

5 Using Conformiq Modeler

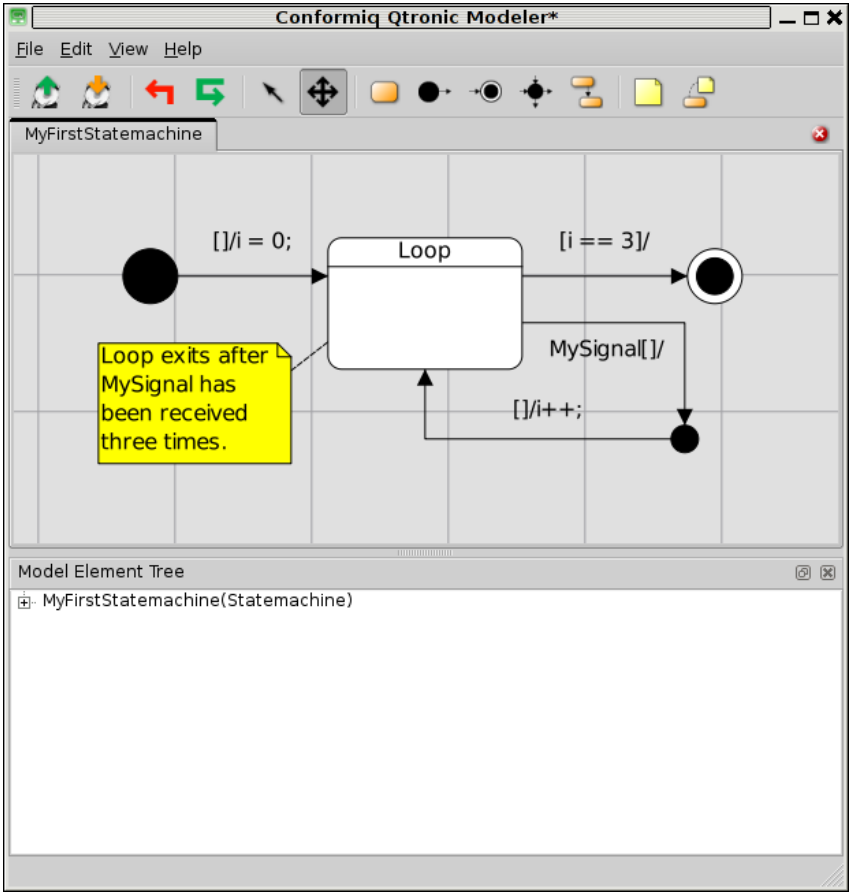
Conformiq Modeler is a simple tool for drawing UML statemachine diagrams. It is used for the graphical notation of QML.

With **Conformiq Modeler** you can have any number of statemachines in a model. For each statemachine there is a diagram which represents the statemachine in the graphical notation. Even though a statemachine and a diagram are not the same thing, in case of **Conformiq Modeler** there is no need to make a distinction between a statemachine and the diagram representing the statemachine.

The **Conformiq Modeler** main window contains possibly an open diagram, a Model Element Tree, a toolbar, and menus. If no model is open, or a model is open but all diagrams are closed or do not exist, then the tool proposes creating a new model or a new statemachine.

The toolbar contains the most often needed actions from the menus. The highlighted tool indicates which drawing action is in use.

Diagrams are shown in tabs where the tab name is either the name of the statemachine, or in case of a sub-state diagram, the name of the parent state.



An Example Model in Conformiq Modeler

The dockable Model Element Tree is by default at the bottom of the window. The Model Element Tree is a tree view for all the statemachine elements of the model. The names of the statemachines or states can be modified also from the Model Element Tree by clicking the corresponding element. Also a diagram for the statemachine is opened or made active in the tab view if you double-click the statemachine or a basic state with sub-states. Most notably, the Model Element Tree does not contain notes which are only additional textual comments

for the state machine but only semantical elements of the model.

5.1 Opening a model

You can open a model by selecting Open from the File menu. You can also open ten most recently opened models from the Open Recent menu under the File menu.

5.2 Saving a model

A model can be saved any time by selecting Save from the File menu. Also if you want to save the model with a different filename, choose Save As... from the File menu. A dialog is shown where you can select a new filename for the model to save as.

5.3 State machines

A model can contain a variable number of statemachines. When you have neither a statemachine nor a sub-state diagram open, you will see button "New state machine" which can be used to create a new statemachine to the model. You can also at any time create new statemachines from the Edit menu.

Diagrams can be closed from the upper right corner of the diagram where the red button with a cross × is shown. You can open closed diagrams by double clicking an element from the Model Element Tree.

5.4 Drawing

When you have a statemachine created and a diagram open in the main window, you can choose a drawing tool from the toolbar. Click the tool you want to use, e.g. basic state to create a new basic state. Then just press the left mouse button down somewhere in the diagram, and move mouse while pressing the button so that you can select a region (size) for the state. Release the button when you are finished. To draw a transition, choose transition tool from the toolbox, and click inside a source state first, and then inside a destination state.

