

The many meanings of UML 2 Sequence Diagrams: a survey



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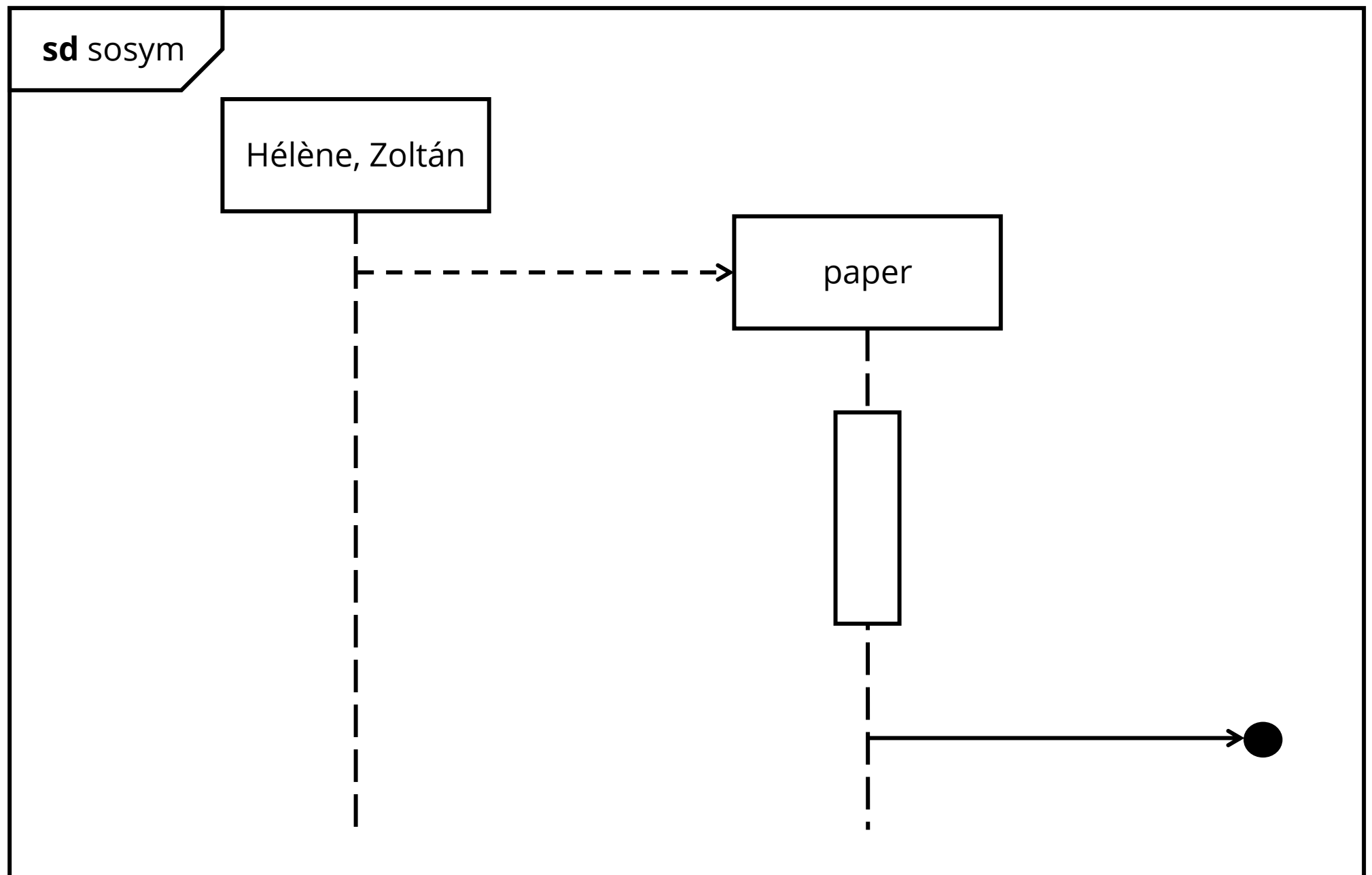
homepages.laas.fr/waeselyn/

