# GReAT : The Graph Rewriting and Transformation Language

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# Overview

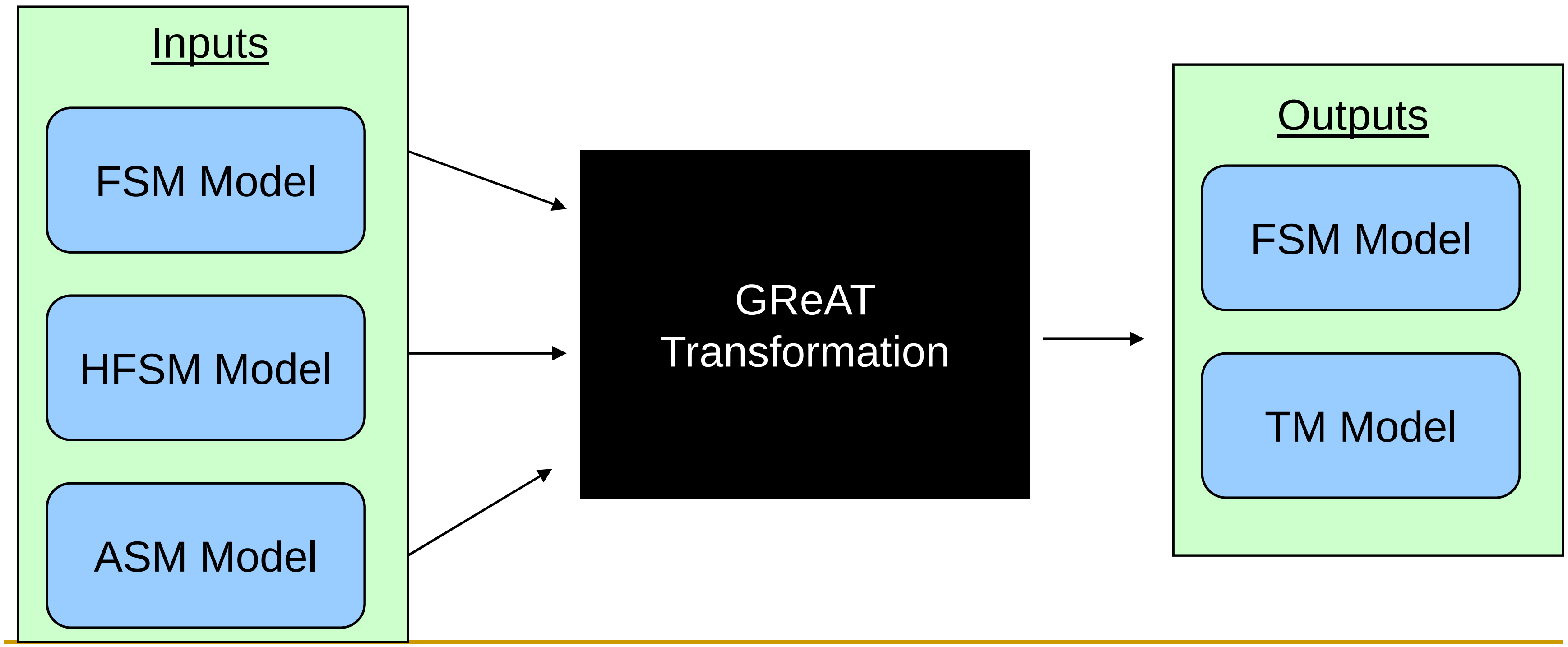
- Introduction
  - What is GReAT?
- Overall picture
- Example rule
- Where to begin
- Running the transformation

# What is GReAT?

- A graphical way of specifying model transformations
- Incorporates the meta-models of the input and output models directly
- Specify the transformation inside GME
- Can run the transformation from inside or outside GME
  - Inside: GR-Engine, Debugger
  - Outside: GR-Engine (command line), Code Generator (fastest)

# Overall picture

- Arbitrary number of input and output models
  - Each of these models can be of any domain

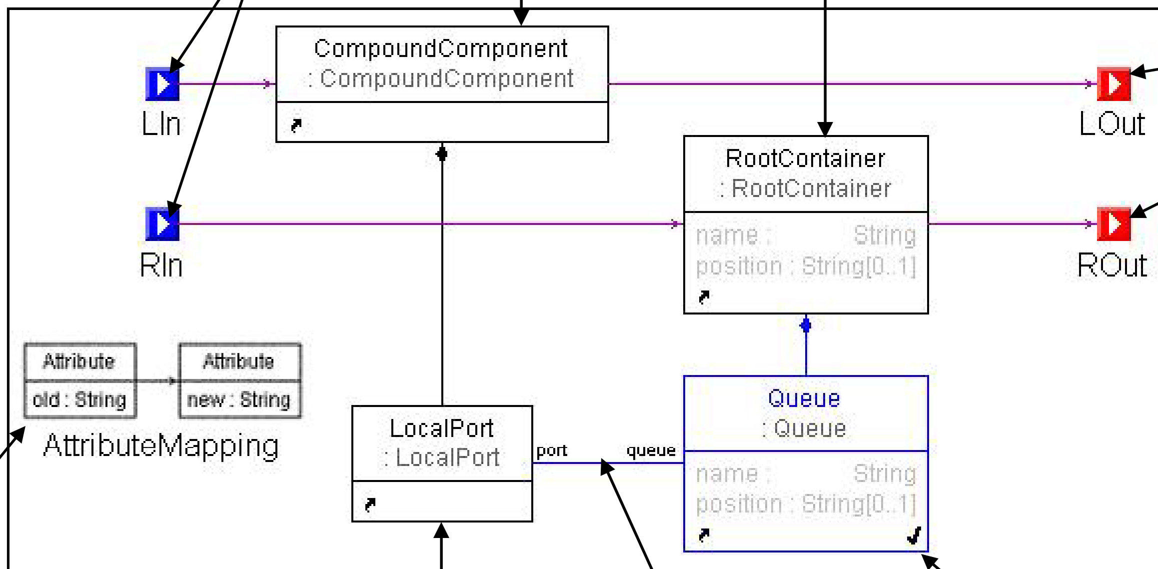


# Transformations

- Sequence of explicitly sequenced transformation rules
- Rule patterns are drawn using UML notation with elements from the meta-models
- Once a pattern is found
  1. Existing elements can be deleted
  2. New elements can be created
  3. Elements can be selected and passed to the next rule
  4. Attributes of any existing objects can be accessed and manipulated

# Example rule

These are passed in from the previous rule




These pass objects to the next rule

This gives access to object's attributes

For every LocalPort we find in the incoming Compound Component, we create a new Queue, and we create a new simple association between the port and the queue

# Overall process

- All transformations begin by creating a new UMLModelTransformer (UMT) project in GME
  - This is a specific GME paradigm; that is, it is a modeling language for creating model transformations
  - What is defined in this project? (next slide)

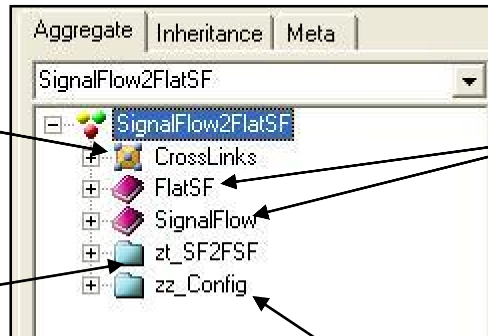
# What is inside a UMT Project?

1. Configuration information
   - Gives information about the input and output files and the names of the meta-models, etc.
2. Transformation rules
   - A sequence of patterns that are matched; if a match occurs, an action can take place (objects can be created, destroyed, or attributes changed)

# Parts of a UMT Project

Package that holds temporary class diagrams (crosslinks)

Folder that holds the transformation rules




The meta-models of the input/output models

Configuration folder that contains configuration info, user includes, etc.

# Performing the transformation

- After giving the configuration information and specifying the transformation rules, we have three ways of performing the transformation
  - GR-Engine : interpreter, used while developing transformation for fast testing
  - Debugger : used during development to debug transformations
  - Code Generator : used once a transformation reaches a mature state – produces executable code (very fast)

# Transformation Artifacts

- A number of intermediate artifacts are generated to perform the transformation

1. -gr.xml file: the xml representation of the transformation rules
2. Udm/ directory: contains .h and .cpp files used to access models
3. Config.mga: contains configuration information in a separate file

# Next tutorials

- Initial setup
- Defining rules
- Advanced features

# GReAT Tutorial Part I : Initial Setup

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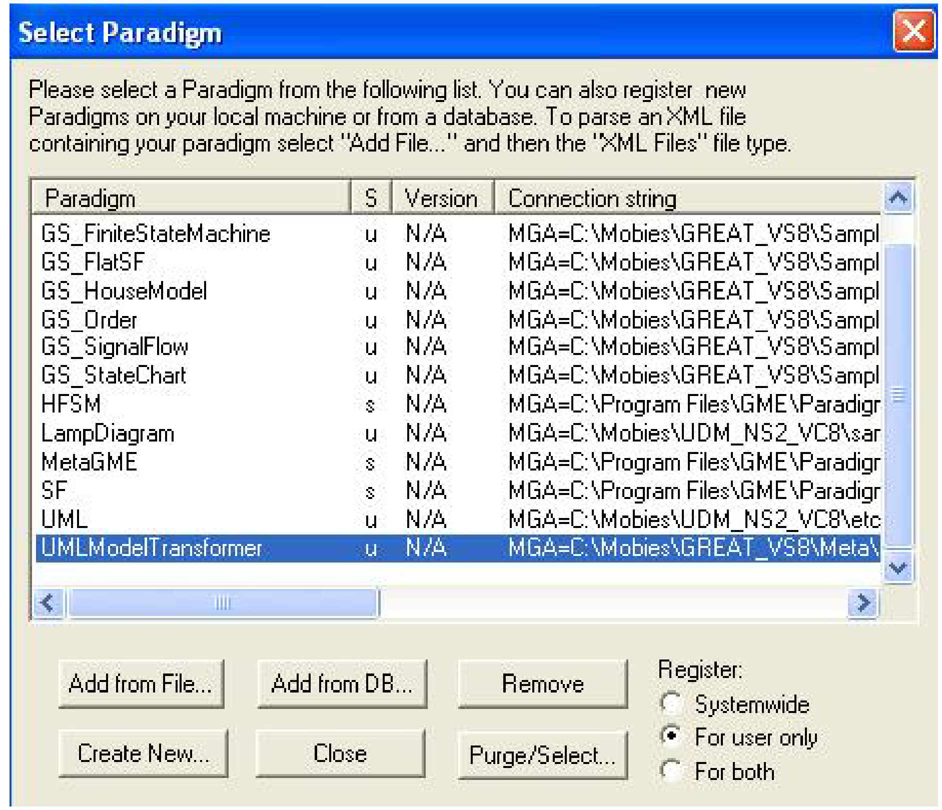
# Overview: 5 steps to transformation

1. Create a UMLModelTransformer project
2. Attach meta-models for all input/outputs
3. Specify configuration information
4. Define transformation (next presentation)
   - For example purposes, we'll describe how to set-up the SignalFlow2FlatSF sample that comes with GReAT (samples/SignalFlow2FlatSF.mga)
5. Run Transformation

