Aspect Oriented MDE

AOM = (Model Composition)$^{-1}$

Prof. Jean-Marc Jézéquel

(Univ. Rennes 1 & INRIA)

Triskell Team @ IRISA

Campus de Beaulieu

F-35042 Rennes Cedex

Tel : +33 299 847 192 Fax : +33 299 847 171

e-mail : jezequel@irisa.fr

http://www.irisa.fr/prive/jezequel

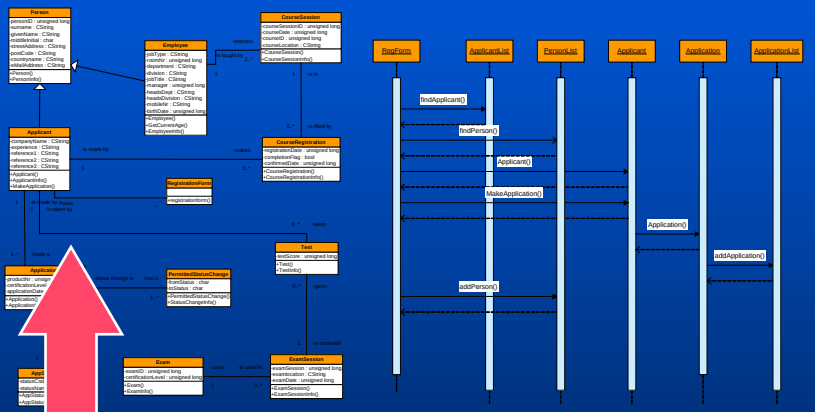
Modeling in Science & Engineering

- A Model is a *simplified* representation of an *aspect* of the World for a specific *purpose*

Specificity of Engineering: Model something not yet existing (in order to build it)

M_1 (modeling space)

Is represented by

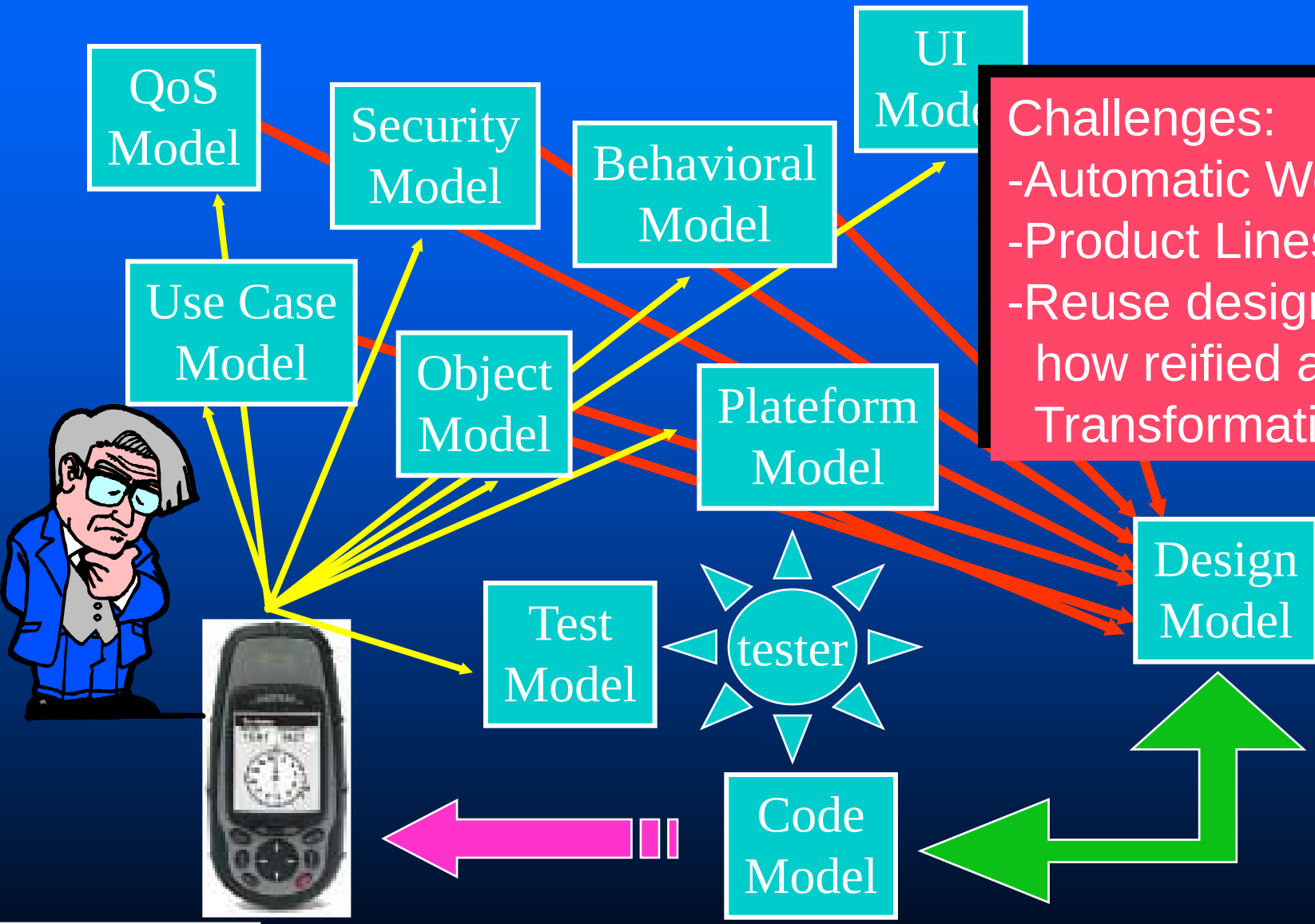


M_0 (the world)

AOSD

- Large and complex systems compose many different concerns
  - This affects modularization
  - Need to manage interactions between concerns
- Scattering
  - One concern distributed all over the system, not put in a well identified unit
- Tangling
  - One unit contains elements from different concerns

Modeling and Weaving



Aspect Oriented Modeling

- Separation of concerns in a model
  - A concern is not necessarily cross-cutting
- Model composition
  - Build a global view from a set of concern models
- AOM is a wide domain
  - Captures a large variety of modeling practices
  - A large number of composition approaches

Aspect Oriented MDE (AOMDE)

- Why ?
- When?
- What?
- Where?
- How?

AOMDE: Why?

- Intent of separation of concerns
  - Handle complexity by decomposition
  - Product line modeling : features and variation points are modeled as separate concerns
  - Reusable aspect models : build models that can be reused in the design different systems
  - Analyzable concerns : separate the characteristics of a system in order to analyse them separately before building a larger system

Separation of concerns: Why?

- Separation at different levels of granularity
- Fine grained decomposition for finer grain / model construction
  - Ex: the transaction concern in RAM
- Coarse grained decomposition
  - Analyse the concerns separately
  - Ex: security

Composition : Why?

- Collaborative development: compose models that have been developed in parallel
- Compose different variants to limit the maintainance cost
- Analyze the result of composition
- Use the result of composition as a new model

Composition vs. Interconnection

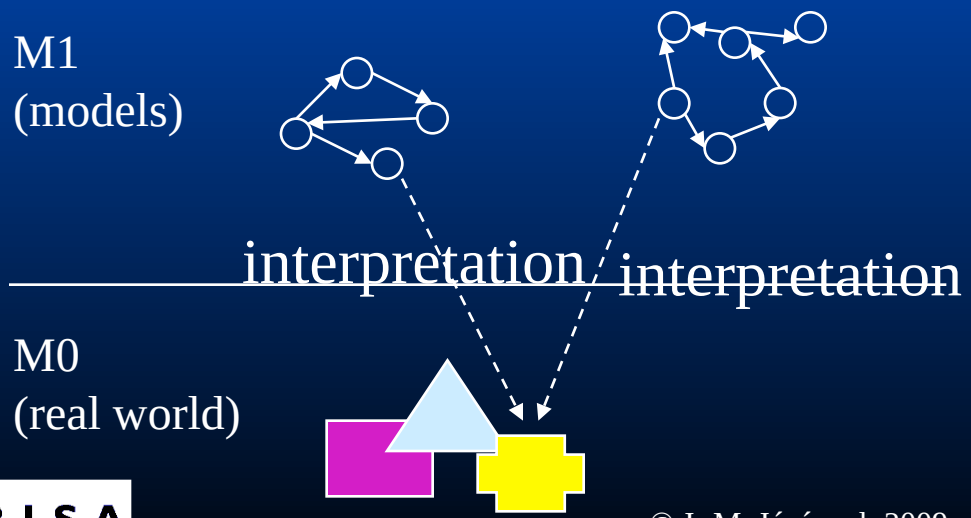
- Interconnection
  - A = C1 + C2 + C3 : C1 can be connected to C2, and C2 to C3, because some syntactic match between I/O
  - Behavior of A cannot really be anticipated
- Composition
  - A = C1 + C2 +C3 : we are interested in reasonning about the composition
    - » Commutativity, associativity…
    - » Foreach i and property Pi, Pi(A) = f (Pi(C1), Pi(C2), Pi(C3))

AOMDE: When?

- Separate concerns at different stages
  - Requirements engineering: identify features and cross-cutting concerns from requirement documents
  - Feature modeling: AOM for product derivation
  - Architecture
  - Design
  - Runtime (for system dynamic adaptation)
- Implies different techniques for composition

Composition: what?

- Identify the similar elements in both models
- Elements are similar in two models if they have the same meaning



Composition: what?

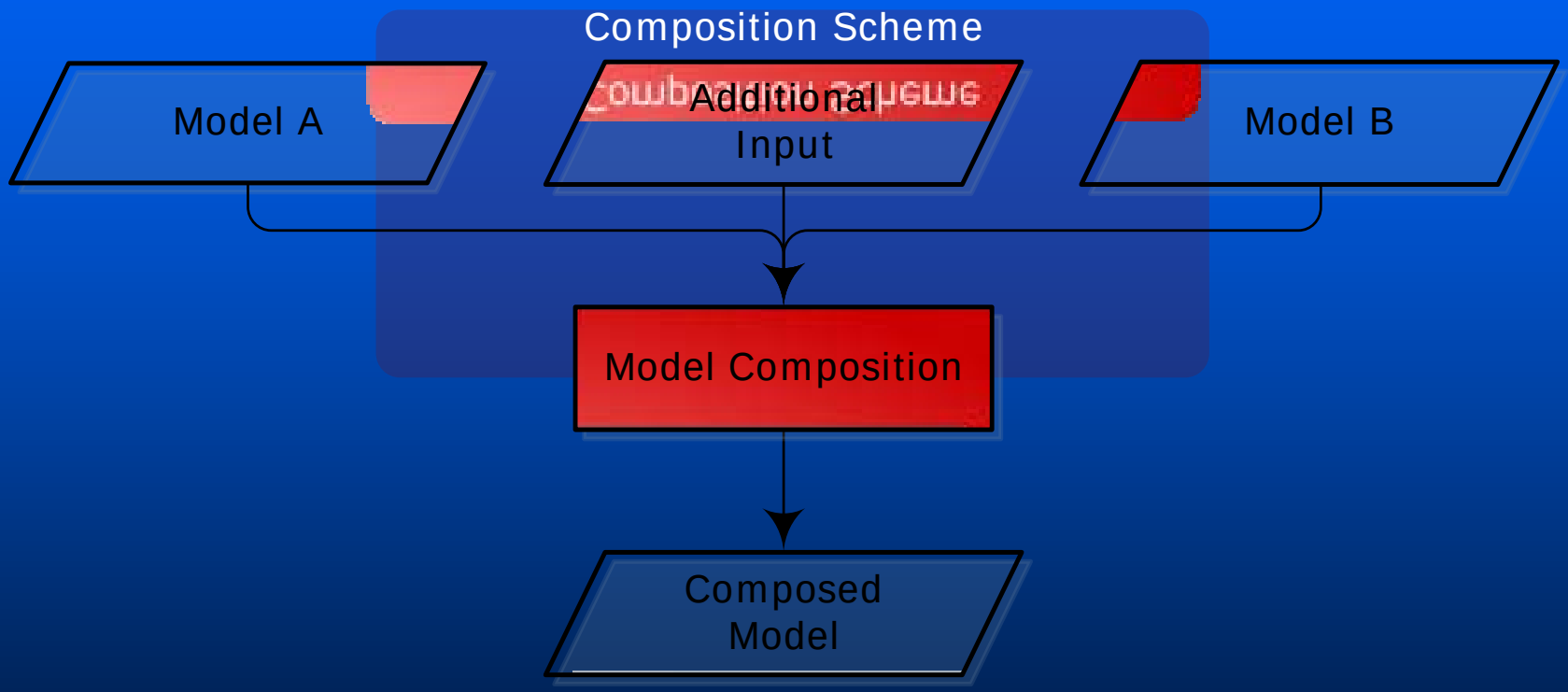
- Difficult to establish the interpretation relation for each element in the model
- A little bit easier to compose elements from the same metamodel
  - Only elements that have the same type can have the same interpretation
  - When the models to compose have different metamodels it is necessary to specify interpretation at the meta level

Composition: where?

- Critical for behavioural models
  - When composing scenario A after B does not mean the same as B after A
- The place where the elements should be composed can be declared with a pattern language
  - Mata, Smartadapters, Klein's

Composition: how?

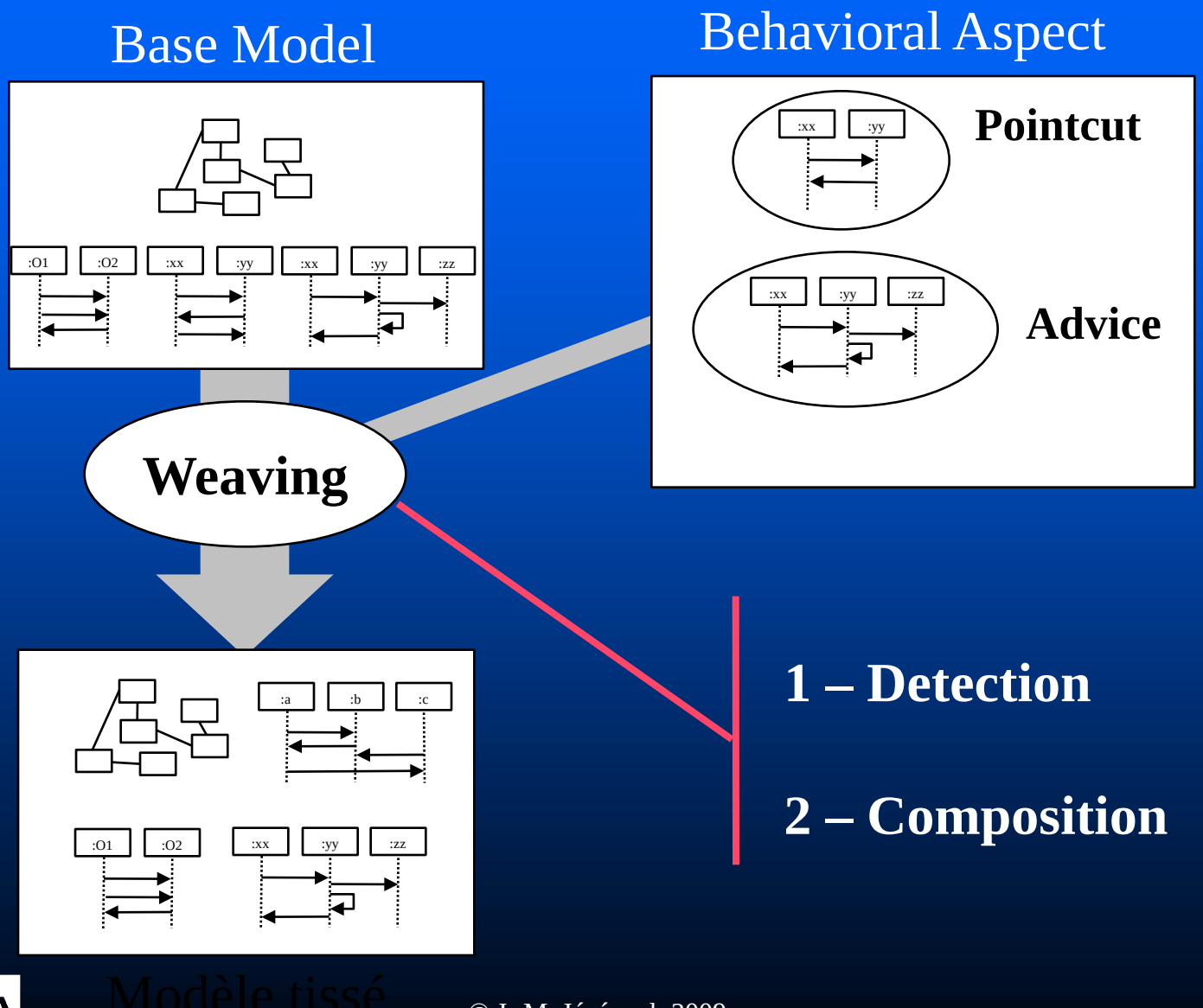
Model Composition - Scheme



Base Models and Aspects

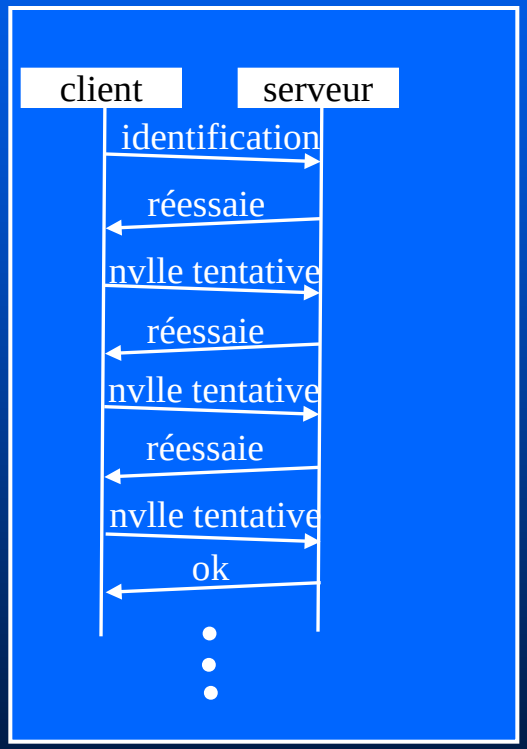
- Ideally, all aspects are equally important
  - Symmetrical AOSD
- In practice, a base model is useful to provide a backbone (canvas) on which aspects are woven
- An aspect is then described as
  - A pointcut
    - » pattern describing relevant points in the execution
  - An advice
    - » New behavior to replace (or complement) the matched ones