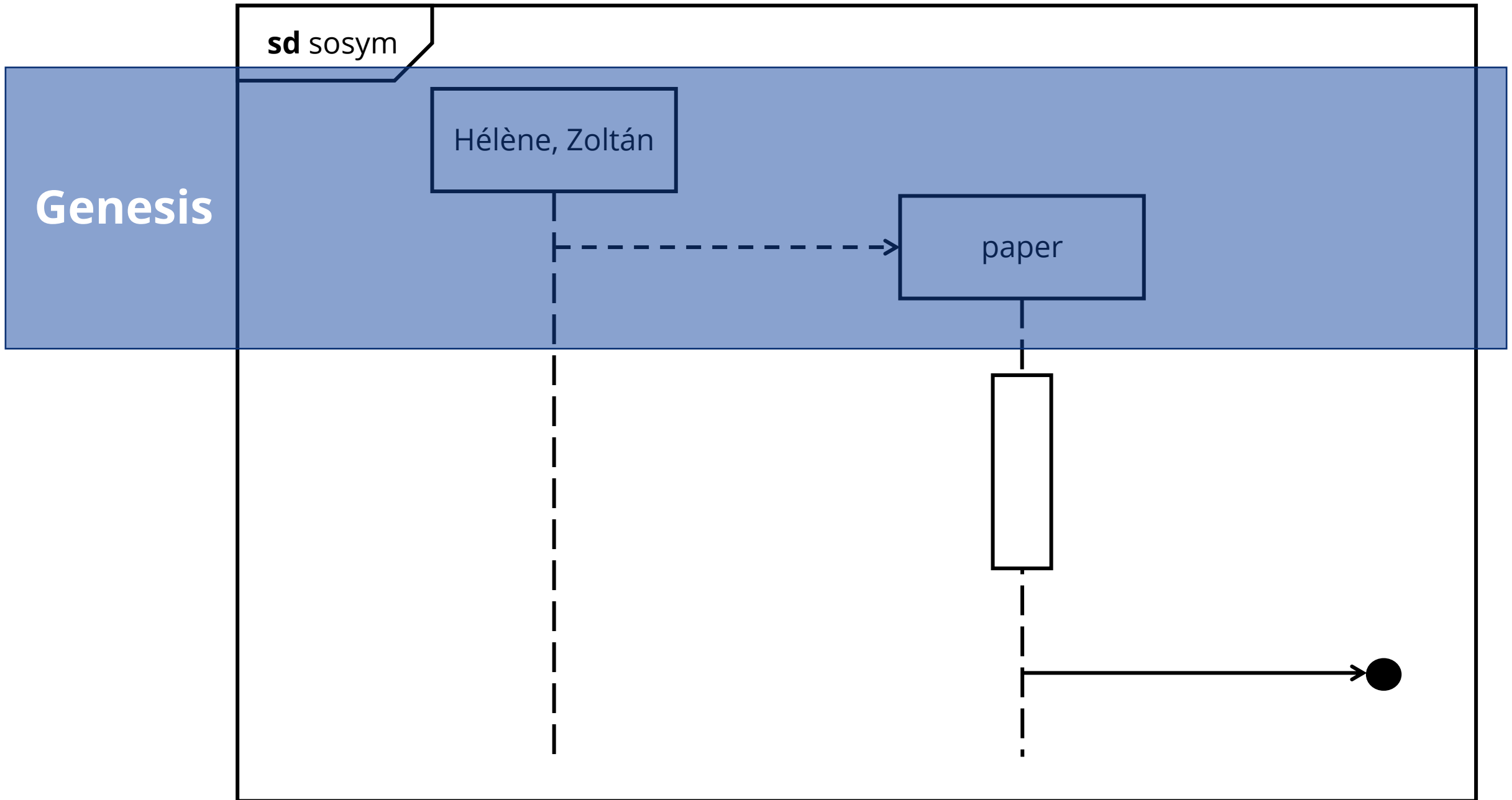
LAAS-CNRS
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**Critical Systems
Research Group**



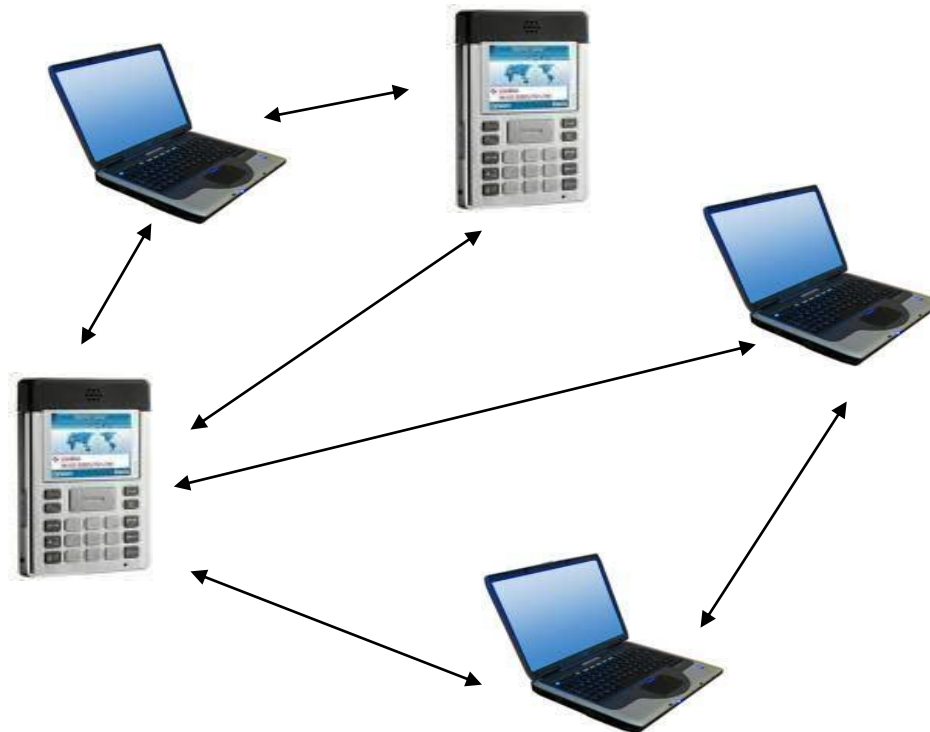




Birth & timeline

2006

Working on testing mobile systems



Motivating example:
a group membership
protocol based on
spatial proximity

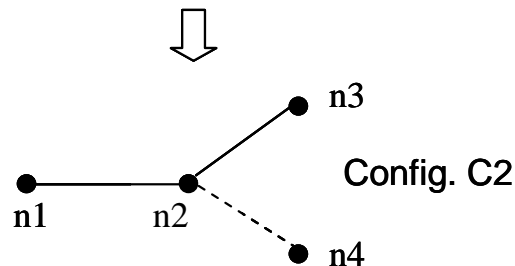
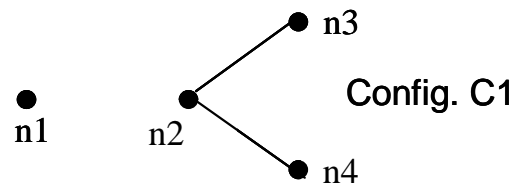
Birth & timeline