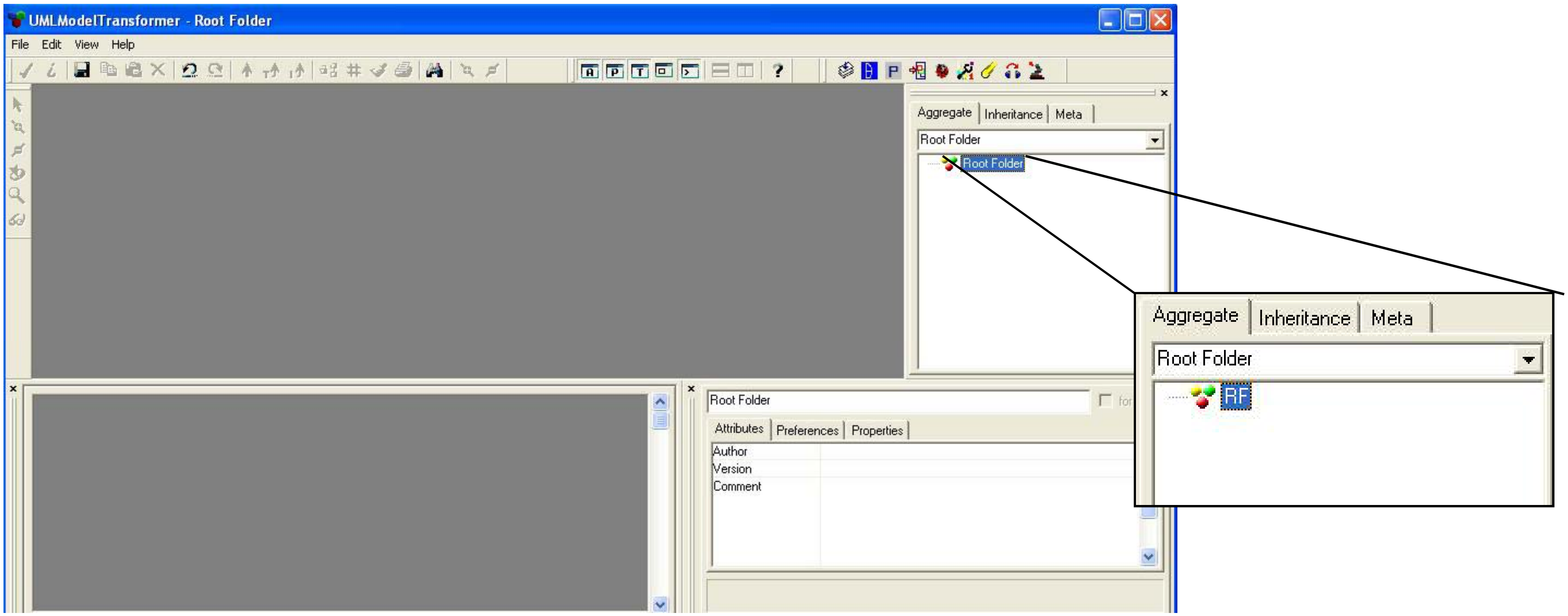
# Step 1 : Creating the project

- In GME :
  - File > New Project…
  - Select UMLModelTransformer
  - Select Create New
  - Create Project File
  - Give filename



# Step 1 (continued)

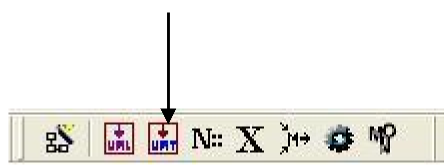
- You should have an empty project that looks like the following
  -Rename the Root Folder element to "RF"




- Now save the project and exit

# Step 2 : Attaching meta-models

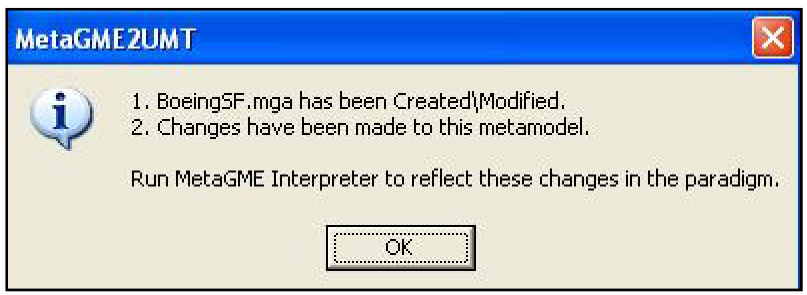
- Open the meta-models for all input and output models (may have to repeat this several times) – these are MetaGME style MMs
- Invoke the MetaGME2UMT interpreter



- Select the UMT project you created in step 1 when asked where to save

# Step 2 (continued)

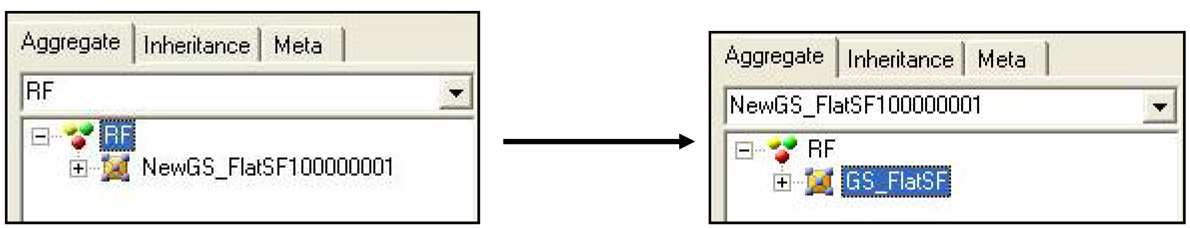
- If asked if you want to copy the constraints, say no
- You'll see a dialog like this:




- Click OK, and then run the MetaGME interpreter (be sure to say yes when asked if you want to register your paradigm)

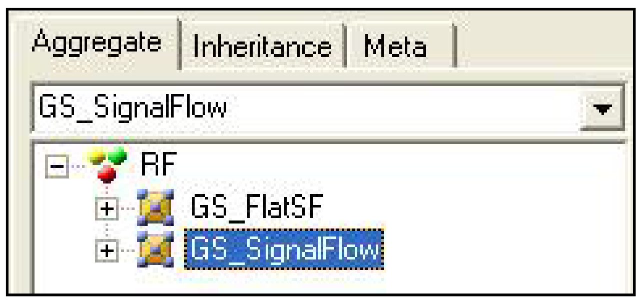
# Step 2 (continued)

- Open the UMT project -- the meta-model will be attached and should look like the following
- Rename it so that the “New” prefix and the post-fixed numbers are gone



# Step 2 (continued)

- Repeat this process for all other meta-models involved during the transformation
  - For our SignalFlow transformation, we'll have two meta-models attached (GS_SignalFlow and GS_FlatSF)
  - After attaching both, the browser should look like the following:

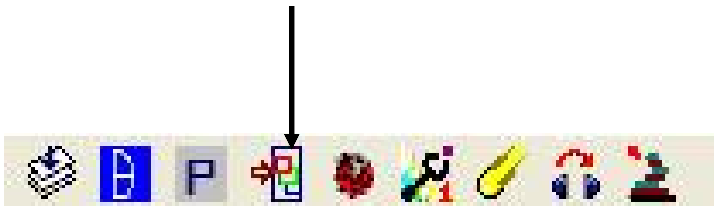


# Step 3 : Specify Configuration

- The configuration information gives information on input/output files, meta-information, etc.
- The configuration model editor (interpreter with GReAT) assists in quickly creating configurations

# Step 3 (continued)

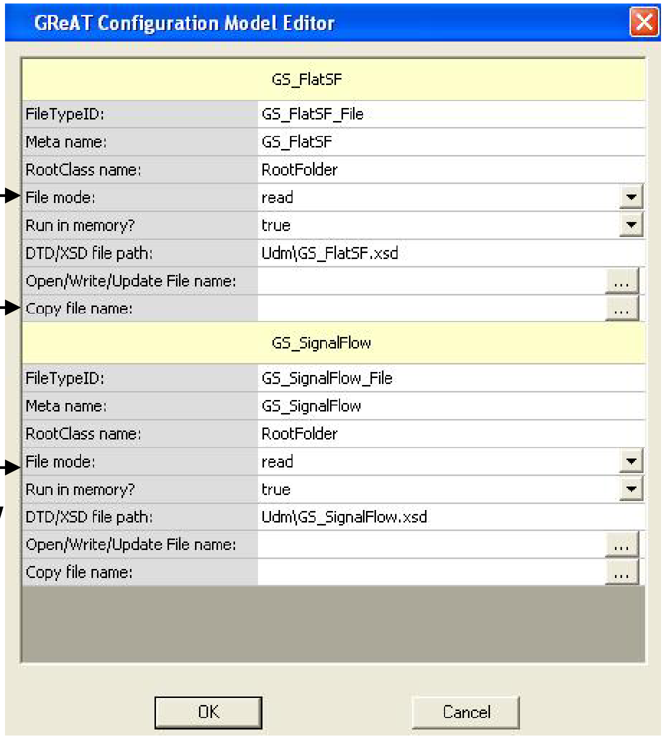
- Invoke the configuration model editor



- This will bring up a dialog box like the one on the next slide

# Step 3 (continued)

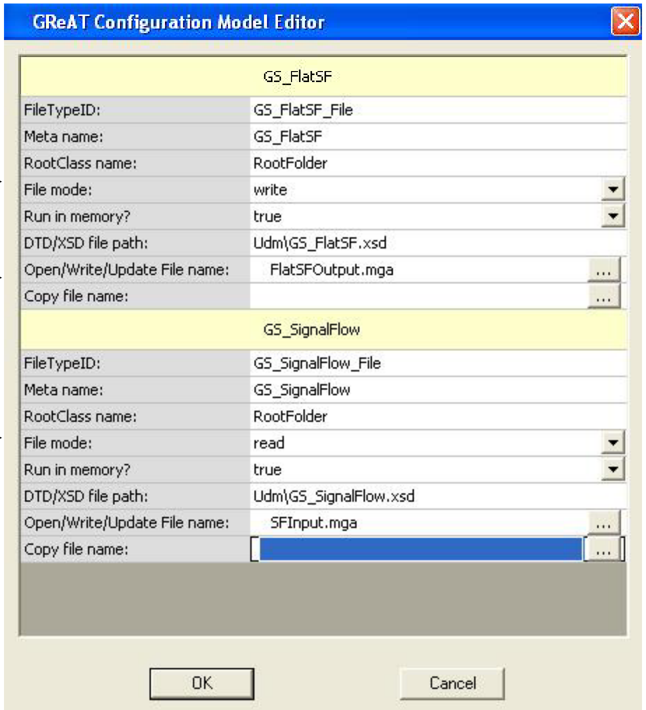
- Fill in the file names, and be sure to change the “File mode” to:
  - “Write” if the file doesn’t yet exist
  - “Read and Write” if the file exists but will be modified
  - “Read and Write to a Copy” if you want to open an existing file and make any changes on a new file

