System documentation

ABI team 33
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Abstract

This document contains the system documentation for the xMAS Model Designer. It describes the design and implementation details of the designer, the integration with verification tools, changes to existing code and techniques used for the implementation.

1 Story tree

Stories of the xMAS model designer project are available through the Agilefant tool and can be found in the xMAS repository. Agilefant must be set-up on a web server before the repository data xmas/6-transition/08-agilefant/Agilefant_xMAS.zip can be imported. Once imported, stories can read or changed.

The stories are based on three roles:

- A **researcher** develops formal verification methods to test on xMAS models.
- A **designer** creates and verifies xMAS models with the xMAS model designer toolkit.
- A **maintainer** that maintains the xMAS model designer toolkit project.

Figure 1 is a small copy of what this story tree looks like in the Agilefant tool.

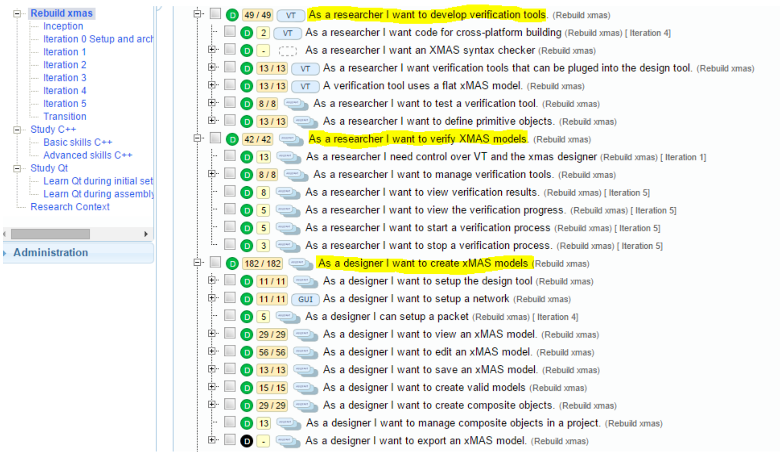


Figure 1: Agilefant story tree

2 Changes to the data model

Due to requirements imposed by the designer, several changes and additions have been made to the data model. Most of these changes are related to the additional support for hierarchical networks in the designer. This section present an overview of new and modified classes and functions.

2.1 XMASNetwork

XMASNetwork is a new class designed to represent an xMAS network. This class can be used to model both flat and hierarchical networks. When used to model hierarchical networks, an XMASNetwork represents a single level or subnetwork in the hierarchy. Multiple networks are combined to form the complete network.

The main responsibility of XMASNetwork is to serve as a container of XMASComponent instances. Internally, XMASNetwork stores the components in a map relating a components name to its in-memory instance. Prior to the introduction of XMASNetwork, the concept of an xMAS network was directly represented by such a map. Verification tools still use this approach, although they could be easily adapted to use XMASNetwork as well.

The promotion of XMASNetwork to its own class definition has two reasons:

- The designer uses additional network properties like the canvas size. These properties must be stored somewhere in the data model (i.e. in XMASNetwork).
- Support for hierarchical networks requires management of multiple network models. Using an explicit class to represent networks eases this task.

Extending networks XMASNetwork implements the same extension mechanism as used by the XMASComponent and Port classes. For this, a new class named XMASNetworkExtension has been created. Currently, the designer uses two network extensions. One to store network properties common to all models, and one to store network properties specifically for network models that are to be used as composite objects. In the future, additional network extensions could be defined, for example to store data required to support parameterization of subnetworks.

MemoryPool All components in an XMASNetwork are stored in a MemoryPool for optimal performance. Multiple networks can share a MemoryPool instance. The XMASNetwork constructors optionally take a pointer to a MemoryPool. Passing the same instance to multiple networks will let these networks share the pool. When no MemoryPool pointer (or nullptr) is provided to the constructor, XMASNetwork will create its own MemoryPool instance. In this case, XMASNetwork also takes care of the MemoryPool destruction.

2.2 XMASComposite

When modeling a hierarchical network, composite objects are used to represent subnetworks as black boxes inside a higher-level network. The addition of composite objects to an xMAS network is reflected in the data model through the new XMASComposite class. Like the eight xMAS primitive types, XMASComposite is derived from XMASComponent. As such, XMASComposites can be used in the same way as the primitive components.

When a new XMASComposite object is created, a reference to an XMASNetwork must be passed to the constructor. The composite object will represent an instantiation of this (sub)network.

The sinks and sources of the subnetwork are used as interface ports or gates between the subnetwork and the higher-level network. An xMAS source component will result in an Input port on the composite object. Likewise, each xMAS sink component in the subnetwork leads to an Output port on the composite object.