Overview

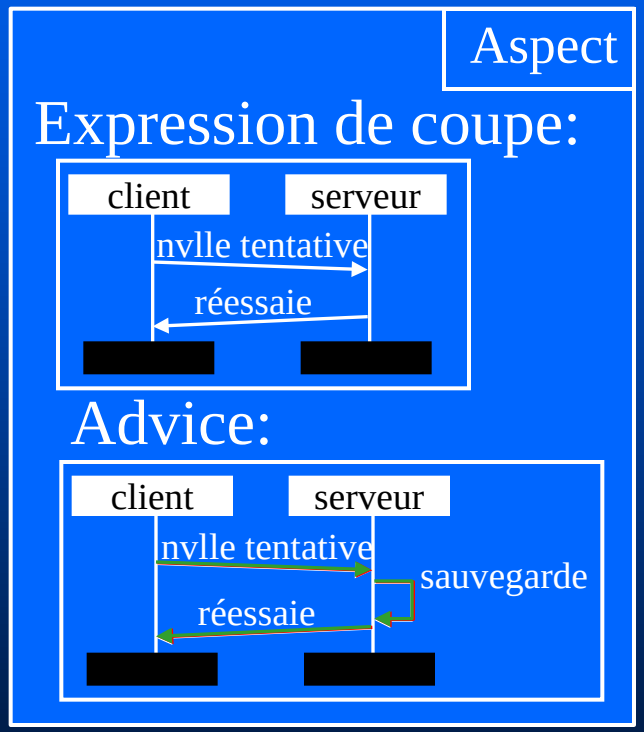


Tissage Statique d'Aspects Comportementaux

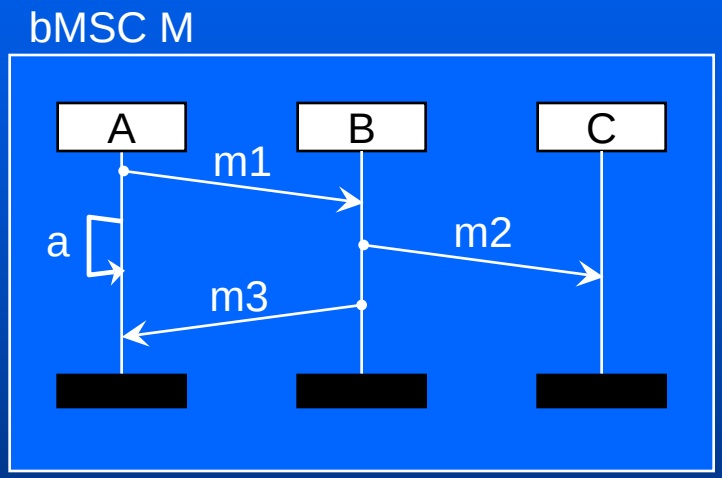
Un scénario de base



Un aspect comportemental

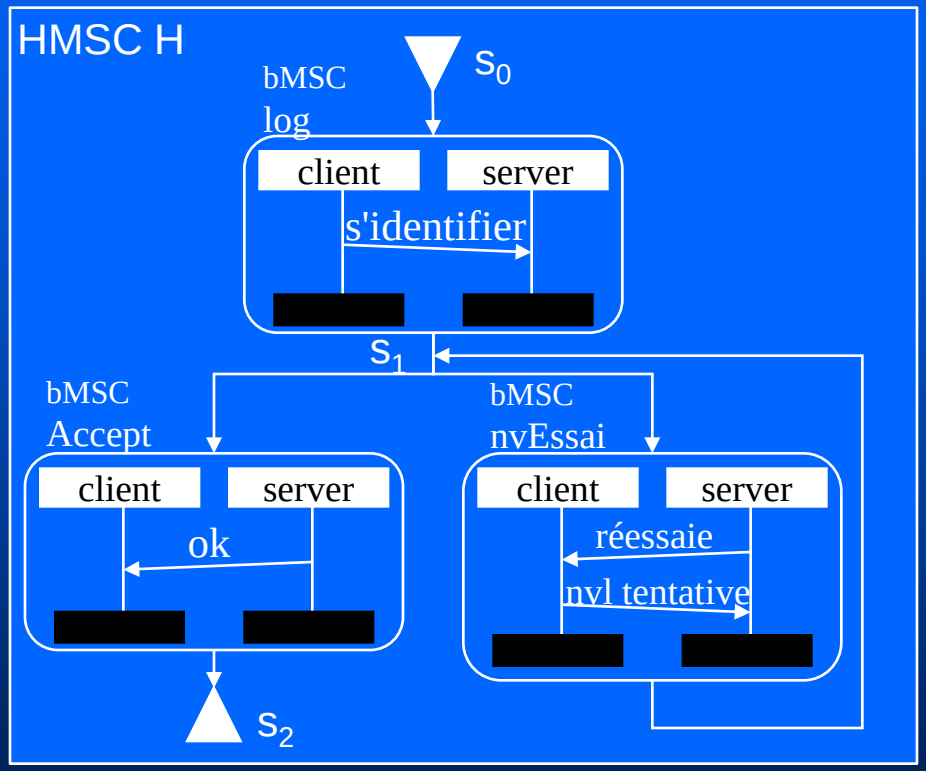


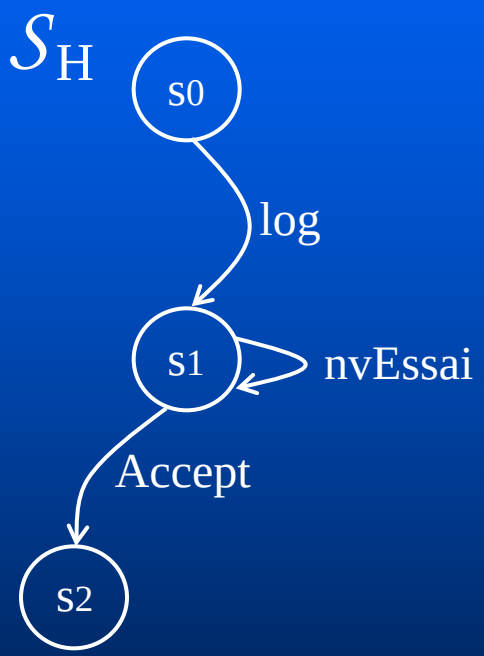
Message Sequence Charts (MSCs) (ou SD)
bas niveau: bMSC



- bMSC définit un ensemble d'événements et une relation de précédence sur ces événements

Message Sequence Charts haut niveau: HMSC

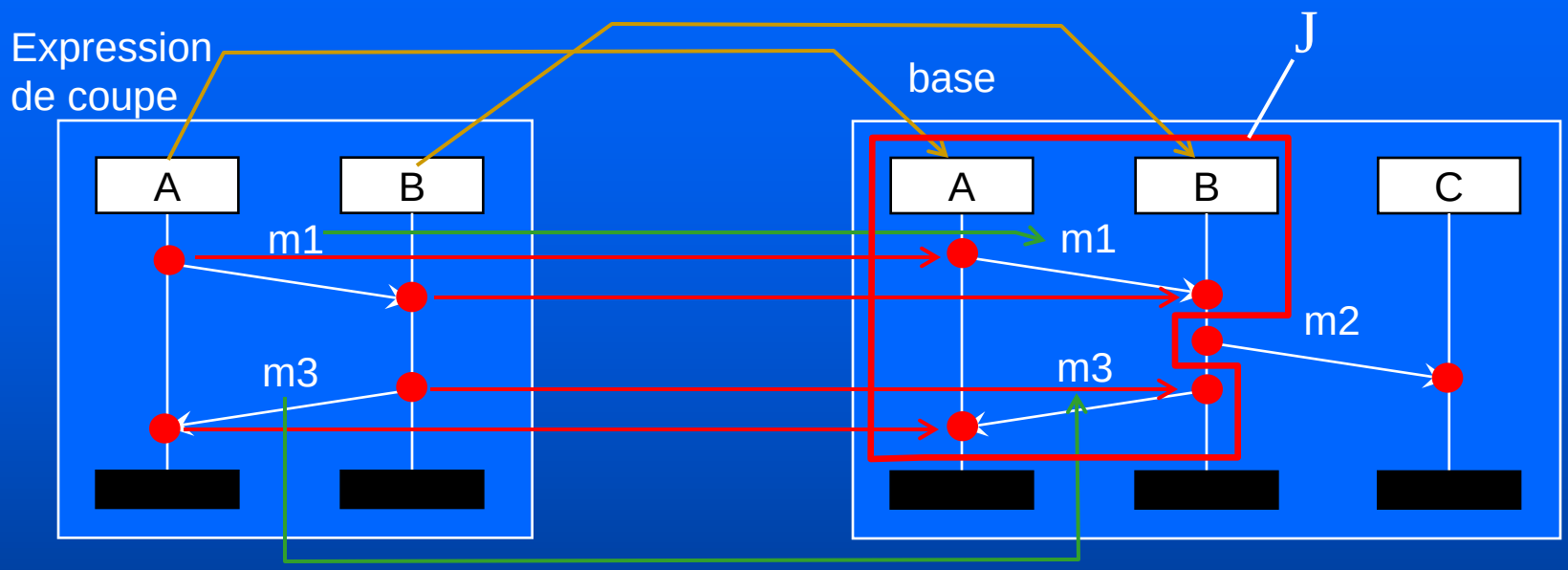




Points de jonction et langage d'expression de coupe

- Lié à un langage d'expression de coupe qui permet de spécifier où un aspect doit être composé avec le modèle de base
- Un point de jonction représente une "zone" où un aspect est entremêlé avec une autre préoccupation
- Le langage d'expression de coupe est le mécanisme qui permet de séparer une préoccupation transversale (un aspect) du modèle de base.

Définition de Points de Jonction

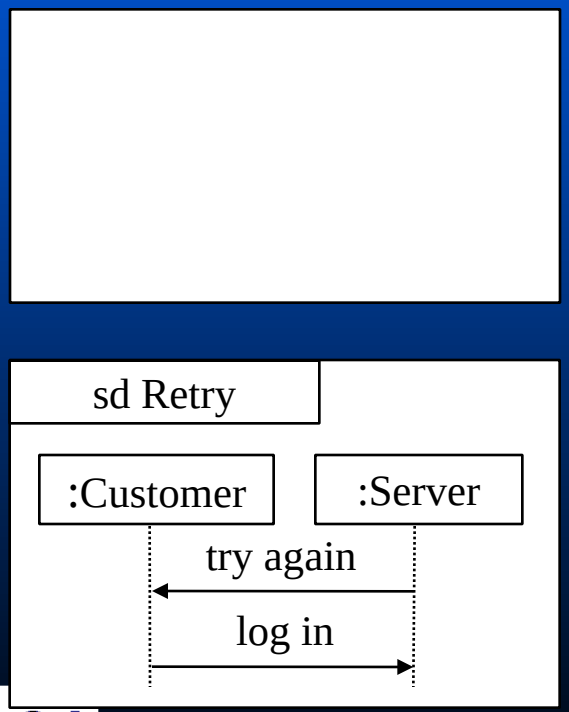


- Une partie J d'un scénario de base est un point de jonction s'il existe un isomorphisme de bMSCs entre l'expression de coupe et J.

Composability & Aspect Weaving

- Unfortunately, traditional aspect weaving (e.g. in AspectJ) has very bad composability properties.
- After weaving aspect A1 into B, maybe A1oB does no longer match A2 pointcut, while B alone did.
  - And conversely…
- Let's explore these issues with scenario languages, as in UML/HMSC etc.
  - And show how it can be automated with Kermeta