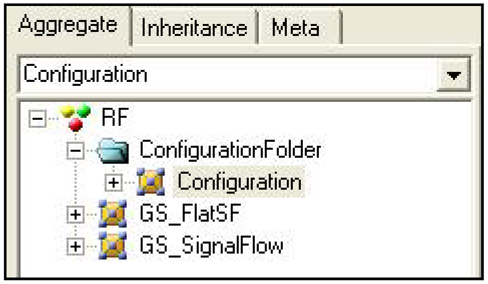


# Step 3 (continued)

- The completed configuration for our example should look like this:

The FlatSF model doesn't exist, so open it as "write"

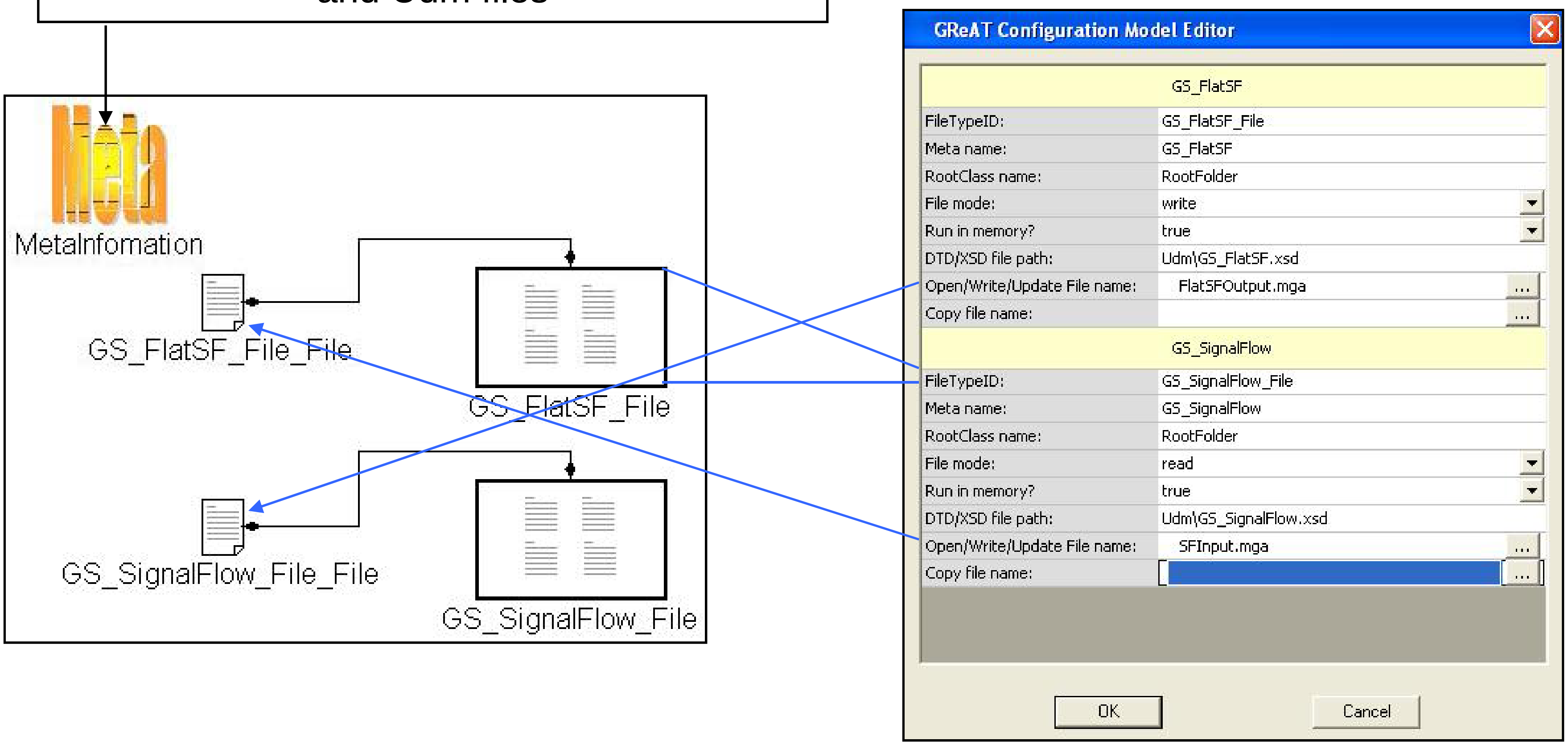



Configuration Folder and Information is created

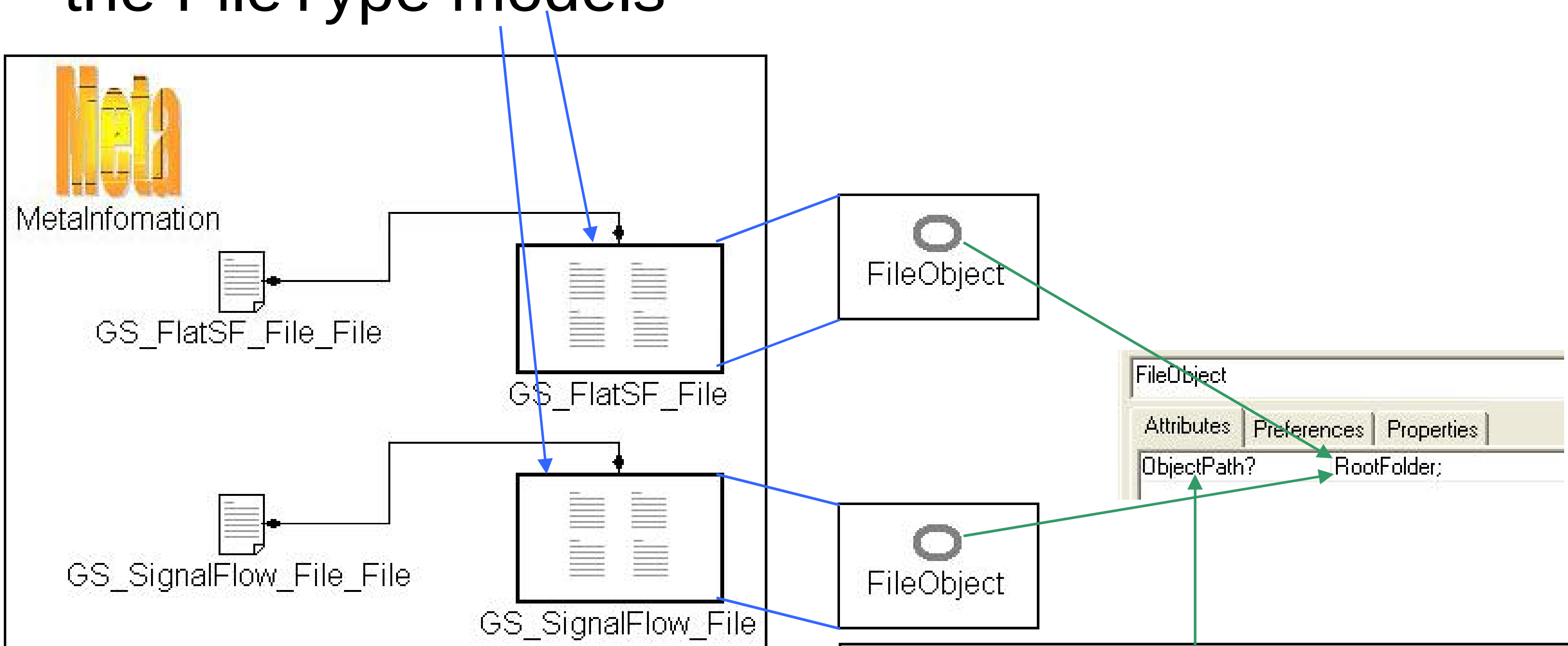
# Step 3 (continued)

Describes info about transformation rules file and Udm files



# Step 3 (continued)

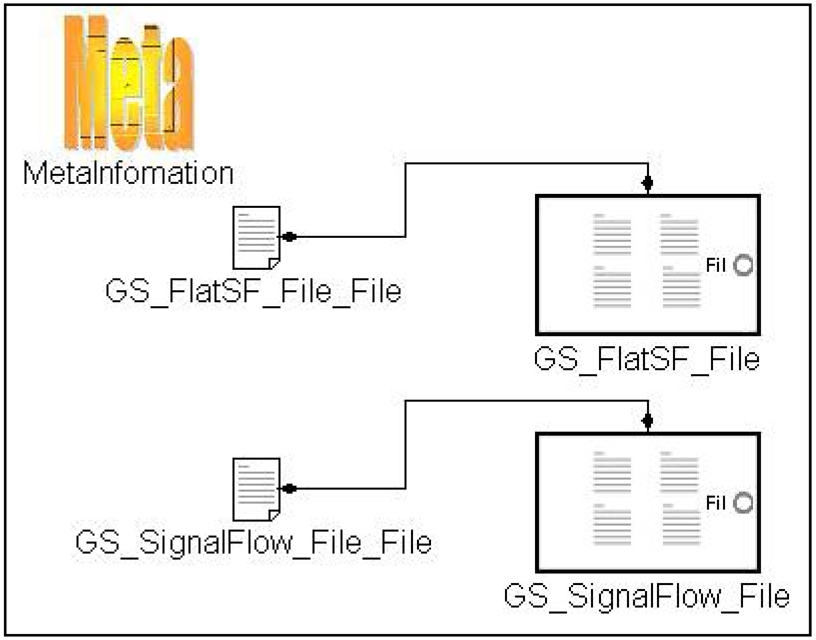
- 1. We need to insert a “FileObject” inside each of the FileType models




2. Set the “ObjectPath” attribute of both FileObjects to “RootFolder;”

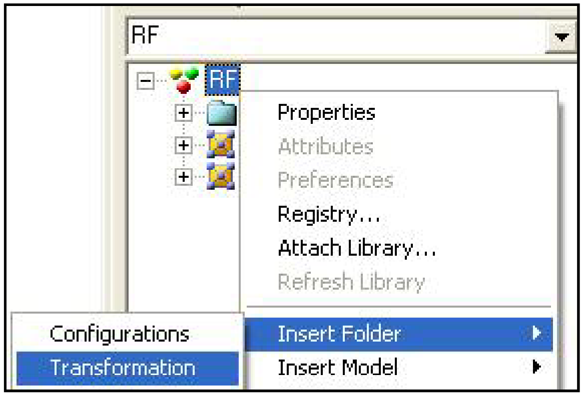
# Step 3 (continued)

- The configuration model should look like this (if you have more than two input/output files, then you will have more elements):