2006

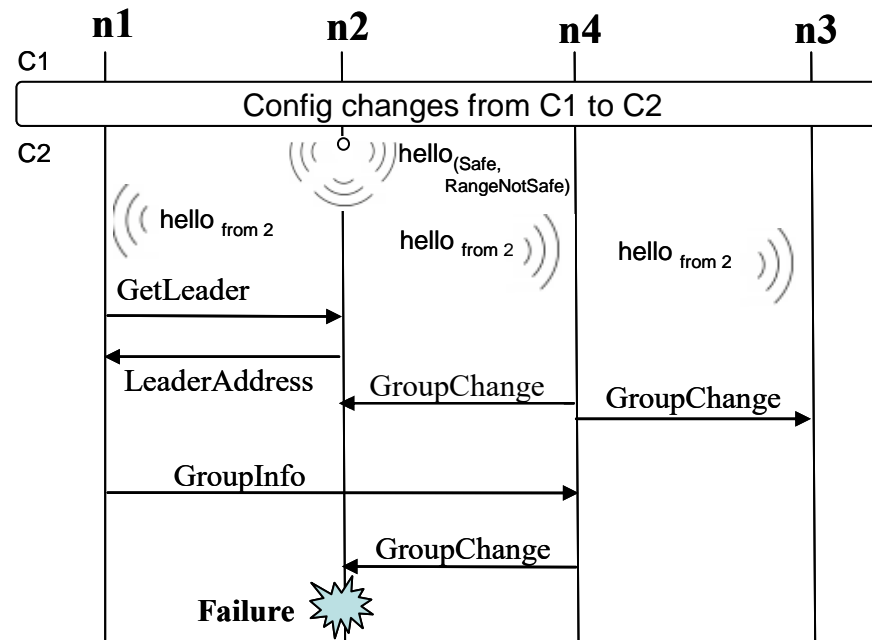
Working on testing mobile systems

2007

A new test language for test scenarios



Spatial view



Event view

A fail scenario for concurrent split & merge

Does this fail scenario occur in the test trace?

1. Detect the occurrence of the spatial configurations
→ **graph matching problem**
2. Analyze the order of events in the identified configurations
→ **UML SD Semantics**

Was expected to be a minor aspect of our work...

Birth & timeline



2006

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A new test language for test scenarios

DETOUR

Check existing semantics and select one (few weeks?)

2011

Semantics paper published in SoSyM 10:4

Birth & timeline



2006

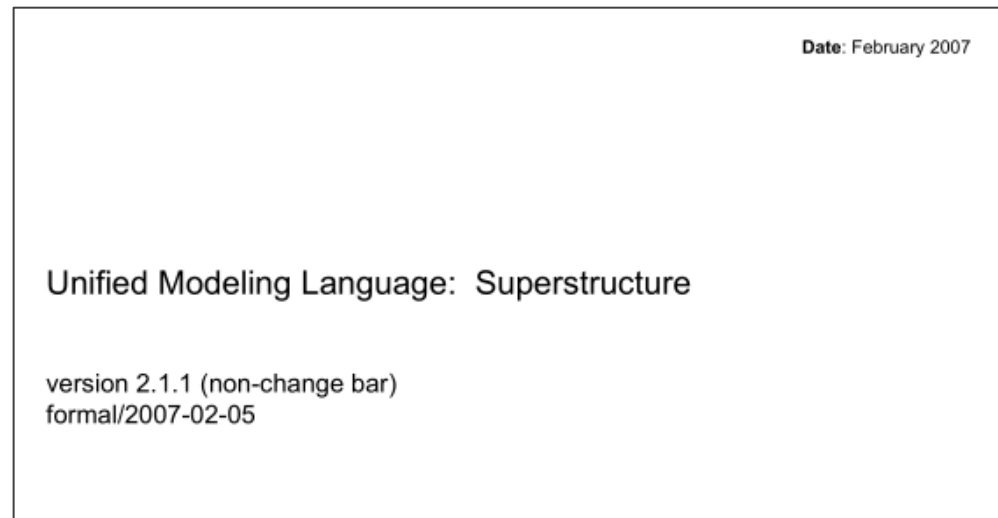
Working on testing mobile systems

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New elements in UML 2.0
Still many questions

“...constructs open up a
veritable pandora’s box”
S. Pickin

Birth & timeline



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2007

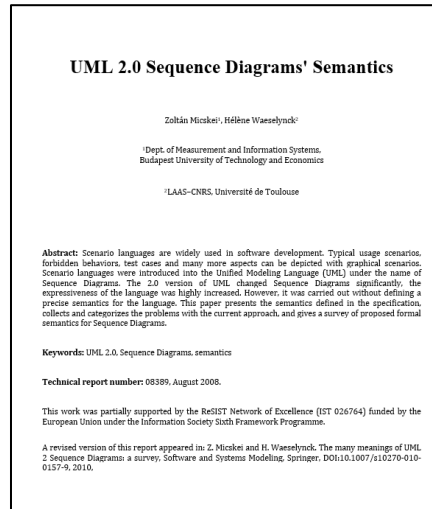
A new test language for test scenarios

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2008

**Collecting 12 works: problems and detailed examples
Tech report & submitting to SoSyM (July)**



Introduction

- + UML Sequence Diagrams in the OMG Specification
- + Semantically Challenging Sequence Diagrams
- + Two detailed examples of semantics
- + Survey of proposed semantics
- + Discussion and Conclusion

Birth & timeline



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"I regret to inform you that..." (Sept)

SOSYM (bad news)



Helene Waeselynck
To ○ Zoltan Micskei

"We encourage you to significantly revise the paper and resubmit as a new manuscript to SoSyM."

Feedback from reviewers

(Many thanks to them!)

I am not sure that I always agree with the authors when they call [...] "problems"

Whether or not this is "counter intuitive" [...] is debatable

in several of the formalizations [...], this is not considered to be a problem.