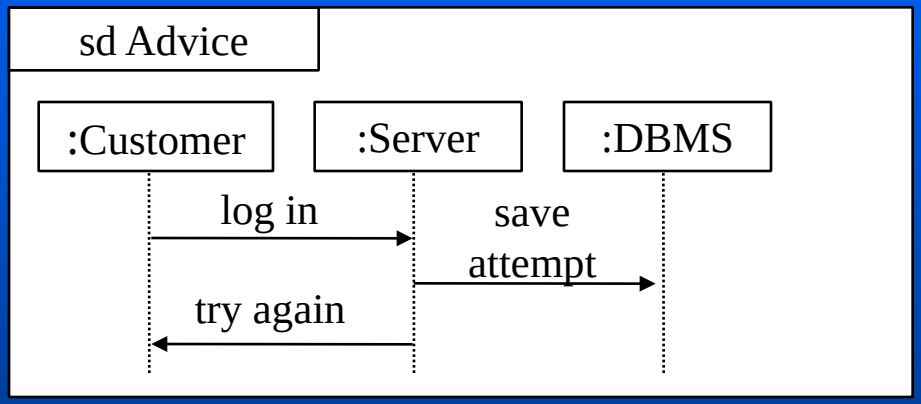
Example: Base Model



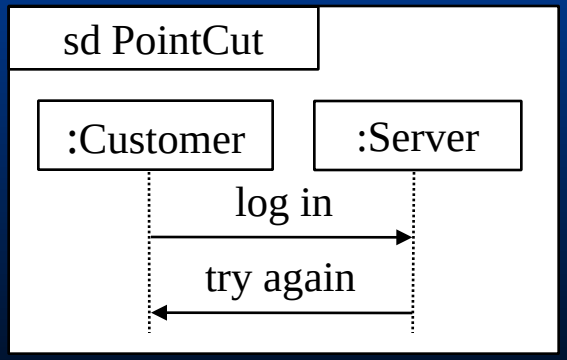
Example: Behavioral Aspect

Behavioral Aspect = Advice + Pointcut + Morphism

Advice

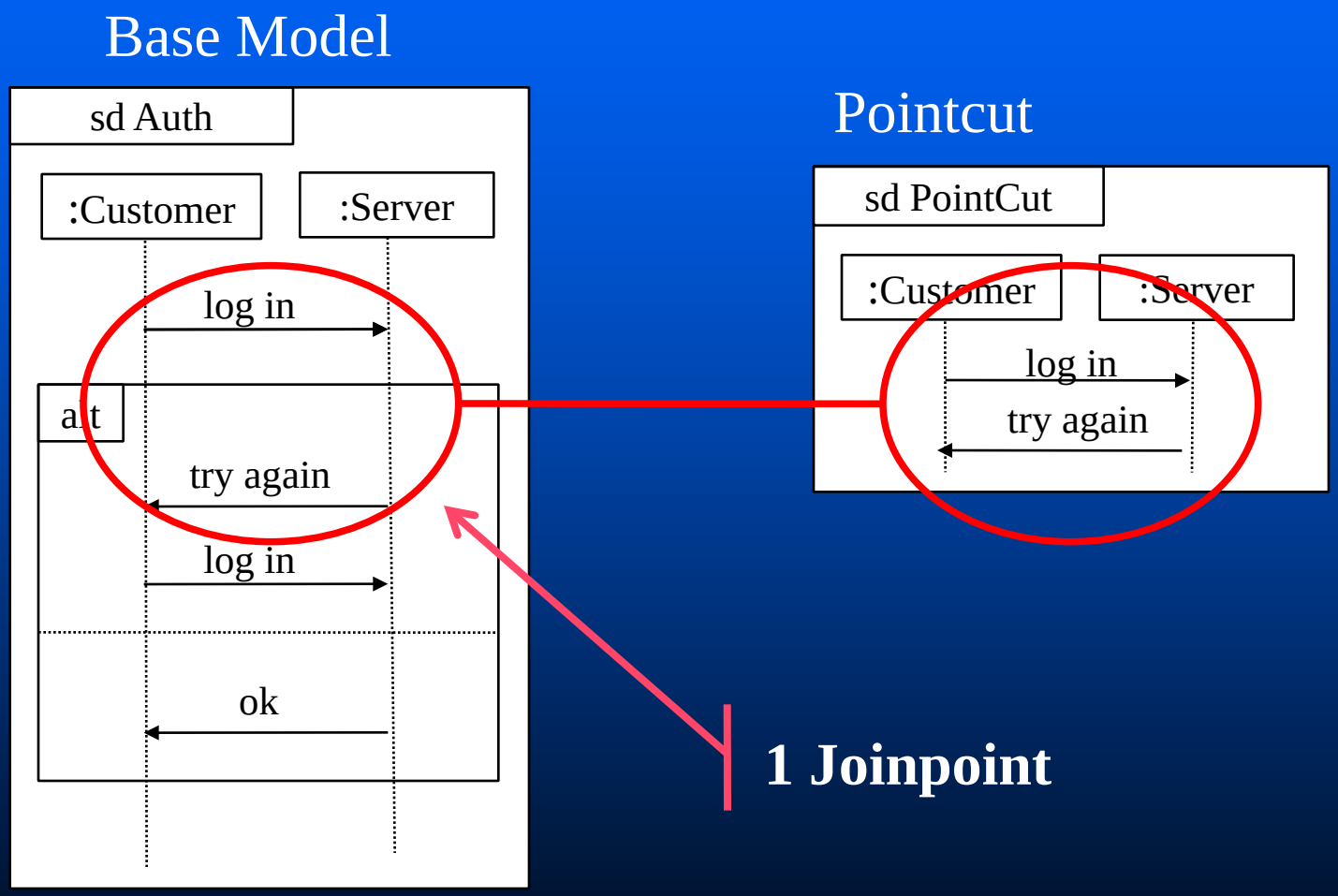


Pointcut



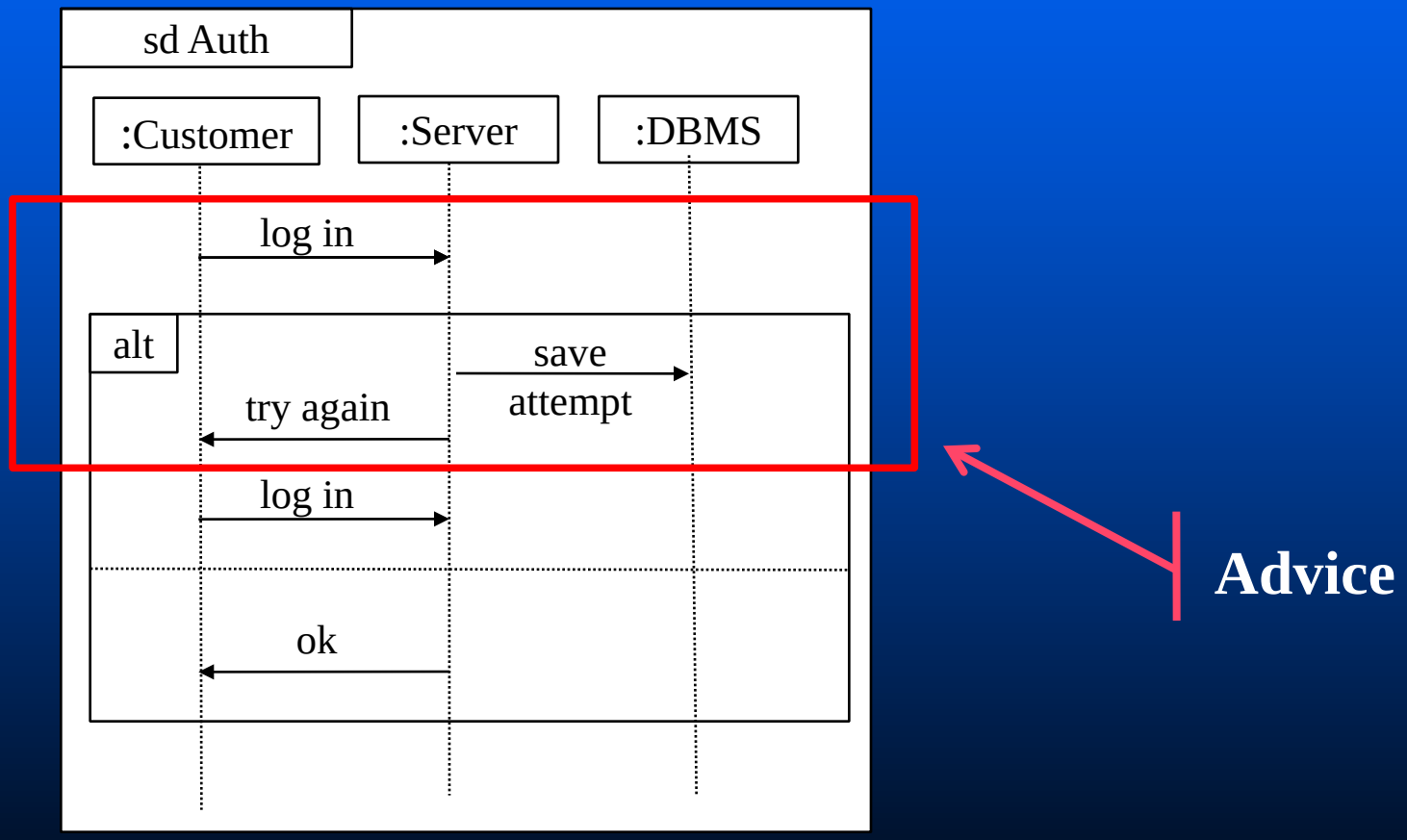
Matching based on sub-SD inclusion

BaseModel = sd1 **seq** *pointcut* **seq** *sd2*



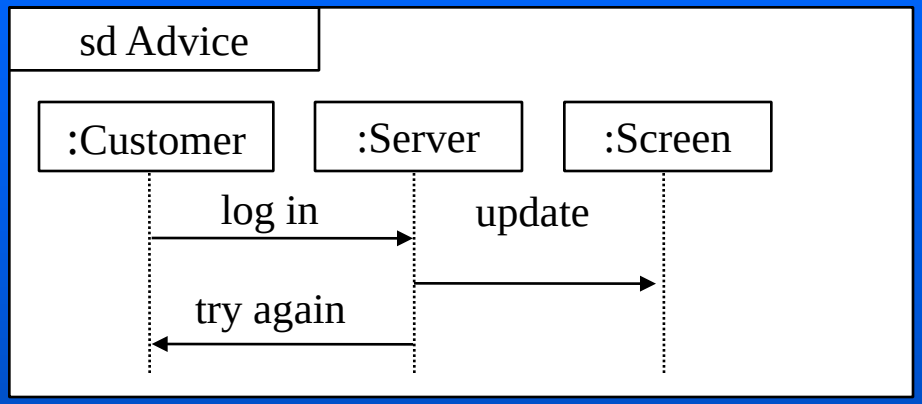
Example: Composition

Result Model

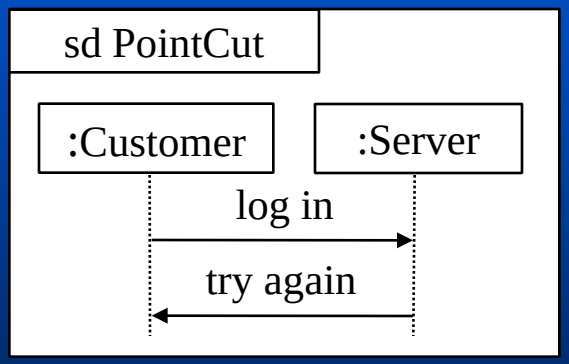


2nd aspect: update screen

Advice



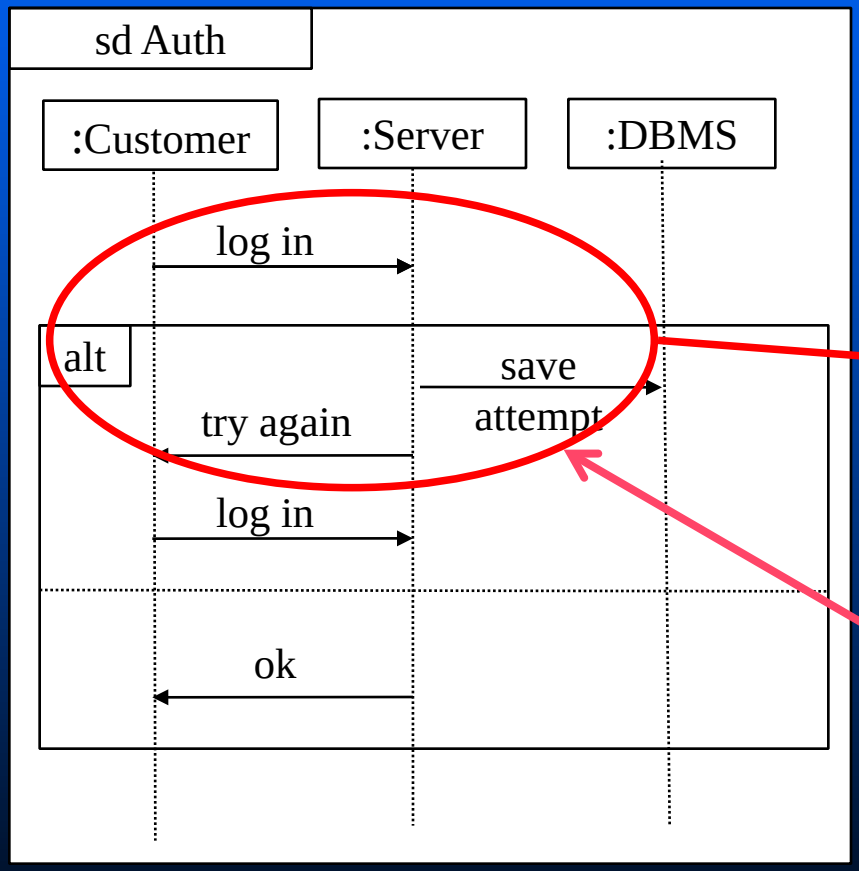
Pointcut



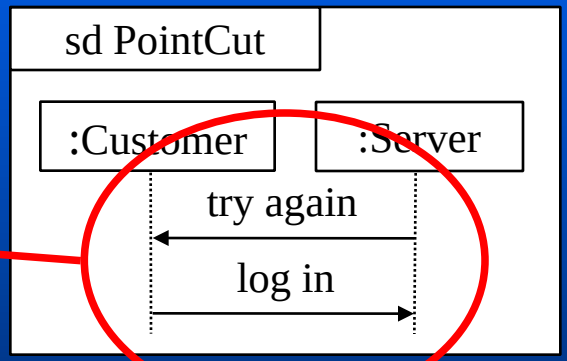
Matches base scenario, but no longer woven one!

Impossible Composition

Result Model



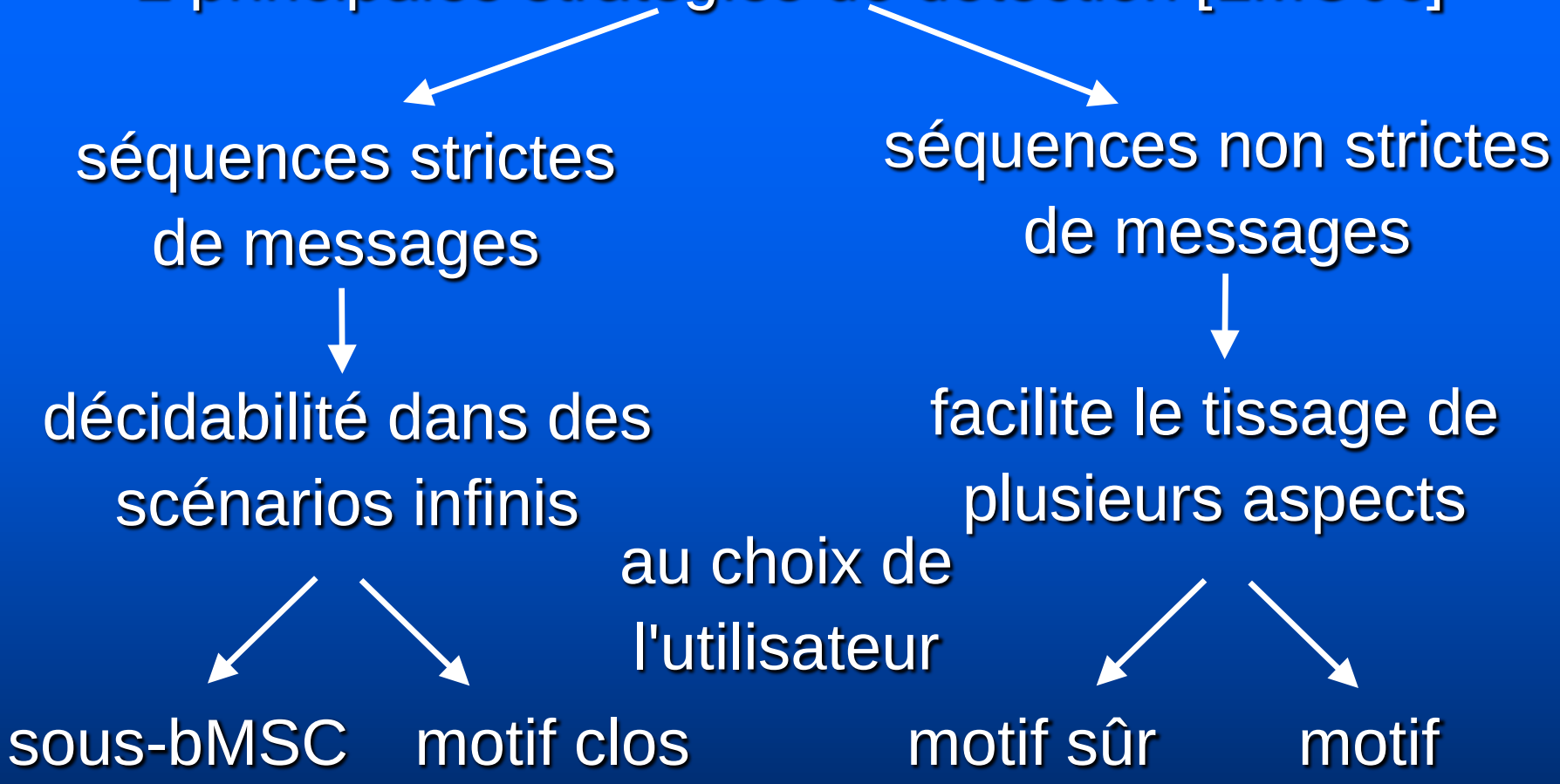
Pointcut



No joinpoint!

More advanced detection needed

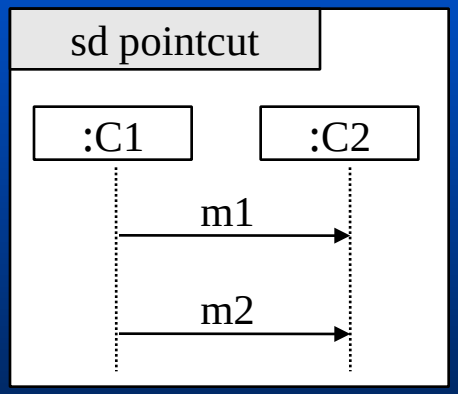
- Two possible strategies beyond sub-sequence diagram
  - Closed part
  - Pattern
- Static Analysis to find Joinpoints over HMSCs (loop unrolling!).

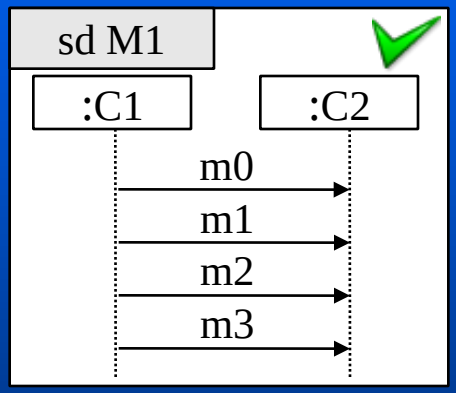


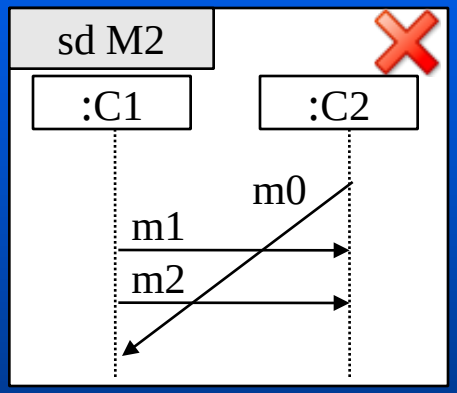
4 définitions de parties

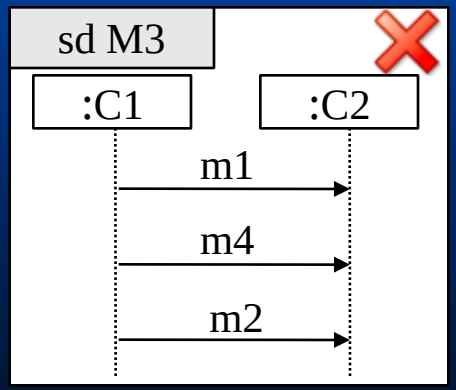
Detection Strategies (1)

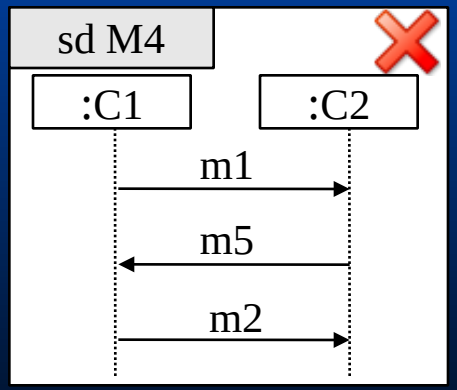
- Sequence Sub-diagram:
  BaseSD = *sd1* **seq** *pointcut* **seq** *sd2*





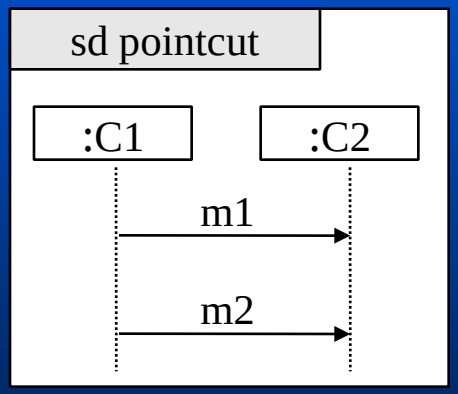


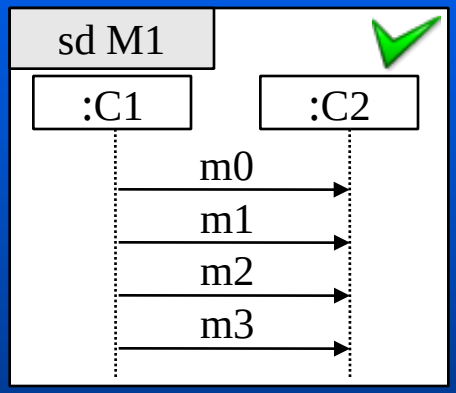


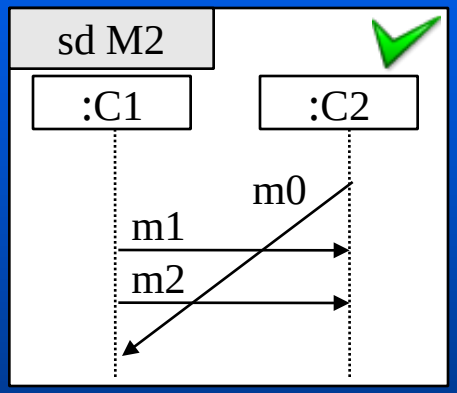


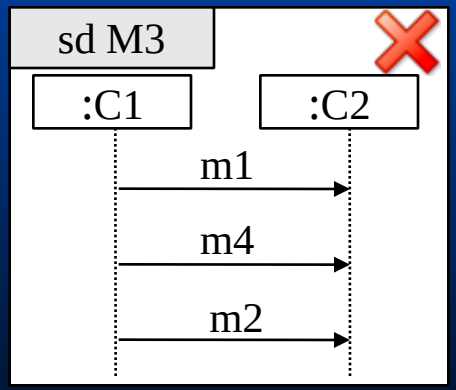
Detection Strategies (2)

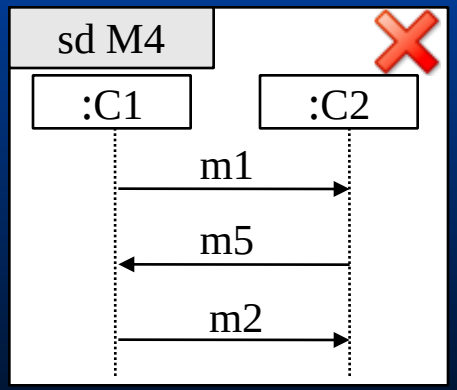
- Closed Part





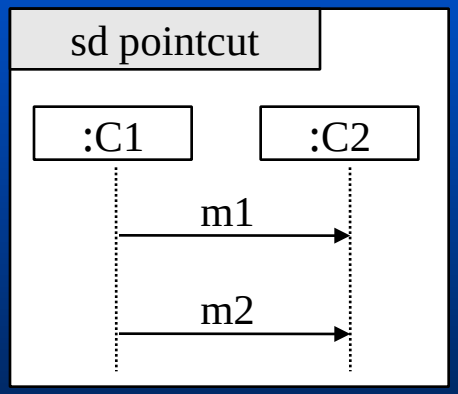


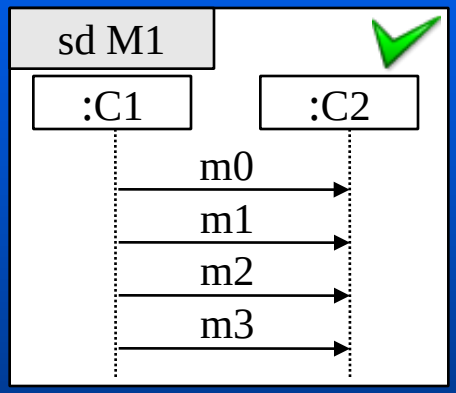


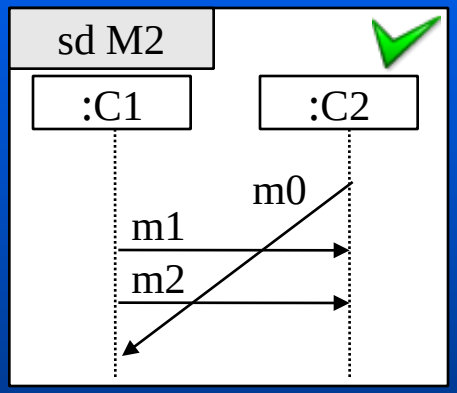


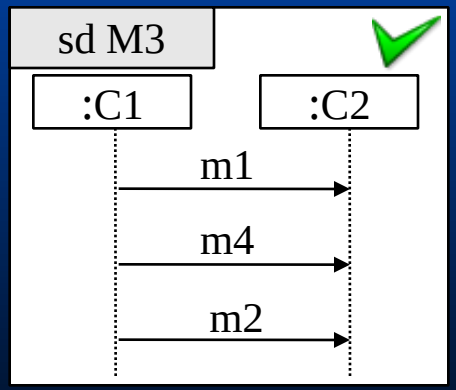
Detection Strategies (3)