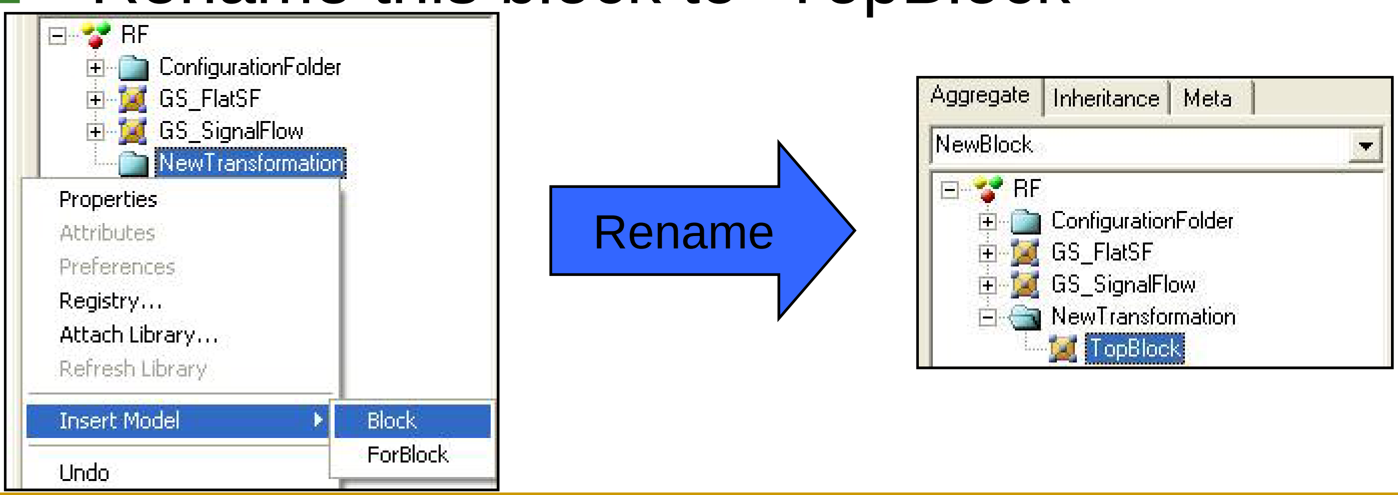
# Step 4 : Specify Initial Rule

- We need to specify at least one rule to have a working transformation
- Insert a transformation folder in the root folder in your project
  1. Right click on Root Folder (named RF)
  2. Select Insert Folder
  3. Select Transformation



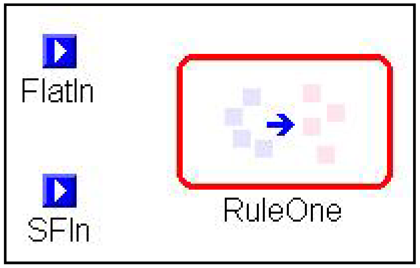
# Step 4 : Specify Initial Rule

- Right click on the newly inserted Transformation folder and insert a block
  - This Block will be the top level container of all transformation rules
  - Rename this block to “TopBlock”



# Step 4 : Specify Initial Rule

- Open this block and insert:
  - Two In-ports
    - Name one FlatIn and the other SFIn
  - One Rule
    - Name this RuleOne

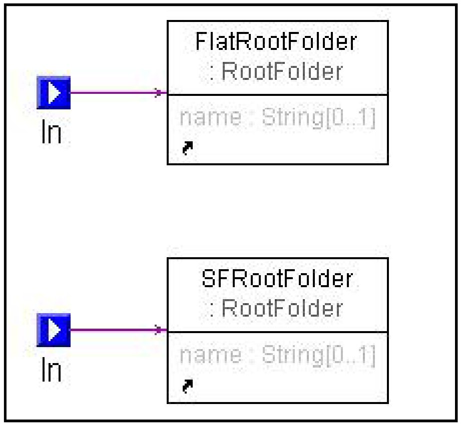


# Step 4 : Specify Initial Rule

- Open RuleOne and insert:
  - Two In-ports (default names are fine)
  - One reference to the RootFolder from the GS_FlatSF paradigm (name this FlatRootFolder)
  - One reference to the RootFolder from the GS_SignalFlow paradigm (name this SFRootFolder)
  - Connect the top In-port to the SFRootFolder
- Connect the bottom In-port to the SFRootFolder
- Connect the top In-port to the FlatRootFolder
  - Select “Binding” for both connection role types

# Step 4 : Specify Initial Rule

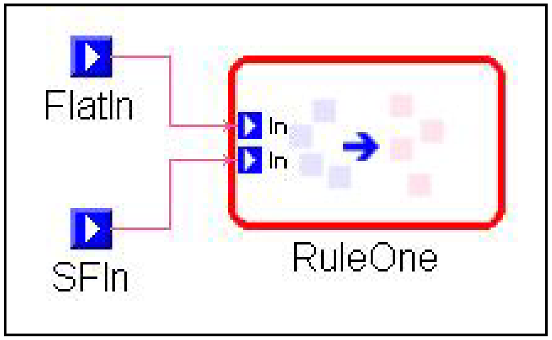
- Rule one should now look like this:




- Now wire the In-ports of TopBlock to the In-ports of RuleOne

# Step 4 : Specify Initial Rule

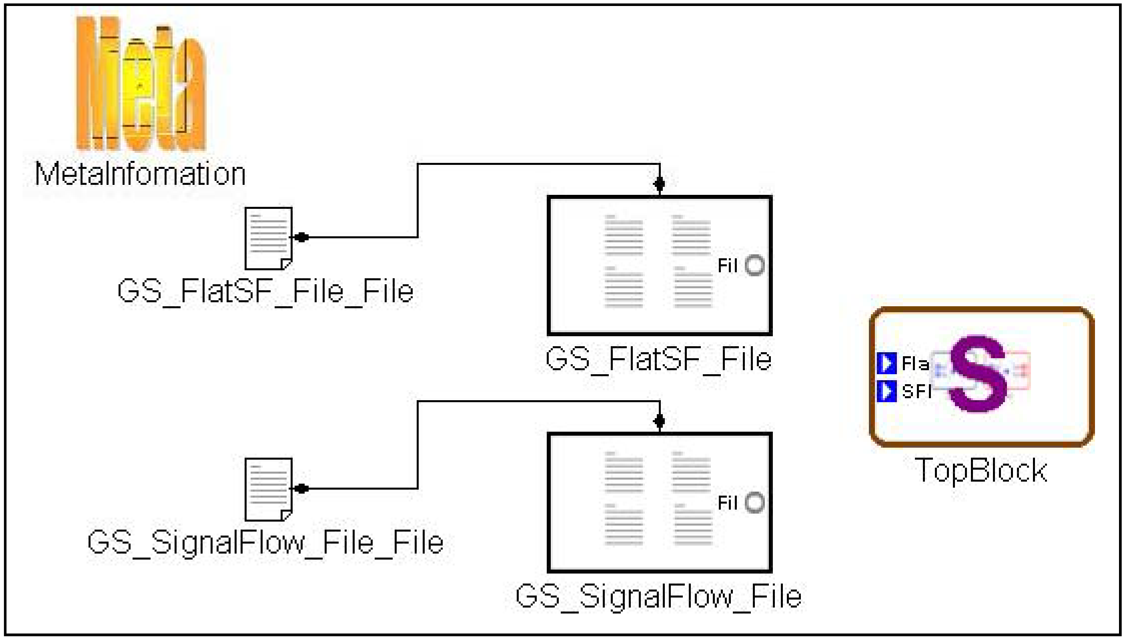
- TopBlock should now look like this:




- Now drag a reference to TopBlock inside the Configuration Model

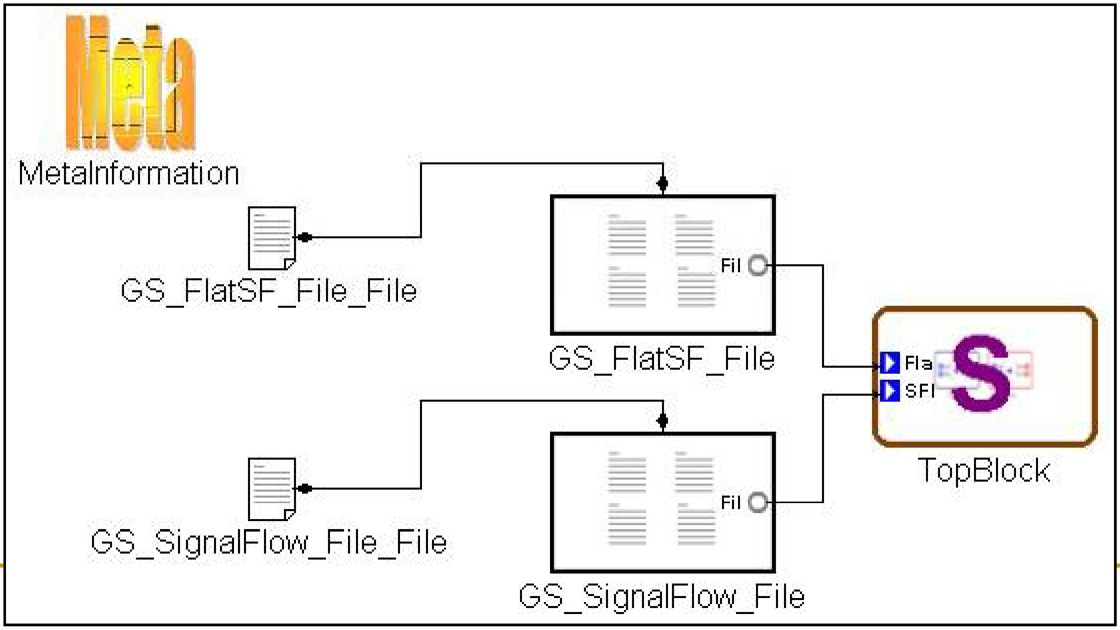
# Step 4 : Specify Initial Rule

- The configuration model should now look like this:



# Step 4 : Specify Initial Rule

- Connect the FileObjects to the In-ports of TopBlock
  - This passes the Root Folders of the input files to the transformation



# Next tutorial

- Defining transformation rules
- Running the transformation

# GReAT Tutorial Part II : Transformation Rules

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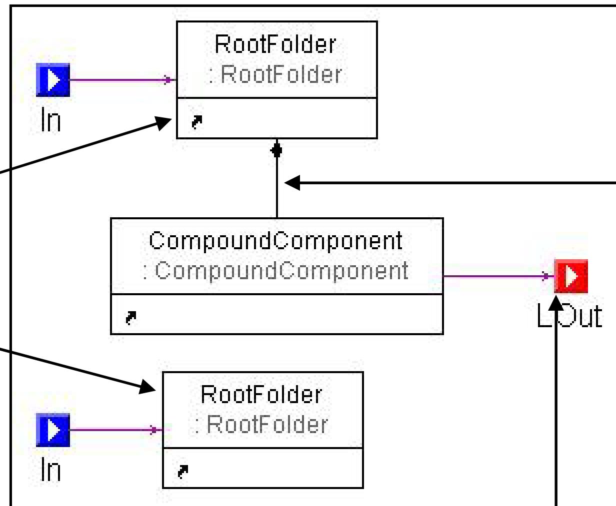
# Overview

- The easiest way to understand the semantics of rules is through examples
- We'll start from simple rules and work to complex patterns