It seems to be assumed that interactions should [always] have a (direct) operational interpretation

- The discussion of the semantics was too much biased by our initial objective (analysis of test traces)
- The paper was a catalogue of problems.
A catalogue of solutions would be more helpful!

Birth & timeline



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2009

Change perspective, rework paper & submit again

**Focus on choices and options
instead of problems**

From this feedback, it became clear to us that we should change the perspective from which the survey had been conducted. We realized that we had been too much biased by our on-going work, which aimed at defining a semantics for a test language based on sequence diagrams. It induced strong emphasis on the direct operational interpretation of diagrams, as well as some preconceived ideas of how some constructs should be interpreted (hence the “counterintuitive” judgment). Also, we acknowledged that the insights gained from the survey could be improved – at that time, we had identified some problems, but it was still unclear which solutions we should choose for our language.

We thus decided to go back to the existing semantics, but this time changing the angle of attack:

- We should remove any preconceived ideas about problems, and focus on how the approaches work.
- We should try to systematically identify the points in which the reviewed semantics differ. These points indicate *choices* faced by semantic approaches, the different solutions adopted yield *options* for the choice.
- Our aim would thus be to end up with a clear categorization of choices and related options.
- Our analysis of options should give practical insights to practitioners searching for a semantics (like us). We retained the suggestion of one reviewer, to explore the consequences of options on examples of diagrams, so as to gain a clearer view of which option gives which interpretation on concrete cases.

Cover letter of the second submission to SoSyM

Birth & timeline



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Good news! Minor revision, revise paper

Birth & timeline



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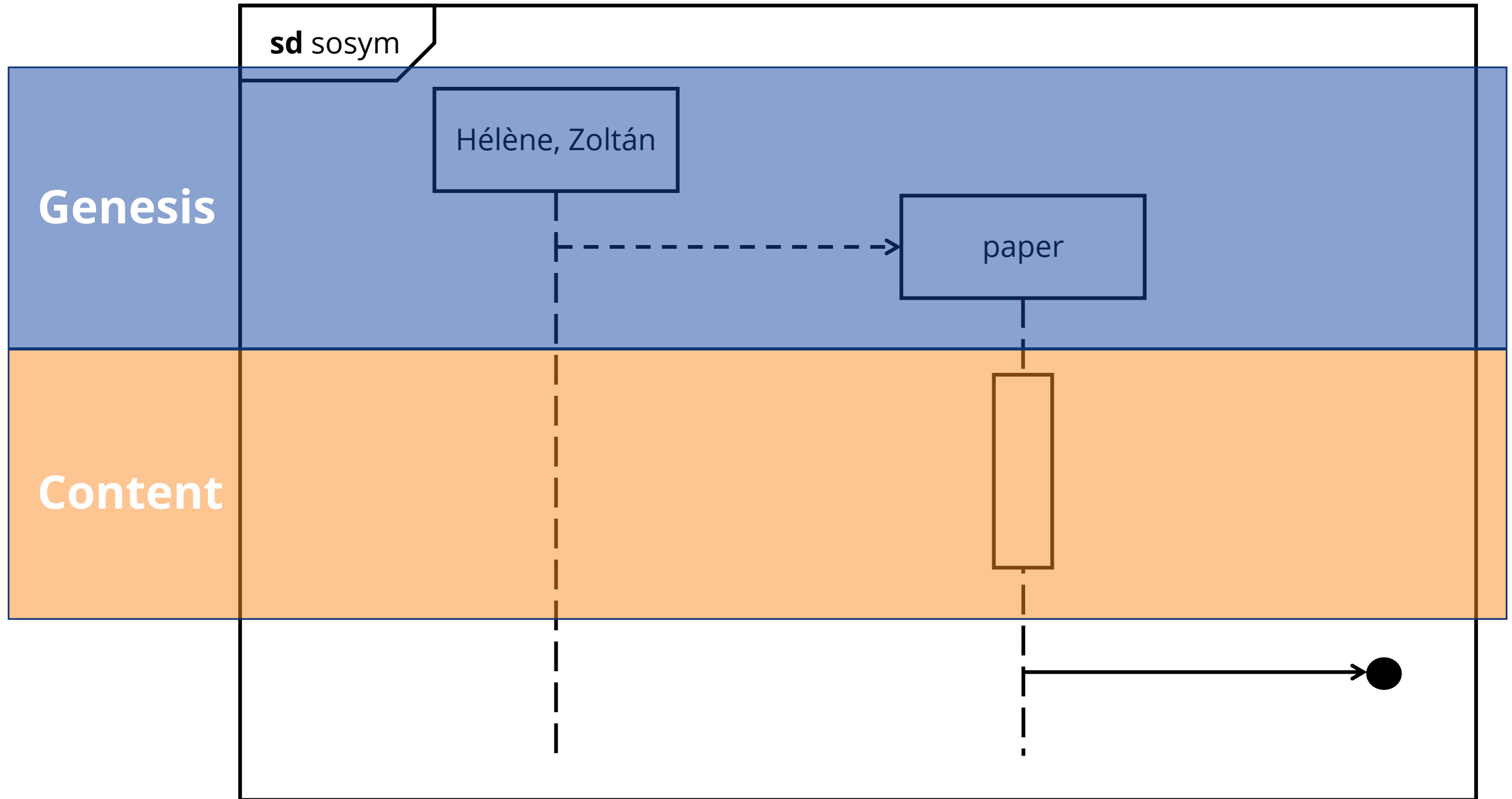
“It is a pleasure to accept your manuscript...”

2011

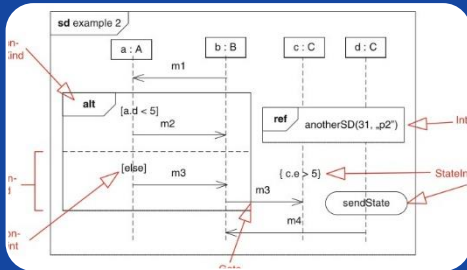
Paper published in SoSyM 10:4

2011

Paper on test language for mobile systems (TERMOS)



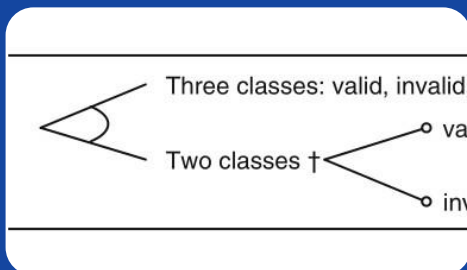
Structure of the final paper



Sequence Diagrams in the
OMG specification

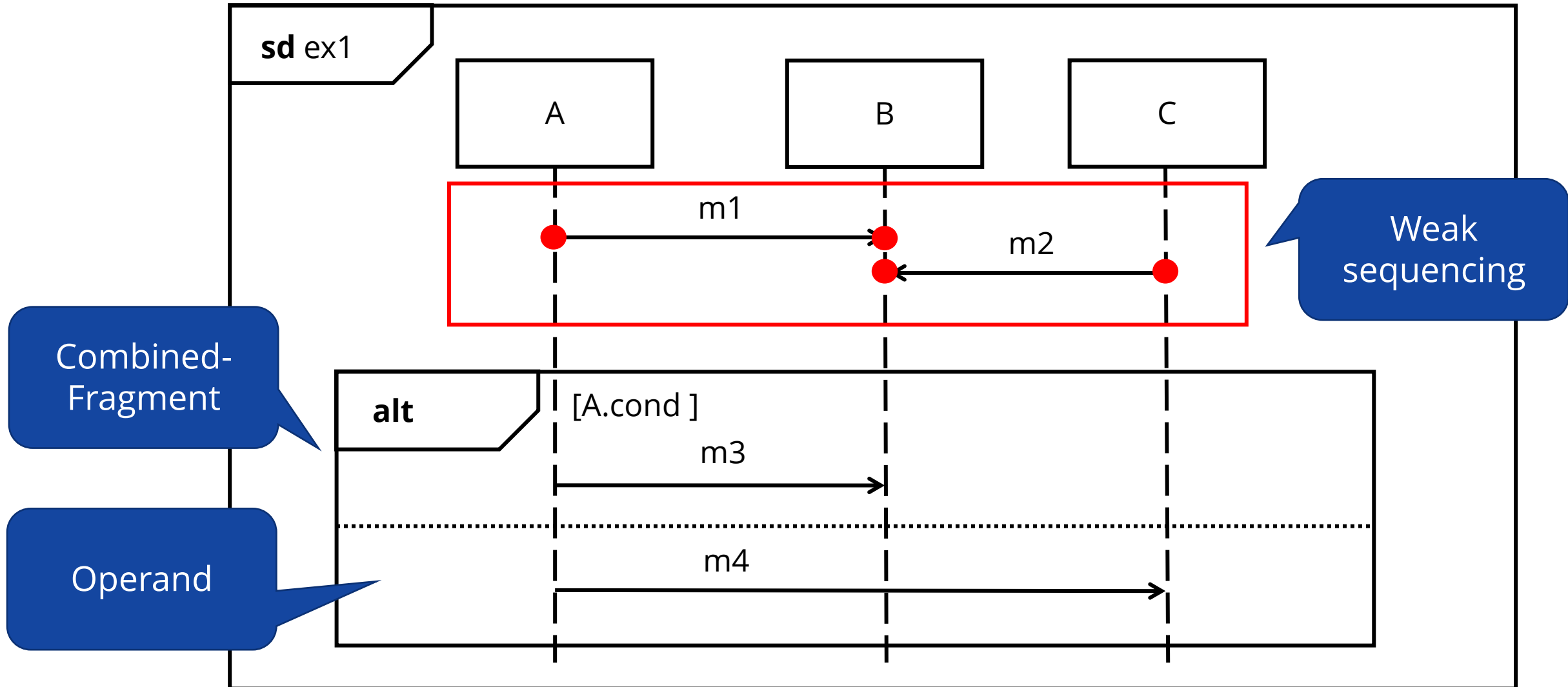
	sequenceDiagram	stateDiagram	stateDiagram-v2	stateDiagram-v3	stateDiagram-v4	stateDiagram-v5	stateDiagram-v6	stateDiagram-v7	stateDiagram-v8	stateDiagram-v9	stateDiagram-v10	stateDiagram-v11	stateDiagram-v12	stateDiagram-v13
sequenceDiagram	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v2	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v4	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v5	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v6	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v7	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v8	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v9	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v10	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v11	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v12	*	*	*	*	*	*	*	*	*	*	*	*	*	*
stateDiagram-v13	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Overview of 13
proposed semantics



Semantic choices in SDs

Sequence Diagrams in the OMG spec.



Diversity of proposed semantics (selection)

Goals

- Checking traces
- Refining requirements

Formalisms

- Set of traces
- Petri nets, automaton...

Approaches

- Denotational vs. operational
- Ideas from other languages (LSC)

Semantic choices: an example

Categorizing traces

- OMG: valid, invalid, inconclusive
- Variations: 2 classes (e.g., safety)

Categorizing traces



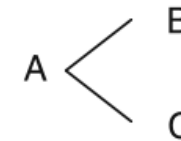
Three classes: valid, invalid, inconclusive

Two classes † valid and other

invalid and other

Visual summary of options (~feature model)

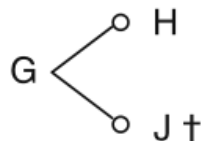
Legend



and



alternative



optional

sd c2

a : A

b : B

m1

m2

m3

Are the following traces valid, invalid or inconclusive?