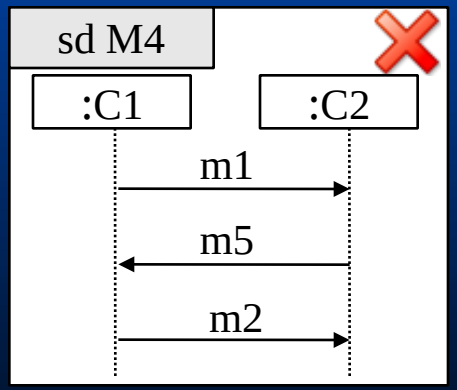
- Pattern





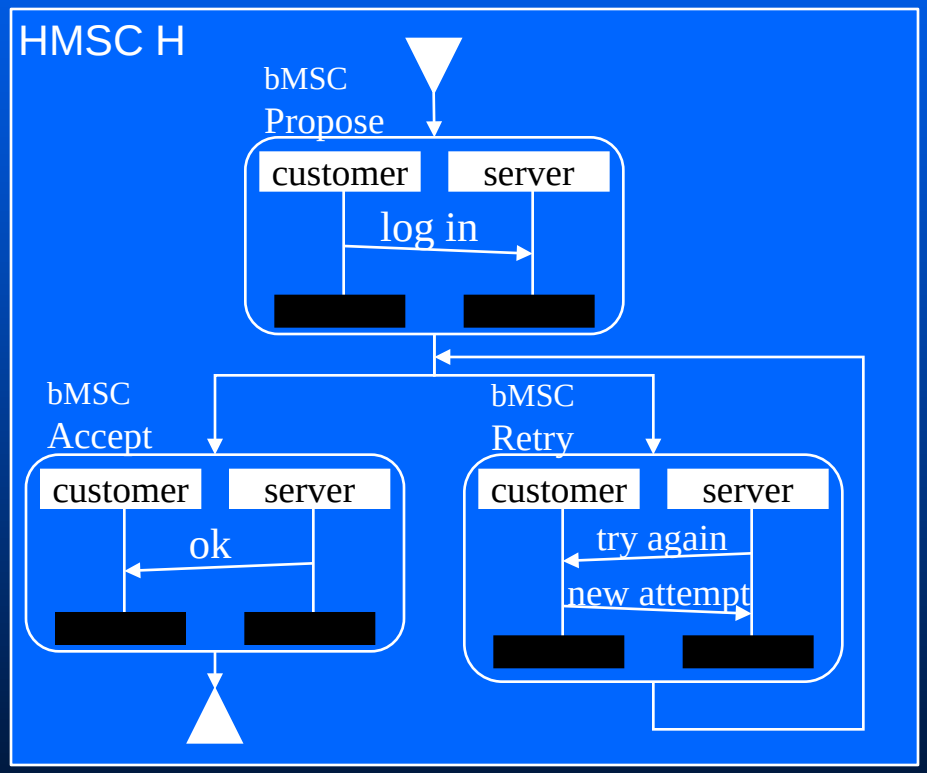




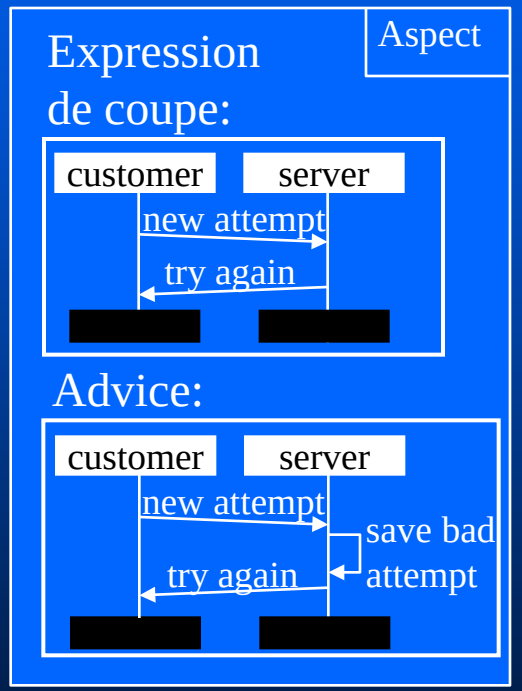


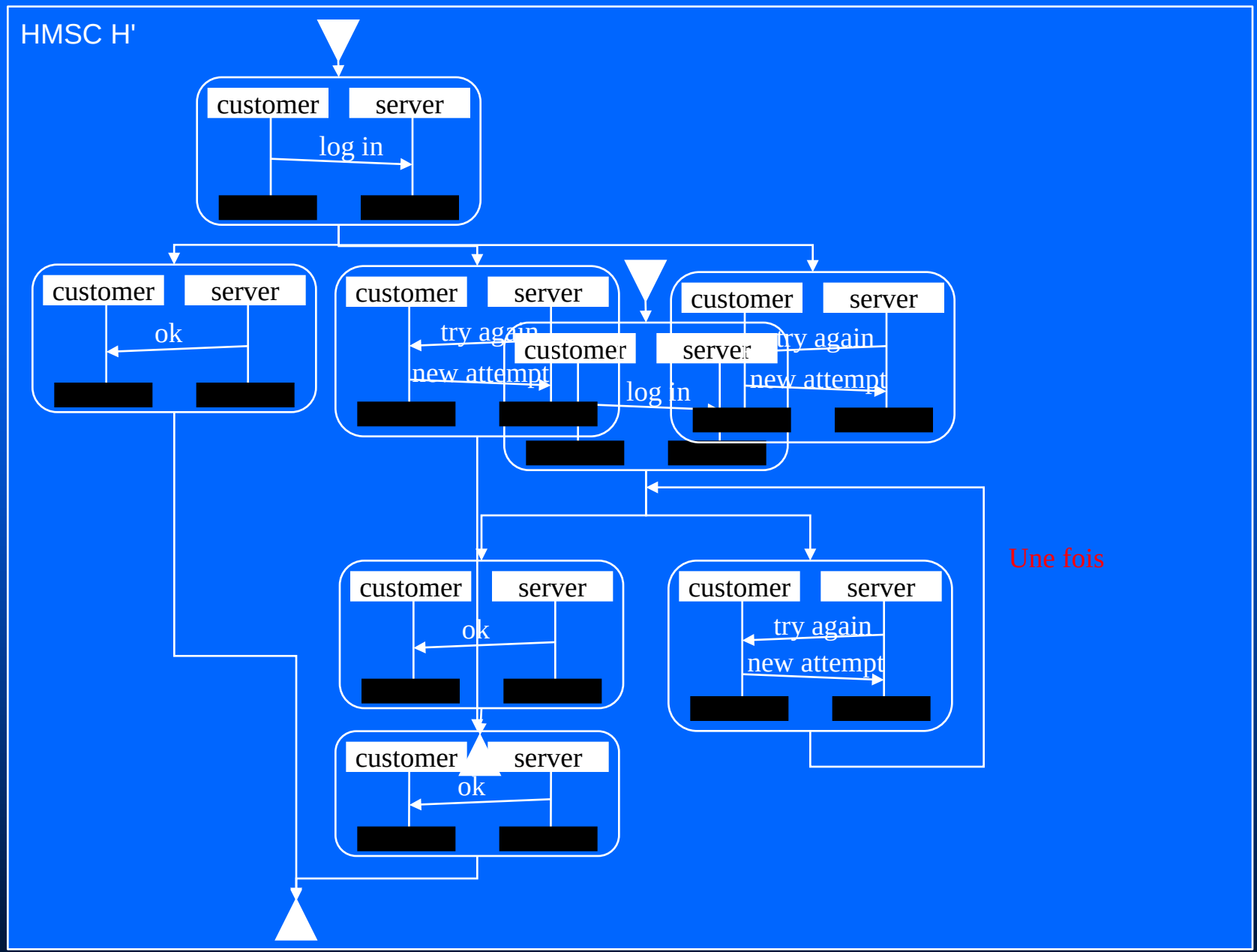
Detection in infinite scenarios

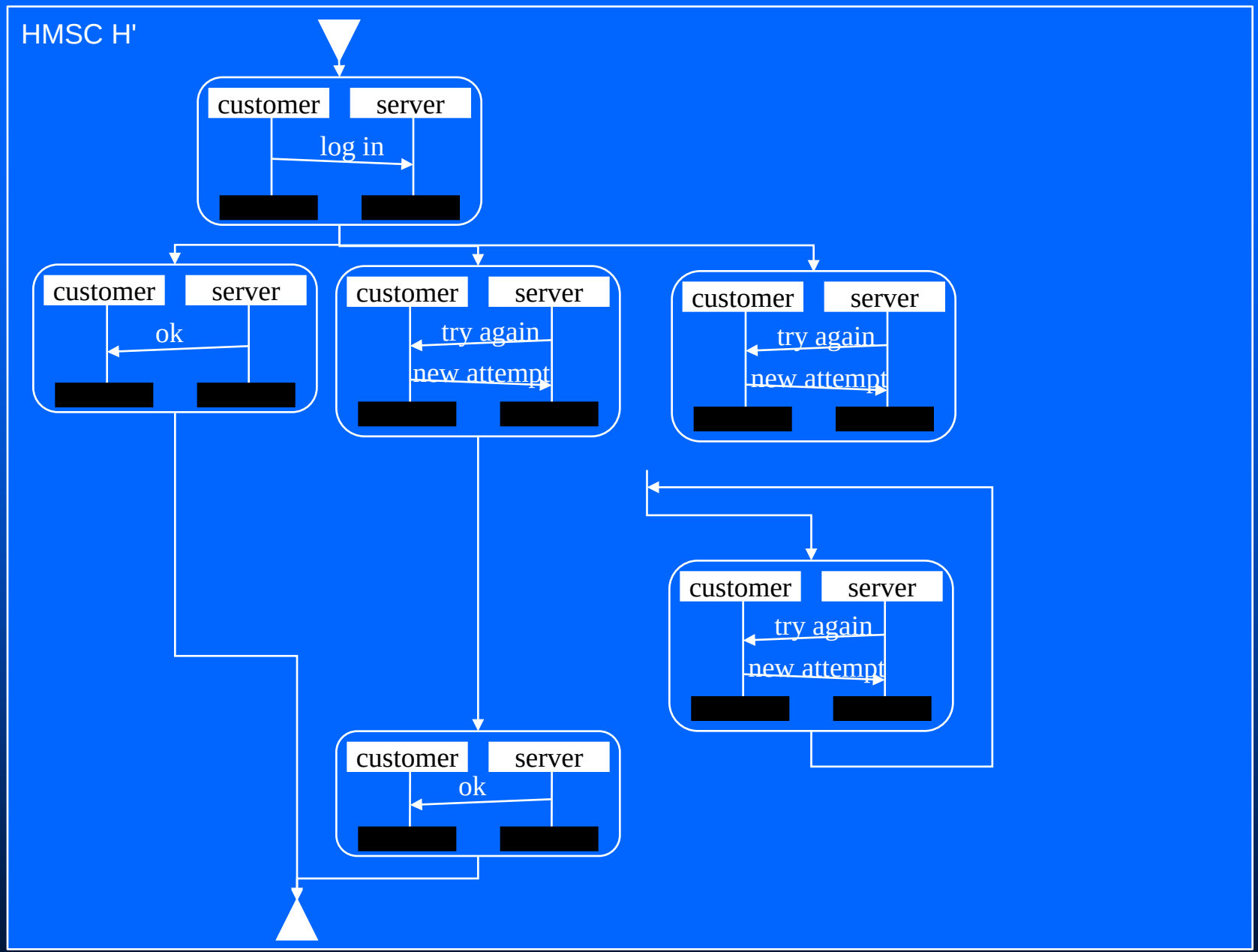
Base scenario

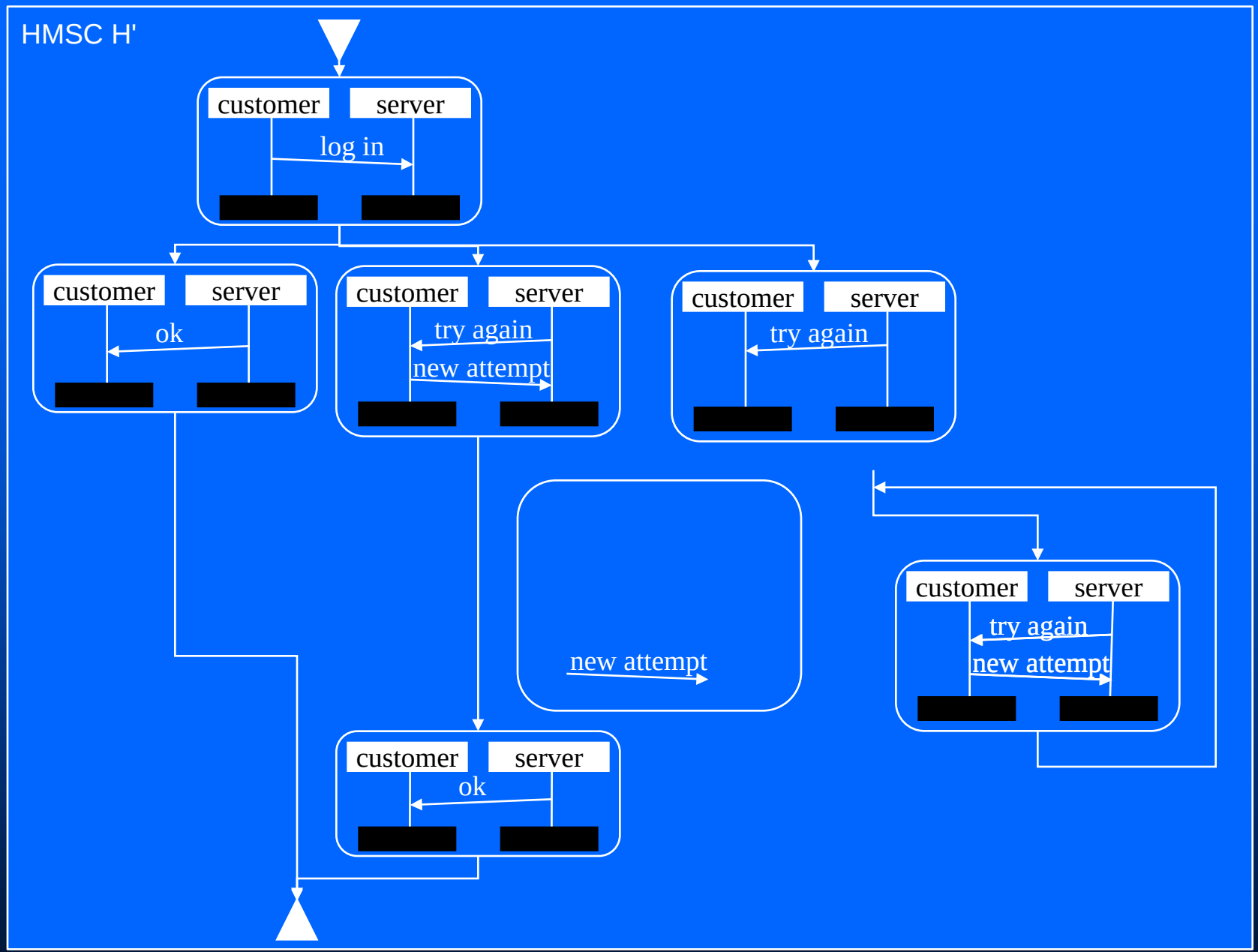


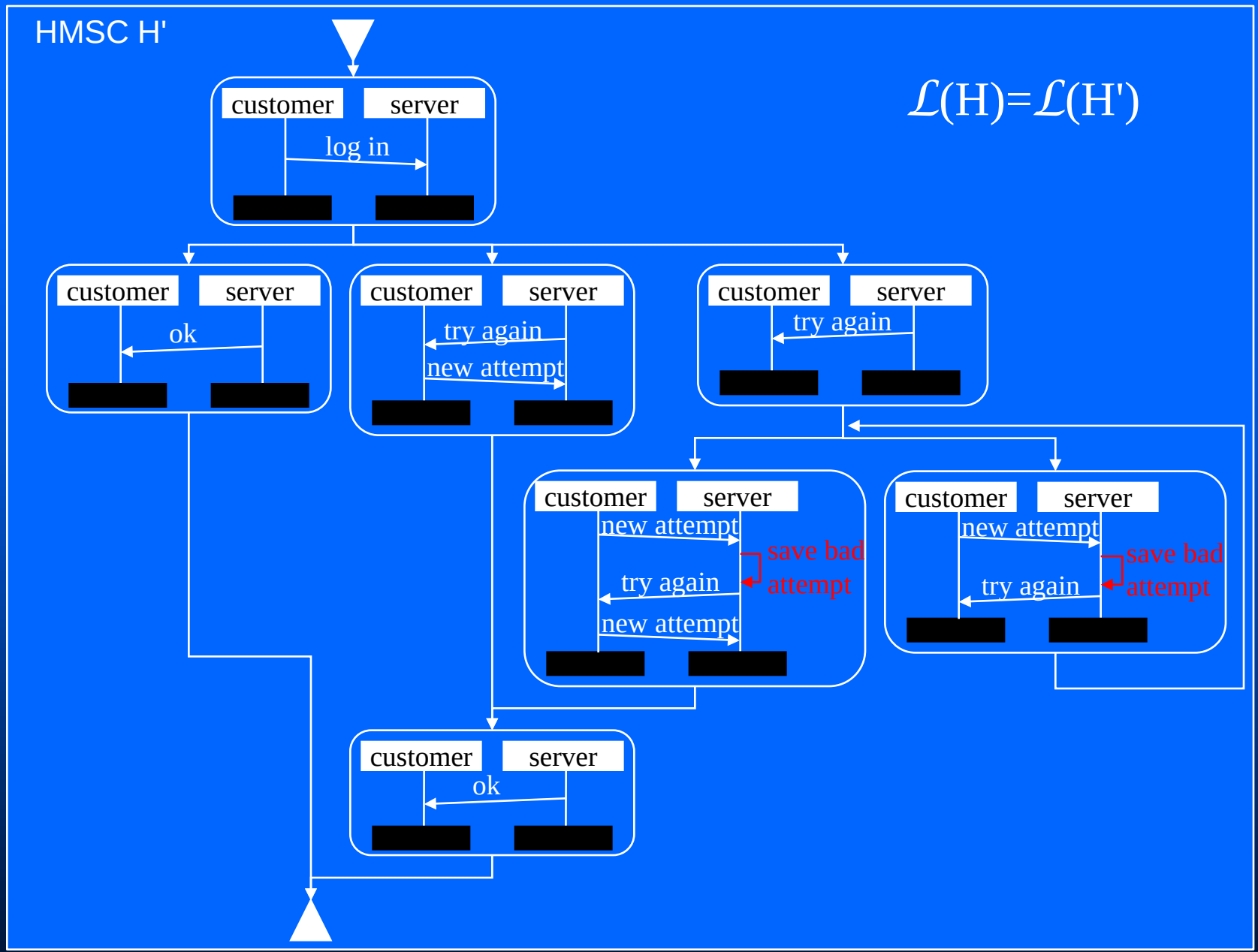
Behavioral aspect






HMSC H'
customer
server
log in
customer
server
ok
customer
server
try again
new attempt
customer
server
try again
new attempt
customer
server
try again
new attempt
customer
server
ok

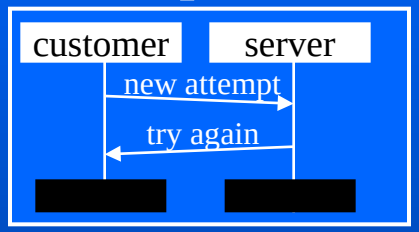




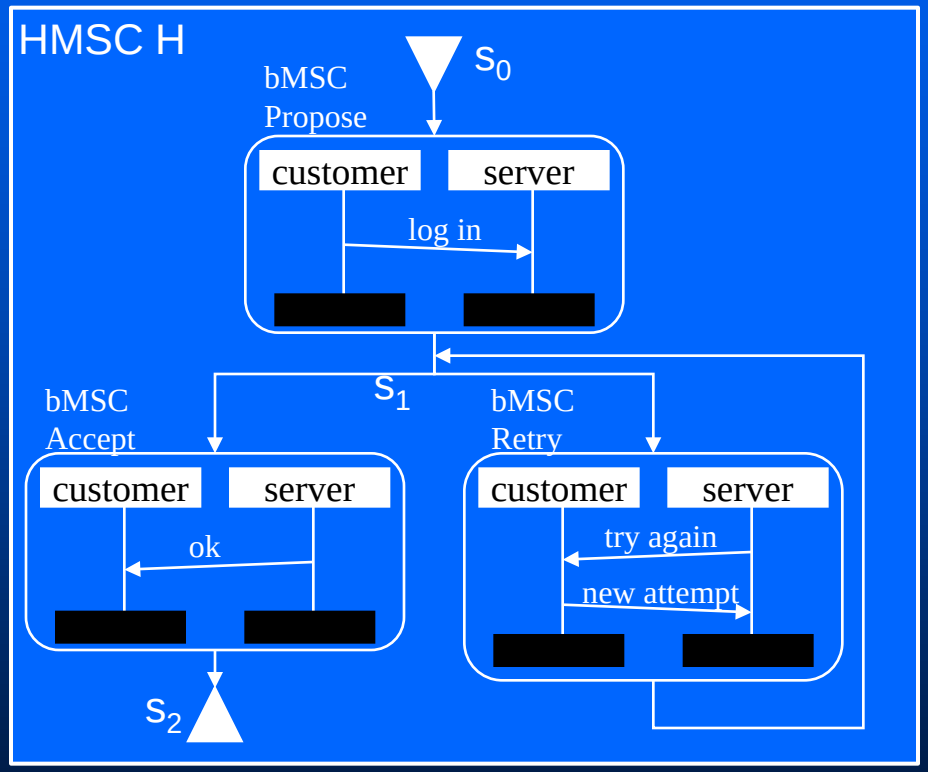
$\mathcal{L}(H)=\mathcal{L}(H')$

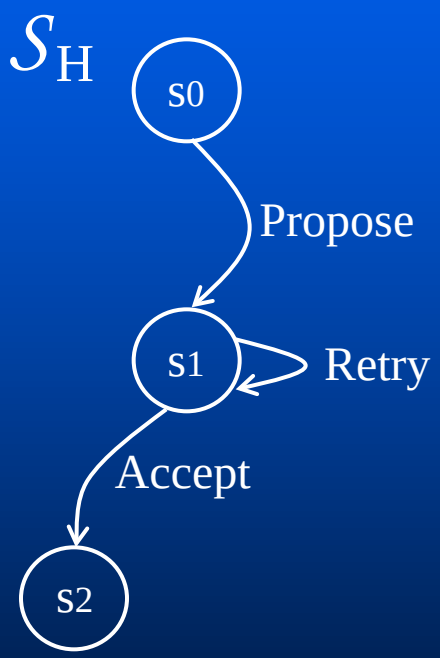
Transformation de HMSC

Expression de coupe



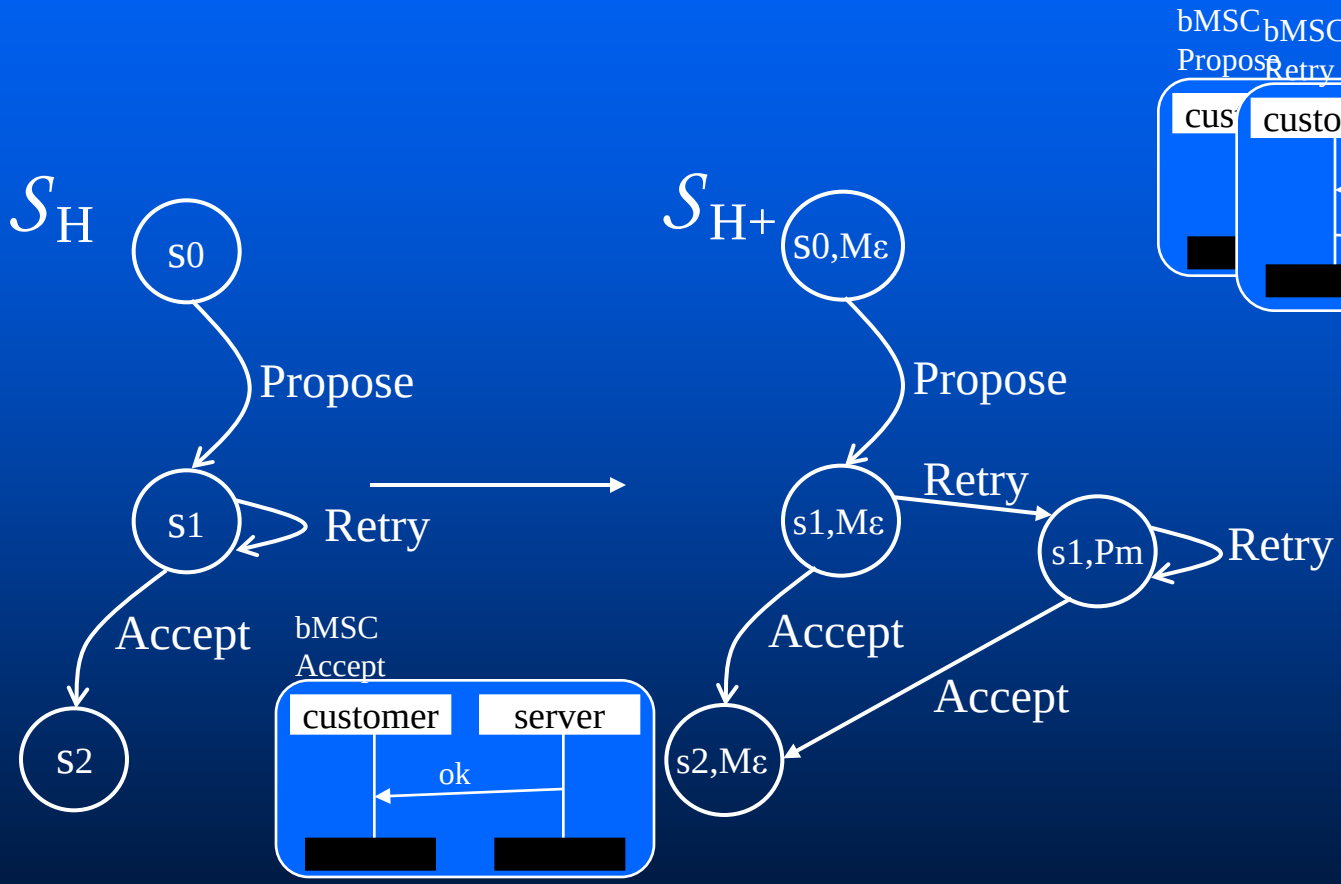
Un scénario de base

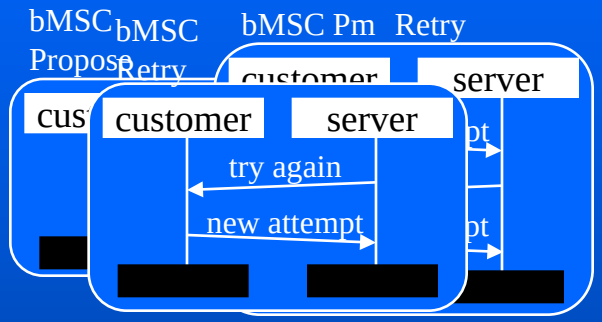


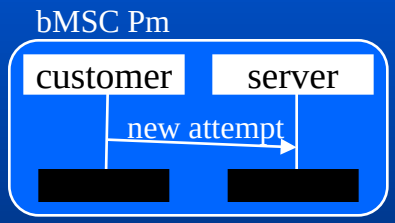


Transformation de HMSC

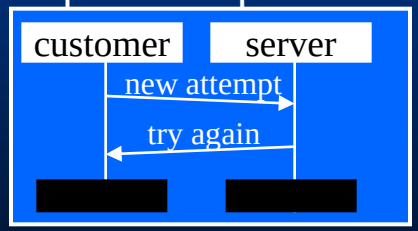
- Première étape: calcul des détections potentielles