# Simple Binding

1. These objects are “bound” to the input ports; this means they are passed in from the previous rule



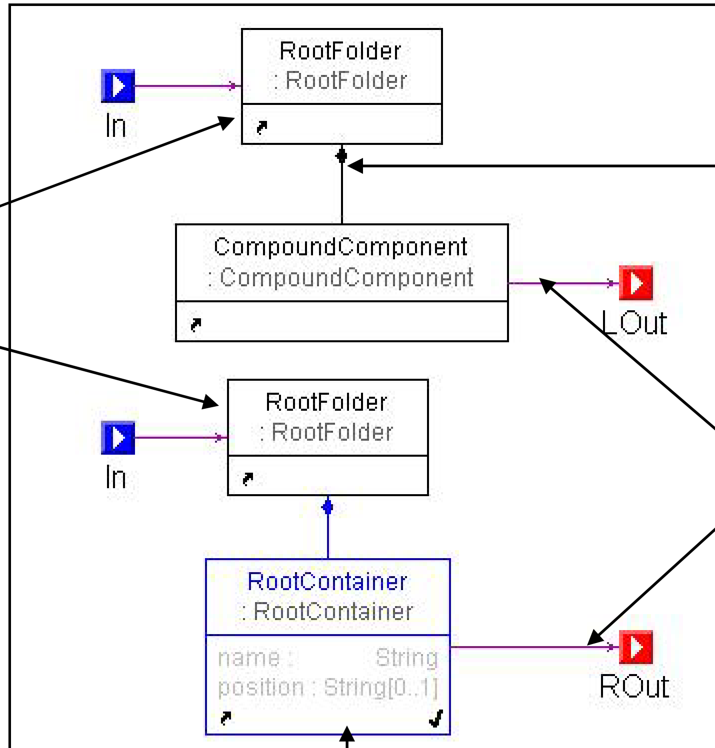

2. This UML composition says that we find all CompoundComponents contained inside this RootFolder

3. For each Compound Component we find, we simply pass it to the next rule

# Simple Creation

1. These objects are “bound” to the input ports; this means they are passed in from the previous rule

2. This UML composition says that we find all CompoundComponents contained inside this RootFolder




3. For each CompoundComponent we fine, we create a RootContainer inside the RootFolder

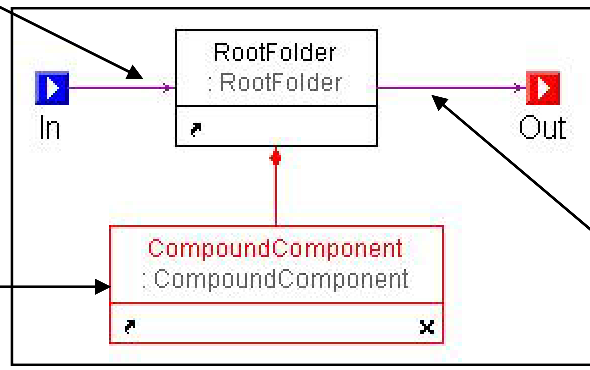
4. We pass the CompoundComponent and the corresponding RootContainer to the next rule

Objects in blue are created new after all objects in black (bound objects) have been found (change the Action attribute in the attribute panel)

# Simple Deletion

1. The RootFolder element is passed in from the previous rule

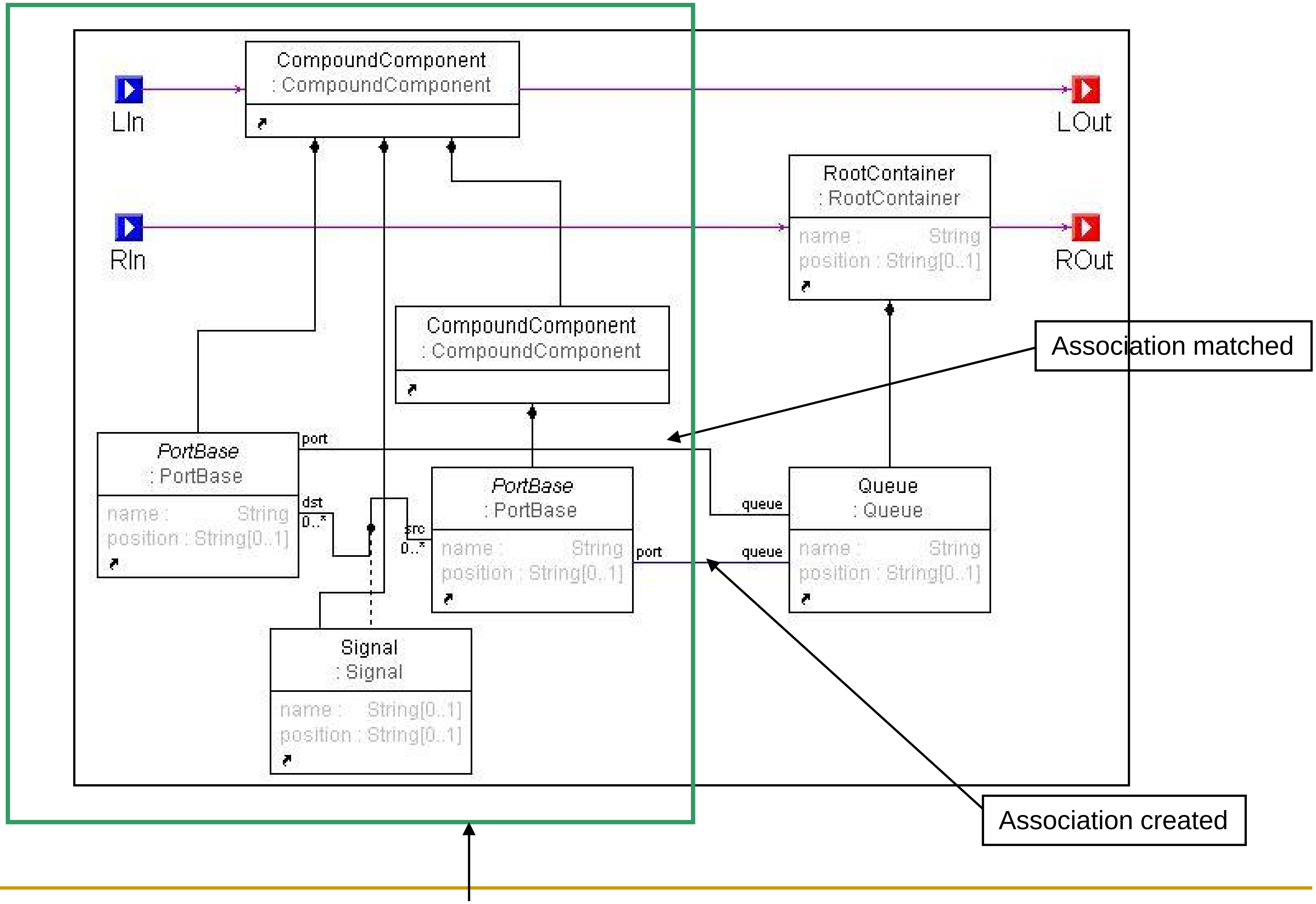
2. For each CompoundComponent in the RootFolder, delete it




3. The RootFolder is passed to the next rule

Objects drawn in red are deleted

# More Complex Pattern




Finds a Signal connection between ports in two different levels of Compound Components