2.2.1 Hierarchical visitors

Due to the introduction of the new XMASComposite type, the XMASComponentVisitor interface has been extended to support composite objects. Unlike the existing pure virtual visit functions, XMASComponentVisitor provides a default implementation to visit XMASComposites. This way, existing implementations of the interface which weren't designed to support composites aren't affected. The default visit implementation for composite objects does throw an Exception however. So, only flat, composite free networks should be passed to these implementations.

2.3 XMASProject

The xMAS designer application uses the XMASProject class to manage a complete hierarchical model. The root network, available through getRootNetwork(), is the network under construction. For each composite object type used, XMASProject additionally stores its network definition. XMASProject is equipped with member functions to insert new components into the network, remove them from the network and change the name of a component. All of these functions act upon the root network. Adding a new composite object to the model requires that its network definition is added to the project in advance. Function insertComposite() automatically does this if necessary. A subnetwork that is no longer of use can be unloaded using unloadNetwork(). Unloading only succeeds if no composite objects in the project (at any level) depend on the network.

XMASProject is also responsible for the construction and destruction of a MemoryPool. All networks loaded in the project share this instance of the pool.

Note: Currently, the designer assumes that all subnetworks used in a project are stored in the same directory as the root network.

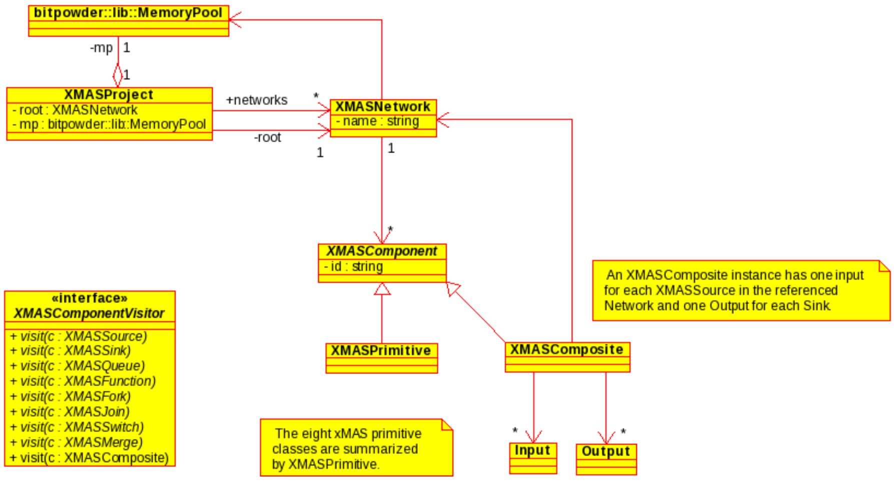


Figure 2: xMAS data-model extended with new classes

2.4 Parser & Exporter

The additional support for hierarchical models and the need to store data used by the designer require a number of modifications to the parser and the exporter.

Position For each component listed in the json data, the parser checks whether canvas data is available in the pos field (see also the file format description). If this is indeed the case, the x, y, orientation and scale fields are read and stored inside an extension of the component (CanvasComponentExtension). If no position data is stored in the json data, the designer will use default values. The exporter has been updated to write the position data, if present, back to json as well.

Composite objects XMASComposite objects are created for all components in the json file with type 'composite'. The parser uses the 'subnetwork' attribute mandatory for composite components to determine what kind of composite object should be created. The parser is not responsible for loading subnetworks. Rather, the caller of the parser must supply a function that is able to map a subnetwork name to an instance of an XMASNetwork. Code that uses the parser should be updated to comply with the new function signature. The implementation in XMASProject can be used as a reference.

3 XMD - XMV integration

3.1 QML

The xMAS model designer was created in QML. QML is a declarative language that promotes quick design of user interfaces. In fact, QML is a complete javascript language with some extra features for Qt, like support for QString. The language uses a declarative, JSON-like syntax that allows developers to describe visual components and their interactions in a readable and compact notation. Being a javascript language, the programmer can use all expressions available in javascript while enjoying Qt enhancements. Additionally, QML provides a C++ API for back-end C++ libraries that connects both environments transparently.

3.2 User interface

The user interface consists of multiple qml files in two folders. The folder `uicontrols` contains controls like the toolbar, console and dialogs. These QML files make up the user interface. The folder `xobjects` contains QML files to draw the xMAS components on the designer canvas.

Finally, the file `mainWindow.qml` represents the root of the interface definition.