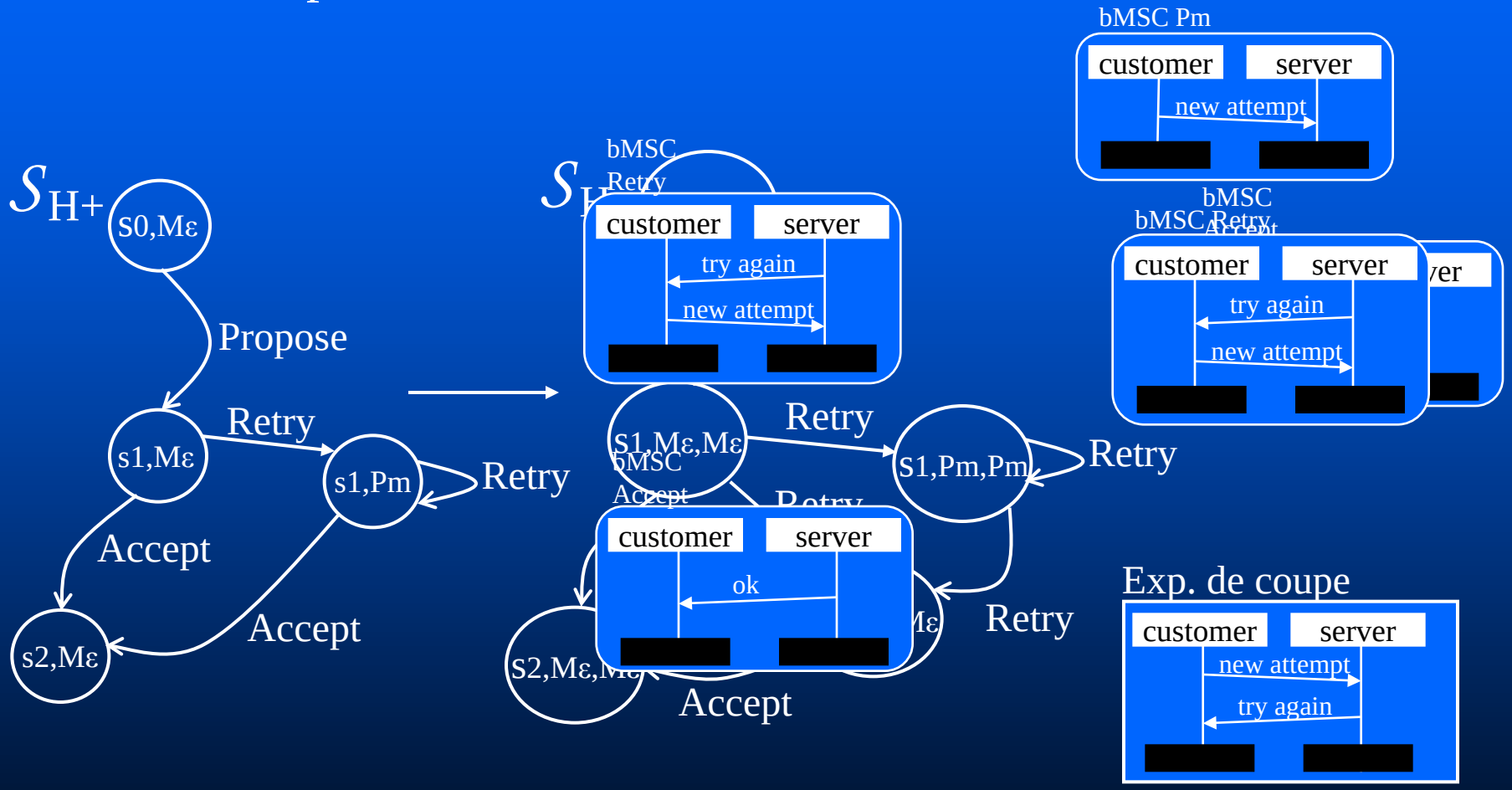


Exp. de coupe



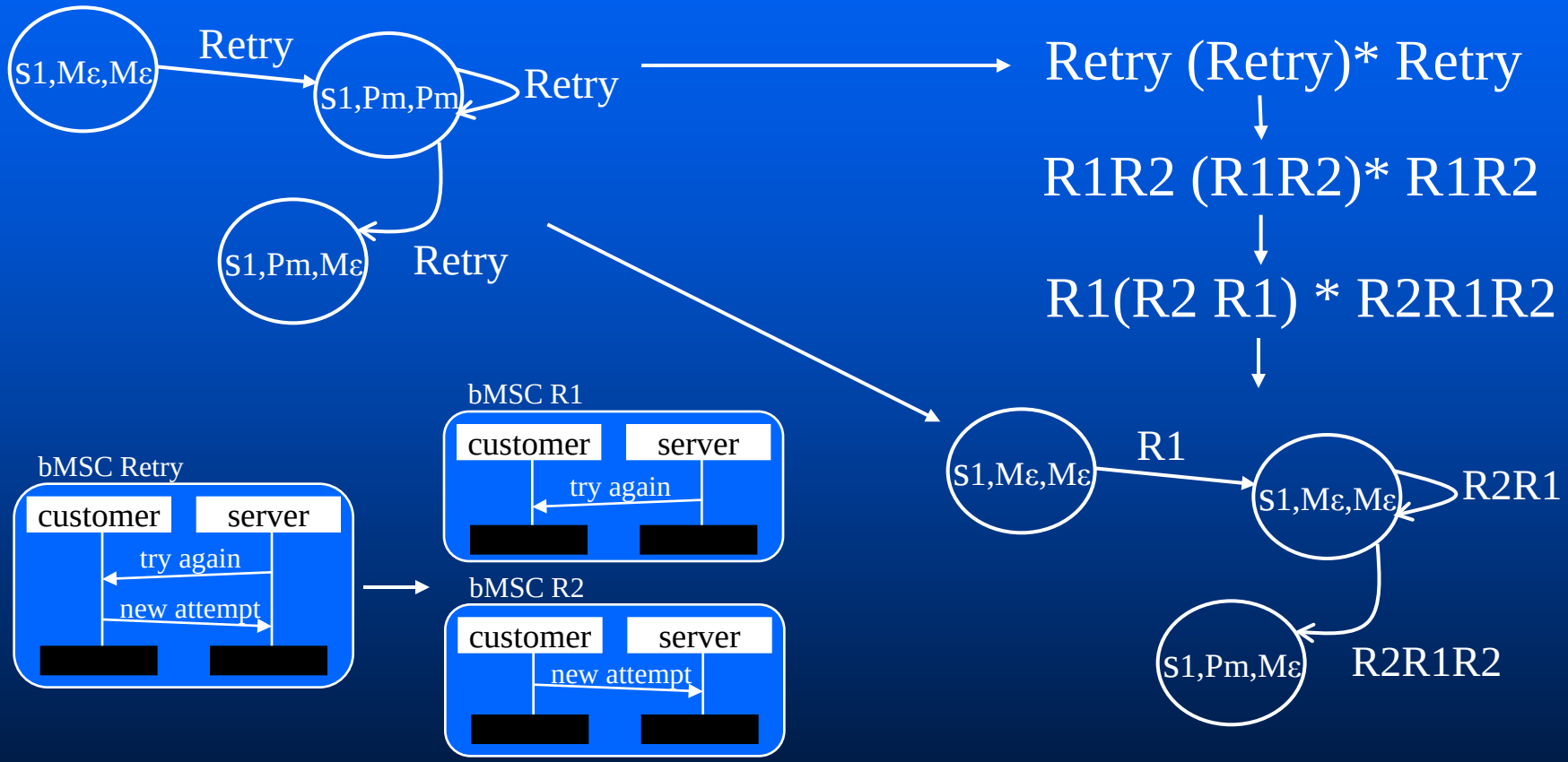
Transformation de HMSC

- Deuxième étape: calcul des détections futures



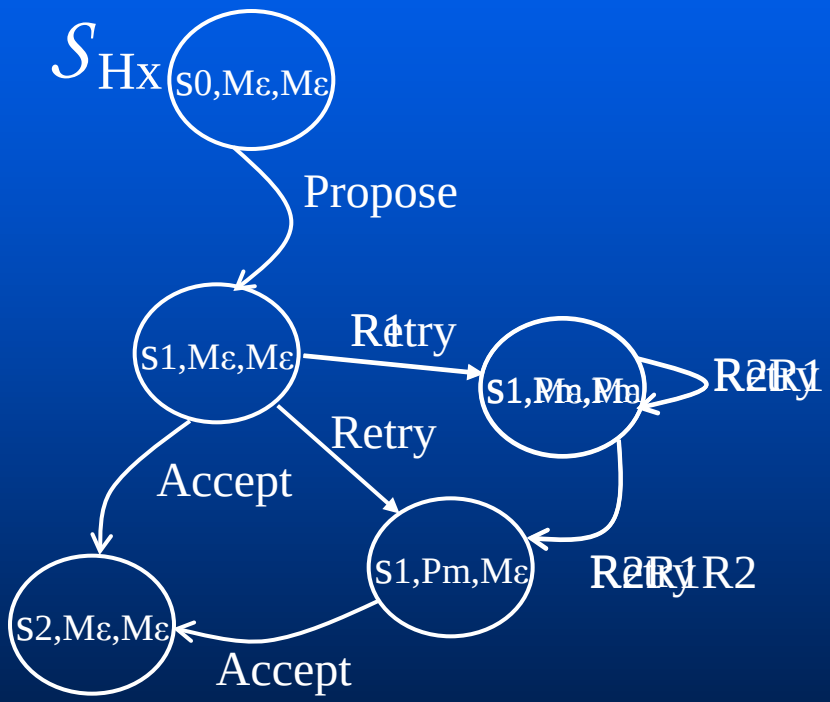
Transformation de HMSC

- Troisième étape: utilisation d'expressions régulières, découpe de bMSCs en atomes et permute ces atomes

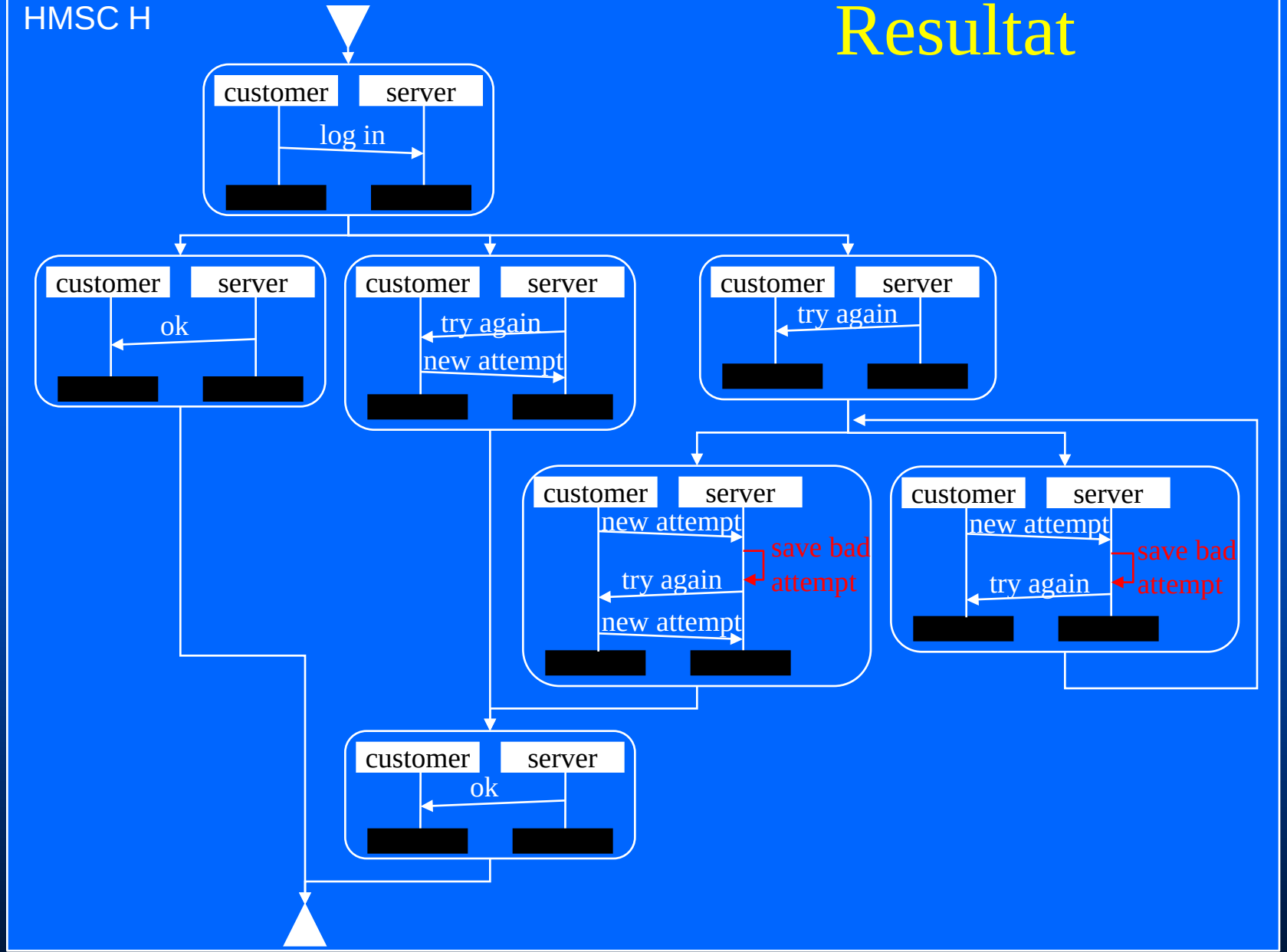


Transformation de HMSC

Resultat

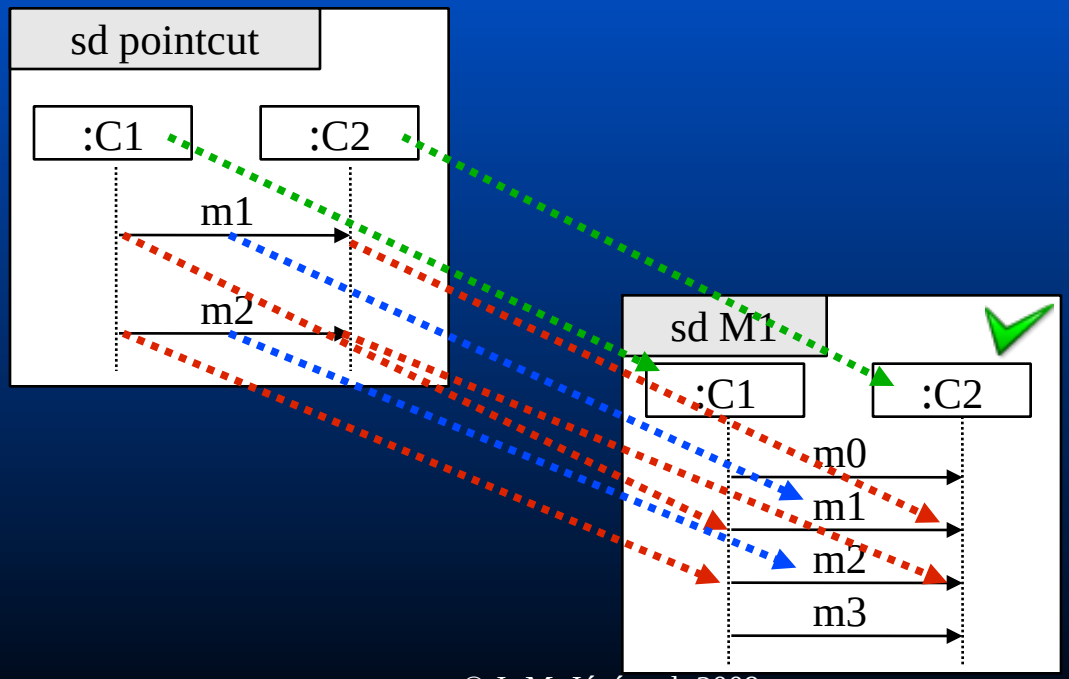


Resultat



Result of the Detection Step

- Create a morphism for each Joinpoint
  - Morphism of instances
  - Morphism of events
  - Morphism of messages (implied)

