QVT Based Model Transformation from Sequence Diagram to CSP

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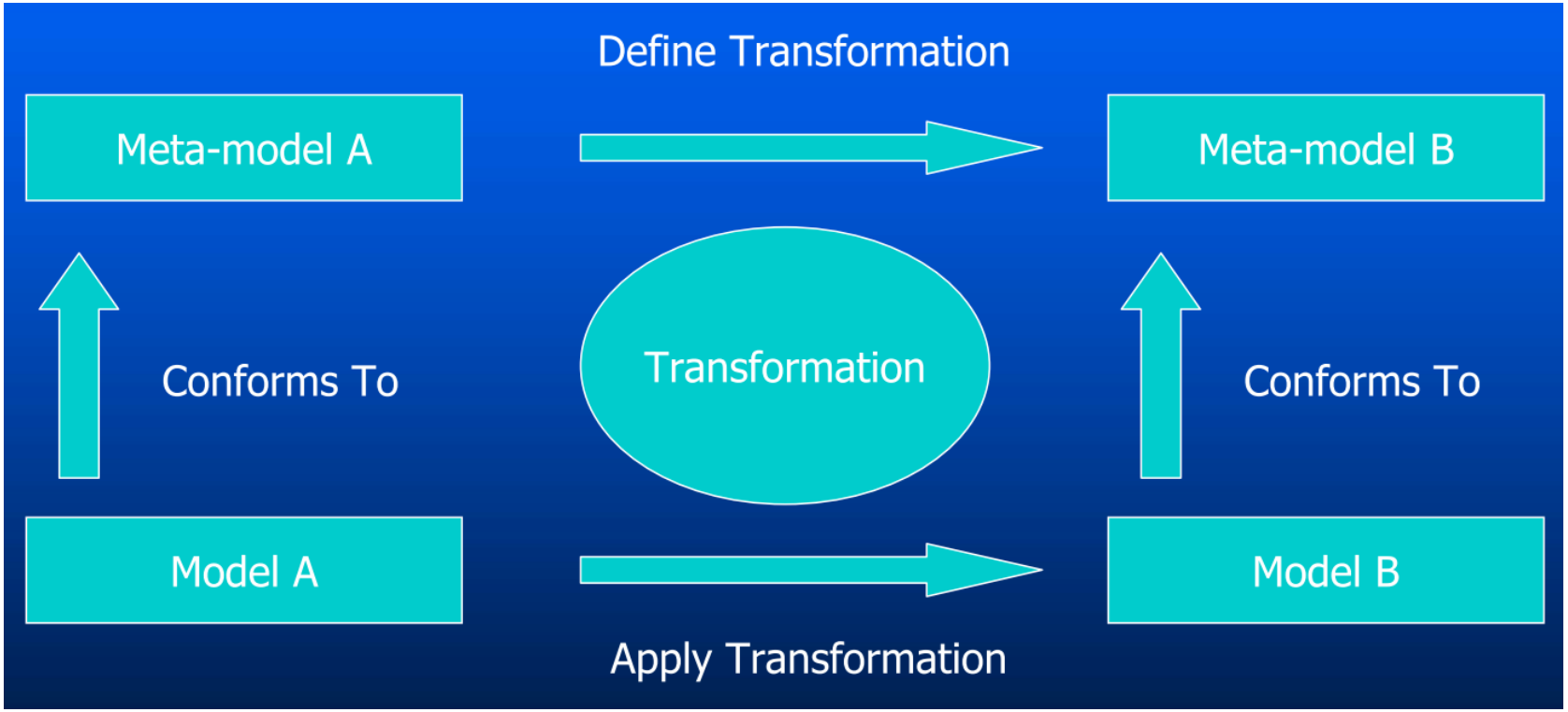
Motivation

- UML sequence diagrams need to be verified and analyzed formally. One of the choices is to translate to *CSP* through model transformation.
- Graphical notation of QVT provides a concise, intuitive way to specify model transformations.
- XSLT is the most common and powerful language for XML transformation. We implement the QVT transformation rules using XSLT for their automatic execution.