Separation of code The QML language contains both procedural code (javascript) and declarative code (JSON). Several `.js` files contain the procedural logic. The `.qml` files contain the declarative code plus a few snippets of javascript logic limited to one or two lines. The division of declarative and procedural code promotes clean, uncluttered code. The ability to include `.js` files into a qml file promotes reuse of code.

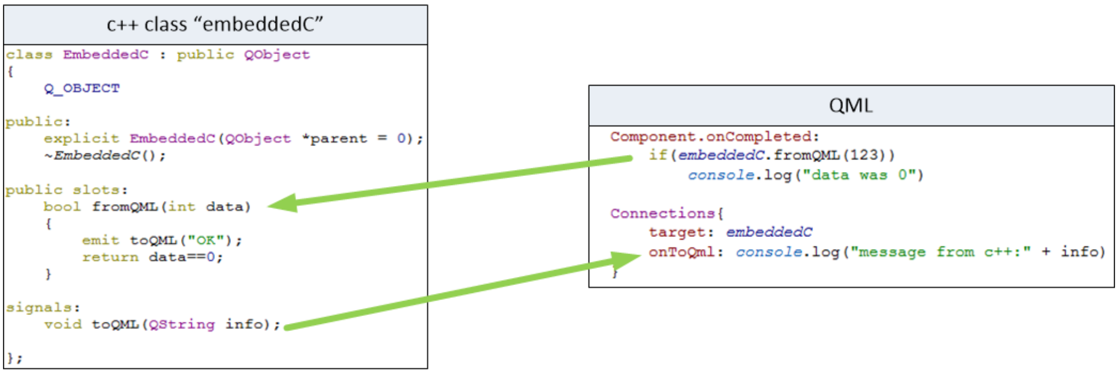
3.3 C++ integration

QML objects can interact with each other and with their C++ counterparts either directly by accessing their property values or through the signal/slot mechanism. Interaction between QML and C++ classes is more complicated than the QML internal interaction. Especially the timing of coordination could result in surprises for the unsuspecting QML/C++ programmer who is well served reading the official QML documentation in case of problems.

The application uses two methods provided by QML to integrate QML and C++ objects.

3.3.1 QML Context property

Each QML application operates in a certain QML context. The QML context stores properties that are available throughout all QML code. C++ classes can be exposed to the QML world by setting a C++ object instance as the value of a property on the QML context. XMD uses context properties to provide access to three C++ classes:




```
QQmlApplicationEngine engine;
QQmlContext* ctx = engine.rootContext();
EmbeddedC *embedded;
ctx->setContextProperty("embeddedC", embedded);
```

Figure 3: Registering a QML context property

- **datacontrol** (of class DataControl) to provide access to the underlying xMAS data model to both QML and the other C++ classes
- **plugincontrol** (of class PluginControl) to provide access to the plugins that manage starting and stopping of verification tools. Only Qml uses the plugin control program.
- **util** (of class Util) to provide utility functions for C++.

QML Documentation More information on context properties is available at: `http://doc.qt.io/qt-5/qtqml-cppintegration-contextproperties.html`

3.3.2 Embedding C++ classes in QML

QML applications can also be extended with C++ code by registering C++ classes with the QML type system. Any C++ class that derives from QObject can be used in this way. Registering the class to QML not only allows access to the properties, methods and signals of an object. Additionally, QML code can directly instantiate new objects of the registered classes (see figure 4).

Usage XMD registers four C++ classes to the QML type system. These classes are Channel, XPort[1], Network and Component. The definitions of each of the four classes is split into three files. The .h and .cpp files contain normal C++ header and

[1]This class has been named XPort to avoid confusion with the Port class defined in the xMAS data model. Any confusion in names can lead the QML/C++ API astray and could lead to difficult to find errors.