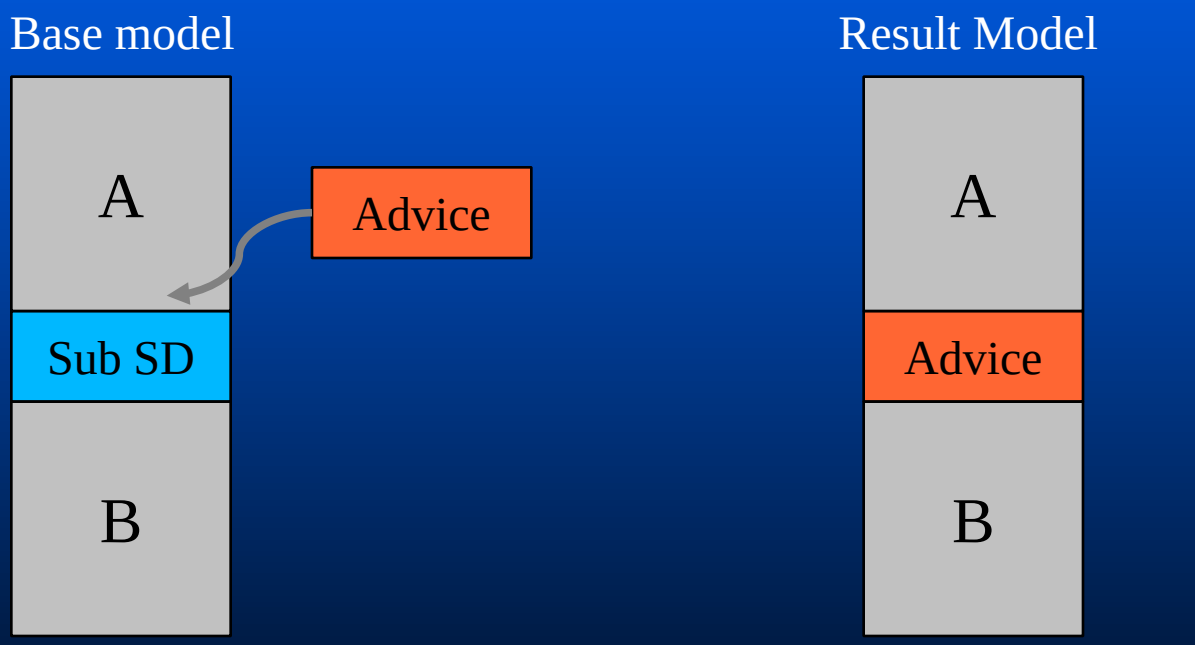


Composition

- Compose the advice into the base model
- Depend on the detection strategy

Composition

- Sequence sub-diagram
  - Weak Sequential Composition



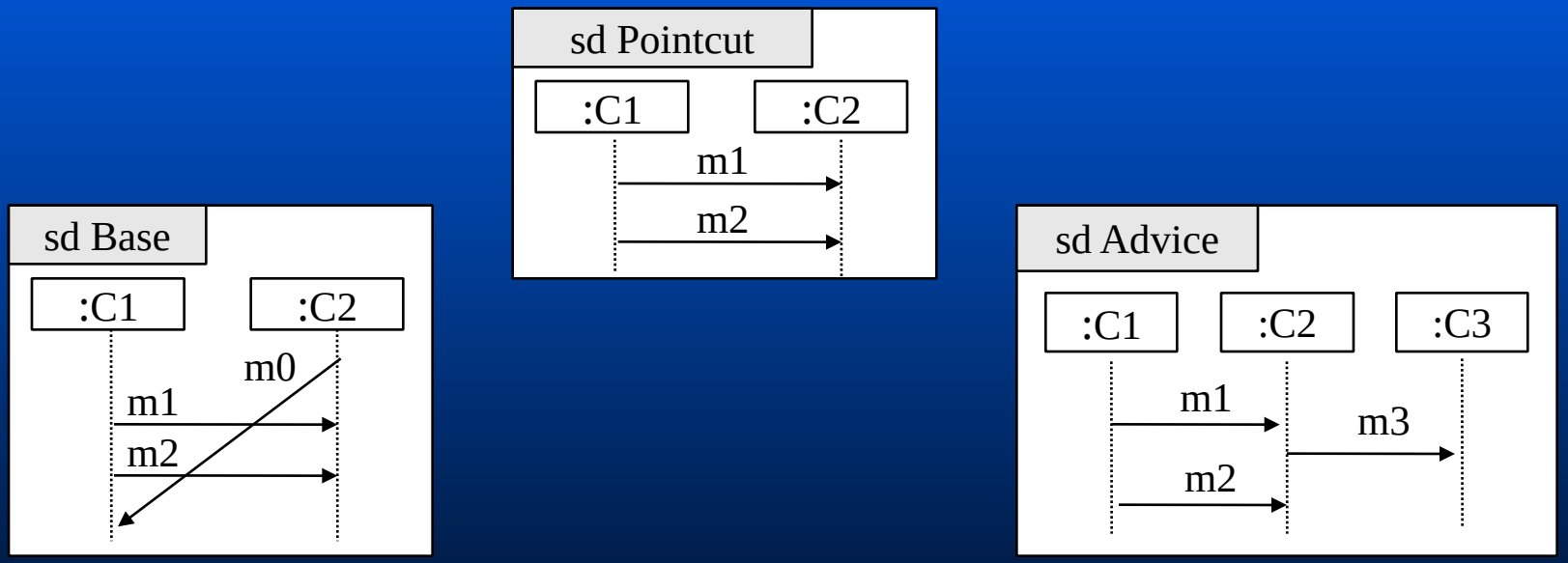
A • Sub DS • B

A • Advice • B

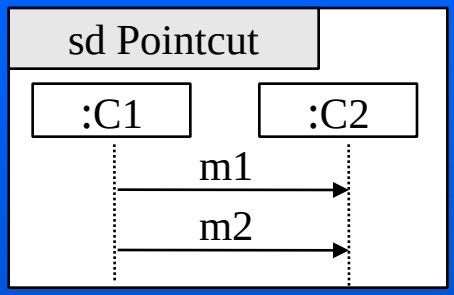
Amalgamed Sum

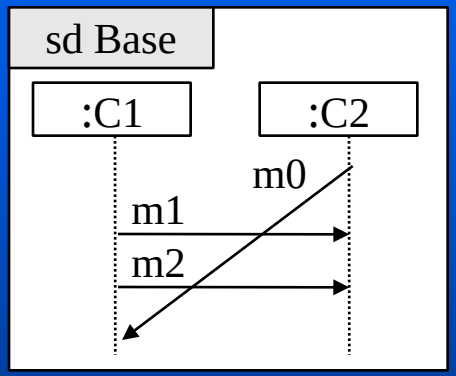
- For matching on Closed Part & Patterns

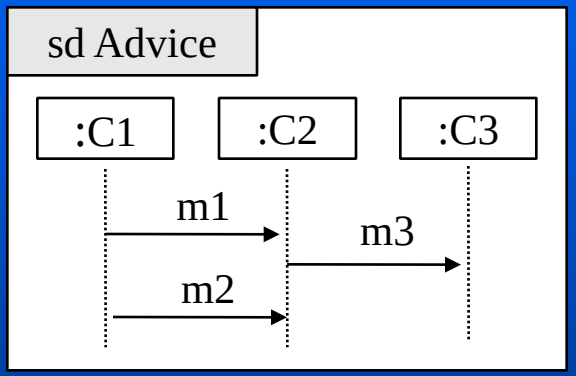
  ➡ Simple composition not possible

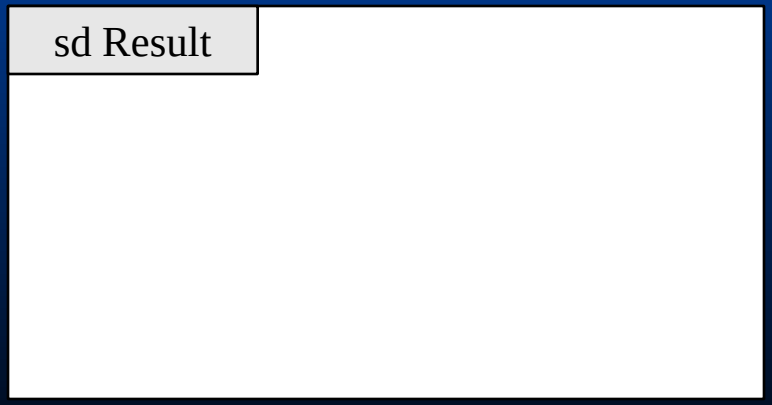


Amalgamed Sum

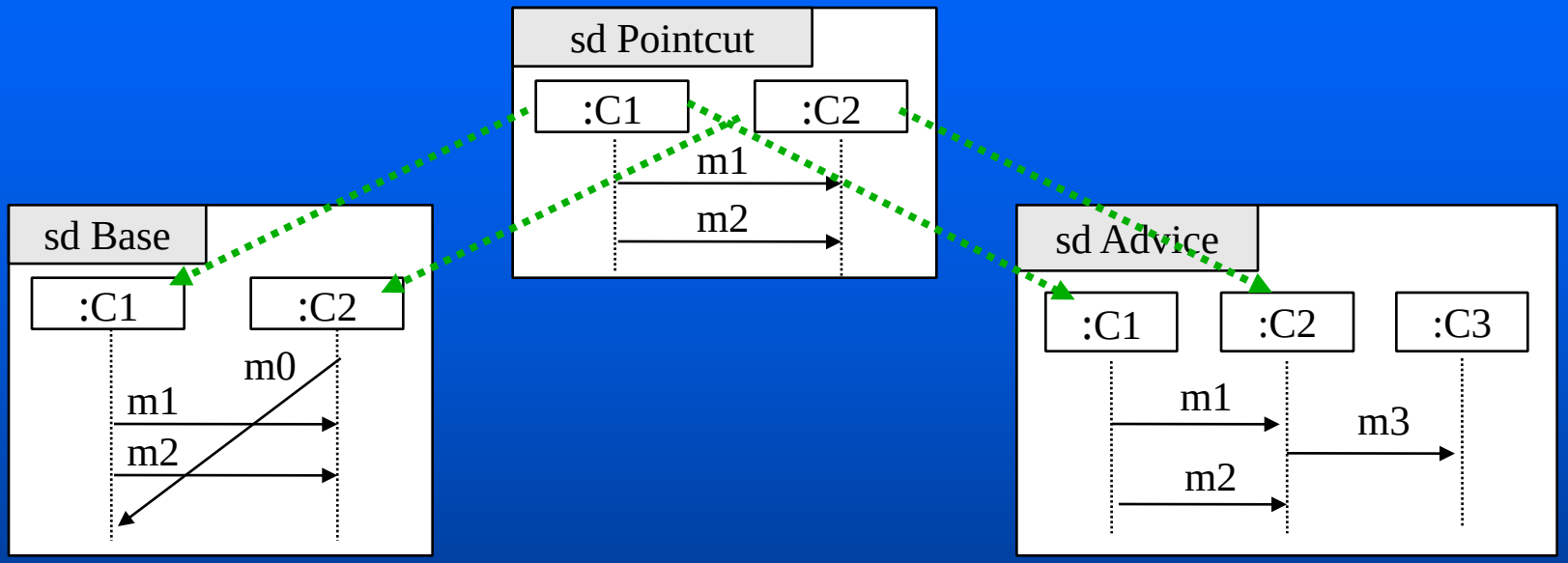


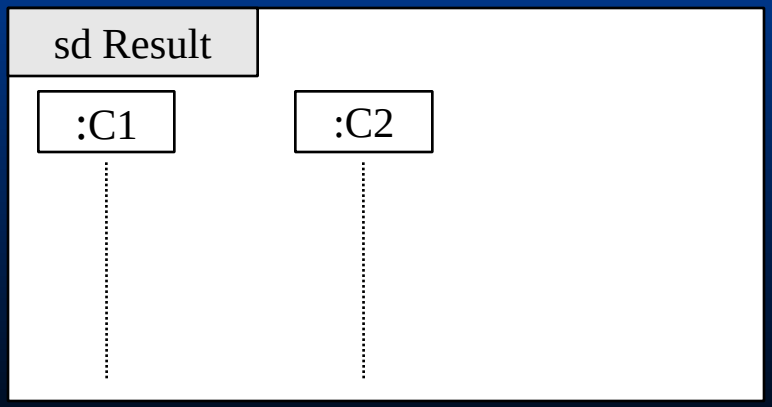




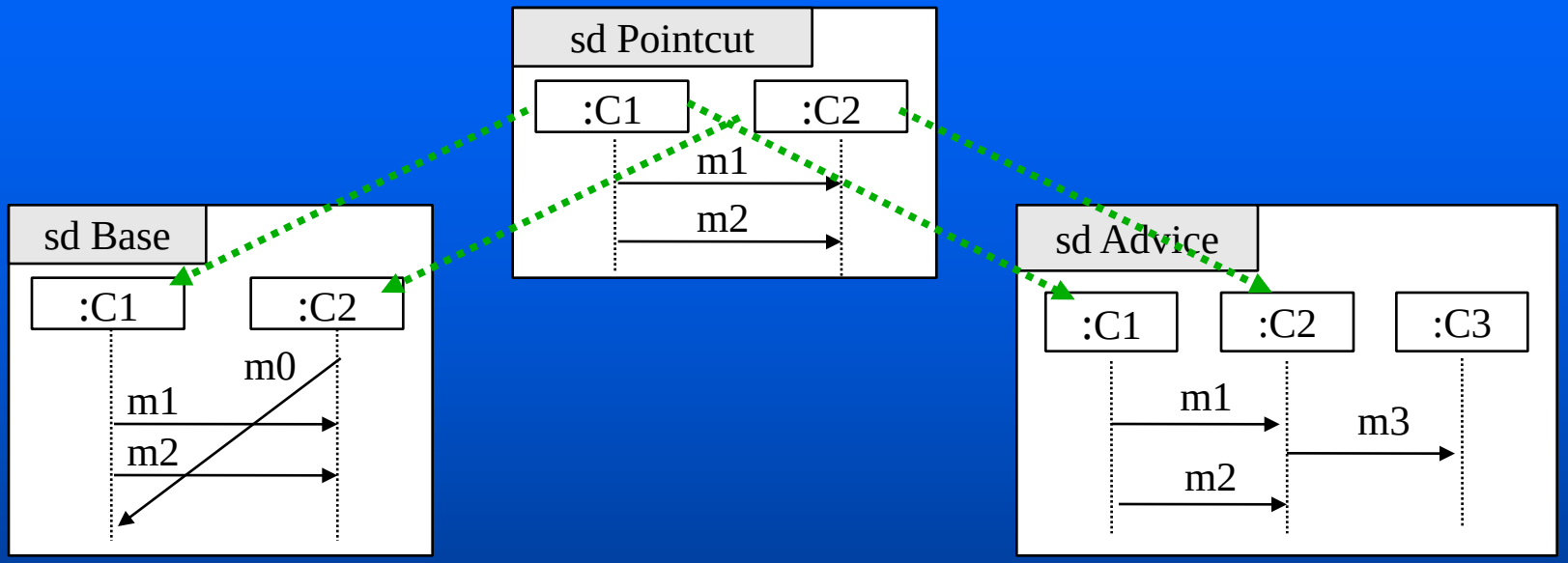


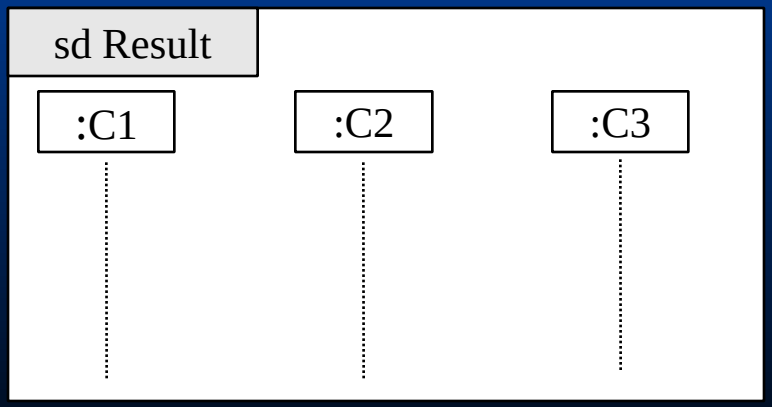
Amalgamed Sum



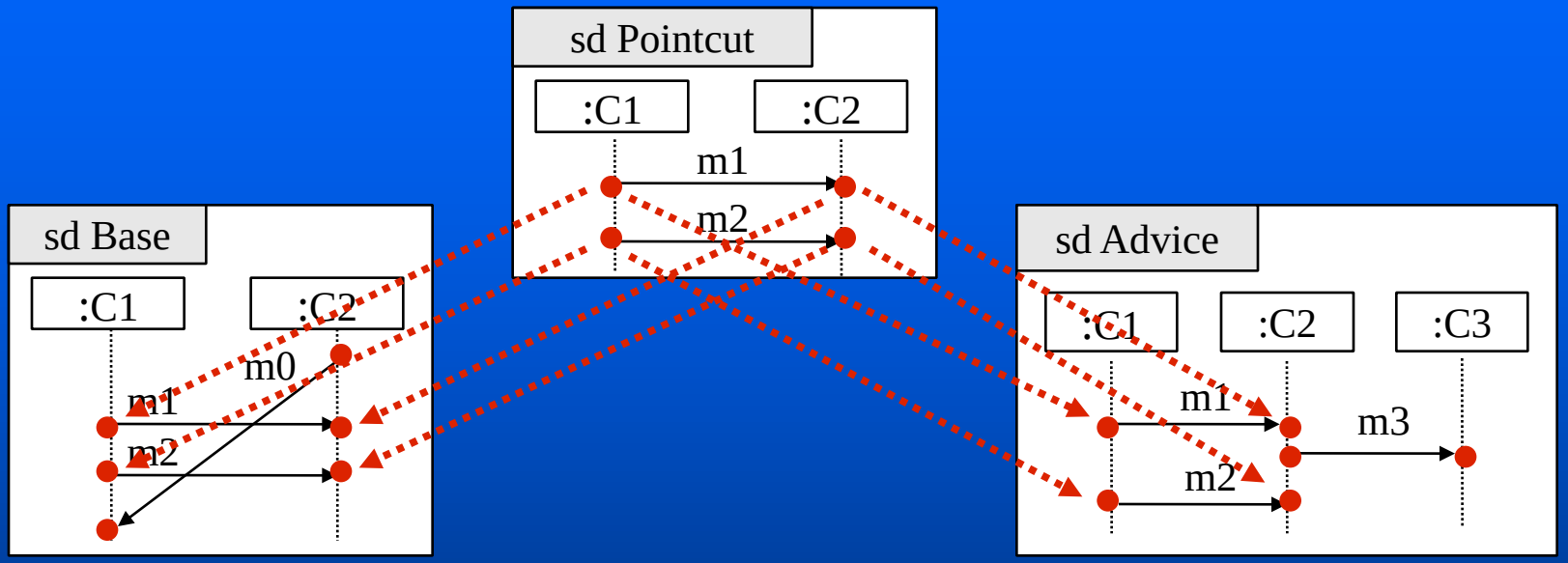


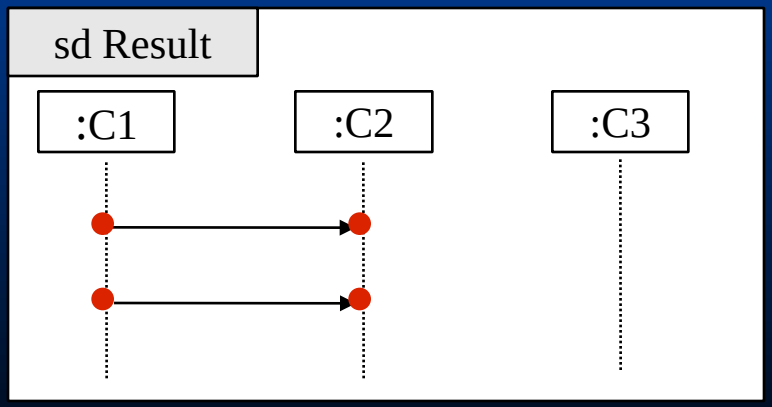
Amalgamed Sum



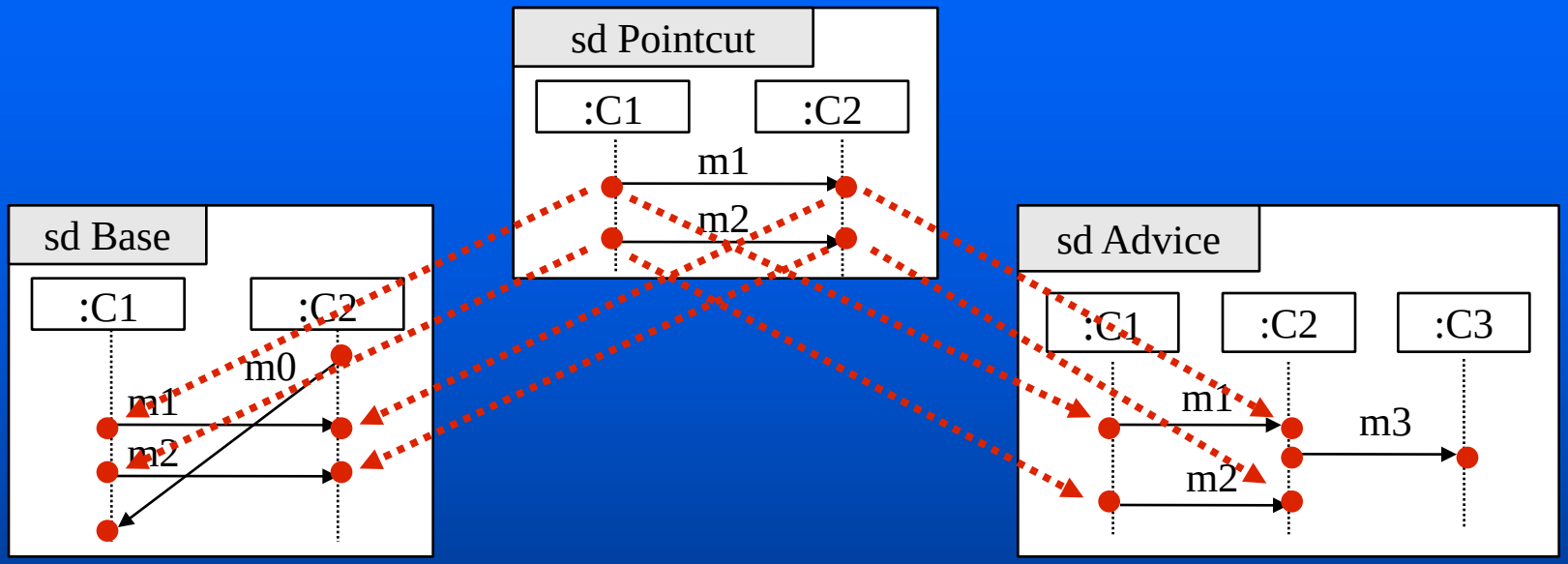


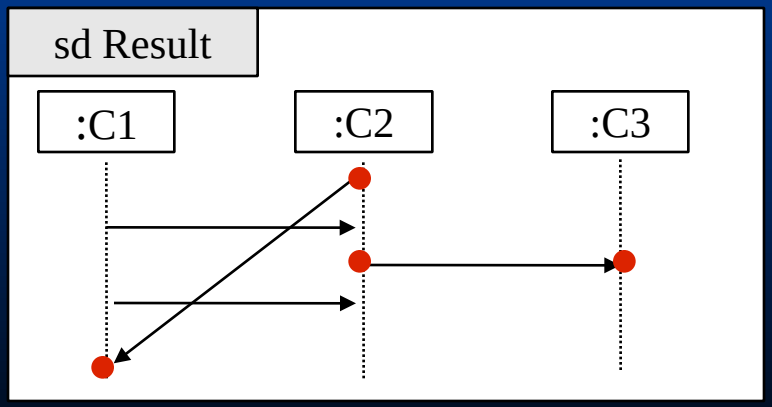
Amalgamed Sum



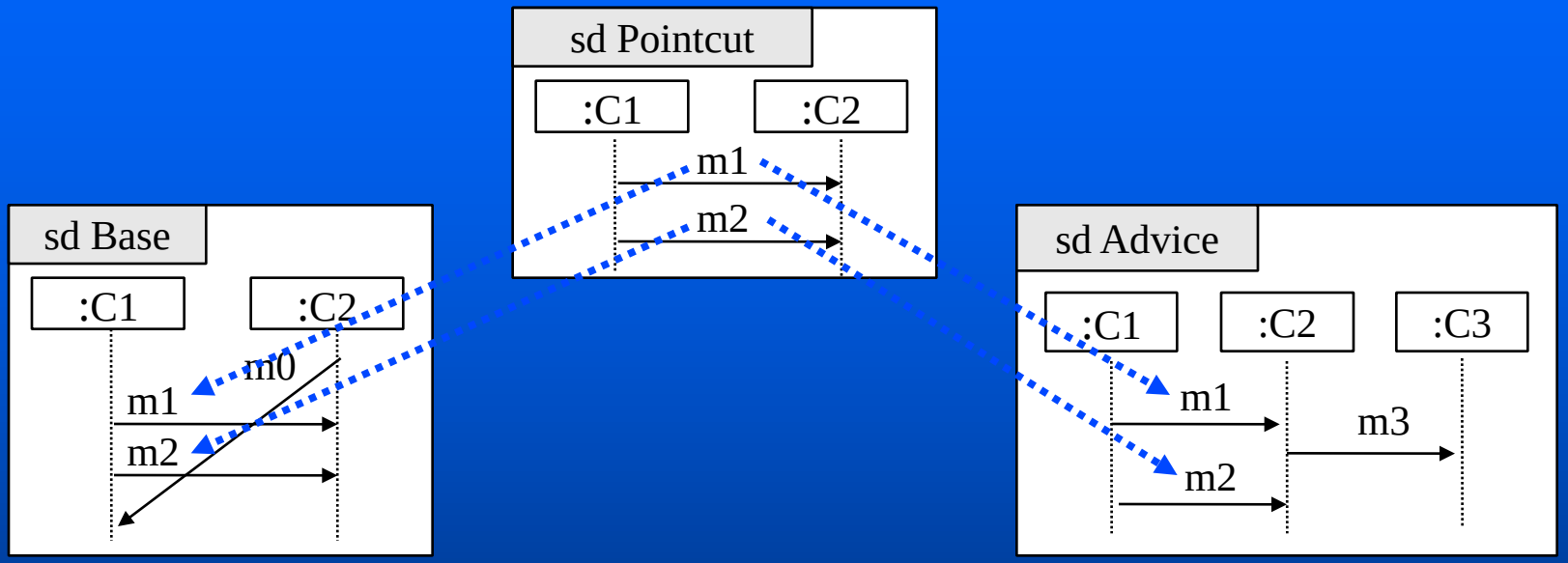


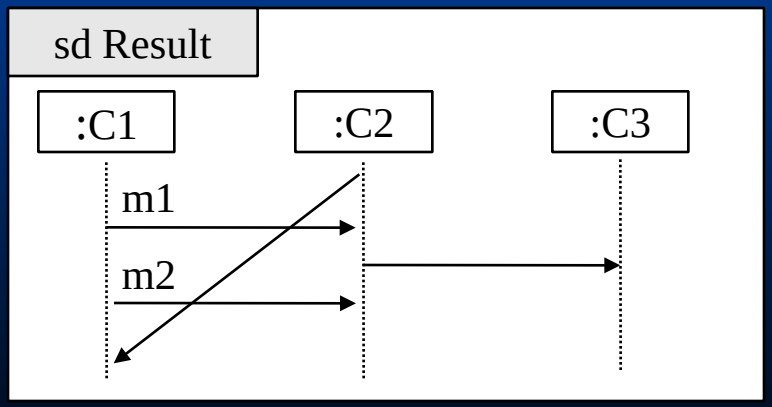
Amalgamed Sum



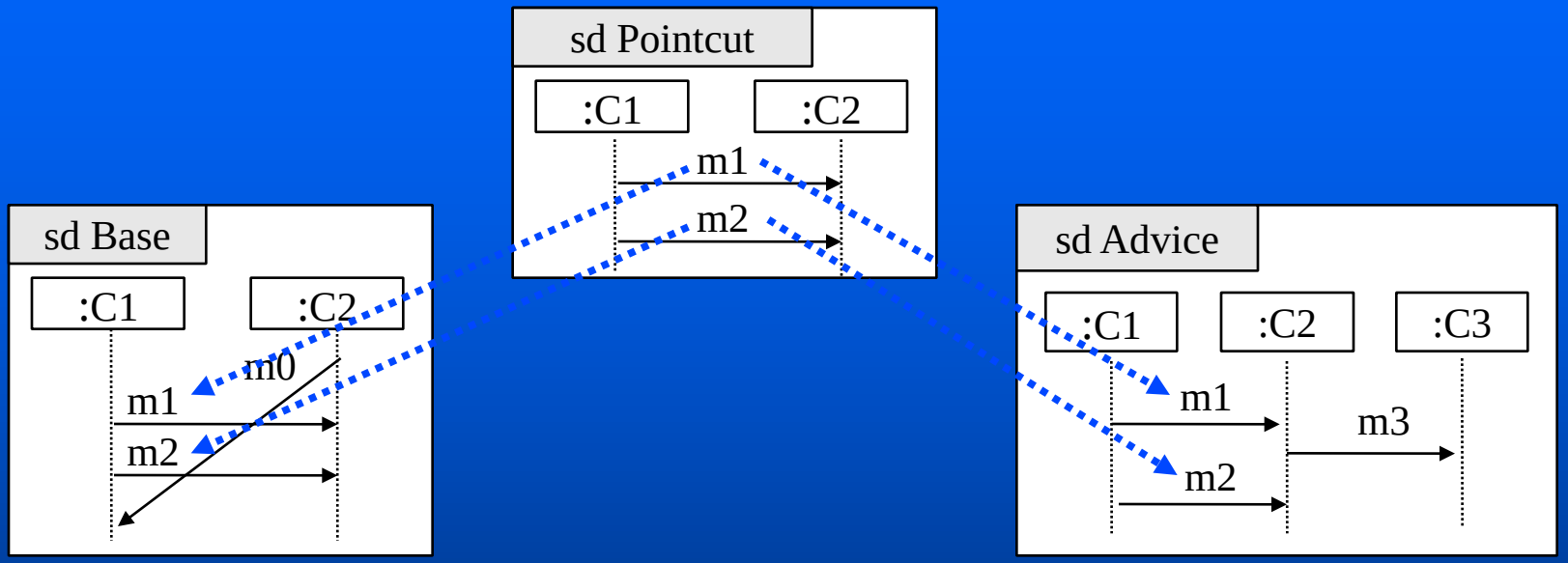


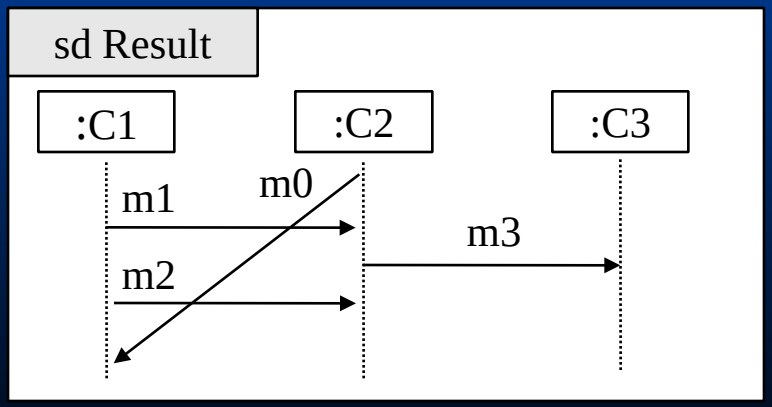
Amalgamed Sum



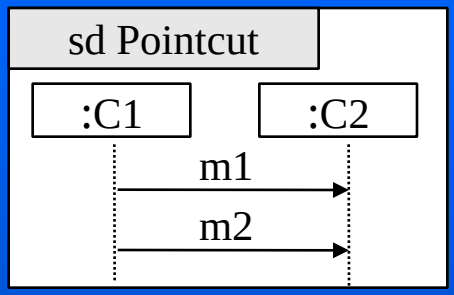


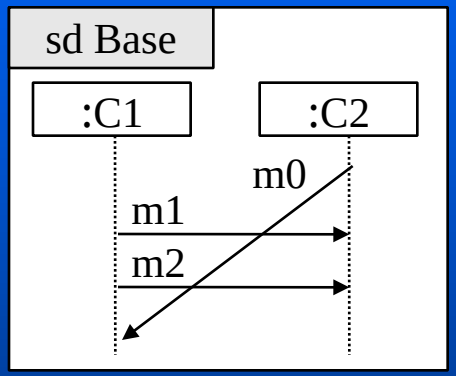
Amalgamed Sum

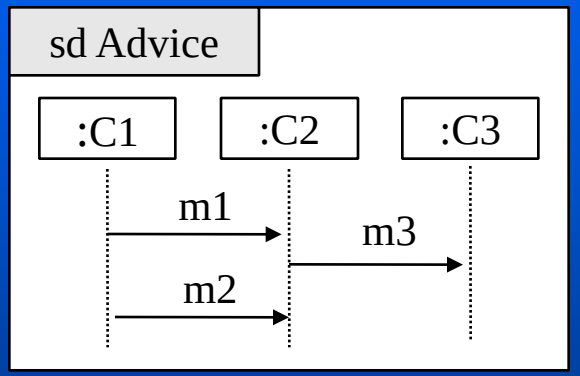


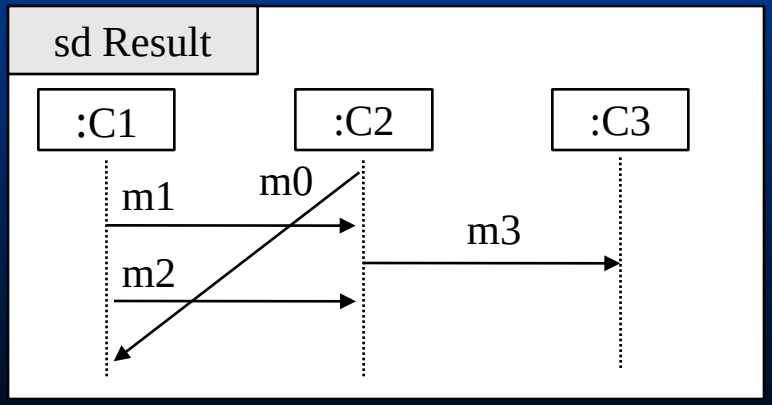


Amalgamed Sum

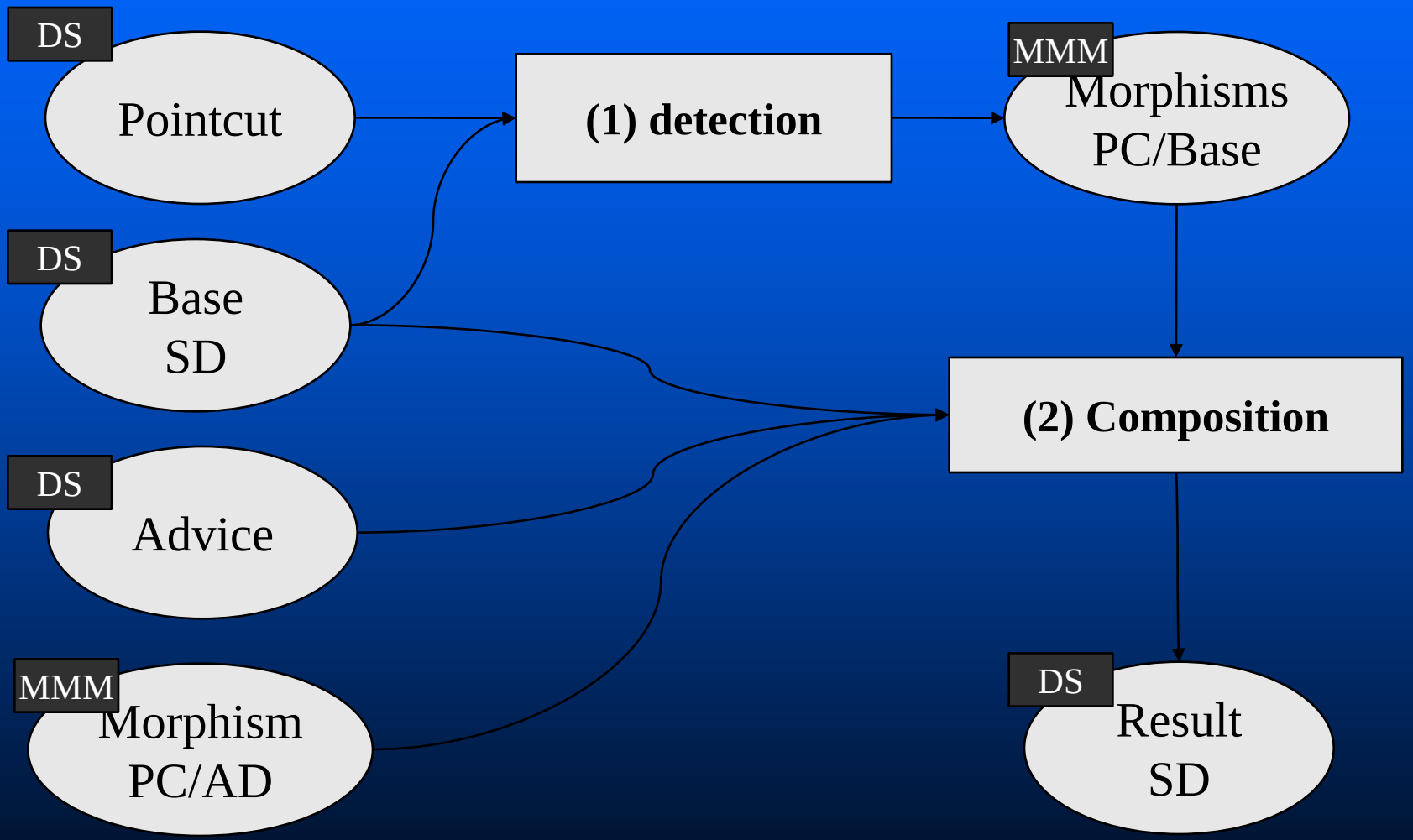








Implementation



KerMeta in a NutShell

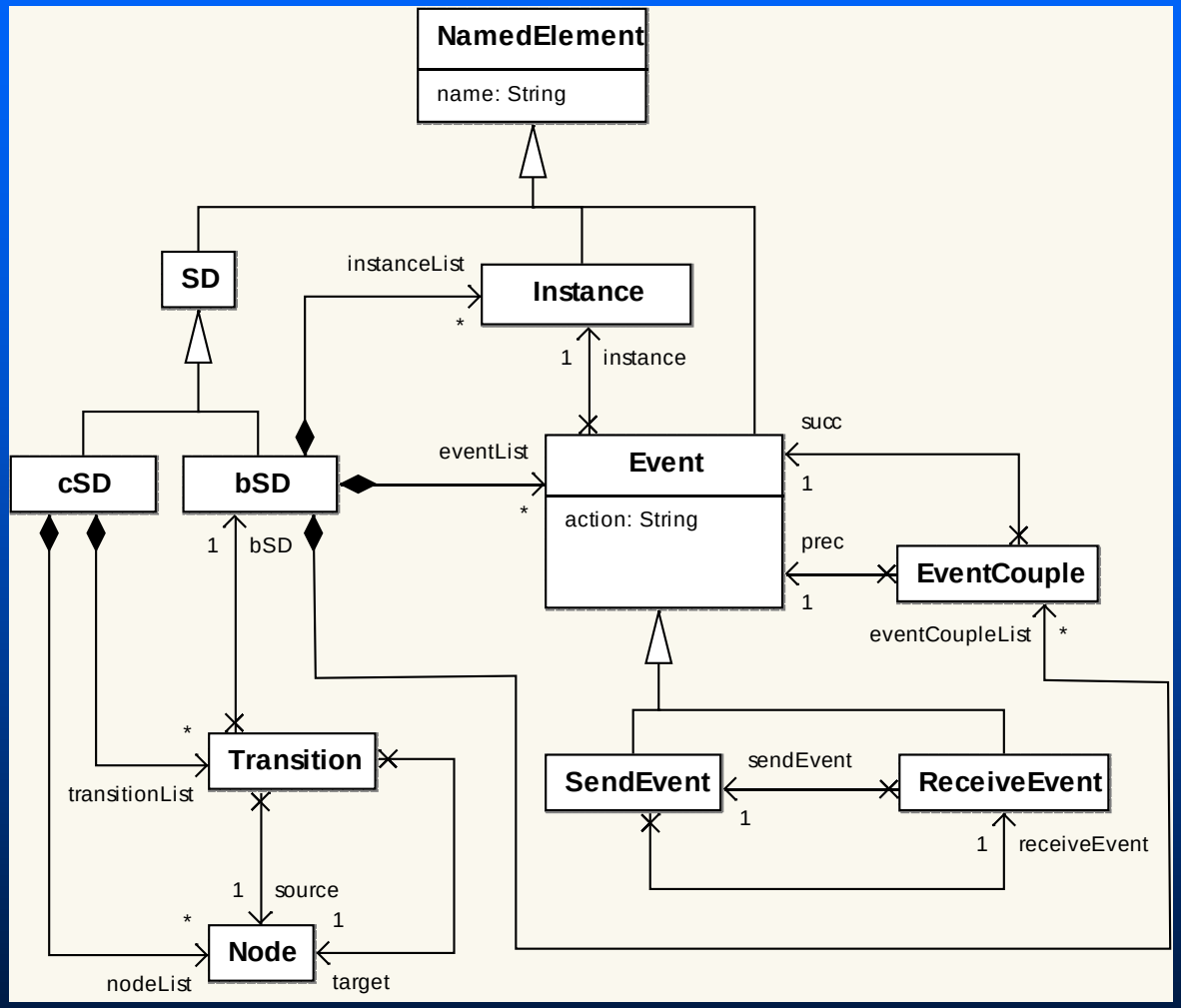
- EMOF superset
  - Any EMOF MetaModel is a valid KerMeta program, and conversely
- Object-Oriented
  - Multiple inheritance / behavior selection
  - Operation overiding / late binding
  - Full reflection (read-only at this time)
- Statically Typed
  - Generics
  - Function types to allow OCL's *forall/exist/iterate*