!m1 . ?m1 . !m2 . ?m2 . !m3 . ?m3 . !m1 . ?m1

!m1 . ?m1 . !m4 . ?m4 . !m2 . ?m2 . !m3 . ?m3

!m1 . ?m1 . !m3 . ?m3 . !m2 . ?m2 . !m3 . ?m3

!m1 . ?m1 . !m1 . ?m1 . !m2 . ?m2 . !m3 . ?m3

Simple diagram illustrating the consequences of each option

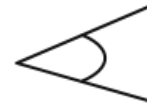
List of identified semantics choices

Interpretation of a basic Interaction	What is a trace? Categorizing traces Complete or partial traces
Introducing CombinedFragments	Combining fragments
Computing partial orders	Processing the diagram Underlying formalisms Choices and predicates
Introducing Gates	Gates on CombinedFragments Formal and actual Gates
Interpretation of conformance-related operators	Assert/Negate Ignore/Consider Conformance-related operators in complex diagrams Both valid and invalid traces

Semantic choices: Combining fragments

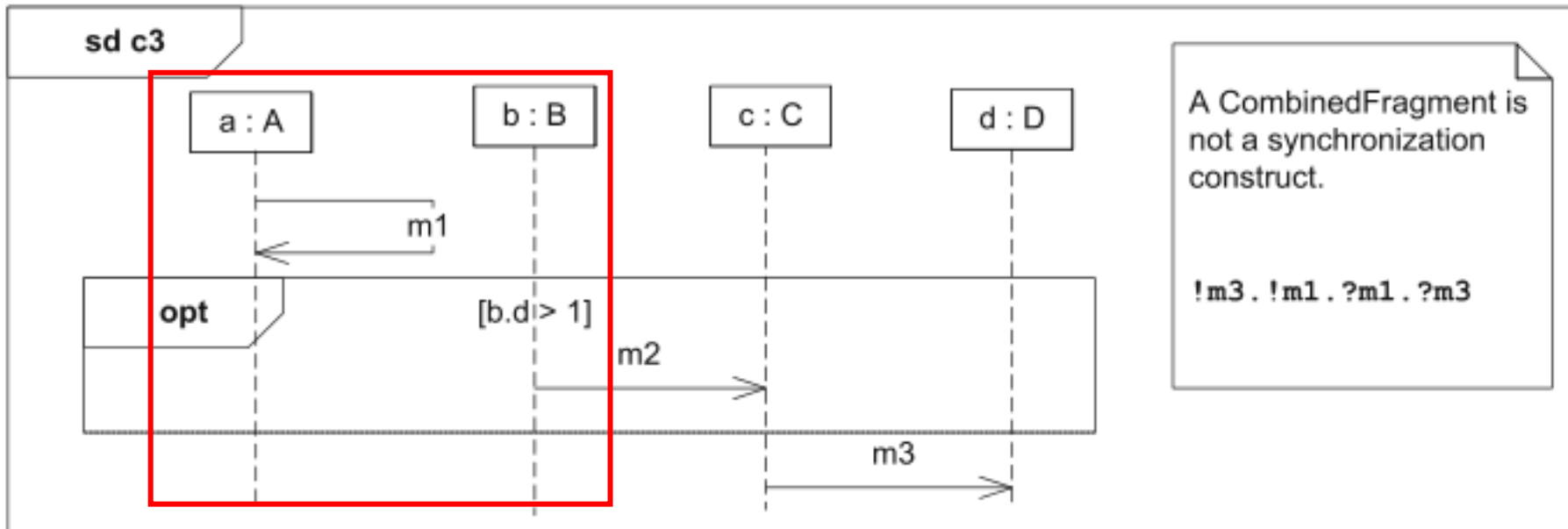
To synch, or to not

Combining
fragments



Use standard interpretation with weak sequencing

Synchronize on entering or exiting a CombinedFragment †



**Message
above or
below a CF
might be
misleading!**

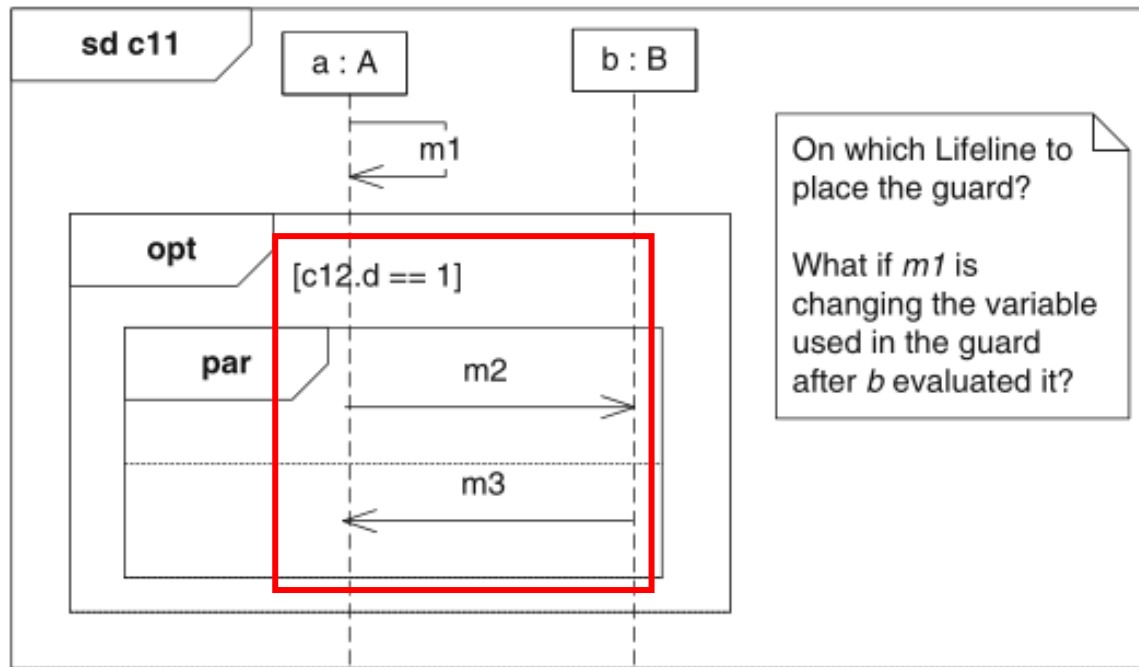
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Choices and predicates