A new transition appears by default with its route autolayouted, i.e. **Conformiq Modeler** places the transition in a straightforward way for you. You can edit the transition text by double-clicking over the transition text. By default, a new transition text contains no signal, empty guard, and no action. (This means that the transition text is initially "[]/".)

For each element type, some extra actions can be done. Such actions are found from the top menu, and also from the context menu. A context menu appears by clicking right mouse button in diagram area. If multiple elements are selected, then context menu covers actions which are meaningful for the whole selection.

5.4.1 Zooming

If the diagram does not fit in the window, you can freely zoom in and out the diagram with the mouse wheel, and from the View menu. The zoom can be reset to 1:1 from the View menu.

5.4.2 Scrolling

You can select the Hand tool from the toolbar and freely scroll the viewable area by dragging it. The arrow keys are shortcuts for scrolling. Also the scrollbars will appear if some elements are outside the viewable area of the diagram.

5.4.3 States

Conformiq Modeler supports initial states, basic states, junctions and final states. A basic state can contain sub-states. Sub-states can be drawn for a basic state by choosing "Expand" from a context menu of the basic state. If a basic state has at least one sub-state, an icon resembling two small states with a transition between them is shown in the lower right corner of the basic state. A basic state can also contain a set of internal transitions. A name of a basic state can be edited by double clicking the state name. Internal transitions can be edited by double clicking below the header line which separates the name and the body of the state.

Junction states are similar to basic states, but they have no name, and they cannot contain

sub-states.

Each diagram may contain only one initial state; a diagram having two or more initial states is erroneous. An initial state is similar to a junction with an additional meaning that the execution of the state machine or the sub-state starts from the initial state. A final state is also similar to a junction with an additional meaning that the execution ends there. Also a final state cannot be a source point for a transition, and an initial state cannot be a destination point for a transition.

5.4.4 Transitions

A transition is shown as an arrow between a source state and a destination state, and it can have multiple route points. When you draw a transition, autolayout places it by default. However, if you while drawing the transition enter more than one middle point, autolayouting is disabled for the transition.

When a transition has autolayout in use, any move of a state, or adding more transitions to the source or the destination state can intelligently modify the route where the transition is drawn. Autolayout can be switched on or off from the context menu of the transition. When autolayout is off, you can also add and remove middle points from the context menu, and move the transition text freely.

Each transition contains a text block, where a trigger, a guard, and/or an action can be entered. See Transition Strings for more information about the syntax of the text blocks.

5.4.5 Notes and note connectors

Notes and note connectors are elements used only for commenting; **Qtronic** does not give any semantical meaning for them during testing. A note is a yellow box where you can write arbitrary text. A note connector is simply a line which points from a note to the element which the note concerns.

5.5 Undo and Redo

Conformiq Modeler has a global undo feature. You can undo any change in the model regardless of the diagram currently visible. You can also redo changes. You will find Undo and Redo from the Edit menu and also in the toolbar.

6 Importing Models from Third Party Tools

As mentioned in Chapters Using Qtronic Modeler and Creating Models in QML, Qtronic Modeler can be used to create the graphical parts of a design model. Once the textual and graphical parts of the model have been created, all the files that must be compiled and imported into Qtronic are placed in a manifest file. This manifest file is given as a *System Model* or as a *Use Case Model* to Qtronic.

However Qtronic Modeler is not the only tool that can be used to create the graphical parts of the model. Instead Qtronic can import also UML state machine and class diagrams from a number of third party tools. As with Qtronic Modeler, the action language used in these models is the textual notation of QML (Conformiqs extended Java/C# language. See Chapter Creating Models in QML for more details).

This Chapter covers the details of how to export a model from a given third party tool and how to import it to Qtronic.

6.1 Enterprise Architect

Sparx Systems (www.sparxsystems.com) Enterprise Architect is a UML analysis and design tool for specifying, designing and managing system development.

6.1.1 Imported Components

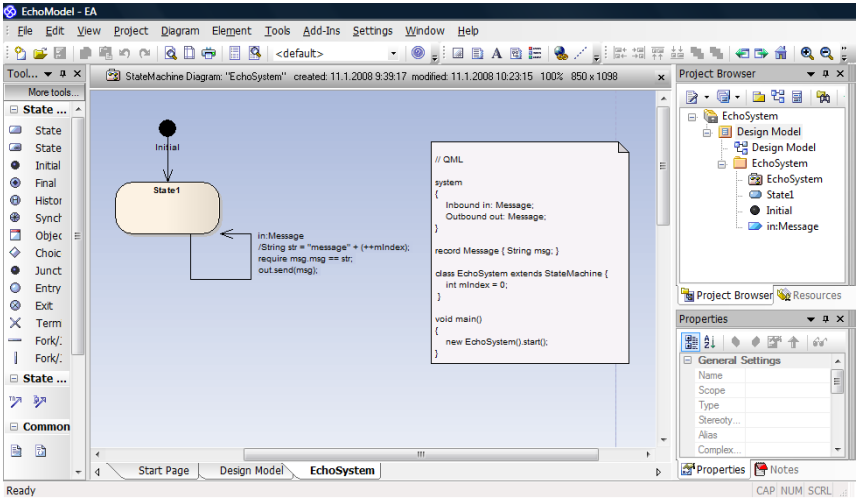
From models created with Enterprise Architect, Qtronic can import state machine diagrams. The following list shows conventions that must be used in order to import state machine diagrams from Enterprise Architect:

- The subset of supported state machine diagram elements is basically the same that Qtronic Modeler supports, i.e.:
  - State machines
  - Sub state machines
  - Initial states

  - Final states
  - Junction states
  - Choice points
  - Transitions
- As mentioned before, the action language used in models created with third party tools is always the textual notation of QML and this is also true for Enterprise Architect. Therefore for example the text on transition strings must be QML.
- In transitions there can be *Signal* and *Time* triggers. Signal triggers must have the form '<port>:<type>' as explained in the Section Trigger. Time triggers take a numeric value.
- There can be multiple top-level state machines in the model but each state machine (not sub state machine) must be in separate package; the name of the package is used to name the containing state machine.
- QML textual notation (for example for class definitions and for main entry point) can be written to text files just like when modeling using Qtronic Modeler or to comment boxes. When placing textual notation of QML to comment boxes, the first line of the comment box must start with '`// QML`'. When this is read by Qtronic model importer, all of the comment box is treated as textual notation of QML and it is parsed, type checked, and imported to Qtronic.
- Before importing Enterprise Architect model to Qtronic, the model must be exported as XMI from Enterprise Architect. The convention is to name the exported XMI model using .xmi file extension. The type of the exported XMI must be either "UML 2.0 (XMI 2.1)" or "UML 2.1 (XMI 2.1)".

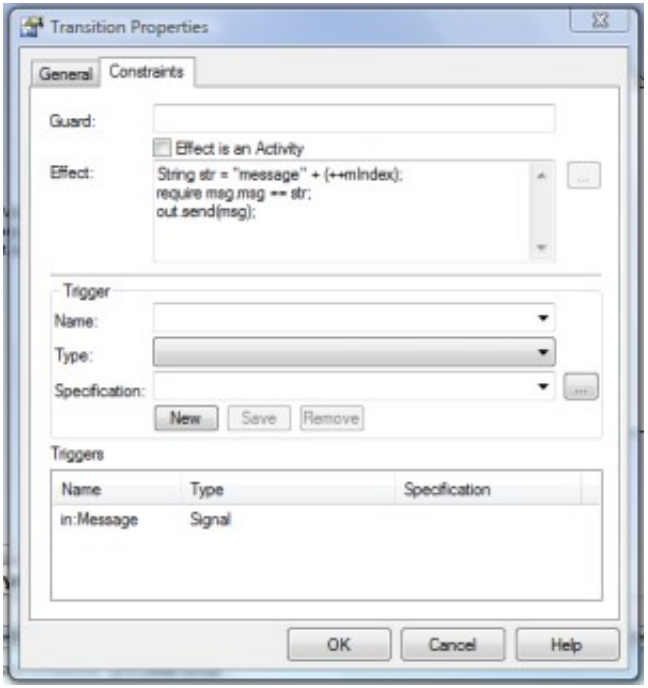
6.1.2 A Simple Example

This Section shows a simple example of how to create a model using Enterprise Architect and then how to export the model as XMI and how to import this XMI model to Qtronic.



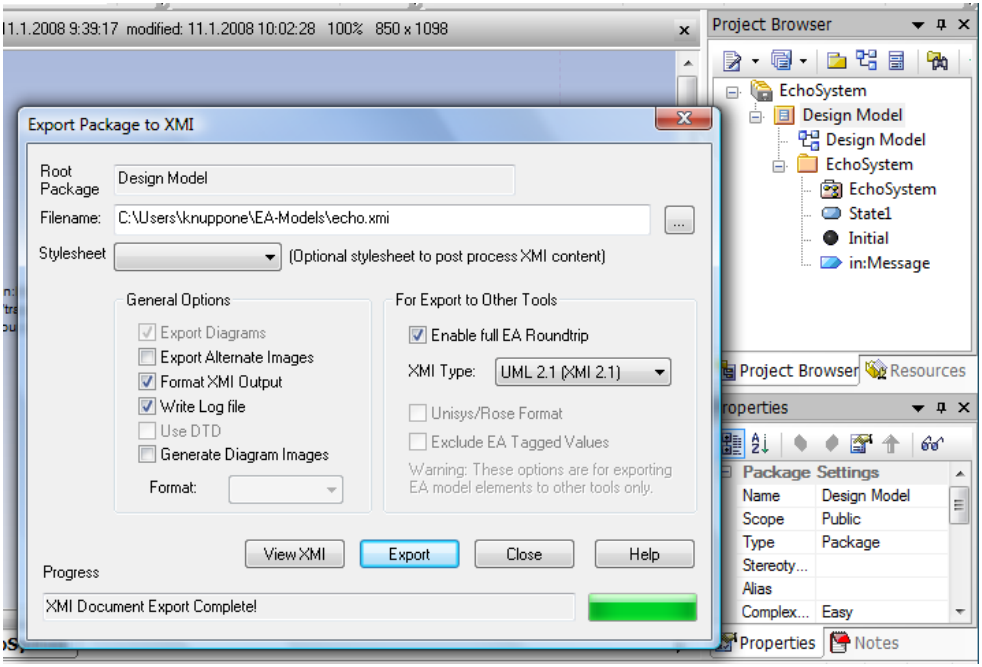
A simple echo system created using Enterprise Architect