“Programming style” Issues

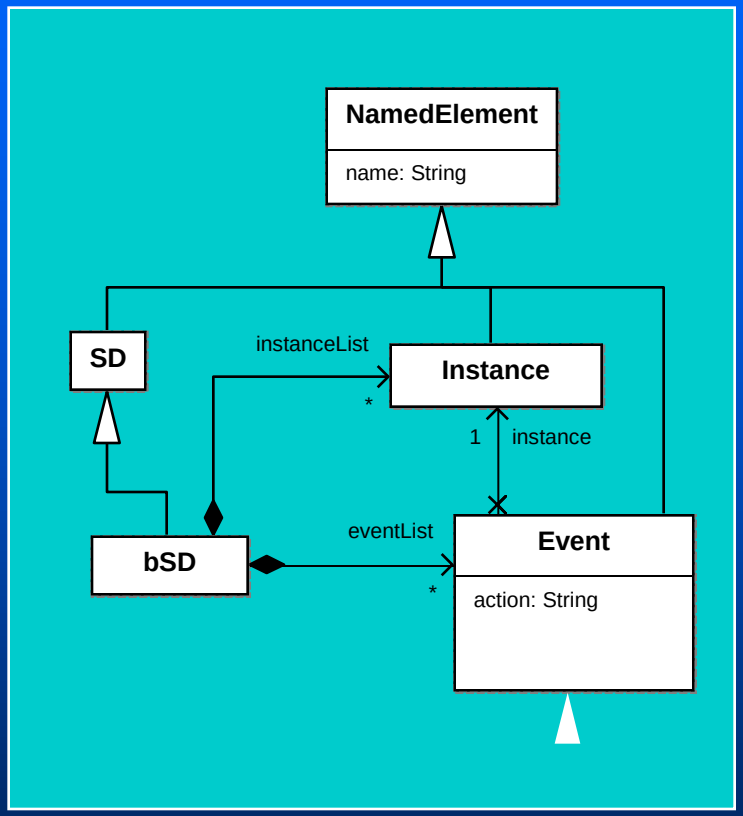
- The transformation is simply the model of an object-oriented program that manipulates model elements
  - Navigation through model is first class though (like in OCL)
- OO techniques
  - Customizability through inheritance/dyn. binding
  - Pervasive use of GoF like Design Patterns

Defining the metamodels

input and output metamodels are the same

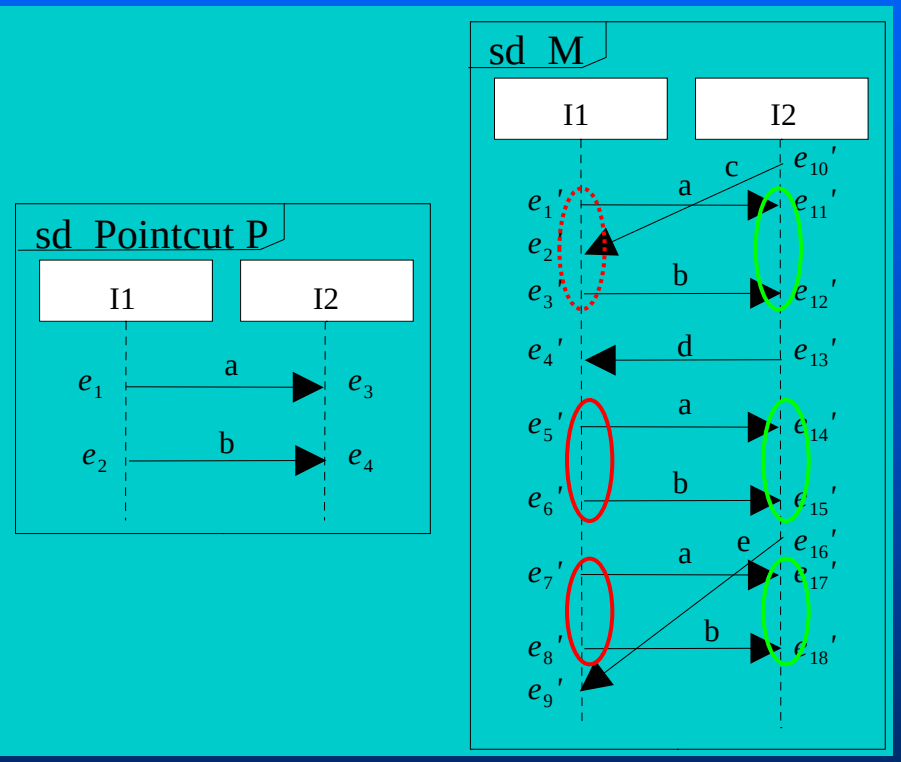


Visual/Textual



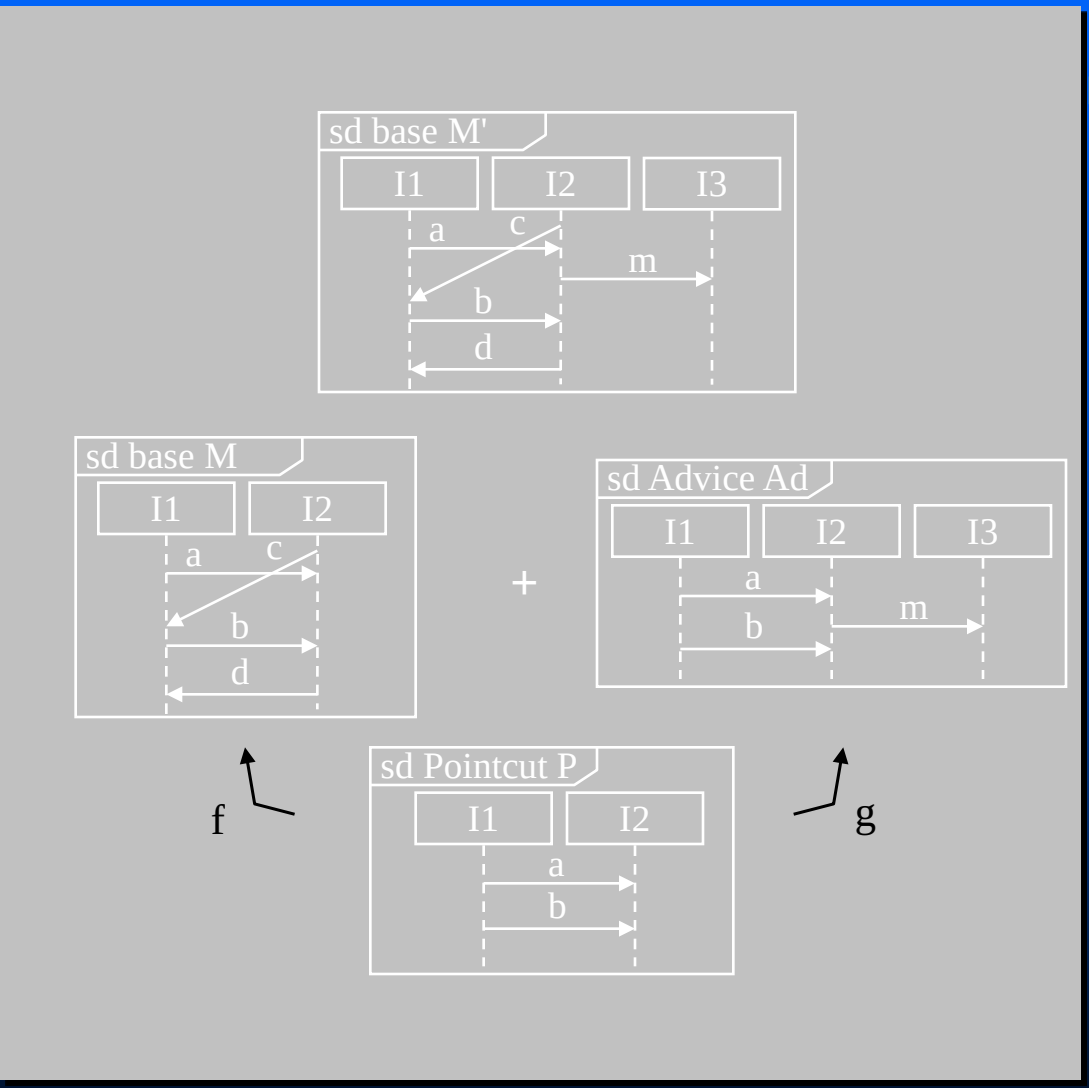

```
package bigSd;
using kermeta::standard
using kermeta::persistence
abstract class NamedElement
{
    attribute name : String[1..1]
}
abstract class SD inherits NamedElement
{}
class BSD inherits SD
{
    attribute events : Event[0..*]
    attribute couples : EventCouple[0..*]
    reference instances : Instance[0..*]
                                ...
}
abstract class Event inherits NamedElement
{
    attribute action : String[1..1]
    reference onInstance : Instance[1..1]
    ...
}
```

Sequence Diagrams Weaving



- Choice of the join point policy
- Detection step:
  - for each object, we compute the sets of (successive or not) events which have the same label as the events of P
  - compute the minimum set of events, called Jm, which satisfies the properties related to the join point policy
  - build isomorphism μ from P to Jm
  - repeat on M-Jm while Jm is not empty

Sequence Diagrams Weaving

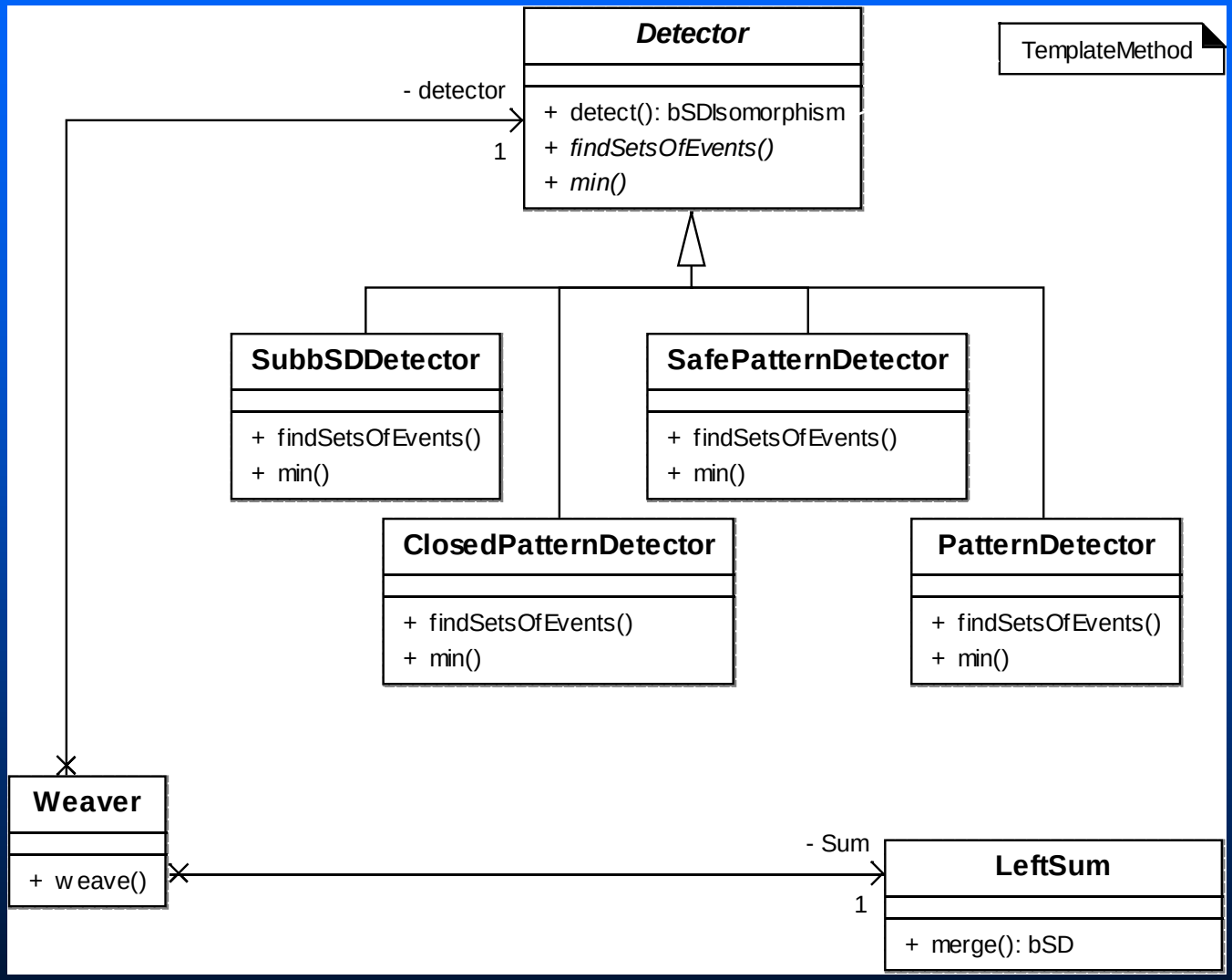


- Composition step: amalgamated sum
  - use P and two morphisms f and g (f being computed by the detection step)
  - keep the common parts between M and Ad
  - add new object I3
  - add the events of M by respecting the order specified on M
  - add the events of Ad by respecting the order specified on the advice

Object-orientation

- Classes and relations, multiple inheritance, late binding, static typing, class genericity, exception, typed function objects
- OO techniques such as patterns, may be applied to model transformations
  - Template method to encapsulate basic *detect* algorithm
    - » Substeps redefined in subclasses

SD Weaver Architecture



Writing the transformation: Weaver

```
require kermeta   require "../models/bigSd.kmt" require "../detectionAlgorithm/Detection.kmt"
require "../amalgamatedSum/LeftSum.kmt"
using kermeta::standard    using bigSd

class Weaver {
 operation weave(base : BSD, pointcut : BSD, advice : BSD, g : BSDMorphism) : BSD is do
        result := BSD.new                                                          Initialization
        //Choice of join point policy
        var detection: Detection init ClosedPatternDetection.new
        var sum: LeftSum init LeftSum.new
        var f: BSDMorphism init BSDMorphism.new
        var setOfMorphism : Set< BSDMorphism > init Set< BSDMorphism >.new

        //Detection Step                                                           Detection Step
        f:= detection.detect(pointcut, base)
        while (f != null)
              setOfMorphism.add(f)
              f:= detection.detect(pointcut, minus(base,f))
        end

        //Composition Step                                                         Composition Step
        setOfMorphism.each{f | result := sum.merge(result, pointcut, advice, f, g)
end
```

Writing the transformation: Detection

```
require kermeta     require "../models/bigSd.kmt"
using kermeta::standard     using bigSd
abstract class Detector{                                                    abstract method
  operation findSetOfEvent(evtsOfP: Set<Event>, evts: Set<Event>): Set<Set<Event>>is abstract
  operation min(setOfEvent: Set<Set<Event>>) : Set<Event> is abstract
  operation detect (pointcut : BSD, base : BSD) : BSDMorphisms is do
        result := BSDMorphisms.new                                          initialization
        var evts : Set<Event> init Set<Event>.new  var evtsOfP : Set<Event> init Set<Event>.new
        var V : Set<Set<Event>> init Set<Set<Event>>.new
        var setOfEvent: Set<Set<Set<Event>>> init Set<Set<Set<Event>>>.new
        pointcut.instances.each{ instance |
              //projection on an instance
              evts := base.events.select{e|e.onInstance== instance}
              evtsOfP := pointcut.events.select{e|e.onInstance== instance}
              //sets of events which have the same action name as the events of P on instance
              // findSetsOfEvent depends of the join point definition
              V := findSetsOfEvent(evtsOfP, evts)
              setOfEvent.add(V)
        }
    // take the first set of events satisfying the properties     // min depends of the join point definition
    Epart=min(setOfEvent)
    // build the isomorphism from pointcut to Epart
   result := buildIsomorphism(pointcut, Epart)
  end
```

Writing the transformation: amalgamated Sum

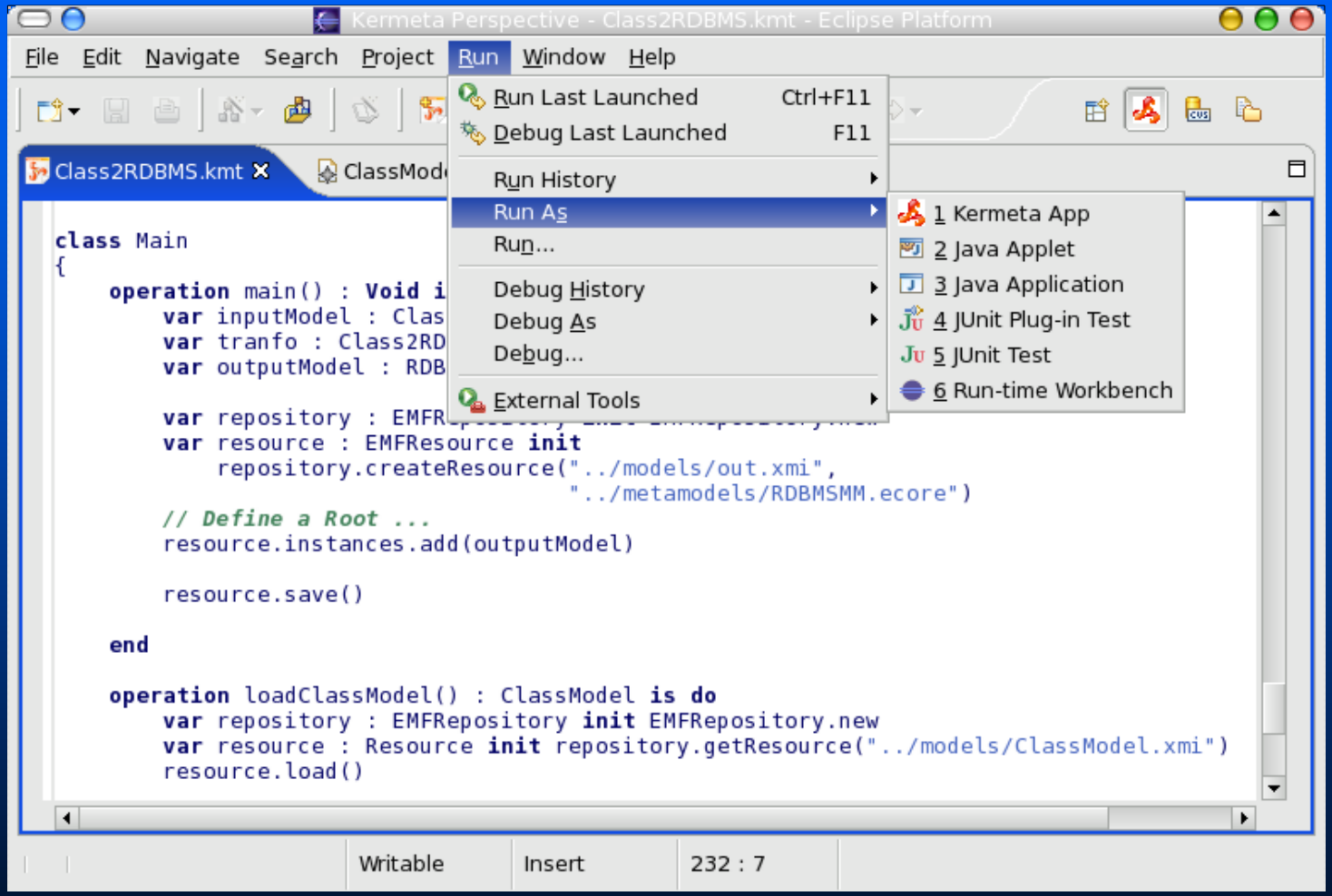
```
require kermeta   require "../models/bigSd.kmt"
using kermeta::standard    using bigSd
class LeftSum {
 operation merge(base : BSD, pointcut : BSD, advice : BSD, f : BSDMorphism, g : BSDMorphism) : BSD is do
        result := BSD.new
        var map: MyHashtable init MyHashtable.new

        result.name:= "woven-"+  base.name                                    new instances set
        result.copyInstances(base.instances)
        result.copyInstances(self.complementaryUnion(advice.instances,g.rinstancesMappings))

                                                                              new events set
        result.copyEvents2(self.complementaryUnion(base.events,f.reventsMappings),void,void)
        result.copyEvents2(self.complementaryUnion(advice.events,g.reventsMappings),g.rinstancesMapping
                                        s,f.instancesMappings)
        result.copyEvents2(self.twoTimesMapped(base.events,f.reventsMappings,g.eventsMappings),void,void)

                                                                              new events order
        result.events.each{ event |
                if SendEvent.isInstance(event) then
                        var e: SendEvent
                        e?= event
                        result.addCouple(e,e.receiveEvent)
                end
         ...
end
```

Executing the transformation



Smoothly interoperates with Eclipse/EMF
Open Source
- **Download it *now!***

A statically typed object-oriented executable meta-language

- Home page
  - http://www.kermeta.org
- Development page
  - http://kermeta.gforge.inria.fr/

References

- Jean-Marc Jézéquel. -- Model driven design and aspect weaving. -- *Journal of Software and Systems Modeling (SoSyM)*, 7(2):209--218, may 2008.
- Jacques Klein, Franck Fleurey, and Jean Marc Jézéquel. -- Weaving multiple aspects in sequence diagrams. -- *Transactions on Aspect-Oriented Software Development (TAOSD)*
- Jörg Kienzle, Wisam Al Abed and Jacques Klein. -- Aspect-Oriented Multi-View Modeling. – *Proc. of AOSD'09*, March 2009, Charlottesville, USA