Who / when / what
to choose

- OMG specification is permissive
- Non-deterministic choices
- Variations: various restrictions



UML: “guard should be placed on the lifeline where the first event occurrence will occur”

“First” event might be a set of events!

List of identified semantics choices

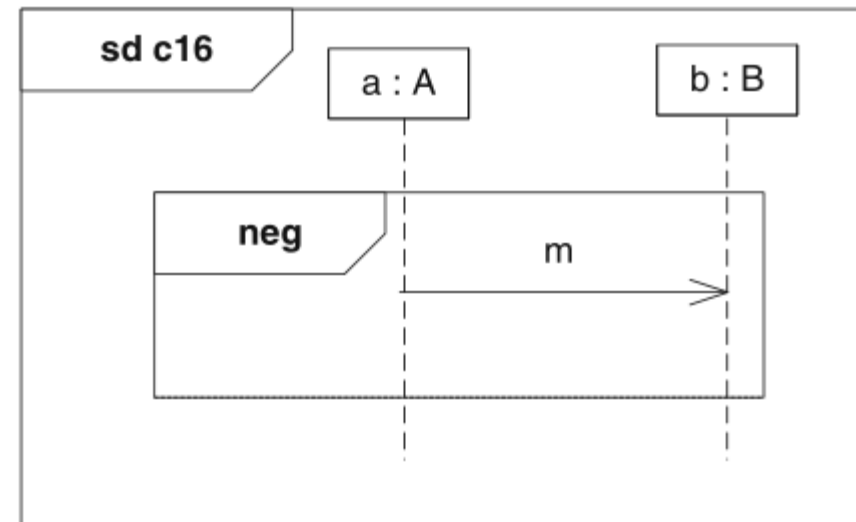
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Example: A more puzzling choice

Negative (neg) fragment

Approach	Valid	Invalid	Inconclusive
Störrle	\emptyset	$\{!m.?m\}$	$\Sigma^* - \{!m.?m\}$
Cavarra & Filipe, Küster- Filipe	\emptyset	$\{!m.?m\}$	$\Sigma^* - \{!m.?m\}$
STAIRS	$\{\epsilon\}$	$\{!m.?m\}$	$\Sigma^* - \{\epsilon, !m.?m\}$
Cengarle & Knapp	$\{\epsilon\}$	$\{!m.?m\}$	$\Sigma^* - \{\epsilon, !m.?m\}$
Grosu & Smolka	$\Sigma^* - \{!m.?m\}$	$\{!m.?m\}$	\emptyset

- OMG: "...represents traces that are defined to be invalid"
- Vastly different options based on where SDs are used (refinement, safety properties...)