- Start by creating a new project. Enterprise Architect prompts for models that are added to the project and you can select either *Class Model* or *Design Model*.
- Right click the created model in the *Project Browser* and select *Add->Add Package* in order to create a new package to which a simple state machine will be created later on.
- Now right click the created package in the *Project Browser* and select *Add->Add Diagram* in order to create a new state machine diagram. From the opened window, select *UML Behavioral* and *State Machine*. The name of this diagram must be the same as the name of the package containing the created state machine diagram.
- Draw a simple state machine as shown in the screenshot. In the example model the textual parts of the model are placed into a comment box visible in the right hand side of the screenshot.



Transition properties showing the Signal trigger and action of transition string

- Once the model has been created, it must be exported as XMI that is imported to Qtronic. In order to export the model as XMI, right click the created root package in the *Project Browser* and select *Import/Export->Export Package to XMI file...*. From the opened window specify the filename and the XMI type. The XMI type must be either "UML 2.0 (XMI 2.1)" or "UML 2.1 (XMI 2.1)".



Exporting Enterprise Architect model as XMI

- Once the model has been created and exported from Enterprise Architect, all the files must be compiled and imported into Qtronic. Because the textual parts of the model was placed in a comment box, the only file that will be imported to Qtronic is the exported XMI file. In Conformiq Qtronic 1.X these files are placed in a manifest file and in Conformiq Qtronic 2.X these files are individually selected in the Qtronic Eclipse UI.

```
echo.xmi
```

7 Creating Qtronic2 Scripting Backends

There are software processes wherein it is beneficial to generate separate test scripts that can be stored in version control systems, maybe sent around, and executed independently afterwards. To meet this need, Qtronic provides the means for generating test scripts using configurable *scripting backends*. Simply, a scripting backend is a plugin component that is connected to Conformiq Qtronic using a well-defined API. Scripting backends and open API's enable the creation of custom output formats and the utilization of test libraries in generated test scripts to seamlessly integrate to your existing test execution environment.

These plugins can be created by the organization that employs Conformiq Qtronic for testing, or they can be outsourced or, in some cases, bought as off-the-self software components. Qtronic is shipped with a number of scripting back-ends as mentioned in Section How to Export Test Cases, namely

- An HTML scripting backend for generating browsable HTML documents.
- A TTCN-3 scripting backend for generating test script in TTCN-3.
- A TCL scripting backend for generating test scripts in TCL.

Multiple scripting back-ends can be used in parallel, they can be distributed over TCP/IP networks, and different data filters and manipulators can be added in front of the back-ends. These capabilities are provided by standard components supplied with Conformiq Qtronic. The only custom components that must be created are the basic scripting backends.

The following Sections details the process of creating custom scripting backends using Java as the implementation language and Eclipse as the development environment.

7.1 Communicating Using QML Datum Interface

The underlying test scripts generated by Conformiq Qtronic are sequences of timed messages. The mapping of these sequences to languages such as C/C++, TCL, TTCN-3, Perl, Python, and Java is mostly straightforward. The main task is to encode the sequence of timed messages, a sequence of QML record instances, to some specific output format. See Sections Record Types and Input and Output for more information about QML records.

The generic datums in Conformiq Qtronic 1.X are omitted from Conformiq Qtronic 2.X thus there is no need for extra step of converting generic datums to QML datums. As the models are created using QML, it is more coherent and meaningful to deal with objects that "look like" QML types.

7.2 Creating Scripting Backends in Java

A scripting backend implemented in Java is a JAR (Java Archive) file that can be used to create test scripts.

A scripting backend written in Java is a class extending the abstract base class **com.conformiq.qtronic2.ScriptBackend** from **Qtronic2PluginAPI.jar** provided in the Conformiq Qtronic product. This base class contains a set of methods which Qtronic calls when there is useful information available for script generation. Scripters are synchronous meaning that most of the methods must return a Boolean value: the methods are expected to return Boolean true if the script generation succeeds and Boolean false otherwise.

When the Qtronic loads Java plugin (see Section How to Export Test Cases for more information about loading scripting backends and exporting test cases) it first instantiates the class that implements **ScriptBackend** and then queries any configuration information that the scripter wishes to expose (All scripters employ common configuration API which allows custom scripters expose hierarchical property-value pairs to Qtronic user interface. Scripting backend configuration is covered in detail in Section Exposing Scripting Backend Configuration).

When user wishes to export generated test cases via scripter, Qtronic will call in sequence the methods described below:

beginScript

Qtronic will invoke this method to indicate the beginning of test script. For example this method can be used for outputting a header to the test script containing information about test generation options, script creation time, and do

on.

beginCase

Qtronic will invoke this method to indicate the beginning of a test case. This method is called zero or more times after a call `beginScript()`. For example this method can be used for outputting a header of the test case with the name of the test case.

After `beginCase()` Qtronic will call the methods below so that the scripter can render the actual sequence of steps in the test case in the selected output format.

testStep

Qtronic will invoke this method to indicate a single test step i.e. a single test message either in the inbound (from the tester to the SUT) or the outbound (from the SUT to the tester) direction. As arguments to this method, Qtronic will pass the content of the message (i.e. an instance of QML record), the name of the thread in the model that is expected to send or receive the message, the direction of the step, and finally the timestamp that is the required or expected time when the message must be sent or received.

internalCommunicationsInfo

Qtronic will invoke this method to indicate a single internal communication step i.e. a single message take-over between internal threads in the model. As this information is derived from the internals of the model and does not relate to external behavior, this should not affect test execution at all, so it is possible to generate valid and executable test scripts while ignoring all calls to this method. However, this method is usually used for documenting the test script (in practice the internal message take-over is encoded into a comment in the test case).

checkpointInfo

Qtronic will invoke this method to indicate that the given model-driven coverage goal has been covered. As with `internalCommunicationsInfo()`, this should not affect test execution at all, so it is possible to generate valid and executable test

scripts while ignoring all calls to this method. However, if you are interested in how the test scripts are mapped to model-driven coverage you can benefit from implementing this method properly.

The following methods are invoked by Qtronic then to indicate the end of a test case and finally the end of the test script:

endCase

Qtronic will invoke this method to indicate the end of a test case.

endScript

Qtronic will invoke this method to indicate the end of test script.

A Simple Scripter Backend

Here is a very simple scripting backend that simply outputs information to the console.

```
import com.conformiq.qtronic2.*;

public class ExampleScriptBackend extends ScriptBackend {
    private NotificationSink mSink = null;
    private MetaDataDictionary mDict = null;

    public boolean beginScript(String testsuiteName)
    {
        mSink.notify("info", "Beginning script: " + testsuiteName);
        return true;
    }
    public boolean beginCase(String tcName)
    {
        mSink.notify("info", "Beginning test case: " + tcName);
        return true;
    }
    public boolean checkpointInfo(Checkpoint cp, int status, TimeStamp ts)
    {
        if (status == Checkpoint.CheckpointStatus.COVERED)
            mSink.notify("info", "Covered checkpoint " + cp.getName());
        return true;
    }
    public boolean testStep(QMLRecord datum, String thread, String port,
                            boolean isFromTester, TimeStamp ts)
    {
        mSink.notify("info", "Test step: " +
                     (isFromTester ? "tester" : "SUT") + " sends " +
                     datum + " to " + port + " at " + ts.seconds + "." +
                     ts.nanoseconds);
        return true;
    }
    public boolean internalCommunicationsInfo(QMLRecord datum, String sender,
                                              String receiver, String port,
                                              TimeStamp ts)
    {
        mSink.notify("info", "Internal communication: " +
                     sender + " sends " + datum + " to " + receiver +
                     " via " + port + " at " + ts.seconds + "." +
                     ts.nanoseconds);
        return true;
    }
    public boolean endCase()
    {
        mSink.notify("info", "Ending test case");
        return true;
    }
```

```
    public boolean endScript()
    {
        mSink.notify("info", "Ending script");
        return true;
    }
    public boolean setConfigurationOption(String property, String value)
    {
        mSink.notify("info", "Set configuration option '" + property +
                     "' to '" + value + "'");
        return true;
    }
    public boolean trace(String message, TimeStamp time) { return false; }
    public void setNotificationSink(NotificationSink sink) { mSink = sink; }
    public boolean setMetaData(MetaDataDictionary dict)
    {
        mDict = dict;
        return true;
    }
}
```

7.3 Exposing Scripting Backend Configuration

All scripting backends employ common configuration API which allows custom scripters expose hierarchical property-value pairs to Qtronic user interface.

The scripter defines these property-value pairs in an XML document. This information will be handled and presented by the Qtronic user interface and once user has configured the scripter as she wishes, the configuration will be passed to the scripter via calls to `setConfigurationOption()` defining the property and the user defined value.

setConfigurationOption

> Set value of configuration option. Scripting backend can use this method to get access to two kinds of configuration options:

(1) Configuration options that are set in the Qtronic user interface (f.ex. used testing heuristics and model level coverage options).

(2) User defined configuration options that are based on the XML document 'Configura-

tion.xml' inside the JAR file of the scripter.

In the case there is a subtree in the user defined configuration option, property contains tree in dot separated format (e.g. "dir1.dir2.item"). Return value indicates if this is acceptable value for this property or not. E.g. if property is TCP port number and user enters non-number, scripter should return false.

XML document

A scripter defines an XML document called **Configuration.xml** that is placed into the root of the scripter JAR file. This document can define arbitrary number of hierarchical options. After reading in this document, Qtronic will show the options in the **Plugin Configuration Wizard** (See Section How to Export Test Cases). For example the scripter generates a test script which contains *hooks* (function calls to user-written code) can define two sub groups for options: one which contains output file and another contains hook related options. The scripter is informed about user defined configuration performed by using Plugin Configuration Wizard via calls to `setConfigurationOption(String property, String value)`, where property contains hierarchical structure separated with dots, e.g. "Output.-Generated file" with value "C:\TEMP\MyOutput.tc".

This example defines two groups, "Output" and "Hooks". Output contains "Generated file" property where user of the scripter enters filename of output file. "Hooks" group define start and end hook for both test cases and test scripts. User can for example set "Testcase start hook" to value "mymodule.startSUT();" and then the scripter generates test scripts where each test case starts with "startSUT" call from "mymodule".

```
<?xml version="1.0" encoding="UTF-8"?>
<configuration>
 <tree category="Output">
  <option property="Generated file" value="out.xxx" kind="file"/>
 </tree>
 <tree category="Hooking">
  <option property="Use hooking" value="true" kind="boolean"/>
  <option property="Testcase start hook" value=""/>
  <option property="Testcase end hook" value=""/>
  <option property="Testscript start hook" value=""/>
  <option property="Testscript end hook" value=""/>
 </tree>
</configuration>
```

Valid XML document can contain arbitrary number of options as defined by following *Document Type Definition*:

```
<!ELEMENT configuration (option|tree)*>
<!ELEMENT tree (option|tree)*>
<!ATTLIST tree category CDATA #REQUIRED>
<!ELEMENT option EMPTY>
<!ATTLIST option property CDATA #REQUIRED>
<!ATTLIST option value CDATA #REQUIRED refresh CDATA #IMPLIED>
<!ATTLIST option kind (boolean|file) #IMPLIED>
```

The "kind" field in an option is used to define the dialog widget that QEC will use.

file

This will make a file dialog that displays a dialog window from which the user can select a file. This is useful for defining the output file, for example.

boolean

This will make a check box that can be selected (for true) or not (for false)

7.4 Preparing Eclipse Workbench

The recommended way of building Java plugins is to use Eclipse. This and the following sections detail the process of building Qtronic Java plugins using Eclipse as the development environment. For more information about Eclipse and Java development in Eclipse, please refer to *Java Development User Guide* that is part of the Eclipse distribution.

The first step is to verify that the Eclipse is properly set up for Java development i.e. the JRE (Java Runtime Environment) installation.

1. On the main menu bar, select **Window > Preferences...** and select **Java > Installed JREs** page to display the installed JREs. Confirm that a JRE has been detected by Eclipse and it should appear with a mark in the list of installed JREs.
2. On the Preferences Wizard, select **Java > Compiler** and set **Compiler compliance level** to **6.0**.
3. In order to automatically build the Java code, select **General > Workspace** page to display Workspace related preferences. Confirm that the **Build automatically** has been checked.
4. Click **OK** to confirm the changes.

7.5 Creating Java Project for Scripting Backends

Once Eclipse has been configured properly, we can proceed into building a Java project for the plugin. The following steps detail this process.

1. On the main menu bar, select **File > New > Project...**. This will open **New Project** wizard.
2. Select **Java Project** and click **Next** to launch **New Java Project Wizard**.
3. Enter a name for the project and click **Finish**.

Once the project has been created, click the newly created project in the Project Explorer view and select **Properties** from the drop down menu.

1. From **Properties for ...** Wizard, select **Java Build Path**.
2. Add **Qtronic2PluginAPI.jar** to the build path by selecting **Add External JARs** and finally click **OK**.

Before creating the actual implementation of the scripting backend, we will create the configuration file for scripting backend explained in Section Exposing Scripting Backend Configuration.

1. Select the newly created project in Project Explorer and select **New > File** from the drop down menu.
2. Enter **Configuration.xml** as the name of the file and click **Finish**. Note that this file must be located in the root of the project so that when the scripter is exported as a JAR archive, Qtronic is able to find the configuration file.
3. Select the **Configuration.xml** file in Project Explorer and select **Open With > Text Editor**. This will open a text editor that can be used to enter the configuration in XML format as explained in Section Exposing Scripting Backend Configuration.

Next we create the *concrete* class that implements the abstract class **ScriptBackend**.

1. Select the newly created project in Project Explorer and select **New > Class** from the drop down menu.
2. Enter a package name to the **Package** field.
3. Enter the name of the class that implements the **ScriptBackend** to the **Name** field. Java convention is to name this class with Capital letter.
4. Make sure that **public** modifier is set.
5. Enter **ScriptBackend** as the **Superclass**.
6. By selecting **Inherited abstract methods** Eclipse will generate you a stub file with all the methods that needs to be implemented. Naturally, these stub methods are not abstract. Make sure that you do not generate **public void main** method.

7. Click **Finish**.

Next you will need to actually implement the methods. A very simple example is given in Section Creating Scripting Backends in Java. Once the scripter has been implemented, we will need to generate a JAR file that will contain the compiled byte code which is the topic of the next Section.

7.6 Creating Scripting Backend JAR

Once the scripting backend has been developed and the Java source files have been successfully compiled, we need to export the implementation as a JAR file.