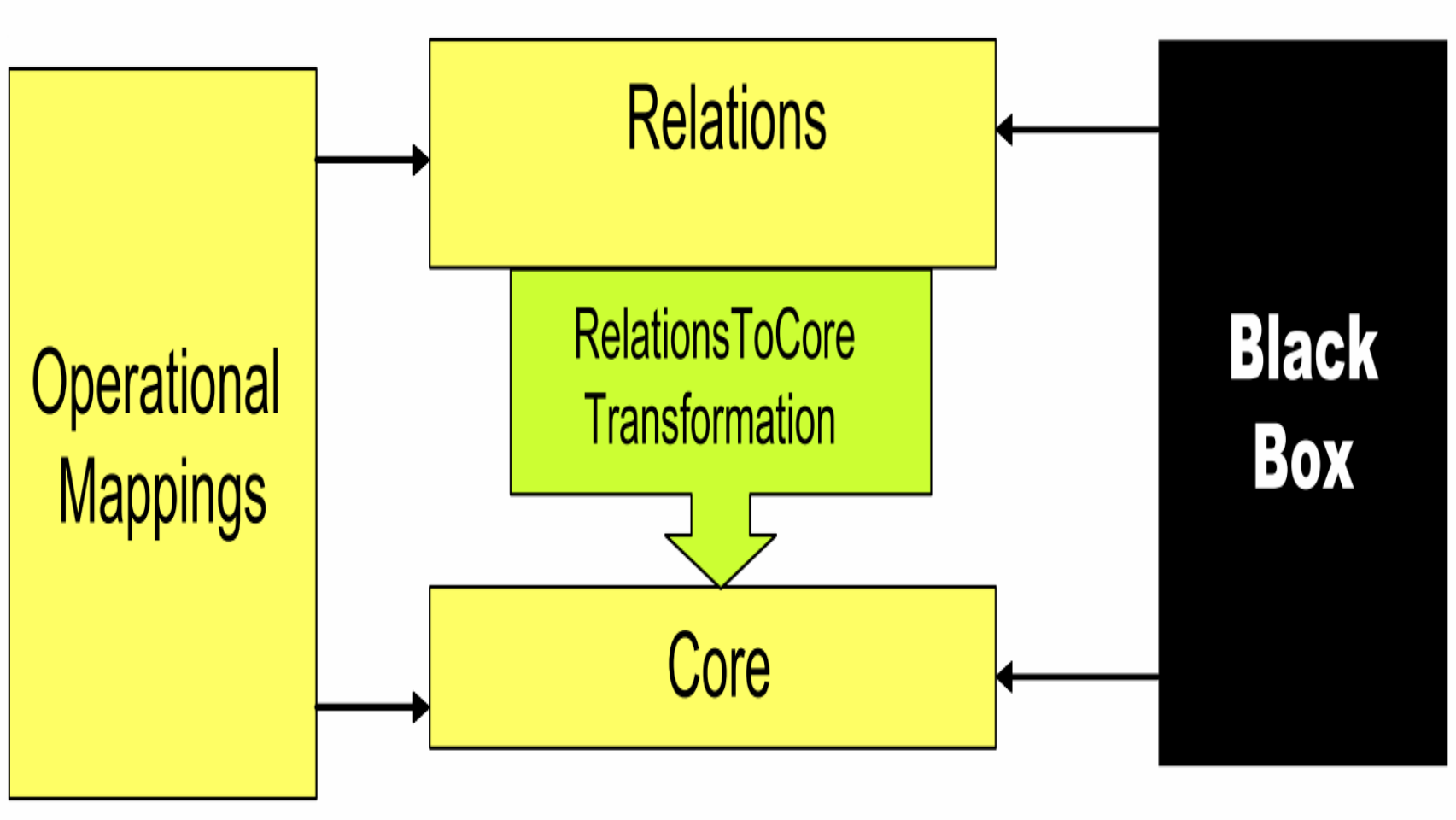
Model Transformation



What is QVT

- MOF 2.0 *Query*, *View*, and *Transformation* language
- A standard for model transformation proposed by the Object Management Group (OMG)
- QVT is composed of 3 sub-languages
  - QVT-Operational
  - QVT-Relations
  - QVT-Core
- QVT Relations has a graphical notation.

QVT Overview



QVT Relations

- Bidirectional, declarative language
- A transformation is specified as a set of relations (rules) between model elements of the source and the target domains.
- A relation is a transformation declare constraints that must be satisfied by the elements of the candidate models.
- The kernel technique to implement QVT Relations is the *pattern matching*.

Why QVT Graphical Notation

- UML people might expect to continue the graphical tradition of class diagrams and favor a graphical notation
- Graphical specification is a higher-level view that is easier to understand and communicate than the lexical counterpart.
- Can be served as good software design documentations

A picture is worth a thousand words

XSLT

- Extensible Stylesheet Language for Transformations (XSLT) is one of the W3C standards.
- Provide powerful capacity that enable the rule declaration, transformation, navigation, and create of XML content.
- Widely used in developing web application
- Supported by many commercial and open source tools, can be embedded in Java
- XSLT has strong support to complex pattern matching.

XMI / XSD

- XML Metadata Interchange (XMI)
  - An OMG standard that specify how to produce XML documents from MOF model.
  - EMF XMI is an XMI implementation, supported by many major modeling tools, such as MagicDraw and Topcased
- XML Schema (XSD)
  - used to define the syntactic structure of XML documents
  - XMI also gives rules to produce an XML Schema from a MOF model

Our Transformation Approach

Get the best of both worlds:

- Define the transformation using QVT relations language in graphical notation
- Implement the transformation using XSLT

Steps in the Approach (1)

1. Define metamodels for both SeqD and CSP. The SeqD metamodel is in EMF XMI format.

2. Generate XSDs from SeqD and CSP metamodels

3. Specify the transformation relations (rules) using QVT graphical notation

4. Implement these QVT transformation relations as XSLT rule-based templates

Steps in the Approach (2)