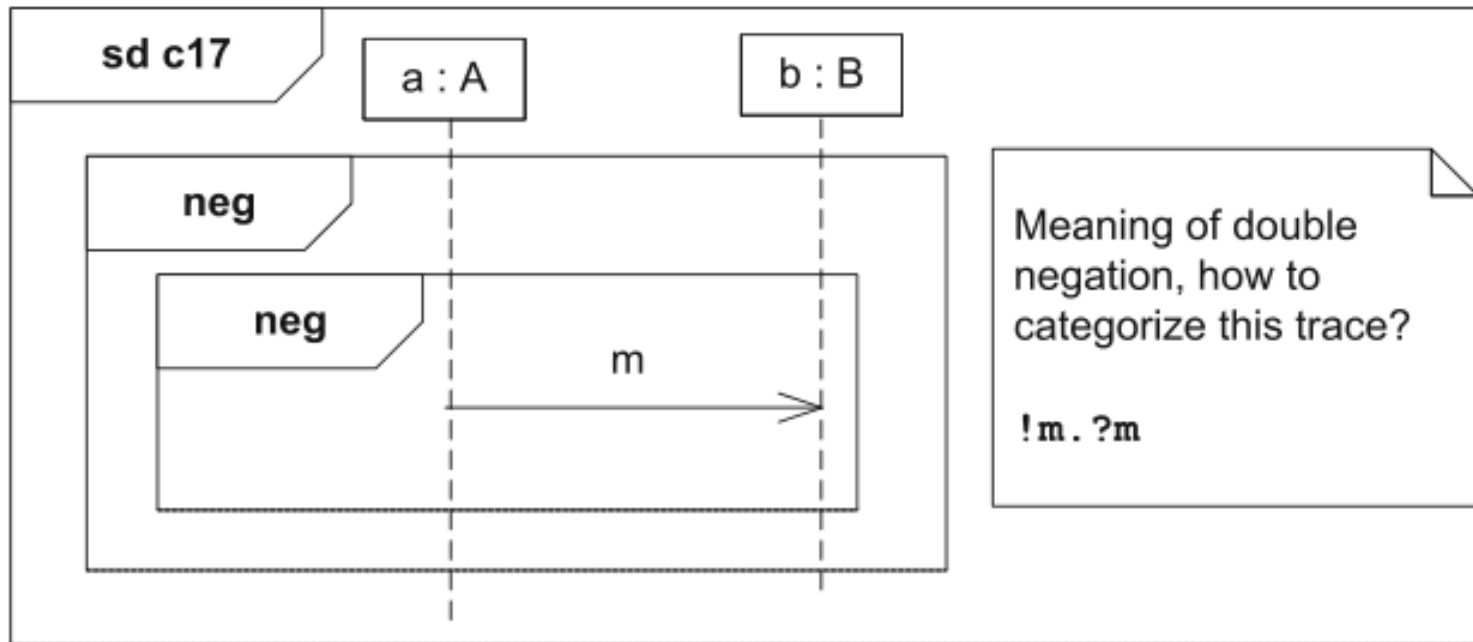


List of identified semantics choices

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Composition of conformance operators

QUIZ: trace in double negation is valid, invalid or inconclusive?



Suggested options:

- Double neg is identity, thus trace is **valid**
- A negative trace cannot turn into positive, thus **invalid**
- Trace is **inconclusive**

Many meanings, but assigned meaning may be surprising

List of identified semantics choices

Interpretation of a basic Interaction	What is a trace? Categorizing traces Complete or partial traces
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Summary: using the choices framework

Example: What choices did we select for our test language?

Complete or partial?	Allow partial traces
Combining fragments	Synch on entering and exiting
Choices and predicates	Explicit global time point for the choice
Assert/negate	Instead neg as operator, global false predicate at the end of diagram
Conformance operators	Nesting is restricted

sd sosym

Genesis

Hélène, Zoltán

paper

Content

Impact

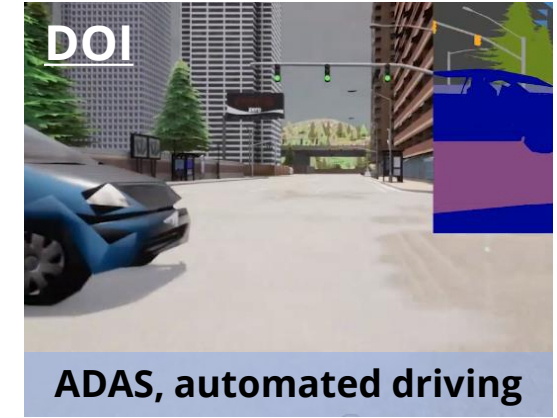
Using the results of the paper

TERMOS: A Formal Language for Scenarios in Mobile Computing Systems

Hélène Waeselynck^{1,2}, Zoltán Micskei³, Nicolas Rivière^{1,2},
Aron Hamvas³, and Irina Nitu^{1,2}

DOI

Design choices in a test language
for mobile computing systems



Test scenarios for autonomous robots and vehicles

Possible variations

	c15			c16		
Approach	Valid	Invalid	Inconclusive	Valid	Invalid	Inconclusive
Störle	\emptyset	$\{e\}$	$\Sigma^* - \{e\}$	\emptyset	$\{!m.?m\}$	$\Sigma^* - \{!m.?m\}$
STAIRS	$\{e\}$	$\{e\}$	$\Sigma^* - \{e\}$	$\{e\}$	$\{!m.?m\}$	$\Sigma^* - \{e, !m.?m\}$
Cengarle & Knapp	$\{e\}$	\emptyset	$\Sigma^* - \{e\}$	$\{e\}$	$\{!m.?m\}$	$\Sigma^* - \{e, !m.?m\}$
Grosu & Smolka	$\Sigma^* - \{e\}$	$\{e\}$	\emptyset	$\Sigma^* - \{!m.?m\}$	$\{!m.?m\}$	\emptyset
Cavarra & Filipe	\emptyset	Σ^*	\emptyset	\emptyset	$\{!m.?m\}$	$\Sigma^* - \{!m.?m\}$
Küster-Filipe						

For other choices and variations see: Z. Micskei and H. Waeselynck: *The many meanings of UML 2 Sequence Diagrams: a survey*, SoSyM, 10(4):489-514, Springer, 2011.

44

ftsrg

Education & training



Industrial consultation & collaboration

Citations in research communities (examples)

Relating computer systems to sequence diagrams: the impact of underspecification and inherent nondeterminism

Ragnhild Kobro Runde¹, Atle Refsdal^{1,2} and Ketil Stølen^{1,2}

¹ Department of Informatics, University of Oslo, PO Box 1080, Blindern, 0316 Oslo, Norway. E-mail: ragnhild.runde@ifi.uio.no

² SINTEF ICT, Oslo, Norway

Modeling languages, semantics...

Regular Paper

Requirements management within a full model-based engineering approach

Yves Bernard✉

First published: 15 November 2011 | <https://doi.org/10.1002/sys.20198> | Citations: 23

Requirements engineering, systems engineering

IEEE TRANSACTIONS ON DEPENDABLE AND SECURE COMPUTING

Sequence Diagram Aided Privacy Policy Specification

Hui Shen, Ram Krishnan, Rocky Slavin, and Jianwei Niu

Security and privacy

This article is the accepted version of "Botnet Communication Patterns" in the journal "Communications Surveys & Tutorials".
Citation information: DOI 10.1109/COMST.2017.2749442 Abstract: <http://ieeexplore.ieee.org/document/8026031/>

Botnet Communication Patterns

Gernot Vormayr, Tanja Zseby, and Joachim Fabini

Communications and networks

Sequence diagrams are used in many domains and communities!

sd sosym

Genesis

DETOUR are
worth to take

Listen to the
editor and
reviewers

Content

Many meanings
can be useful

Focus on
options and
not problems

Impact

Be persistent

Impact is a long-
term matter