

Concurrency-aware eXecutable Domain-Specific Modeling Languages as Models of Concurrency

2nd International Workshop on Executable Modeling (EXE 2016)

co-located with MODELS 2016 in Saint-Malo, France

@see: <http://gemoc.org/exe16/>

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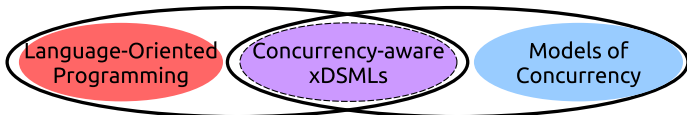
OVERVIEW

THE GEMOC CONCURRENCY-AWARE xDSML APPROACH

TAILORING MODELS OF CONCURRENCY TO xDSMLS

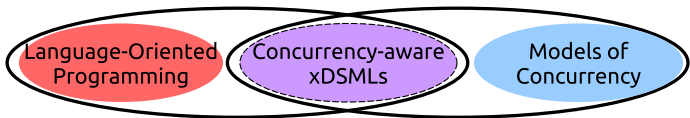
CONCLUSION AND PERSPECTIVES

A Synergetic Language Design Approach

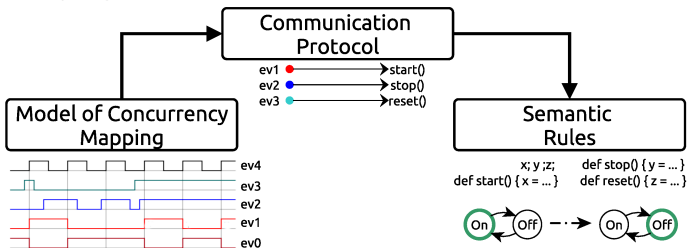


- ▶ Introduced by Benoit Combemale *et al.* in SLE 2012 and 2013.
- ▶ xDSML design approach with a **separation of concerns** in the operational semantics.
- ▶ Concurrency concerns expressed using a Model of Concurrency **at the language level**.

A Synergetic Language Design Approach



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THE GEMOC CONCURRENCY-AWARE xDSML APPROACH

Overview of the Approach

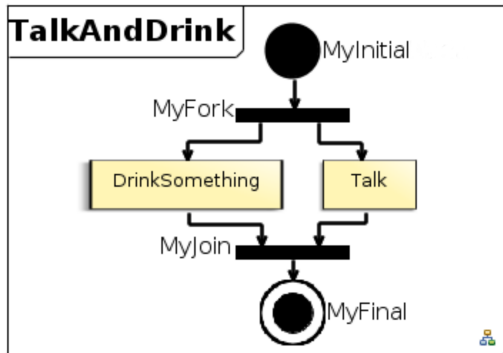
Specification

Execution

Benefits

STRUCTURAL ELEMENTS

Example xDSML:

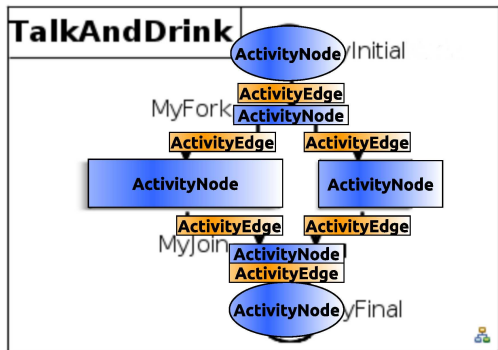


- ▶ Concrete Syntax(es)
- ▶ Abstract Syntax (*metamodel*)

The concurrent aspects are *underspecified*.
⇒ Several possible executions.

STRUCTURAL ELEMENTS

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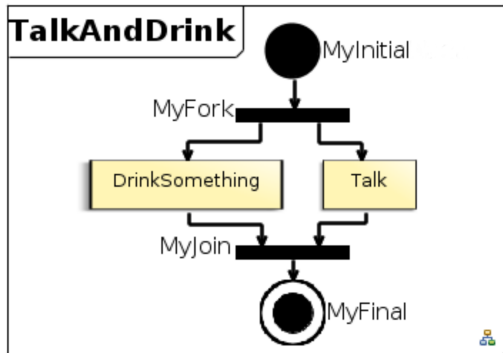


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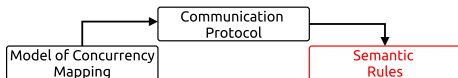
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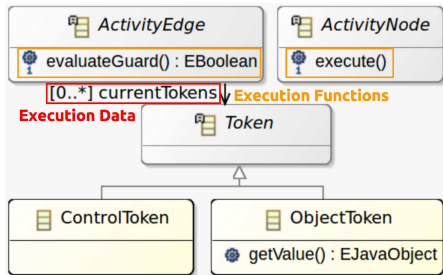
SEMANTIC RULES



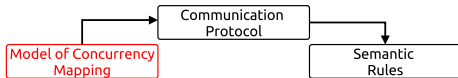
Definition

Dynamic data (**Execution Data**) and their evolution (**Execution Functions**).

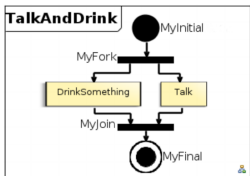
- ▶ fUML Execution Data:
Tokens held by ActivityEdges.
- ▶ fUML Execution Functions:
ActivityNode.execute(),
ActivityEdge.evaluateGuard().



MODEL OF CONCURRENCY APPLICATION & MAPPING



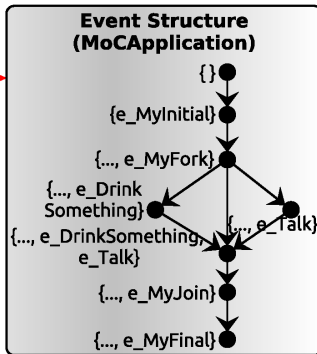
- ▶ MoCApplication: Concurrent aspects of a model.
- ▶ Conforms to a Model of Concurrency (initially only **Event Structure**).
- ▶ Generated based on the **MoCMapping** (EventType Structure).



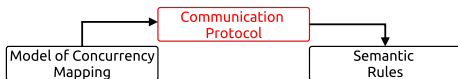
applied to

EventType Structure (MoCMapping)
 for every edge:
 execute source before target

generates

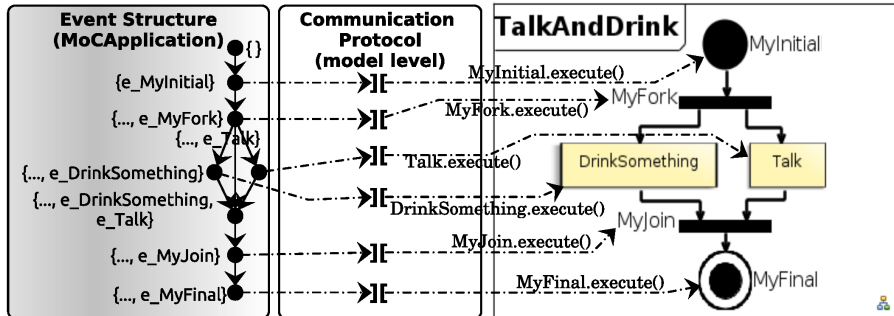


COMMUNICATION PROTOCOL

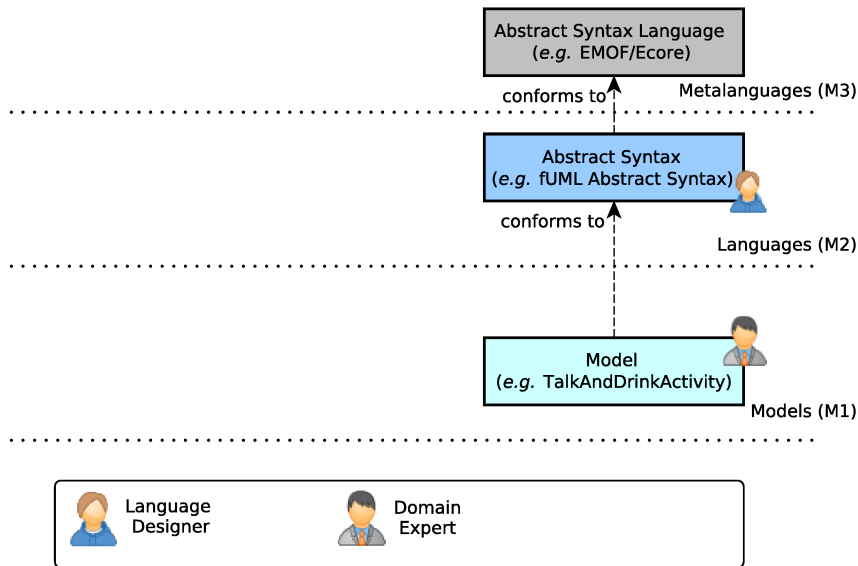


Definition

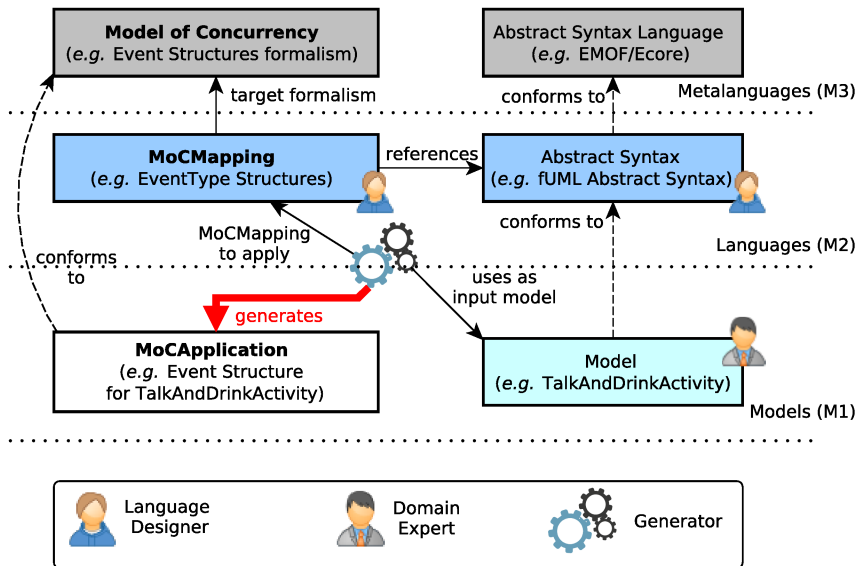
Mappings between the **MoCTriggers** (abstract actions of the MoCMapping) and the **Execution Functions** (concrete actions of the Semantic Rules).



THE CONCURRENCY-RELATED SPECIFICATIONS



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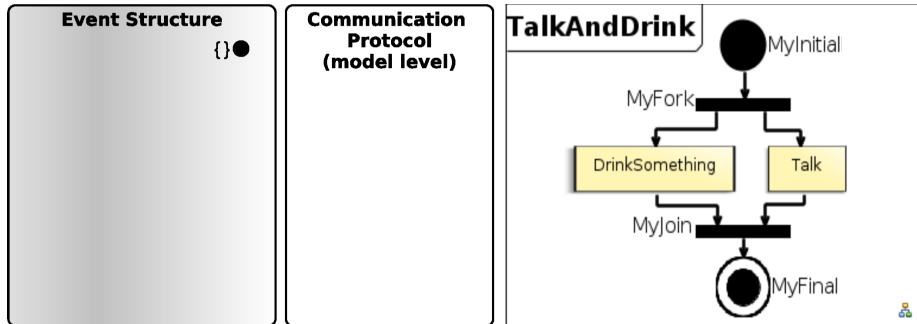
Specification

Execution

Benefits

EXECUTION

The runtimes for each concern are coordinated by the **Execution Engine**.

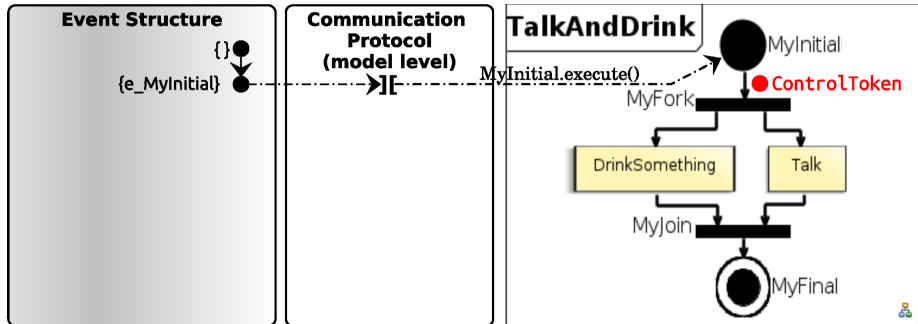


Possible execution step(s):

$e_MyInitial \rightarrow \mathbb{I} \rightarrow MyInitial.execute()$

EXECUTION

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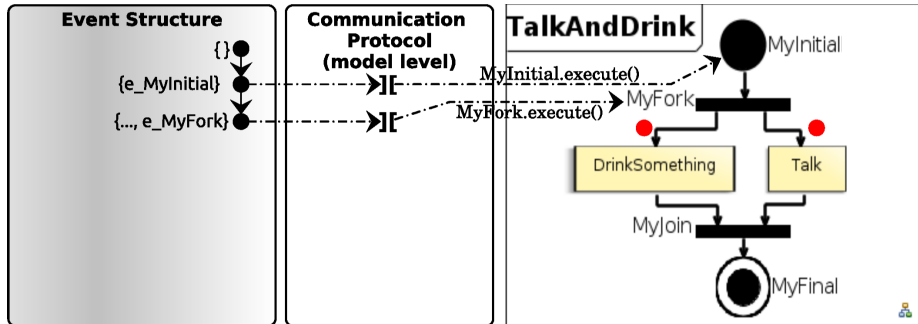


Possible execution step(s):

$e_MyFork \rightarrow \llbracket \rrbracket \rightarrow MyFork.execute()$

EXECUTION

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Possible execution step(s):

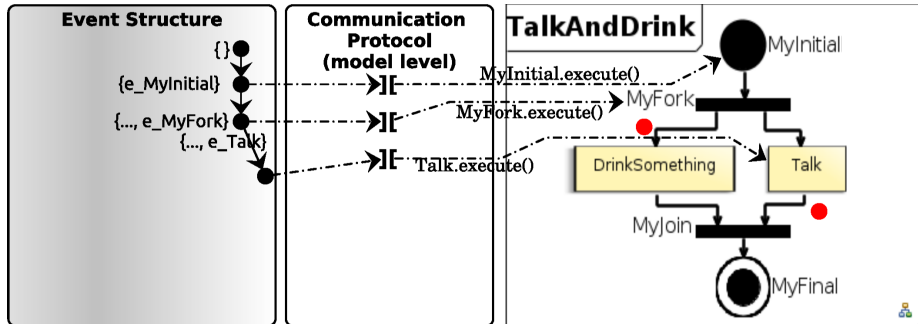
$e_Talk \rightarrow]] \rightarrow \text{Talk.execute}()$

OR $e_DrinkSomething \rightarrow]] \rightarrow \text{DrinkSomething.execute}()$

OR both

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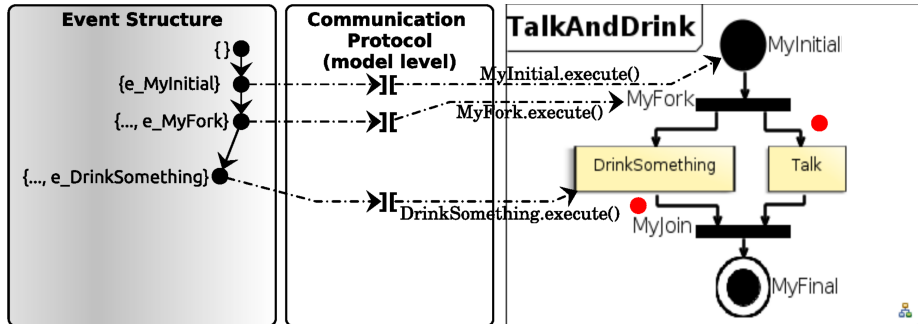
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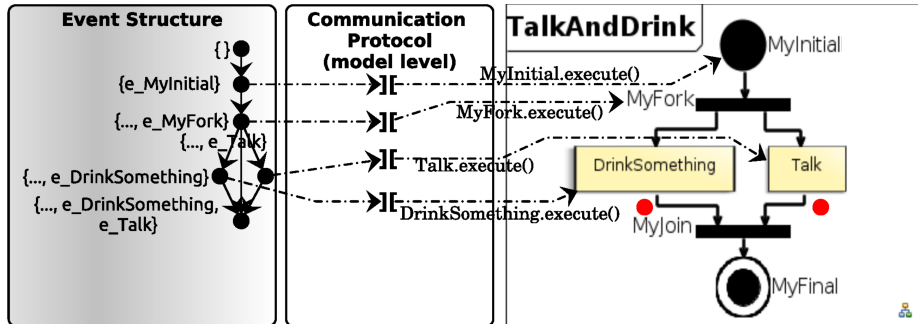
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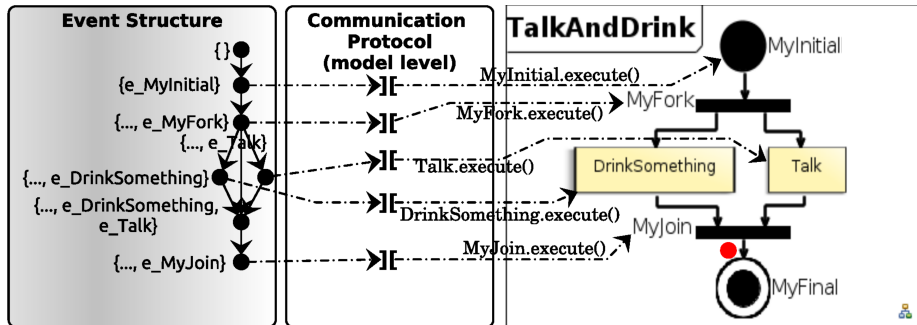


Possible execution step(s):

$$e_MyJoin \rightarrow \parallel \rightarrow MyJoin.execute()$$

EXECUTION

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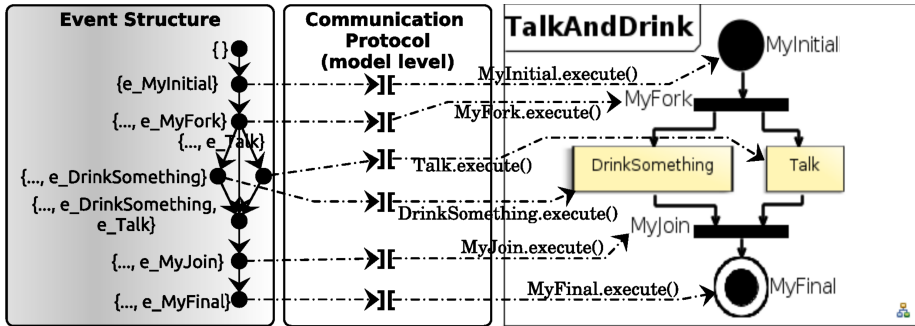


Possible execution step(s):

$e_MyFinal \rightarrow \parallel \rightarrow MyFinal.execute()$

EXECUTION

The runtimes for each concern are coordinated by the **Execution Engine**.



Possible execution step(s):

\emptyset

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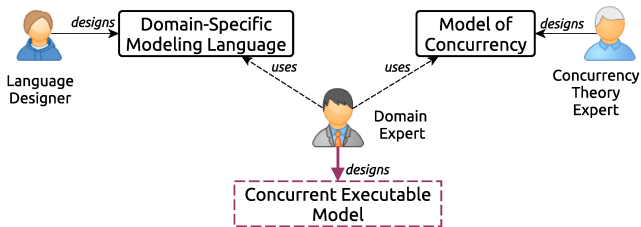
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SYSTEMATIC USE OF A MODEL OF CONCURRENCY

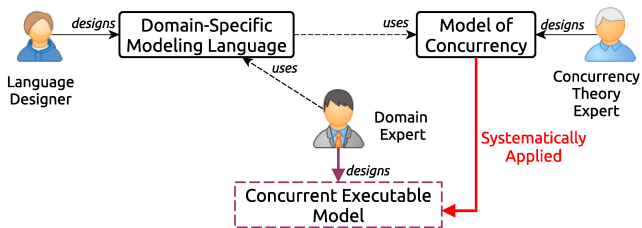
- ▶ Concurrency concepts are not manipulated by the domain experts.
- ▶ By construction, the MoC is used correctly.



- ▶ The different concerns can be implemented and debugged separately.
- ▶ Depending on the Model of Concurrency used, behavioral properties may be assessed.

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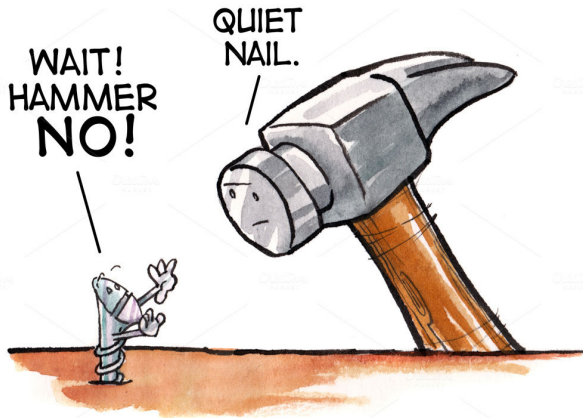
TAILORING MODELS OF CONCURRENCY TO xDSMLS

Motivation

Illustration and Generalization

Validation and Implementation

ADEQUACY OF A MODEL OF CONCURRENCY



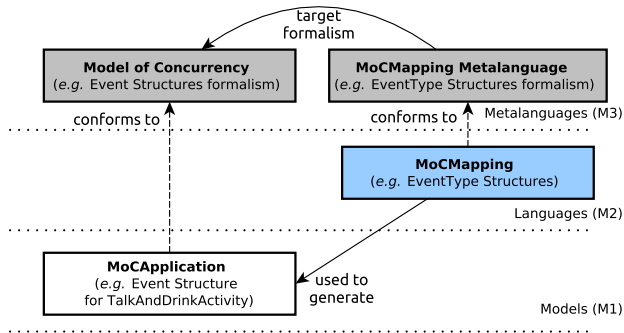
- ▶ In “Why Do Scala Developers Mix the Actor Model with Other Concurrency Models?”, *inadequacies* of the actor model.
- ▶ In the GEMOC project, MoCCML was designed as a merge of CCSL and automata.

INTEGRATION OF NEW MODELS OF CONCURRENCY

Defining and integrating a
Model of Concurrency

=

MoC + MoCMapping + tools
(rich editor, generator, runtime)

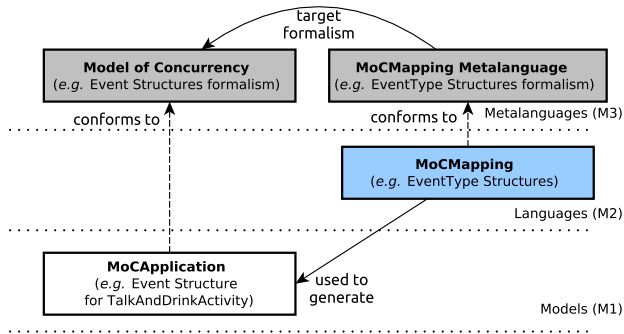


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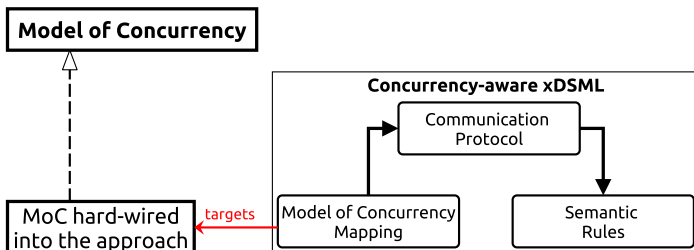
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- ▶ MoCMapping metalanguage often not pre-existing.
- ▶ Identifying the MoCTriggers of the MoCMapping.

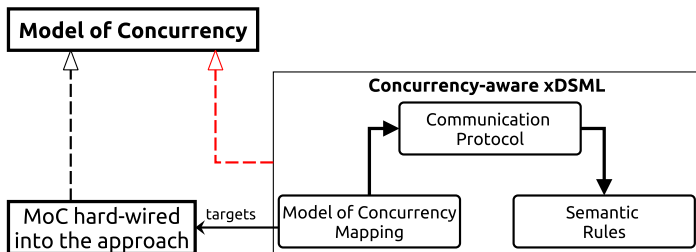
A RECURSIVE DEFINITION OF THE APPROACH



For an xDSML $\mathcal{L}_{\text{DOMAIN}}$:

- ▶ MoC \rightarrow Another concurrency-aware xDSML, hereafter \mathcal{L}_{MoC} .
- ▶ MoCMapping \rightarrow Model transformation from $\mathcal{L}_{\text{DOMAIN}}$ to \mathcal{L}_{MoC} .
- ▶ MoCTriggers \rightarrow Mappings of the Communication Protocol of \mathcal{L}_{MoC} .
- ▶ MoCApplication \rightarrow Model conforming to \mathcal{L}_{MoC} .
- ▶ Runtime \rightarrow Execution Engine of \mathcal{L}_{MoC} .

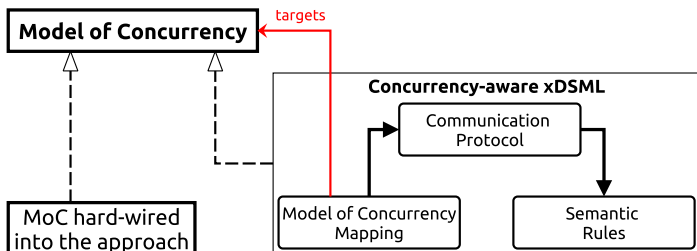
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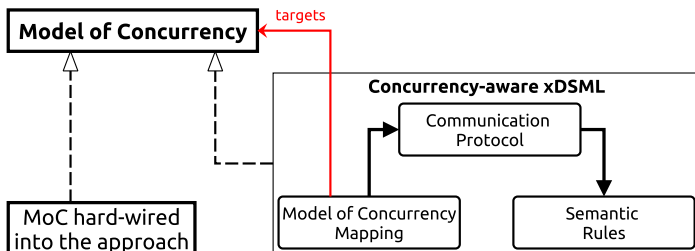
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ILLUSTRATION ON fUML

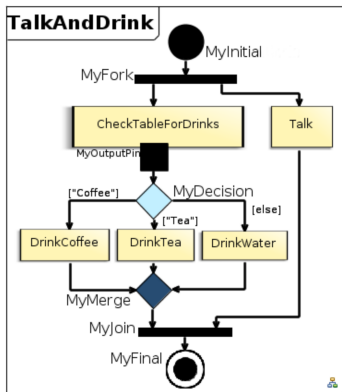
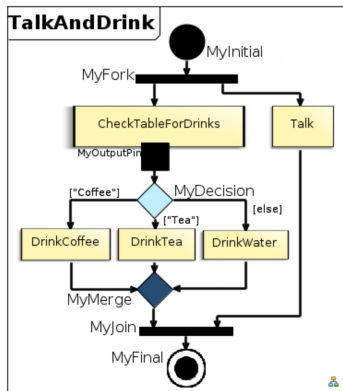
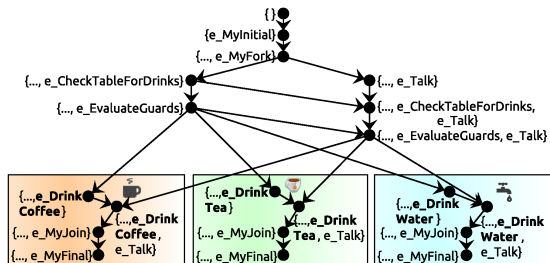


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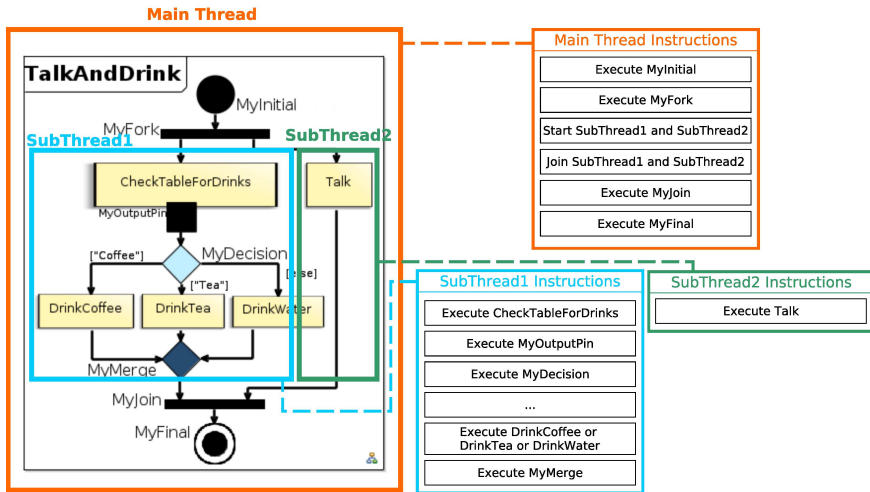


With the Event Structures MoC...




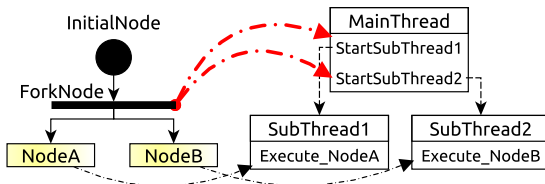
...obtained after manual “translation” of the fUML specification.

ILLUSTRATION ON FUML




LANGUAGE SPECIFICATIONS

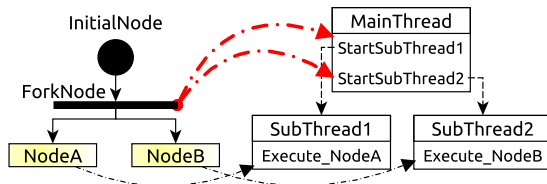
- ▶ MoCMapping: Model transformation from $\mathcal{L}_{\text{DOMAIN}}$ to \mathcal{L}_{MoC} .
- ▶  Used to capture *exclusively* the concurrency aspects. The source and the target are thus *not semantically equivalent*.
- ▶ **Projections:** part of the metamodel of the trace of the MoCMapping. Used to compensate the $1 \rightarrow n$ nature of the MoCMapping.



- ▶ Communication Protocol: Mappings (of $\mathcal{L}_{\text{DOMAIN}}$) connect an Execution Function (of $\mathcal{L}_{\text{DOMAIN}}$) to a Mapping of \mathcal{L}_{MoC} through a Projection).

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VALIDATION ON FUML

new FUML_diagram 11

```

    graph TD
        MyInitialNode((MyInitialNode)) --> MyFork[MyFork]
        MyFork -- ControlToken@112482912 --> CheckTableForDrinks[CheckTableForDrinks]
        MyFork -- MyFork@2091 --> MyDecision{MyDecision}
        MyDecision -- "Coffee" --> DrinkCoffee[DrinkCoffee]
        MyDecision -- "Tea" --> DrinkTea[DrinkTea]
        MyDecision -- "else" --> DrinkWater[DrinkWater]
        DrinkCoffee --> MyMerge{MyMerge}
        DrinkTea --> MyMerge
        MyMerge --> MyJoin[MyJoin]
        DrinkWater --> MyJoin
        MyJoin --> MyFinal((MyFinal))
    
```

Console 11

```

    Default MessagingSystem console
    Starting Thread: MainThread_TalkAndDrinkActivity
    *** InitialNode [MyInitialNode]***
    Executing Task: ExecutionTask_MyInitialNode
    *** ForkNode [MyFork]***
    Starting Thread: Thread_MyFork_MyFork2Check
    Executing Task: StartThreadTask_Thread_MyFork_MyFork2Check
    Executing Task: StartThreadTask_Thread_MyFork_MyFork2Talk
    Starting Thread: Thread_MyFork_MyFork2Talk
    Executing Task: JoinThreadTask_Thread_MyFork_MyFork2Check
    
```

Execution Steps 11

```

    SchedulingSolution [2083921739]
    - ExecuteActivityNode_CheckTableForDrinks OpaqueAction->CheckTableForDrinks.execute():Void
    SchedulingSolution [1166716152]
    - ExecuteActivityNode_Talk OpaqueAction->Talk.execute():Void
    SchedulingSolution [2073553959]
    - ExecuteActivityNode_Talk OpaqueAction->Talk.execute():Void
    - ExecuteActivityNode_CheckTableForDrinks OpaqueAction->CheckTableForDrinks.execute():Void
    
```

Threaded diagram 11

ThreadSystem_TalkAndDrinkActivity

- MainThread_TalkAndDrinkActivity
 - Execute_MyInitialNode
 - StartThread_Thread_MyFork_MyFork2Check
 - StartThread_Thread_MyFork_MyFork2Talk
 - JoinThread_Thread_MyFork_MyFork2Check
 - Execute_MyFinal
- Thread_MyFork_MyFork2Talk
 - Execute_Tsk
- Thread_MyFork_MyFork2Check
 - Execute_CheckTableForDrinks
 - Execute_MyFork@2091
 - Execute_MyDecision
 - Execute_DisjunctionCoffee_EvaluateGuard
 - Disjunction_MayOrMayNotDrinkCoffee
 - ExecutionTask_MayDrinkCoffee
 - ExecutionTask_MayNotDrinkCoffee
 - Execute_DisjunctionTea_EvaluateGuard
 - Disjunction_MayOrMayNotDrinkTea
 - ExecutionTask_MayDrinkTea
 - ExecutionTask_MayNotDrinkTea
 - Execute_DisjunctionWater_EvaluateGuard
 - Disjunction_MayOrMayNotDrinkWater
 - ExecutionTask_MayDrinkWater
 - ExecutionTask_MayNotDrinkWater
 - Conditional_CoffeeTeaWaterAvailable
 - Disjunction_DrinkCoffeeOrTea
 - Execute_DrinkCoffee
 - Execute_DrinkTea
 - Conditional_TeaWaterAvailable
 - Execute_DrinkTea
 - Conditional_WaterAvailable
 - Execute_DrinkWater
 - Execute_MyMerge

Gemoc Engines Status 11

```

    TalkAndDrinkActivity.fuml 5
    TalkAndDrinkActivity_mccc.threaded 5
    
```

IMPLEMENTATION



The GEMOC Studio:

- ▶ Based on the Eclipse Modeling Framework (EMF).
- ▶ Dedicated metalanguage for the different aspects of a language specification.
- ▶ Generic execution, animation and debugging facilities.

Implementation of the contribution in the GEMOC Studio

- ▶ MoCMapping: any model transformation language can be used.
- ▶ Projections: small dedicated metalanguage (using Ecore + Xtext).
- ▶ Communication Protocol: dedicated metalanguage, the GEMOC Events Language (GEL) [5], extended with the use of the Projections.

CONCLUSION

Recursive definition of the concurrency-aware xDSML approach:

- ▶ Seamless integration into the approach.
- ▶ No MoC-specific MoCMapping metalanguage.
- ▶ Common interface for MoCs (*i.e.*, as concurrency-aware xDSMLS).
- ▶ Verification of behavioral properties can be performed based on the selected MoC.



Additional overhead to the runtime performance.

PERSPECTIVES

- ▶ Standard library of Models of Concurrency including a bootstrapping of Event Structures.
- ▶ Integration of existing verification tools for standard MoCs.
e.g., for Petri nets, Actors, etc.
- ▶ Verification of domain properties through higher-order transformations.
i.e., translating the verification results back into the original domain .
- ▶ Generating efficient implementations of the xDSMLs.

Acknowledgement

This work is partially supported by the ANR INS Project GEMOC (ANR-12-INSE-0011).

More information at : <http://www.gemoc.org>

ARTEFACTS AND QUESTIONS

@see: <http://gemoc.org/exe16/>

contains:

- ▶ Videos illustrating:
 - ▶ the **Language Workbench**
(Concurrency-aware specification of the Threading xDSML and of fUML using Threading as its MoC);
 - ▶ the **Modeling Workbench** (Execution of the example fUML Activity).
- ▶ The **GEMOC Studio** with:
 - ▶ our Threading xDSML implementation;
 - ▶ our fUML implementation;
 - ▶ the example fUML Activity.



Thank you for your attention.
Questions?

REFERENCES I



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