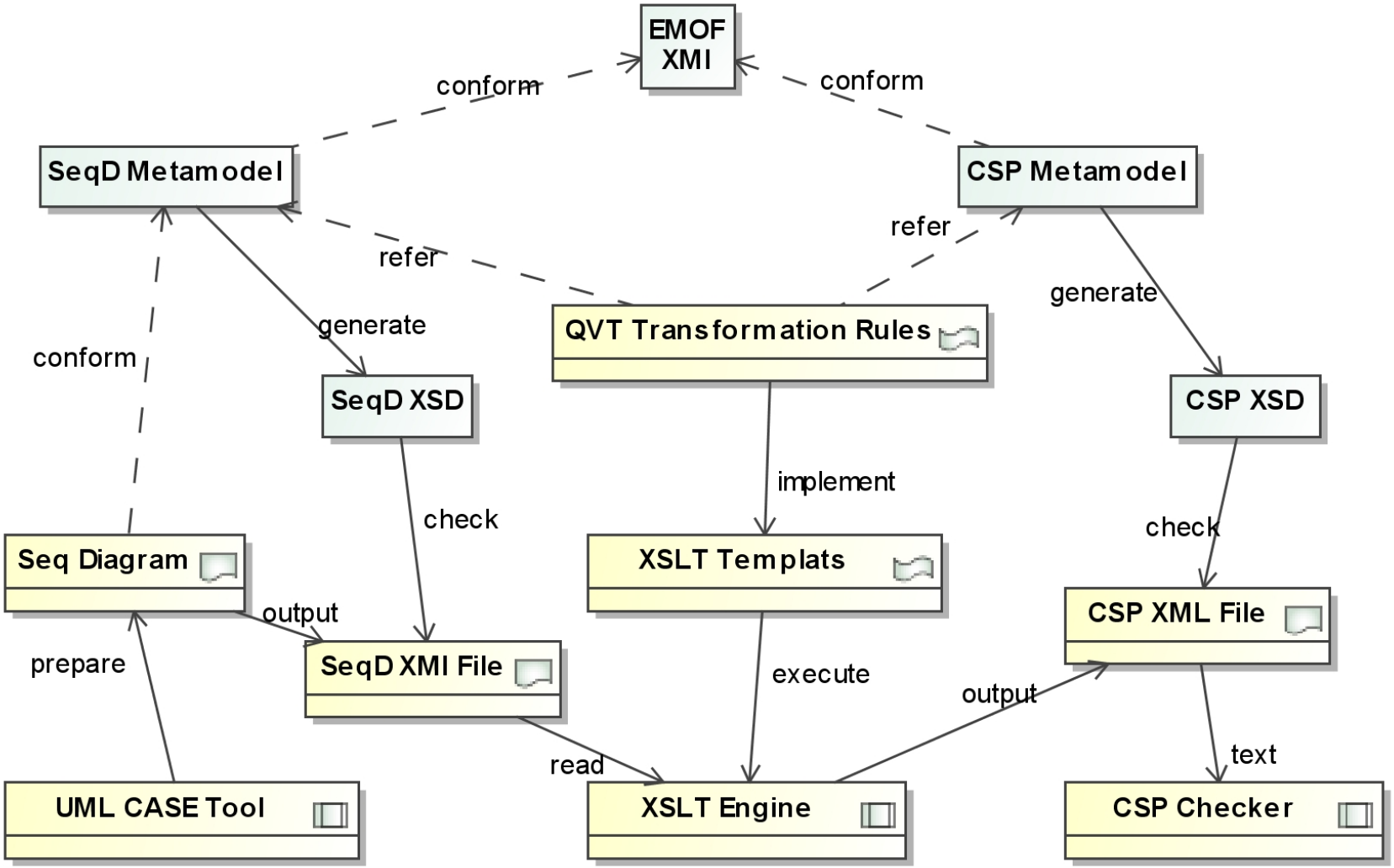
5. Prepare the SeqD in CASE tools, and output it as an EMF XMI file.

6. Validate the SeqD XMI against the SeqD XSD.

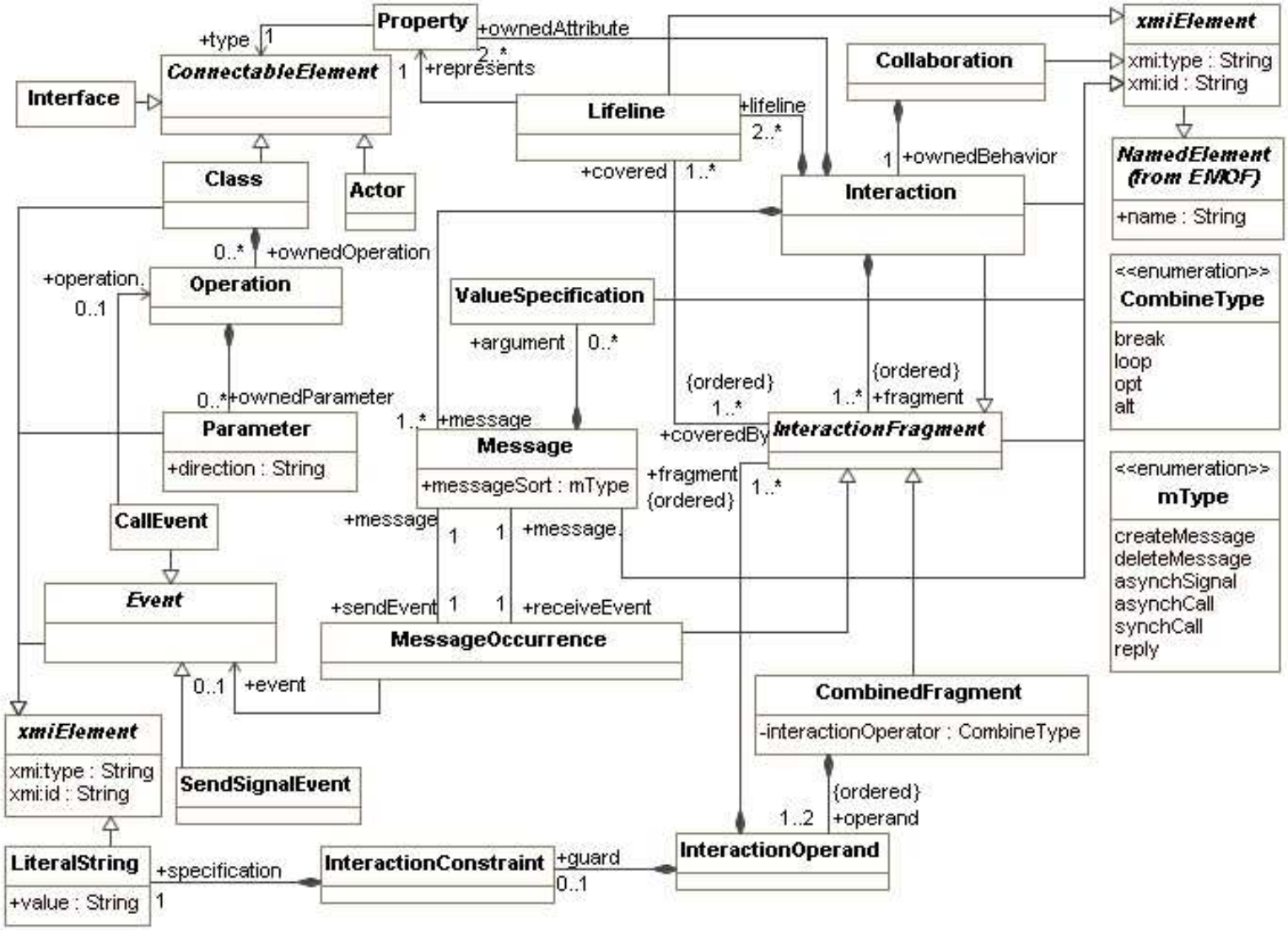
7. Perform the transformation by executing the XSLT templates in an XSLT processor, output result as a CSP model.