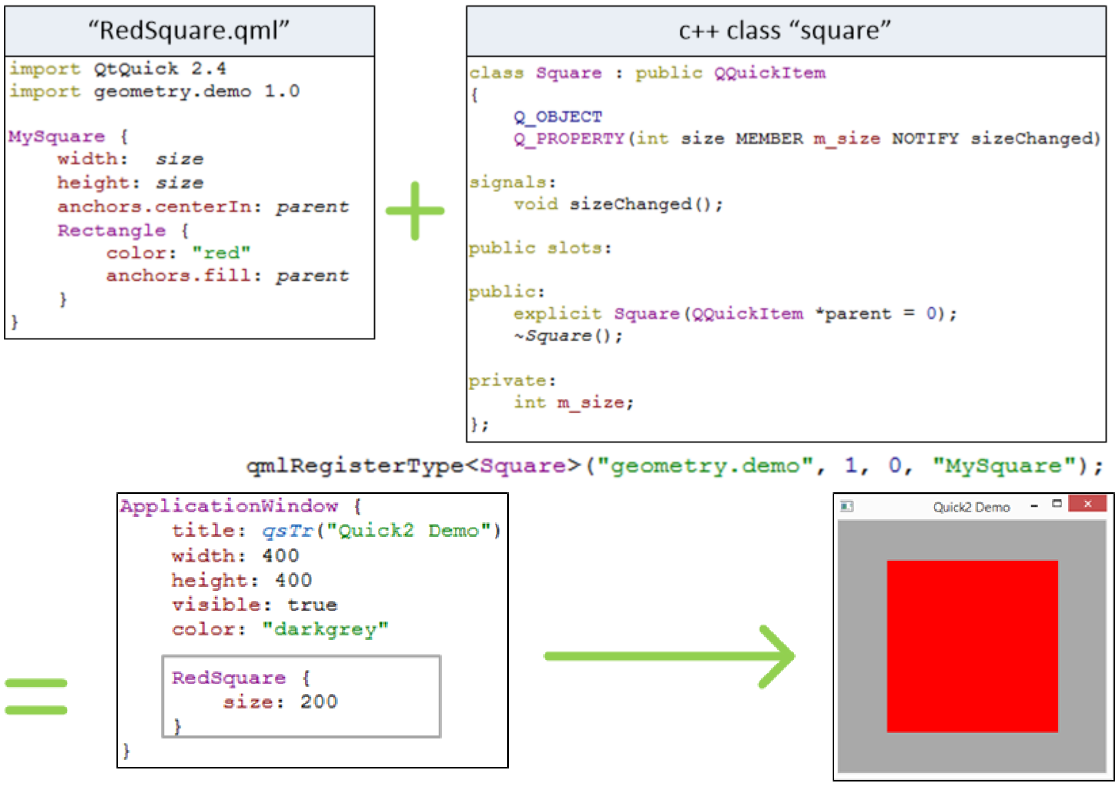


Figure 4: Exposing a C++ class to QML

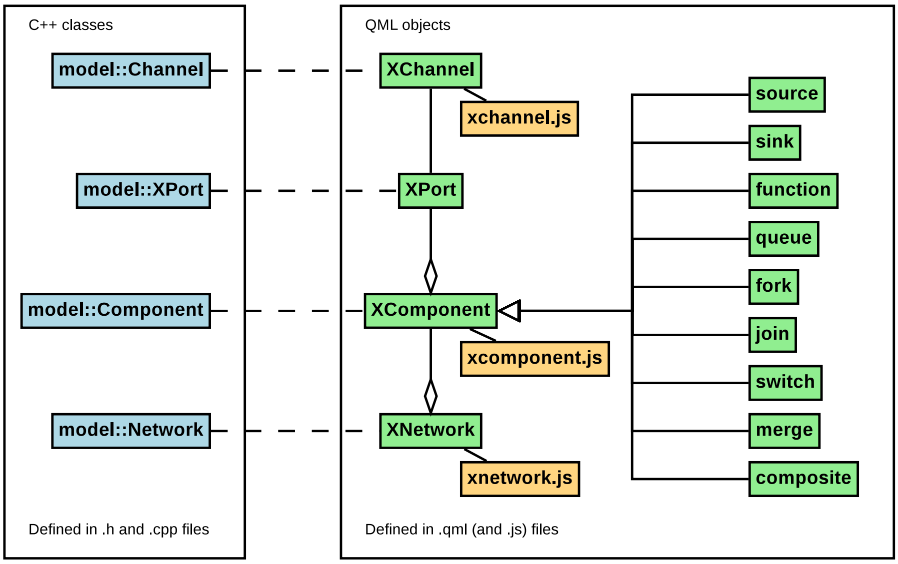


Figure 5: Qml / C++ integration of XMD classes

source files of the classes. Furthermore, each class has a QML file, which contains additional QML code (figure 5). All three files belong to the same class. Even though the class names are sometimes different (e.g. Channel vs. XChannel), the QML type system binds the C++ code and the QML code together to form a single class definition. Registration of types is done by a call to qmlRegisterType, figure 4 shows an example.

QML Documentation More information is available at: `http://doc.qt.io/qt-5/qtqml-tutorials-extending-qml-example.html`

3.3.3 Interaction xmd / datamodel classes

Figure 6 shows the relationship between the classes of xmd and the datamodel. XMD and XMV share the bottom part that contains the model classes. The equivalant (QML) classes that make up the view are located in the upper part. The XMD classes XPORT and COMPONENT do not directly access the PORT and XMASCOMPONENT classes of the datamodel. Manipulation of the datamodel always involves class DATACONTROL. This class has access to the project, its root network and the components and ports of the model under construction.

3.3.4 Architecture

See figure 7 for an overview of the system architecture.

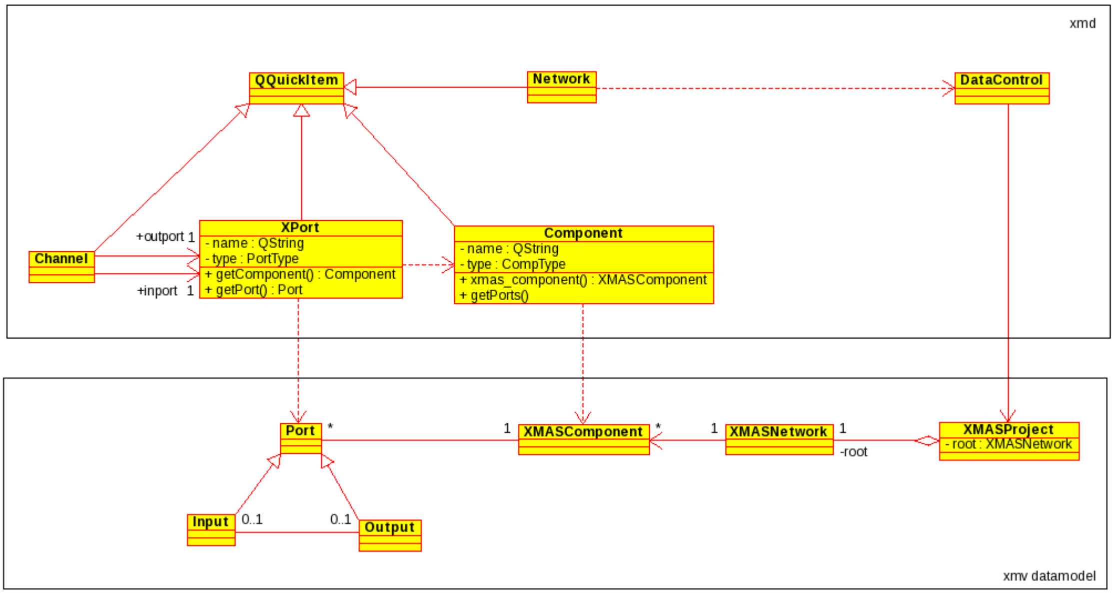


Figure 6: Integration of xmd and xmv datamodel

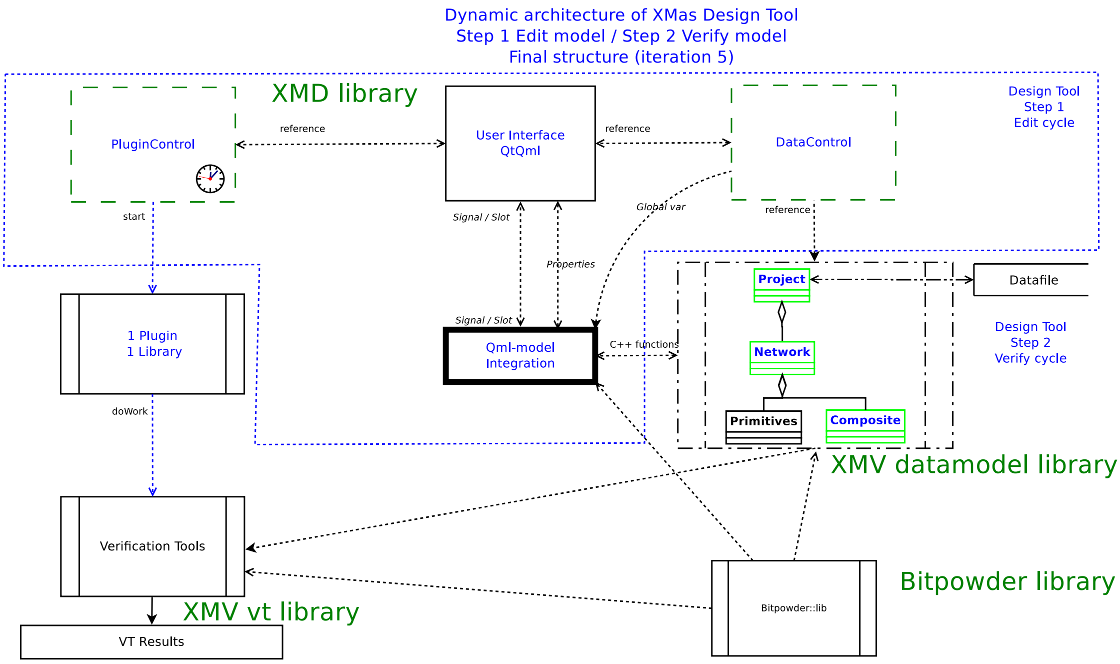


Figure 7: Global system architecture

4 Flattening the network

Hierarchical networks are flattened before they are processed by the verification tools. Flattening produces a new flat network, the original network is not modified. The algorithm broadly consists of the following three steps:

1. Copy the components from the hierarchical network to the flat network.
   - For composite objects, the flattener instantiates a copy of the subnetwork into the target network. Through recursion of the flattening algorithm, this subnetwork is first flattened itself.
2. Connect the channels between the components in the flat network.
3. Connect all (flattened) subnetworks

4.1 Algorithm

The flattening process uses a recursive algorithm to flatten all composite objects. Each recursive call takes two parameters: the destination network, which is the same in all recursive calls, and the source network. In each recursion step, a flat copy of the source network is inserted into the destination network. The projects root network is the source network in the first iteration. In subsequent recursion steps, the subnetworks that define a composite object are used as source networks.

Gates In a subnetwork, sources and sinks are used to define the interface between the subnetwork and the higher-level network. In the flattened network these components are no longer present. Components in the higher-level network are directly connected to the components in the subnetwork. Alternatively, when there is a channel between two composite objects, the components of two subnetworks directly connect to each other. To prepare for connection of the networks, sources and sinks are replaced during flattening by temporary components called gates. An XMASSource component gets replaced by an XMASInGate component. This component has an additional Input port (i_ext) that corresponds to the Input port of the composite object in the higher-level network. Likewise, an XMASSource is converted to an XMASOutGate instance, which has an additional Output port (o_ext). Figure 8 shows the result.

Flattened composite The result of a recursion step is a flattened subnetwork. Moreover, the recursion step generates a number of gates which are still not connected to the external world. Upon return of a recursive call, these gates are collected and stored in another temporary component: XMASFlattenedComposite. This component is the direct equivalent of an XMASComposite in the source network.

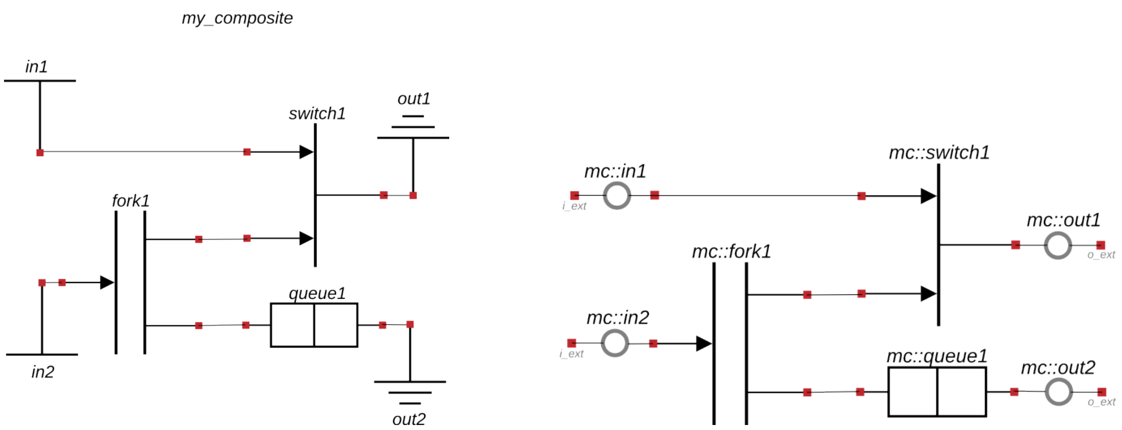


Figure 8: The original composite network (left) and a partial view of the flattened network showing the subnetwork with gates (right); the component names have been qualified with the composite objects name (mc) to prevent name collisions

Connecting channels The second step, connecting the channels between components is easy. Although composite objects are flattened, the temporary XMASFlattenedComposite objects are still present. They provide the same interface (Input and Output ports) as the XMASComposite object in the source network. Connecting to a composite is a matter of connecting channels to the external ports available on the XMASFlattenedComposite instances. Even self-connecting composite objects can be handled this way. Figure 9 details the preceding two steps.