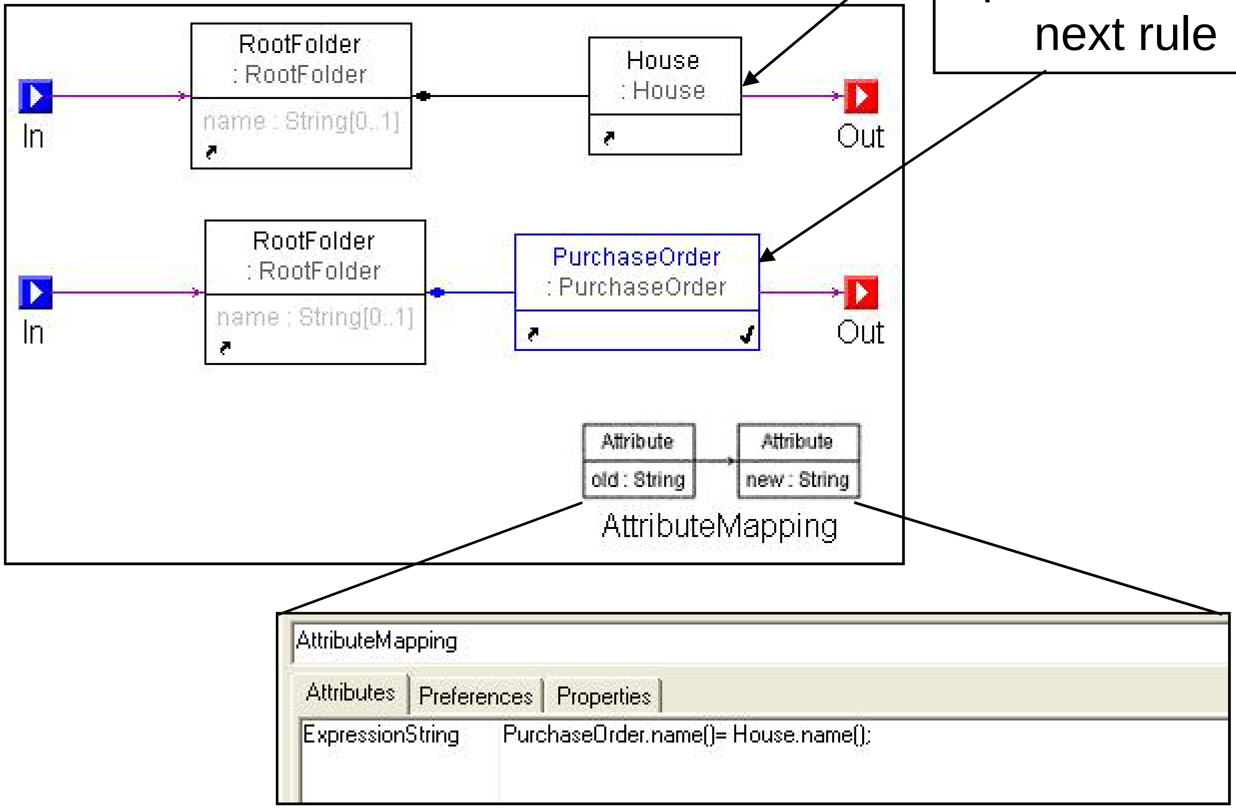
# Attribute mapping

1. The RootFolders are passed in from the previous rule

2. For each House, we create a new PurchaseOrder

3. The attribute mapping sets the name of the PurchaseOrder to the name of the House

4. These are passed to the next rule

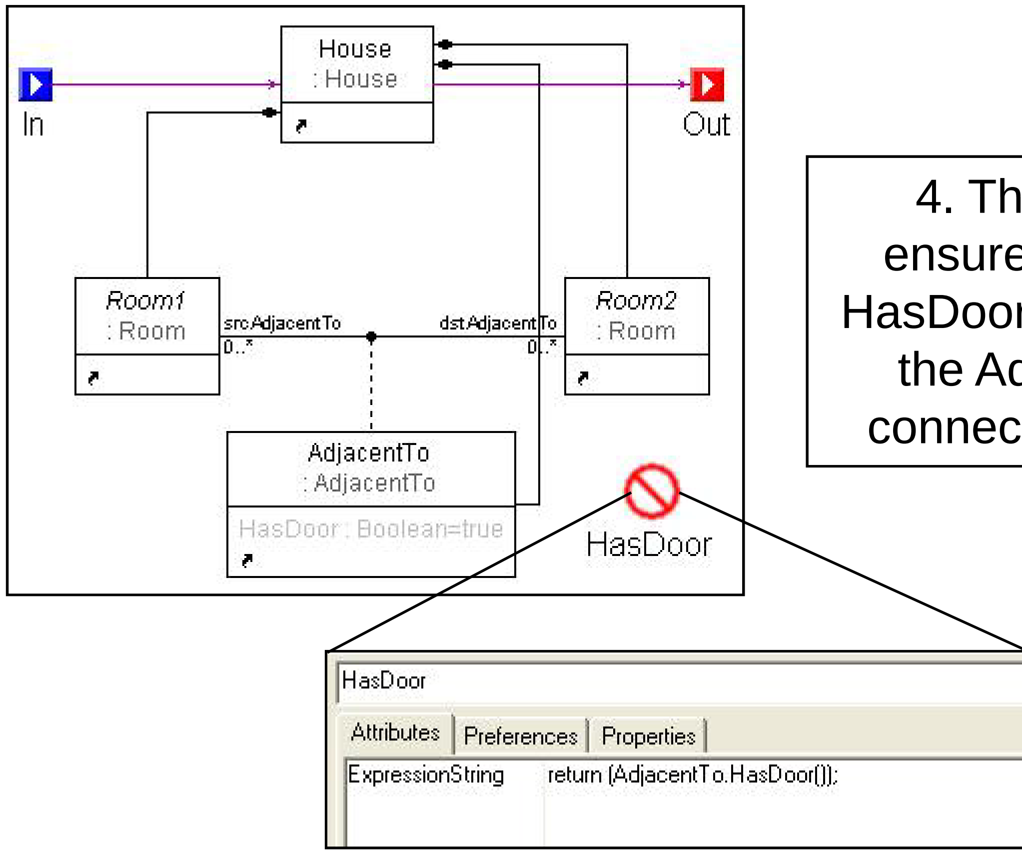


# Guards

1. The House is passed in from the previous rule

2. We find two rooms in the House with an AdjacentTo connection between them

3. A match is only valid if the expression in the guard “HasDoor” evaluates to true

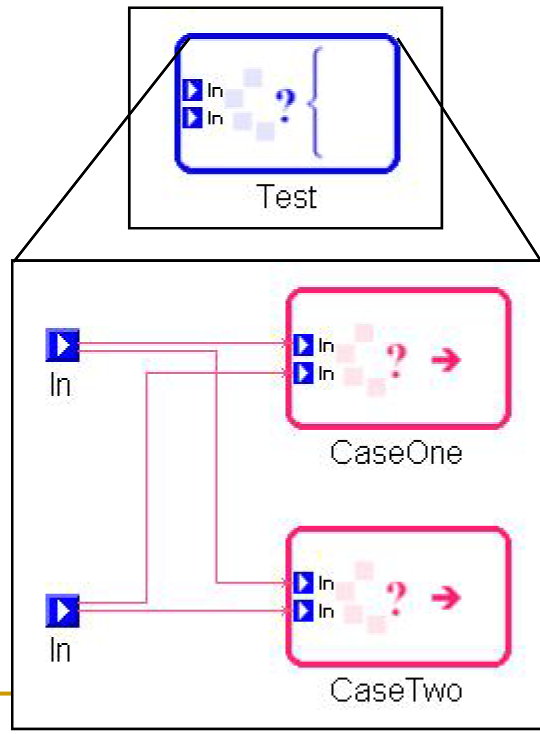


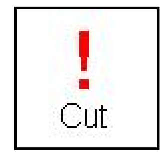

4. This guard ensures that the HasDoor attribute of the AdjacentTo connection is true

# Test/Case Blocks

- A Test block holds Cases
  - Similar to If/Else construct in programming

Cases contain normal patterns; if a match is found, outputs are passed to the next rule, otherwise no outputs are produced




A Cut element inside a Case means that if the pattern matches inside this Case, the inputs are no longer passed to any other Cases

# GReAT Tutorial Part III : Advanced Features

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# Overview

1. Crosslinks
2. Global Objects
3. Sorting
4. Distinguished Merging

# 1 - Crosslinks

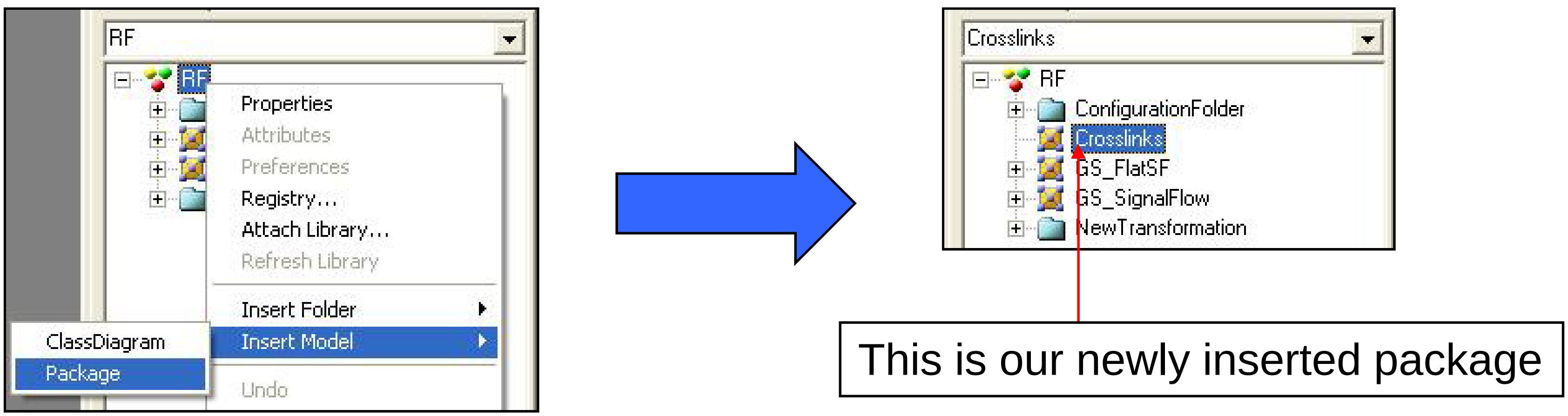
- Often in a transformation, we need to be able to create and subsequently match associations that are not present in the meta-models
  - These can even be between elements of different meta-models

# 1 - Crosslinks

- Consider the SignalFlow2FlatSF example
  - In order to flatten the hierarchy, we need to be able to associate Ports in the GS_SignalFlow MM with Queues in the GS_FlatSF MM
  - These associations are between elements belonging to different meta-models
  - Solution: specify this with crosslinks

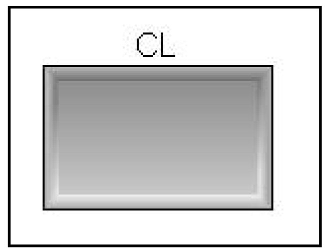
# 1 – How to specify crosslinks

1. Right click on the root folder > Insert Model > Package
2. Rename this package to “Crosslinks” (so that it’s easier to identify)



# 1 – How to specify crosslinks (cont'd)

3. Inside the Crosslinks package, insert a ClassDiagram, and rename it to CL




Class diagram inside our package

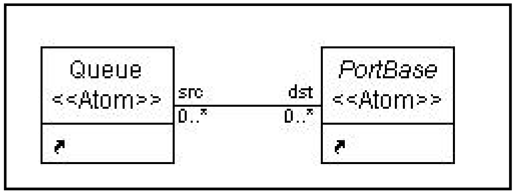
4. Inside this class diagram we will drag references to the meta-model elements to which we want to specify new possible associations

# 1 – How to specify crosslinks (cont'd)

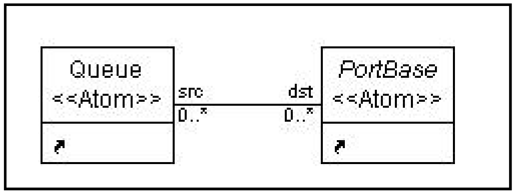
5. Inside the class diagram (CL), drag references to any MM elements you want to be able to associate with each other
    1. For our SignalFlow example, we'll drag a reference to the Queue from the GS_FlatSF MM, and a reference to the PortBase from the GS_SignalFlow MM
6. Switch to connection mode and connect the elements
    1. Choose Association for the connection role type

# 1 – How to specify crosslinks (cont'd)

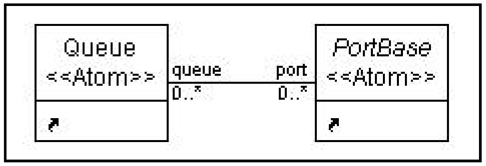
7. The crosslinks class diagram should look like this:




8. Rename the rolenames at the ends of the associations to something unique




Before renaming rolenames




After renaming rolenames

# 1 – How to specify crosslinks (cont’d)

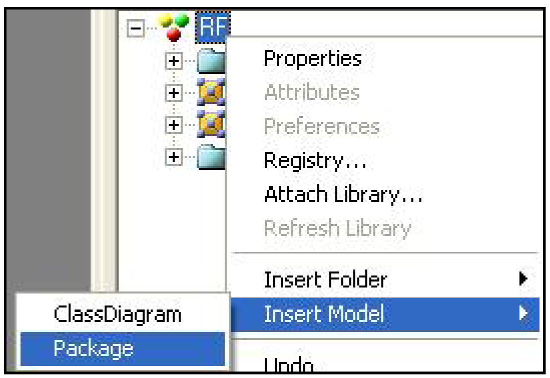
9. You can now create simple associations between ports and queues in your transformation
    1. These will exist only during the transformation
10. Make sure you use the correct rolenames!

# 2 – Global Objects

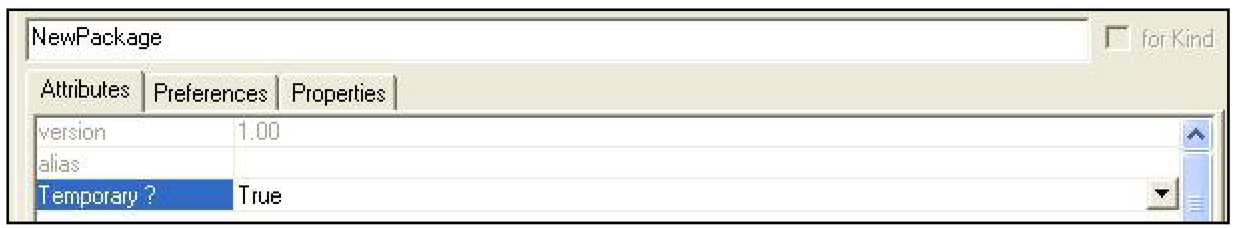
- Motivation: we don’t always want to have to explicitly pass an object between every rule
- Solution: create a global container that can contain objects
  - The global container contains the objects you don’t want to have to pass between rules

# 2 Global Objects (cont'd)

1. Create a new package in the root folder (just as if creating a crosslinks package)
   - <u>Important difference: Set the "Temporary" attribute of this package to True</u>