8. Validate the CSP model using the CSP XSD.

Overall Transformation Process



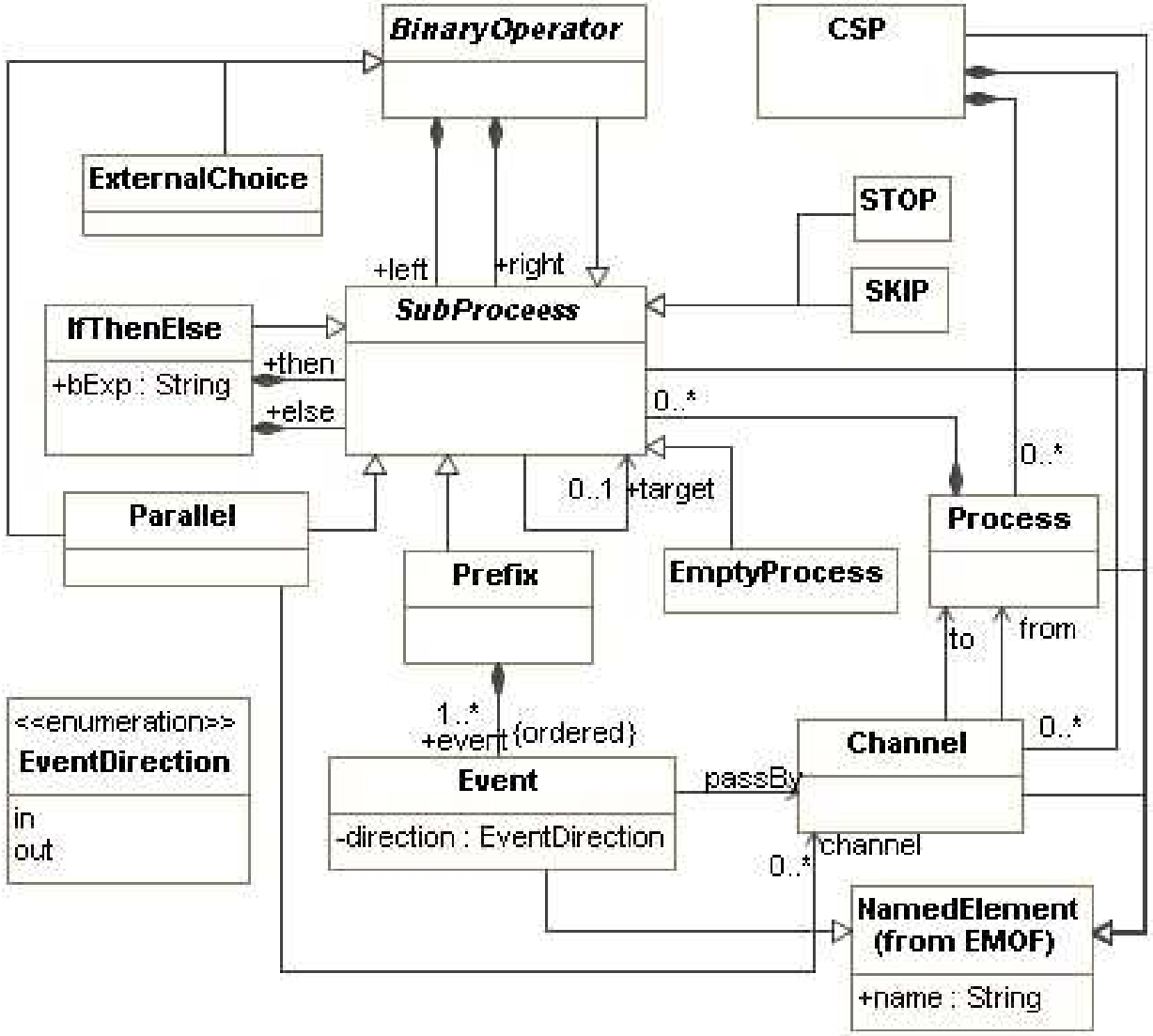
SeqD Metamodel (with XMI Support)



Semantics of SeqD

- Defined as an union of order relations on the set of all the message sending and receiving actions.
- Every object lifeline has its own flow of control, performs its sequence of actions along the lifeline.
- Objects are only synchronized on the sending and receiving actions of same message.