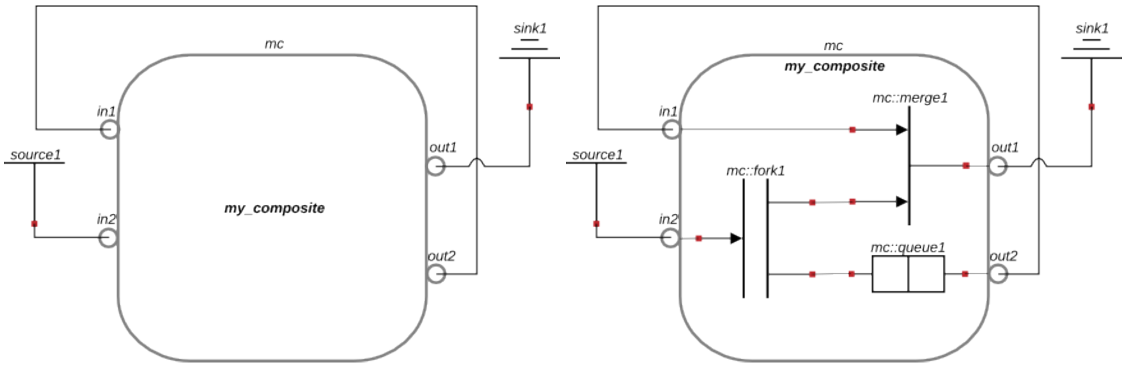


Figure 9: The root network (left) containing a composite object and the corresponding flattened network (right) including the XMASFlattenedComposite object

Cleaning up The final step, per recursion, is to remove the temporary components and gates. For each flattened composite, all gates are iteratively removed by simply updating both ports on the opposite ends of the gates ports so that they directly connect to each other. After this, the XMASFlattenedComposite and its gates are deleted.

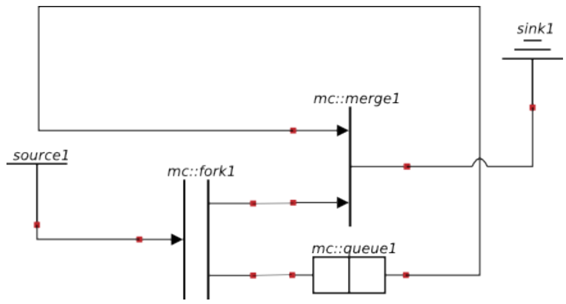


Figure 10: The resulting flattened network

Note: While copying a component, all known extensions that a component can have are copied as well. Which extensions to copy for what component type is currently hard-coded in the flattener. Ideally, this method will be replaced by a more generic copying method. Its implementation has been postponed due to changes required to the underlying bitpowder library.

5 Feedback interface

While analyzing a network, verification tools can generate various types of feedback messages. At this moment, verification tools present this feedback as human readable text messages on the standard output. Although this form is suitable for human consumption when running the verification tools as a standalone application, they are hard to parse and interpret by software like the designer.

Due to time constraints, presentation of feedback from the verification tools has been kept simple. Similar to the standalone application, the text messages are presented to the user in a text console integrated in the designer. Future improvements could enhance the integration between designer and verifications. As an example, problematic components and ports could be highlighted on the design canvas.

To support these kinds of enhancements, a more structured way to pass feedback from verification tools must be used. For this purpose, a feedback message format has been defined along with several functions that can be used by verification tools to generate feedback messages.

5.1 Message format

Feedback messages are structured as follows:

[**sender**] ****type****: **message** (**component list**) (**port list**)

- **sender** is a string to identify the verification tool that sends the feedback message. Each verification tool should define a unique name to identify itself.
- **type** specifies the type of feedback. The following feedback types are defined:
  - **INFO** - informational message, e.g. verification tool has started or finished
  - **WARNING** - non-fatal warning, e.g. non-optimal network configuration detected
  - **FAULT** - fault in the network detected, e.g. a combinatorial cycle
  - **CRASH** - crash / unexpected exception thrown by the verification tool, this indicates a programming error, not a network fault
  - **PROGRESS** - informational message containing progress of a verification tool
- **message** contains the actual feedback message. Verification tools can pass custom text messages. For PROGRESS type feedback, the message field has a fixed format: "progress/total" where both progress and total are positive integers.
- **component list** is an optional list of component IDs to which the feedback applies. The components are listed inside brackets using comma-separated notation and are prefixed by "Comp: ", e.g. Comp: [src1, join2, ...].

- **port list** is an optional list of ports (of components) to which the feedback applies. The ports are listed inside brackets using comma-separated notation and are prefixed by “Port: ”, e.g. Port: [src1.o, join2.a, ...].
- messages are terminated by a newline character

5.2 Example

```
[cycle-checker] **INFO**: Starting cycle checker
[cycle-checker] **FAULT**: Combinatorial cycle detected!  Port: [::frk0.a]
[cycle-checker] **INFO**: Finished!
```

5.3 Current state & future work

The “cycle checker” verification tool has been adapted to output its feedback in the described format. Optionally, this tool could be updated to emit progress information. However, progress information is of little value due to the short runtime of this tool.

As mentioned earlier, the designer does not interpret the feedback message structure yet. Extracting the information from the text string can be accomplished through the use of a regular expression. All feedback formatting code is located in the feedback-interface.h/cpp files. Changes to the message format and new code to parse the message string can be added here.

6 XMAS network file format

This document describes the file format used to store XMAS network models. Both the XMAS designer application and the standalone verification tools use this file format. The structure is based on the flat json format used by the checker application provided at the start of this project. Several new fields have been added in order to support hierarchical networks and information specific to the designer. As the new file format is able to support both flat and hierarchical networks, the (recommended) file extension has been changed from fjson to json.

6.1 Root JSON object

Properties:

- "CANVAS" : the CANVAS object (optional) *NEW*
- "COMPOSITE_NETWORK" : the COMPOSITE_NETWORK object (optional) *NEW*
- "VARS" : the VARS object
- "PACKET_TYPE" : the PACKET_TYPE object
- "NETWORK" : an array of COMPONENT describes all components in the network

6.2 CANVAS

NEW Used by the XMAS designer application to define properties of the designer canvas. When no CANVAS information is specified, default values are used.

Properties:

- "width" : width of the canvas in logical units
- "height" : height of the canvas in logical units

6.3 COMPOSITE_NETWORK

NEW Contains designer specific information to use this network as a composite object. If this information is not present, the network cannot be used as a composite object.

Properties:

- "alias" : displayed inside a composite object to denote the objects type (e.g. mesh)
- "image-name" : name of graphical resource used as a symbol to denote the objects type (e.g. mesh.ico)
- "boxed-image" : set to 1 to use the image as a symbol inside a generic composite object (drawn boxed) or set to 0 to use the image as the graphical representation of the entire component, this can be used to draw common macro's like credit counters and delays using the symbols commonly used in literature to denote these macro's.
- "packet" : The verification system does not use this information yet, although the user interface does allow entering a value. Its value is reserved for later use.

6.4 VARS

TODO[2] Definition taken from original file format.

6.5 PACKET_TYPE

TODO[2] Definition taken from original file format.

6.6 COMPONENT

Describes a component in the network.

Properties:

- "id" : String - unique identifier
- "type" : Component_type enum - type of the component
- "outs" : array of Out - describes all connected output ports
- "fields" : array of Field *(optional)*
- "pos" : Position - *new* - position of the component on the canvas

6.7 Component_type

Enumeration:

- source
- sink
- function
- queue
- xfork
- join
- xswitch
- merge
- composite ***NEW***

6.8 COMPONENT [type="source", type="sink"]

Properties:

- "required" : **Boolean 1/0** - set to 1 when this source/sink is an interface port of a composite network that must be connected by the higher level network. set to 0 when this is optional.

[2] The semantics of this field were not changed from the original file format. It is up to the customer to define the contents of this field.

6.9 COMPONENT [type="composite"]

NEW

Properties:

- "subnetwork" : String - name of the subnetwork
- ("parameters" : (Not determined yet) - reserved property name, to be used in the future to parameterize the network)

Description: The subnetwork reference indicates the relative location of the subnetwork on the filesystem.

E.g. "mesh.json" refers to the network defined in "mesh.json" in the same directory as this network and "spidergon/node.json" refers to the network defined in "node.json" in the subdirectory "spidergon".

Parameterization of composite objects has not been implemented yet. When implemented, composite objects require an additional field in the component description to store the parameters. The property name "parameters" has been reserved for this purpose.

Note: Currently the XMAS designer requires that all used composite networks are defined in the same directory as the root network.

6.10 OUT

Description: Describes channels between the components in the network. For each output port of a component, an **OUT** object describes to which input port of which component it is connected.

Properties:

- "id" : String - reference to the target component
- "in_port" : Number - index of the input port on the target component

6.11 FIELD

TODO[2] Definition taken from original file format

6.12 POSITION

NEW Stores positional data of the component on the canvas.

Properties:

- "x" : Number - x or horizontal position on the canvas
- "y" : Number - y or vertical position on the canvas
- "orientation" : Number - orientation of the component, measured in degrees clockwise.
- "scale" : Number - scale factor of the component