1. Select the Java project in Project Explorer and select **Export** from the drop down menu. From the **Export Wizard**. select **Java > JAR file** and click **Next**.
2. Select the project that you are exporting as JAR archive if it has not been already selected and select all the files from the right hand side view.
3. Enter a name for the JAR file to be exported to field named **Select the export destionation:** and click **Finish**. This will generate the JAR file to the location you specified.

You can use this scripter then in Qtronic as explained in Section How to Export Test Cases.

7.7 Debugging Scripting Backends

Scripting backends can be debugged using **Error Log** view that captures all the warnings and errors logged by QEC. This view is available under **Window > Show View > Error Log**. Full details about a particular error event can be viewed in the *Event Details* dialog by double-clicking on a particular entry or selecting **Event Details** from the context menu of that entry. The details contain information about exception stack trace etc. The information in details view can be copied to the clipboard by pressing the button with the clipboard image.

Note that you need to install *PDE* component (http://www.eclipse.org/pde/) to Eclipse in order to see Error Log. PDE is included in most of the Eclipse packages by default. Conformiq recommends to use *Eclipse Classic* which contains this component.

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8 Support and Troubleshooting

Conformiq Qtronic has been constructed following high quality standards.

Regardless of this, there are situations where you may find the software performing poorly or malfunctioning. This can be caused by one of the following reasons:

1. There can be a programming defect in the Conformiq Qtronic product ifself.
2. You may have tried to push Conformiq Qtronic beyond its natural categorical or quantitative limits.
3. The documentation provided with the tool can have created misconceptions about the behaviour of the tool.

We encourage you to follow the following guidelines when you encounter a problem with your use of Conformiq Qtronic.

8.1 Troubleshooting Guidelines

If you encounter problems with using Conformiq Qtronic, please follow the troubleshooting guidelines given here. If the problems cannot be resolved using these guidelines, please contact technical support of Conformiq (support@conformiq.com).

8.1.1 Troubleshooting QEC

In order to troubleshoot QEC installation related problems, please refer to Section Checking the QEC Installation.

A known problem with Eclipse is that it requires quite much memory and other resources. In case you are experiencing slow performance with QEC or *OutOfMemoryExceptions* errors, consider modifying the virtual machine arguments for the Java virtual machine. This will provide more memory for the Eclipse to operate.

In order to modify the JVM arguments, go to your Eclipse installation directory, open the eclipse.ini file, and add the following to the end of the file:

- For a machine with 1024MB of RAM: `-vmargs -Xms512m -Xmx512m`

`-XX:PermSize=256m -XX:MaxPermSize=256m`

- For a machine with 2048MB of RAM: `-vmargs -Xms1024m -Xmx1024m -XX:PermSize=512m -XX:MaxPermSize=512m`
- For machines with more RAM, adjust to fit your preferences.

Eclipse will pass these arguments to JVM when you start Eclipse again.

8.1.2 Performance Problems

It can happen that the user tries to push Conformiq Qtronic beyond its natural categorical or quantitative limits. Please consult *Modeling Techniques* and *Modeling Best Practices* documetation provided by Conformiq to overcome and workaround some of the performance problems. Here are some very rudimentary actions that you can take when encountering performance problems:

- Use as low *Lookahead Depth* from Qtronic Algoritmic Options as possible. Recall that the *Lookahead Depth* is used to control the exhaustiveness of the test generation. Selecting values from the left correspond to lower amounts of CPU time used — having too high a value can cause very high offline script generation times.
- When developing model incrementally, it is also advised to disable 'Only Finalized Runs' option.
- Experiment with different combinations of *model coverage options*.

8.2 Reporting Problems with Qtronic

If you fail to resolve the problem or the problem is related to the tool itself, please contact technical support of Conformiq (support@conformiq.com). When reporting problems, please provide as much information as possible:

- Provide details about your system.

    - Qtronic version
    - Operating system and version number
        - In Linux, provide also information about libc, libstdc++, and gcc versions.
    - Eclipse version
    - Qtronic licensing details
- Provide detailed list of steps that lead to the problem to occur.
- If it is possible, provide the full Qtronic project with model files and test design configurations. The Qtronic project is stored under the Eclipse workspace in the file system.
- If the problem is related to Qtronic Eclipse Client, provide information available in *Error Log* view which is available under **Window > Show View > Error Log**. Full details about a particular error event is available in the *Event Details* dialog by double-clicking on a particular entry or selecting *Event Details* from the context menu of that entry. The details contain information about exception stack trace etc. Copy the information in details view to the clipboard by pressing the button with the clipboard image and provide this information in the problem report.

A Qtronic 2 Release Notes

Conformiq Qtronic is a revolutionary solution for true design model driven test and quality assurance automation. It enables automated, thorough and cost-efficient testing of complex systems.

A.1 Download and Install

You can try out Conformiq Qtronic without any hassle. Evaluation license generation is automatic, so you do not need to be in contact with our sales personnel to start evaluating Conformiq Qtronic at all. Conformiq Qtronic binaries are available for Linux and Windows for evaluation.

Step 1 — Download Conformiq Qtronic

Conformiq Qtronic Evaluation can be downloaded from http://www.conformiq.com/downloads/

Step 2 — Obtain Evaluation License Automatically

In order to obtain an evaluation license you must provide us your contact details and information about your test design automation needs on http://www.conformiq.com/getlicense.php. An evaluation license will be sent to the e-mail address you provide which must be your **corporate email address**. By requesting the license you allow us the right to use your e-mail address for our legitimate business purposes, including but not limited to discussing your evaluation process with you.

Step 3 — Install Qtronic

Install Conformiq Qtronic on your target machine. On Windows XP and Vista, execute the installer you have downloaded. On Linux, unpack the gunzipped TAR file and run "install.sh" in the directory you unpacked. Qtronic 2.x is a client-server architecture where test generation happens on the Qtronic Computational Server while the user uses client-side working Eclipse-based working environment to create the model and define test design requirements. You must install Qtronic Computation Server on a machine with internet access because the server needs to verify the validity of evaluation license from our license server. In order to install

Qtronic Eclipse Client, Eclipse 3.3 or newer must be installed beforehand. The recommended package is Eclipse Classic.

Step 4 — Activate Qtronic

When you start Qtronic Eclipse Client, configure it to use the evaluation license as follows

- Select **Window > Preferences** in the main menu of Qtronic Eclipse Client. This will open Preferences wizard.
- Select **Qtronic > Licensing** in the Preferences wizard. This will open the Qtronic License Management view.
- Select **Evaluation License** and provide the evaluation code you received via e-mail.

A.2 Qtronic 2.0.3

Release date: March 6th, 2009

What's new or changed

- In order to accommodate the fact that functional requirements often contain a unique name or an identifier and a brief summary with maybe some rationale for the requirement, the `requirement` statement is extended so that a summary or a description can be given as an argument to requirement statement. See Section Requirements for more information.
- In a case that model contains an internal computation error such as a division by zero, Qtronic Eclipse Client user interface will now also present dynamic stack trace that leads to the error.
- Stability of the computation node has been increased.

A.3 Qtronic 2.0.2

Release date: January 16th, 2009

What's new or changed

- Management of client connections has been enhanced
- Management of test asset database has been enhanced
- Stability and performance of the computation node has been increased

A.4 Qtronic 2.0.1

Release date: December 12th, 2008

What's new or changed

- Test cases for multiple Test Design Configurations are generated now in parallel which makes test generation faster by sharing test generation results between multiple Test Design Configurations more efficiently.
- Management of client connections is enhanced to increase redundancy of test generation results in case of connection problems.

A.5 Qtronic 2.0.0

Release date: November 17th, 2008

What's new or changed

- Complete redesign of Qtronic user space as Eclipse plugin. User interface available in platforms where Eclipse is supported (f.ex. Linux, Windows, and Sun Solaris).
- Separation of user interface and test generation engine to distinct components that

can be run on distinct workstations. Test generation engine can be run in Linux or in Windows.

- Incremental test case management and test case generation.
  - Generated test cases are stored after test generation run to a persistent storage.
  - Previously generated test cases are used as input to consecutive incremental test generation runs providing faster test generation.
  - Possibility to name and rename generated test cases.
- Capability to browse and analyze generated test cases (and model defects) in the user interface including graphical I/O and execution trace; no need to export HTML test plan.
- Only supports offline script generation. Support for online testing will be reintroduced in later 2.X releases.
- The generated tests are rendered in formats specified by script backends written in Java.
- Support for multiple design configurations or profiles. Each profile have their own coverage criteria and selection of script backends. There can be more than one script backend in a design configuration, while also generation of test cases is possible without having a script backends at all.
- Improved handling of coverage criteria
  - Finer grained control of coverage criteria as structural features can be individually selected.
  - Capability to also block coverage criteria in addition to marking coverage criteria as a target or "do not care".
  - Status of a coverage criteria is updated in real time and visible all the time in the user interface.
- Simplified plugin API eases the task of developing new plugins.

Benefits

In Qtronic 1.X the tool simply designs and generates the test cases, but the user cannot see the generated tests in the tool itself forcing user to build a scripter plugin before generating even a single test. In addition, Qtronic 1.X leaves it up to the user to manage and store the generated test cases. In Qtronic 2.0, on the other hand, the generated tests are stored in persistence data storage and the generated tests are visible in the Qtronic 2.0 user interface allowing user to do detailed analysis of the generated tests. Only after the tests have been generated, the user has the possibility to export tests in the expected format using a set of scripter plugins.

In addition to test case management, the user interface of Qtronic 2.0 has been redesigned and reimplemented from the scratch making the look and feel more professional and enhancing the user experiences significantly. Also, the user interface and computation engine component have been separated allowing the user to run Qtronic 2.0 on a low end computer without significantly sacrificing the performance of the computer: the heavy computation can be carried out in a high end sever computer with fast CPU and great amount of memory. However, this does not prevent user from running the user interface and computation engine on the very same computer, if this is required.

One additional feature in Qtronic 2.0 is the test generation profiles called design configurations. The design configurations allow user to create different profiles with different coverage settings and scripter plugins for different use cases. For example, user can define a design configuration for verifying the basic requirements and another for generating test cases that stresses the boundary values of integral comparisons in the model.

B Plugin API Reference Manual