CSP Metamodel



Concepts of SeqD and CSP

SeqD

- *Interaction*
- *Lifeline*
- *InteractionOperand*
- *CombinedFragment*
  - *opt, alt, loop, break*
- *Message*
- *MessageOccurrence*
  - *sendEvent*
  - *receiveEvent*

CSP

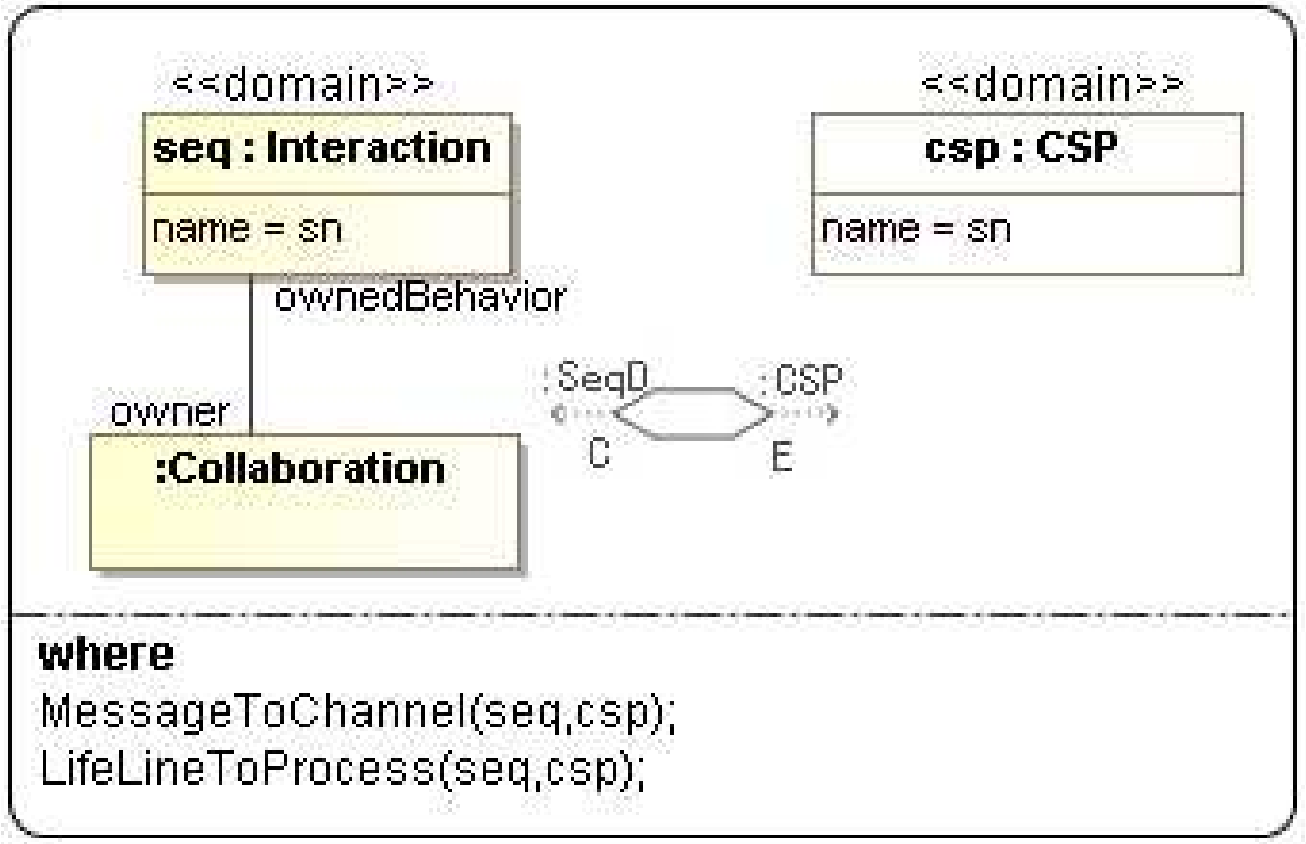
- *CSP*
- *Process*
- *SubProcess*
  - *Prefix*
  - *IFThenElse*
  - *ExternalChoice*
  - *SKIP/STOP*
- *Event*
- *Channel*
- *Parallel Composition*

QVT Rules for SeqD to CSP Tansformation

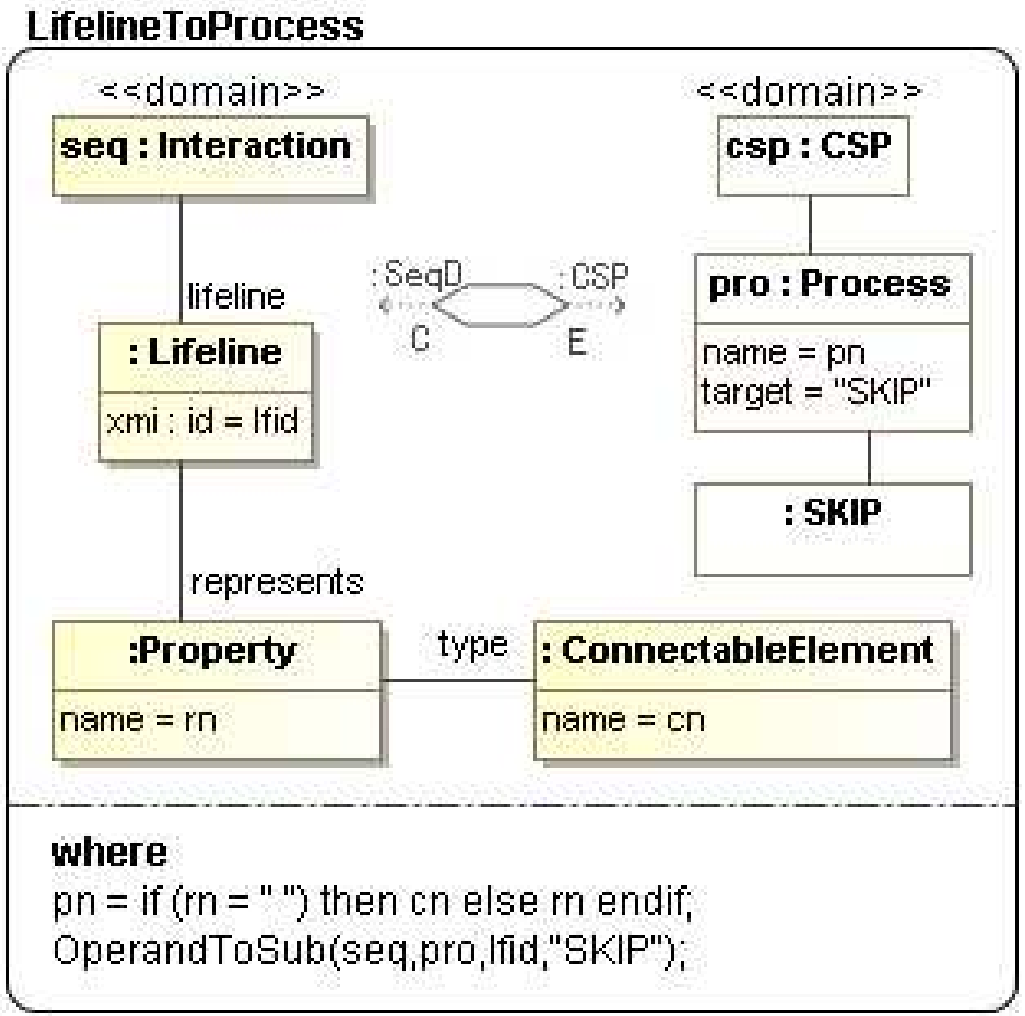
- Interaction to CSP (*Parallel Composition of Processes)*
- Lifeline to Process
- InteractionOperand to SubProcess
- MessageOccurrence to Event
- CombinedFragment to IfThenElse
- Alt (without guard) to ExternalChoice
- Message to Channel

Rule : Interaction to CSP

InteractionToCSP

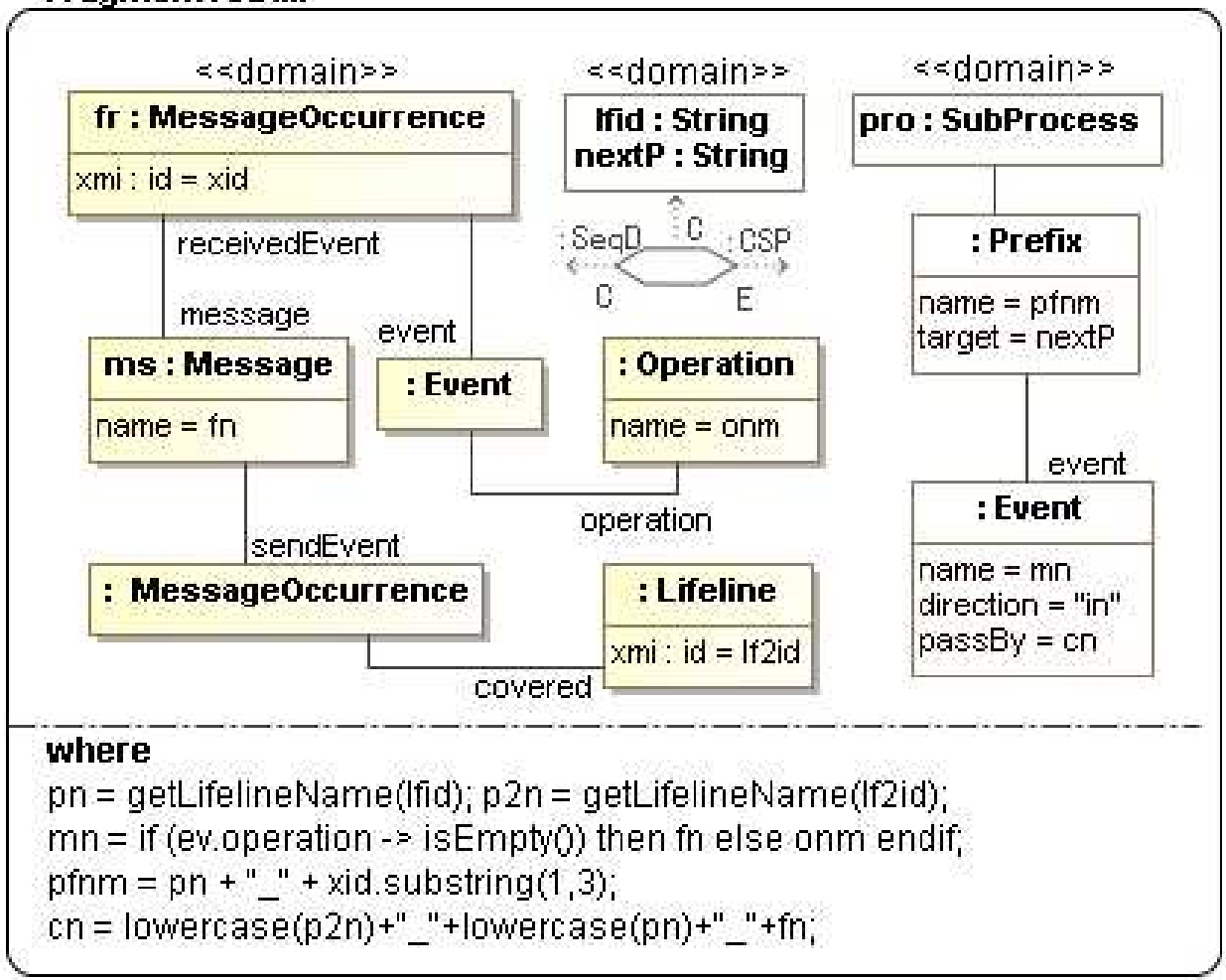


Rule : Lifeline to Process



Rule : MessageOccurrence to Event

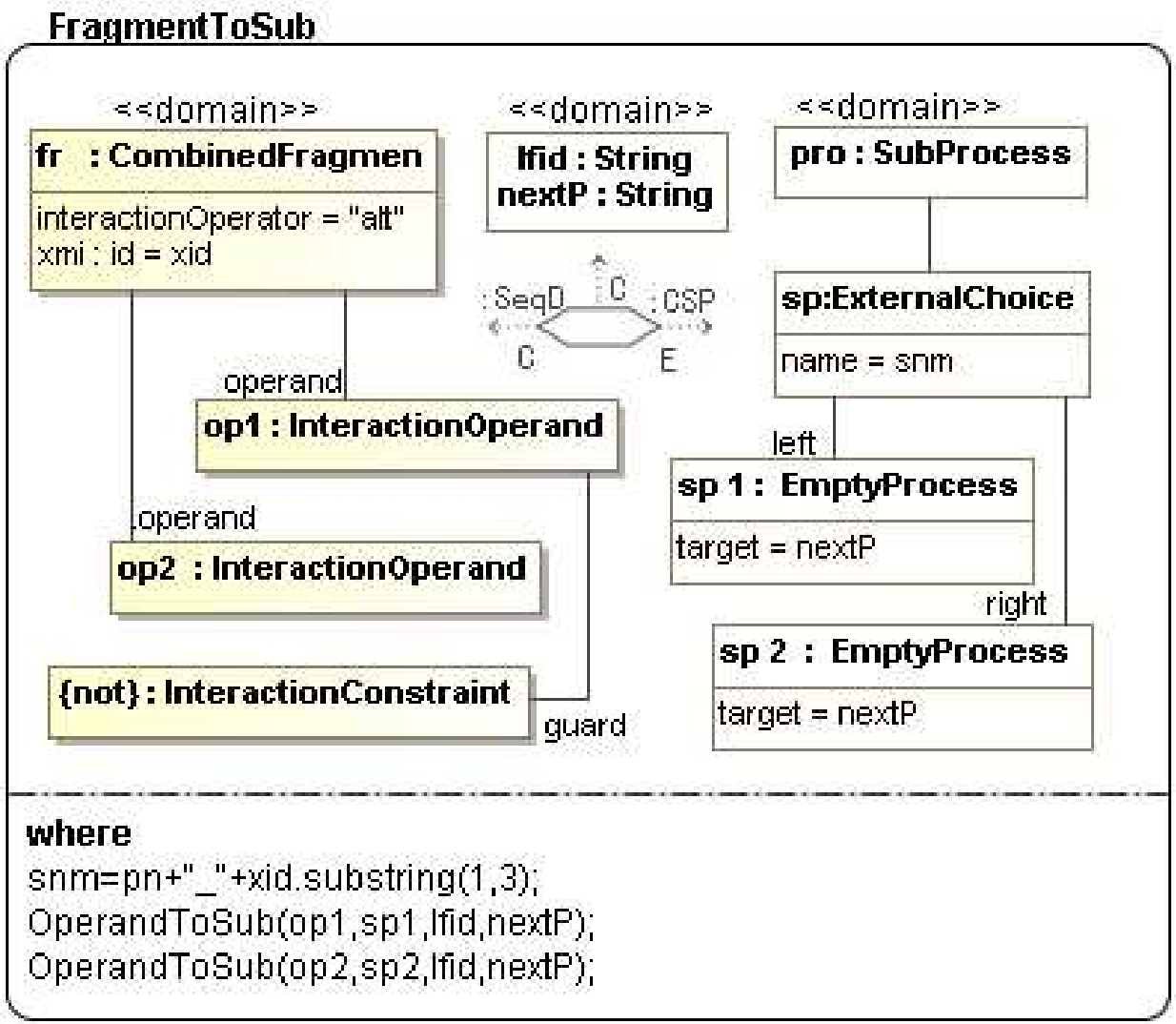
FragmentToSub



where

pn = getLifelineName(lfid); p2n = getLifelineName(lf2id);
mn = if (ev.operation -> isEmpty()) then fn else onm endif;
pfnm = pn + "_" + xid.substring(1,3);
cn = lowercase(p2n)+"_"+lowercase(pn)+"_"+fn;

Rule :Alt (without guard) to ExternalChoice



Implement QVT Rules as XSLT

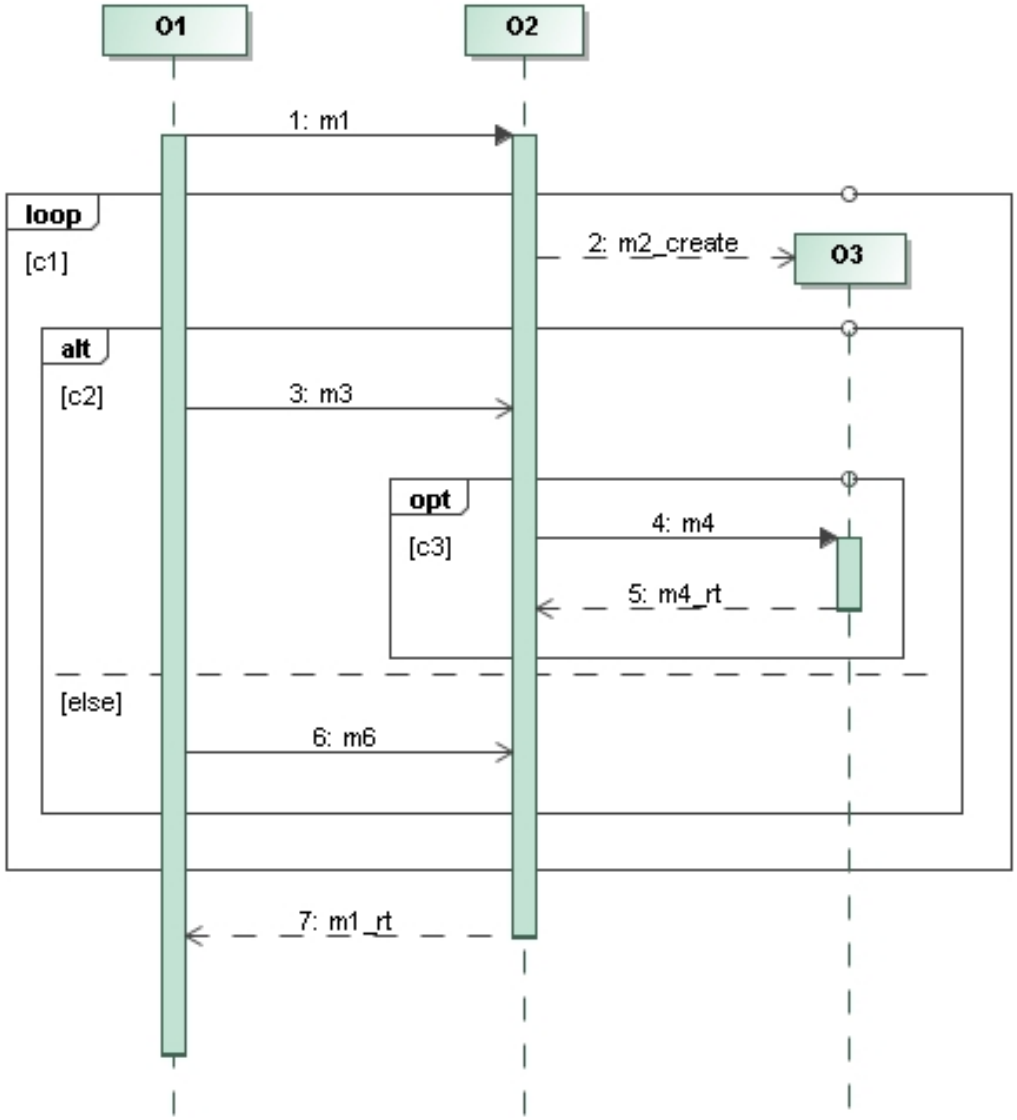
- A QVT rule is implemented as a pair of XSLT templates: a matching-template and a constructing-template.
- The source domain pattern of a QVT rule is implemented as a matching-template to play the searching task in the source model.
- The target domain pattern of a QVT rule is implemented as a constructing-template to create the elements of the pattern in the target model.

XSLT Templates for Rule InteractionToCSP

```
<xsl:template mode="InteractionToCSP"
    match="//packagedElement[@xmi:type='uml:Collaboration']
    /ownedBehavior[@xmi:type='uml:Interaction' ]">
            <xsl:call-template name="InteractionToCSP">
                    <xsl:with-param name="sn" select="@name"/>
            </xsl:call-template>
</xsl:template>

<xsl:template name="InteractionToCSP">
    <xsl:param name="sn"/>
    <xsl:element name="CSP">
            <xsl:attribute name="name" select="$sn"/>
            <xsl:apply-templates mode="MessageToChannel"/>
            <xsl:apply-templates mode="LifelineToProcess"/>
    </xsl:element>
</xsl:template>
```

An Example of SeqD



CSP Model Generated from the SeqD

```
<?xml version="1.0" encoding="UTF-8"?>
<CSP name="Example">
   <Channel name="o1_o2_m1" from="O1" to="O2"/>
   <Channel name="o2_o3_m2_create" from="O2" to="O3"/>
     ......
   <Process name="O1" target="SKIP">
      <Prefix name="O1-582" target="O1-603">
          <Event name="m1" direction="!" passBy="o1_o2_m1"/>
     </Prefix>
     <IfThenElse name="O1-603">
          <bExp>c1</bExp>
           <then target="O1-603">
              <IfThenElse name="O1-643">
                   <bExp>c2</bExp>
                   <then target="O1-603">
                       <Prefix name="O1-422" target="O1-603">
                   ......
```

CSP Generated from the SeqD

```
channel o1_o2_m1, o2_o3_m2_create, o1_o2_m3, o2_o3_m4
channel o3_o2_m4_rt, o1_o2_m6, o2_o1_m1_rt

      O1=o1_o2_m1!->O1-603
O1-603=if (c1) then O1-643 else O1-378
O1-643=if (c2) then o1_o2_m3!->O1-603 else o1_o2_m6!->O1-603
O1-378=o2_o1_m1_rt?->SKIP

      O2 = o1_o2_m1?−>O2-603
O2-603 = if (c1) then (o2_o3_m2_create!−>O2-643) else O2-242
O2-643 = if (c2) then (o1_o2_m3?−>O2-684)
                      else (o1_o2_m6?−>O2-603)
O2-684 = if (c3) then (o2_o3_m4!−>o3_o2_m4_rt?−>O2-603)
                      else O2-603
O2-242 = o2_o1_m1_rt!−>SKIP
```

CSP Generated from the SeqD (con.)

O3=O3-603
O3-603=if (c1) then (o2_o3_m2_create?->O3-643) else SKIP
O3-643=if (c2) then O3-684 else O3-603
O3-684=if (c3) then (o2_o3_m4?->o3_o2_m4_rt!->O3-603)
else O3-603

O1-O2= O1 [|{|o1_o2_m1, o1_o2_m3, o1_o2_m6, o2_o1_m1_rt |}|] O2

CSP=O1-O2 [| {|o2_o3_m2_create, o2_o3_m4, o3_o2_m4_rt |} |] O3

- **Thank You !**