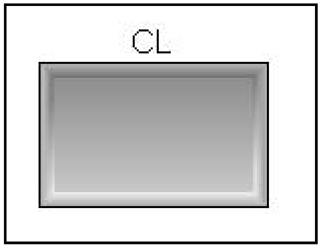

Inserting Package




Setting Temporary attribute to true

# 2 – Global Objects (cont'd)

2. Insert a class diagram in the package
   - Rename to CL (for easier identification)




Class diagram inside our package

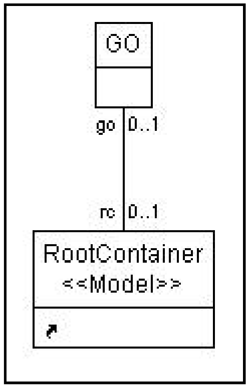
3. Inside CL, create a new class (this will be the global container)
   - Name it GO (for identification)

# 2 – Global Objects (cont'd)

4. Also, drag a reference into CL of the object you want the global object (GO) to contain
   - We'll use the RootContainer object from the GS_FlatSF paradigm
5. Switch to connection mode and create a simple association between the two elements
   - Give meaningful rolenames, and set attribute multiplicity accordingly

# 2 – Global Objects (cont'd)

6. The class diagram should look like this:

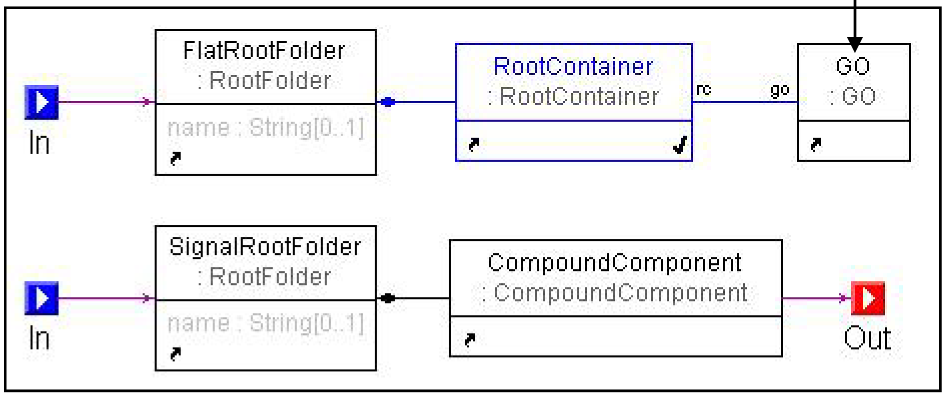



7. There will now be one instance of GO available anywhere in the transformation
    1. We can associate it with an instance of a RootContainer in our rules

# 2 - Global Objects (example)

- Create the assocation between the Global Object and the RootContainer in the following way:

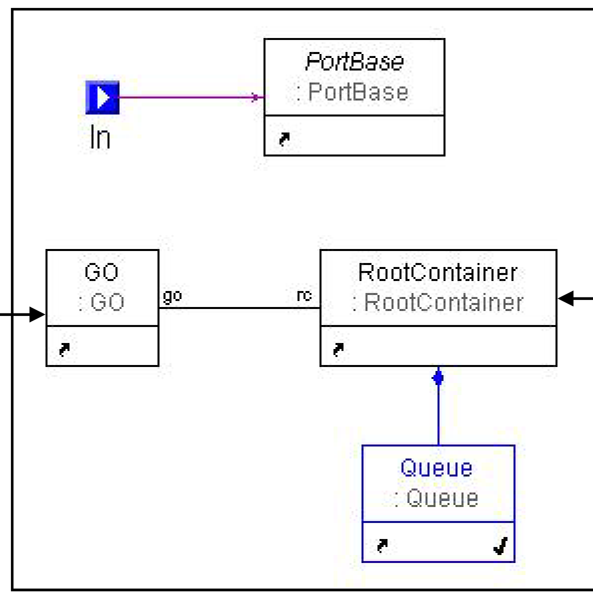
Notice we don't pass GO through an Out-port



# 2 - Global Objects (example)

- Now we can access this RootContainer in a subsequent rule as follows:

GO has global scope, so we don't need to pass it along



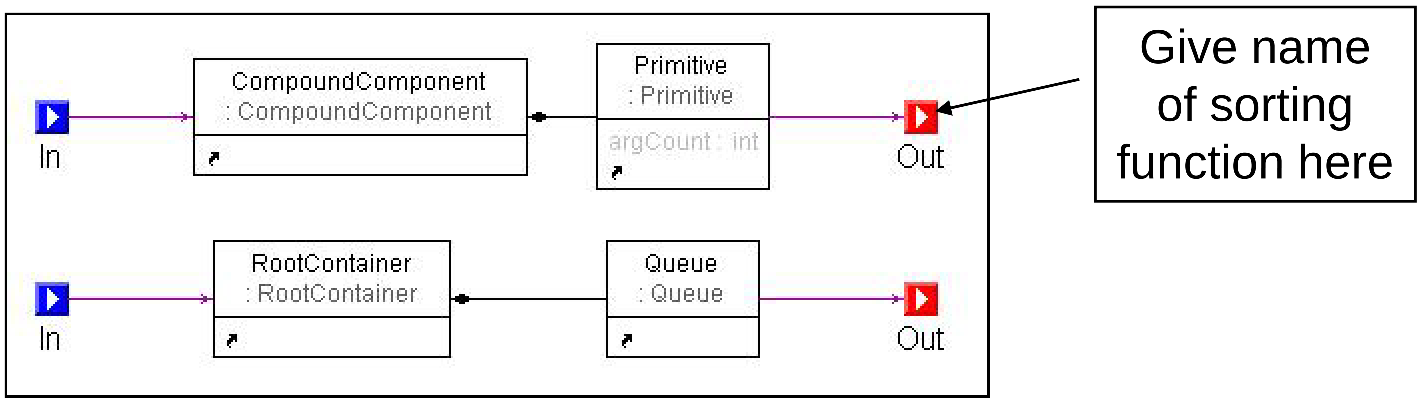

We can find the RootContainer from its association with GO

# 3 – Sorting

- GReAT is non-deterministic in the sense that we don’t know the order in which packets from one rule will be passed to the next rule
- By specifying a sorting criterion based the attributes of an object, we can control the order that packets will be passed

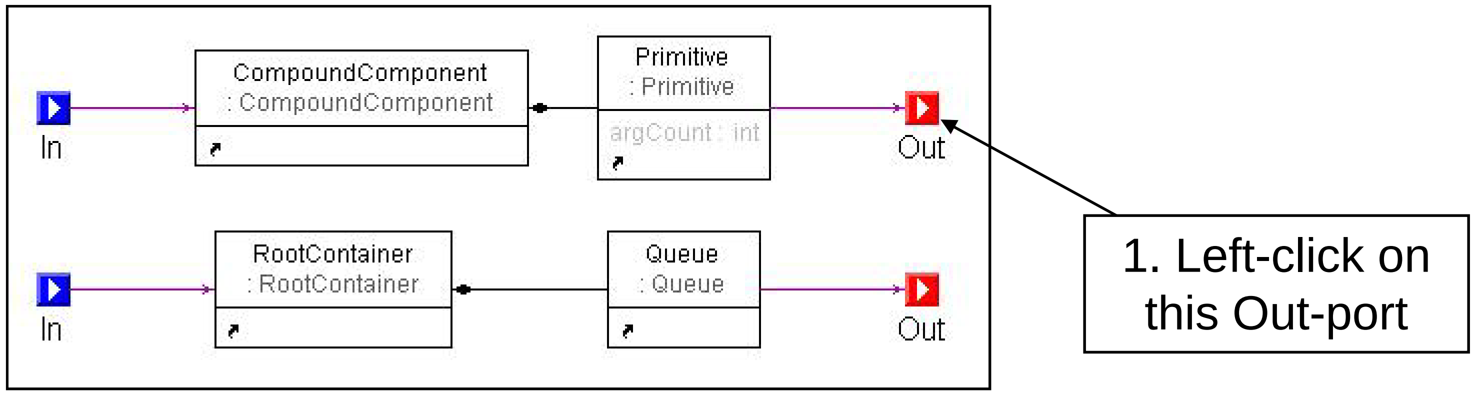
# 3 – Sorting (cont'd)

- Consider this rule:

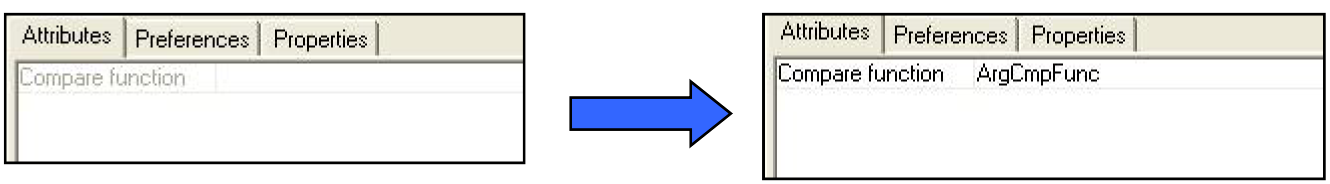



- If we want to ensure that the Primitives are passed to the next rule in order of increasing argCount, we need to give a name of a sorting function on that Out-port
  - We define this function in the Configuration Folder

# 3 – Sorting (cont'd)

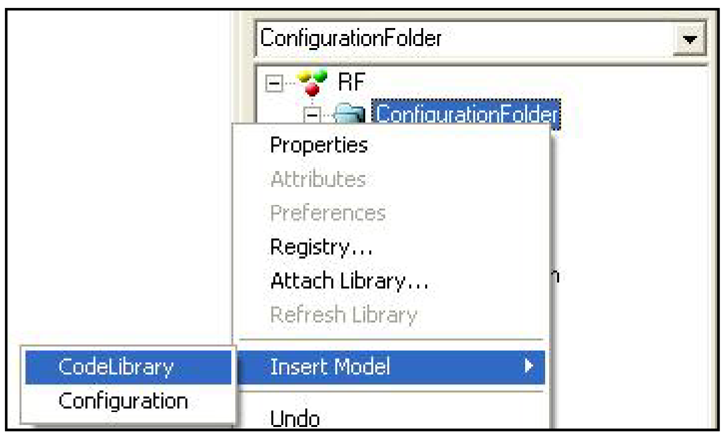



1. Left click on the top Out-port
2. In the attribute panel, there will be a prompt for a sorting function; give a name of "ArgCmpFunc"



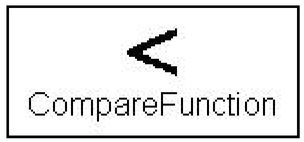
# 3 – Sorting (cont'd)

- We've specified a sorting function, but we haven't defined it anywhere
  - We do this in the configuration folder
  - Right click on the Configuration Folder > Insert Model > Code Library



# 3 – Sorting (cont'd)

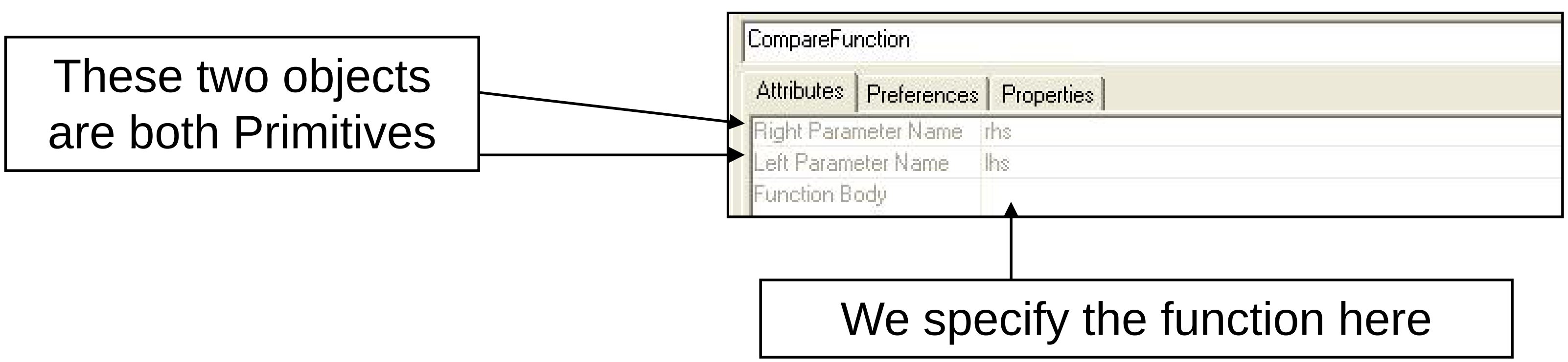
- Open this Code Library model
- Insert a Compare Function element




- Left click on this Compare Function, and the Attribute Panel will look like the following:

# 3 – Sorting (cont'd)

- rhs and lhs are both derived from Udm::Object (in our case, they are both of type Primitive)
  - Their attributes are accessed in the same manner as Udm::Object attributes



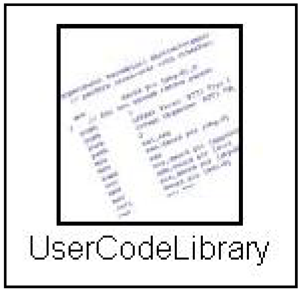
# 3 – Sorting (cont'd)

- Add the following to Function Body


- The names of the two incoming parameters to our sorting function are lhs and rhs
- Our rule states that lhs will be before rhs in a list if its argCount is less than the argCount of rhs

# 3 – Sorting (cont'd)

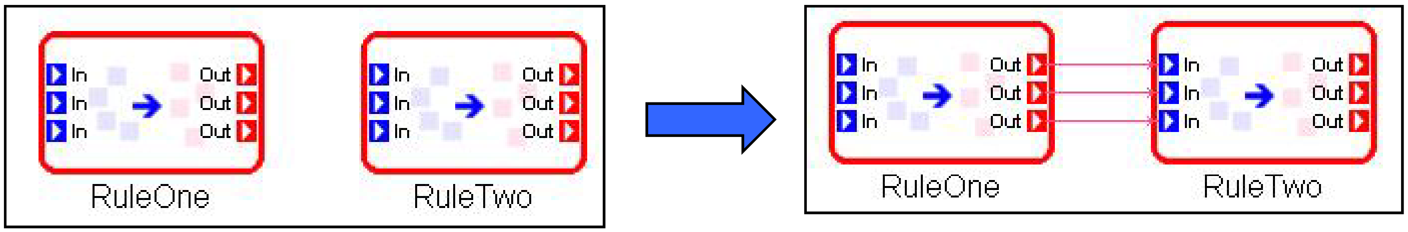
- We can also insert a User Code Library element into the Code Library model




- This gives us the ability to include other headers and libraries that we can reference in any compare functions
    - See user manual for full details

# 4 – Distinguished Merging

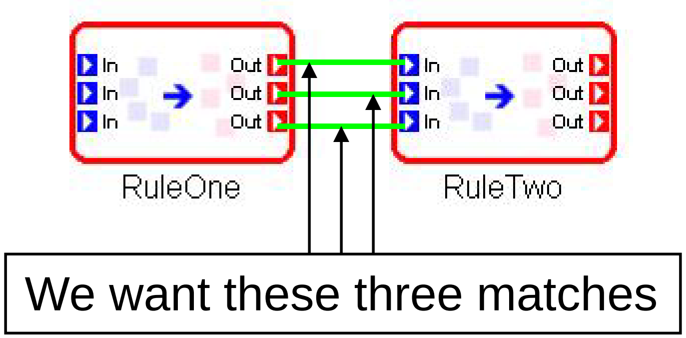
- Consider a situation such as the following:




- We want to connect the output ports of RuleOne to the Input ports of RuleTwo in a one to one manner
- However, we cannot simply find all Out-ports in RuleOne and all In-ports in RuleTwo
  - We only need a subset of the matches

# 4 – Distinguished Merging (cont'd)

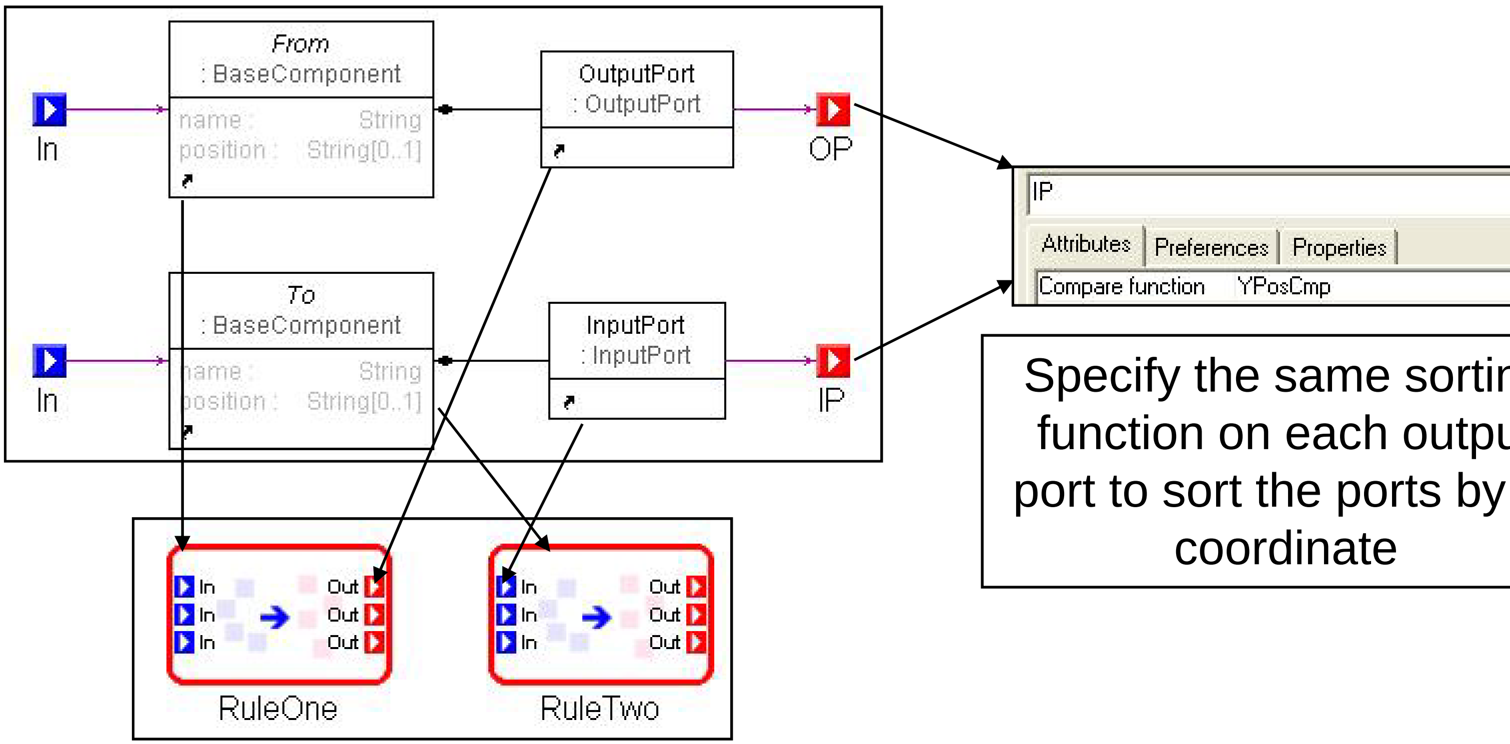
- We divide this into two rules:
  - First rule: select only a subset of matches to pass to the next rule (the correct Out-ports and In-ports)




  - Second rule: connect the ports

# 4 – Distinguished Merging (cont'd)

- Rule one:

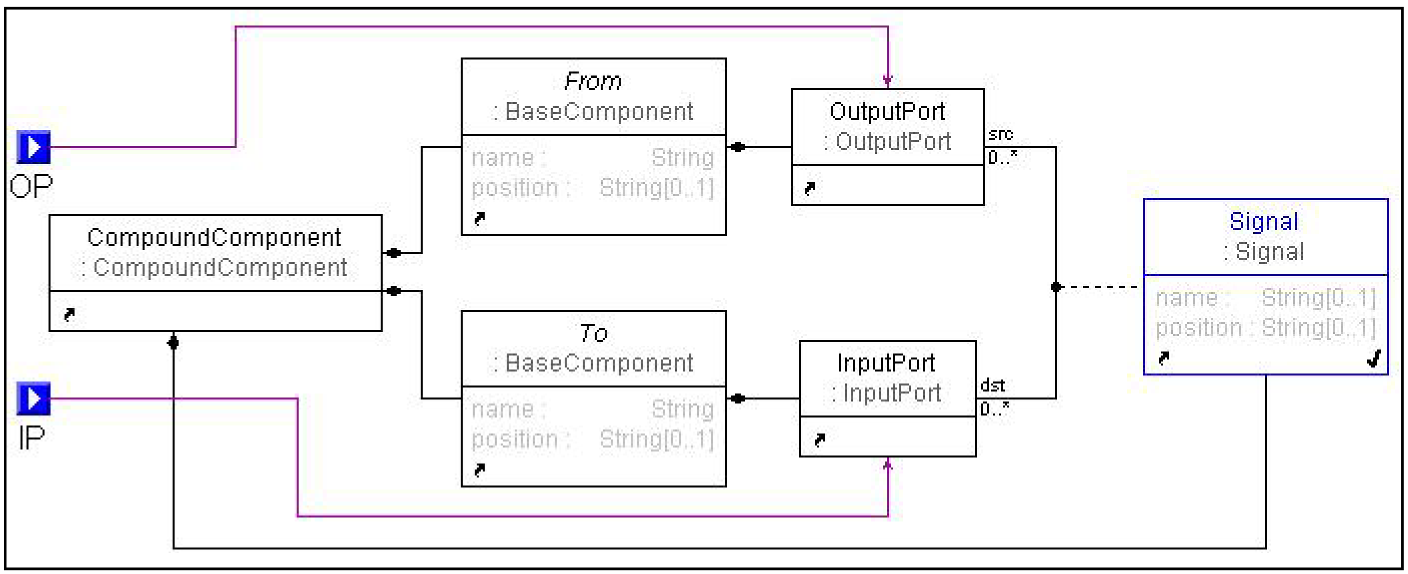



Specify the same sorting function on each output port to sort the ports by y-coordinate

- Also set the "Distinguished cross product" attribute of this rule to true

# 4 – Distinguished Merging (cont'd)

- Rule Two: only correct subset of Input Ports and Output Ports are entering this rule
  - Simply create the signal connection between them



# 4 – Distinguished Merging (cont'd)

- The two rules together look like this: