# Functional Mock-up Interface:

## An empirical survey identifies research challenges and current barriers

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## Motivation

## Method

## Results

Barriers for FMI [1]

Promising standards and tools [2]

Co-Simulation: Strengths – weaknesses – opportunities – threats [2]

## Motivation

Which approach for coupling simulators?

Promising for the future?

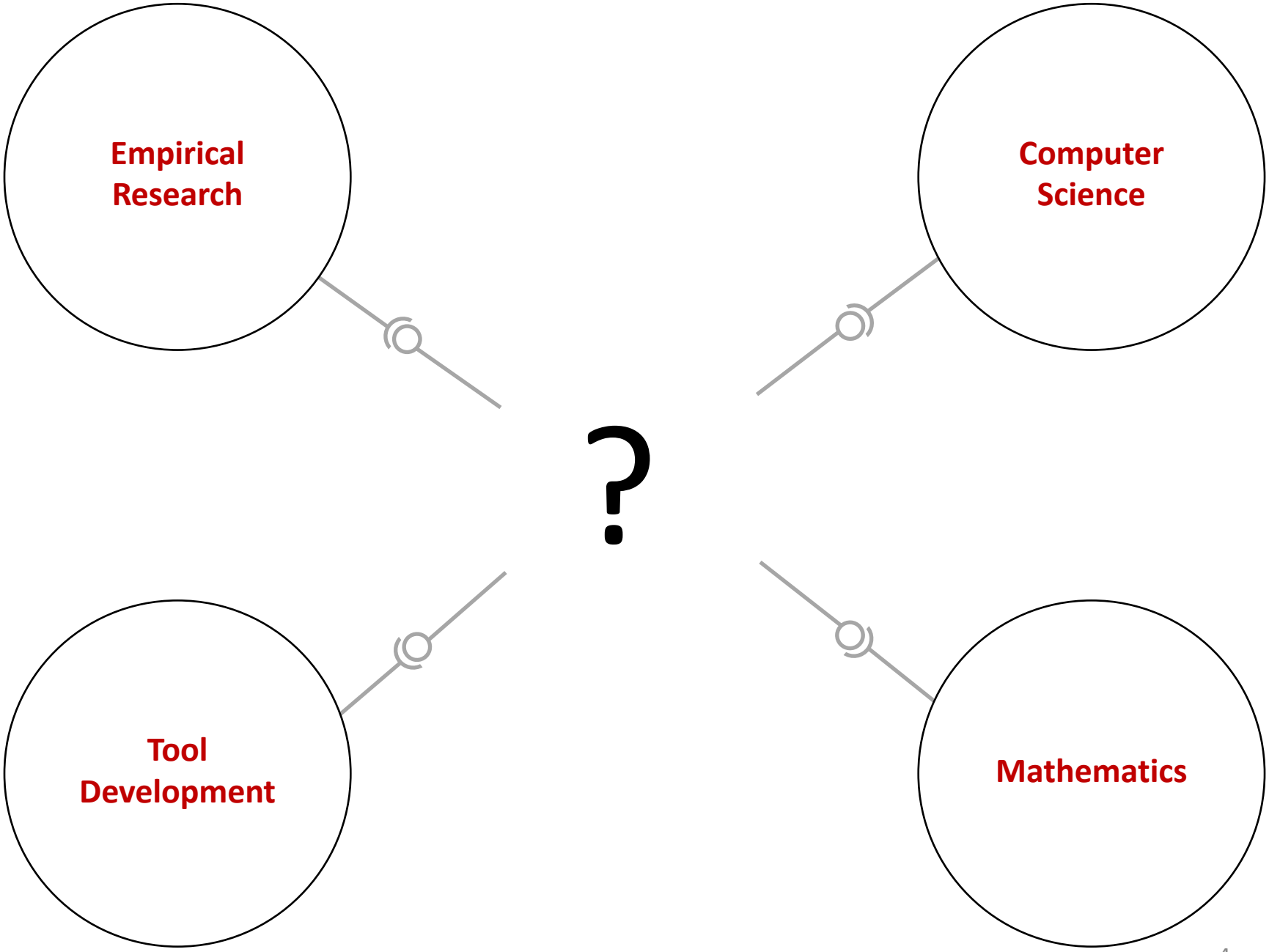
## Goals

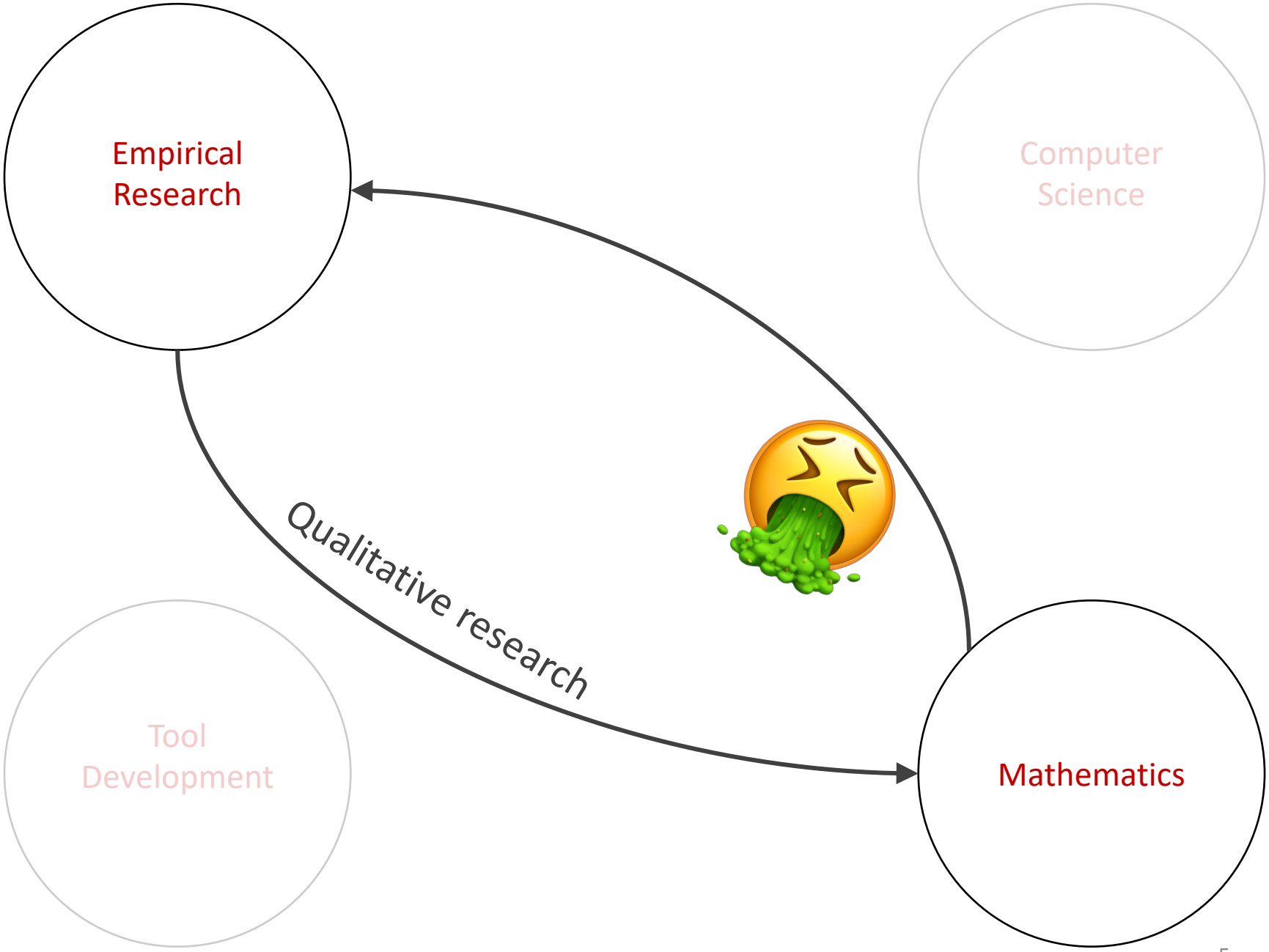
Which standard?

Which tool?

In general: Strengths and weaknesses of co-simulation

…, research needs, current barriers, …


Empirical Research
Computer Science
?
Tool Development
Mathematics


Empirical Research
Computer Science
Qualitative research
Tool Development
Mathematics

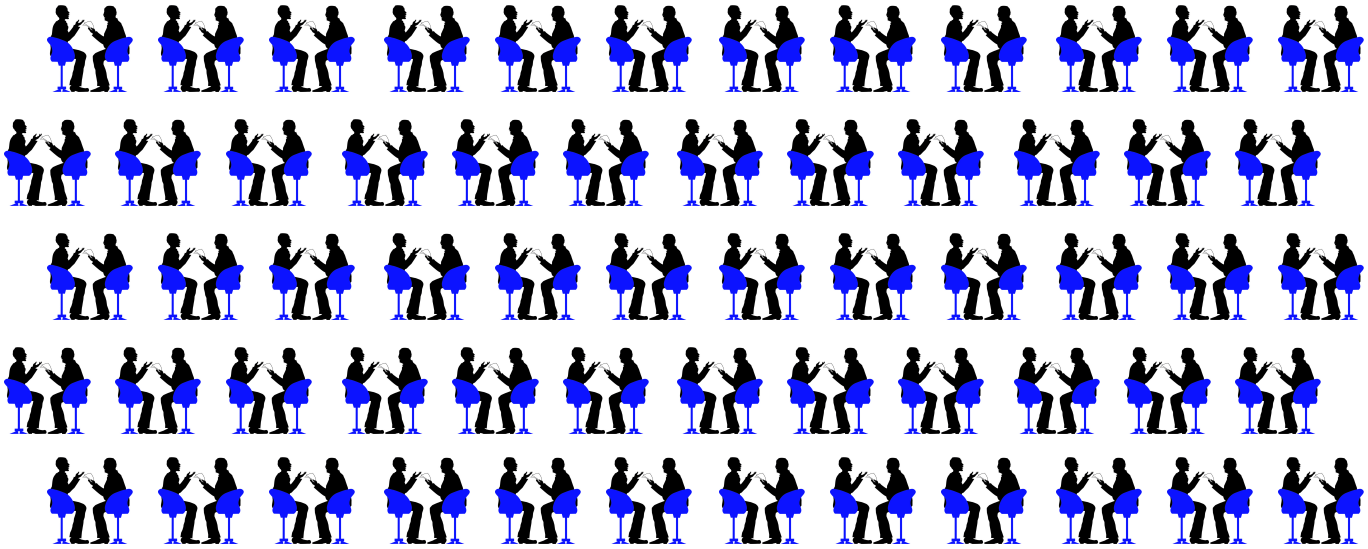
## Delphi Study

- empirical research method that relies on the systematic compilation of knowledge from a selected group of experts
- especially useful for addressing interdisciplinary research problems, where the experts' opinions are heterogeneous
- the Delphi method provides structured circumstances that "[. . . ] can generate a closer approximation of the objective truth than would be achieved through conventional, less formal, and pooling of expert opinion"

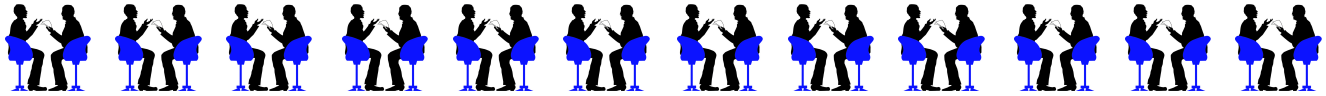
# Two-stage Delphi study

First Round

Second Round



# First round



**Using Qualitative Content Analysis**

- Identifying key-topics
- Identifying contradictions

# First round

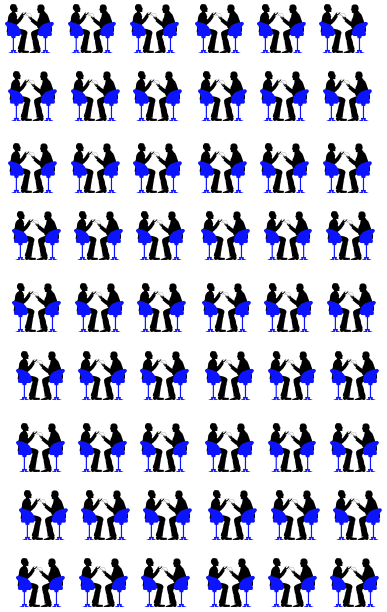
**How to ask the right questions in the first round?**

- Authors published "SOTA" papers in the field of Co-Sim
  - C. Gomes, C. Thule, D. Broman, P. G. Larsen, H. Vangheluwe, Cosimulation: State of the art, 2017.
  - I. Hafner and N. Popper. On the terminology and structuring of co-simulation methods, 2017.
- Comprehensive literature study

**What kind of questions?**

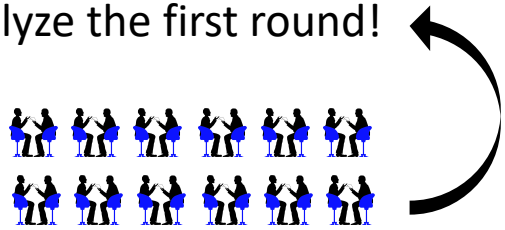
- In the first round, the majority of questions asked were qualitative

# Second round



**How to ask the right questions in the second round?**

- Analyze the first round!



**What kind of questions?**

- In the second round, the majority of questions asked were quantitative

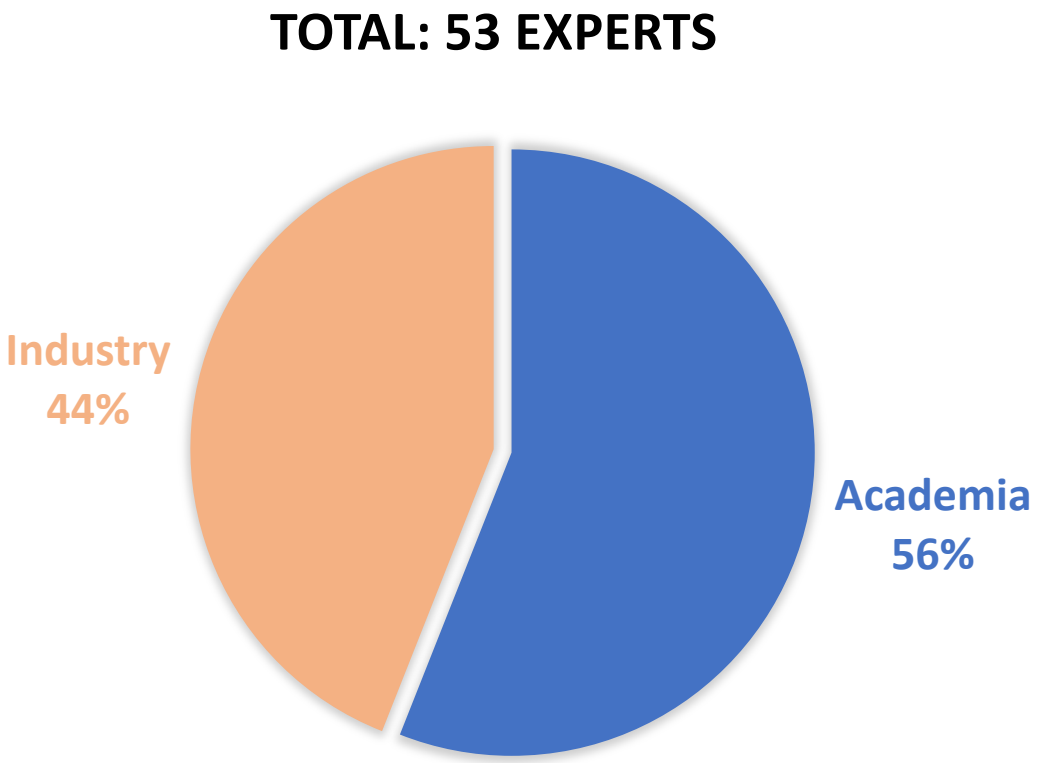
# Experts [Response rate: 76% ]

## Industry

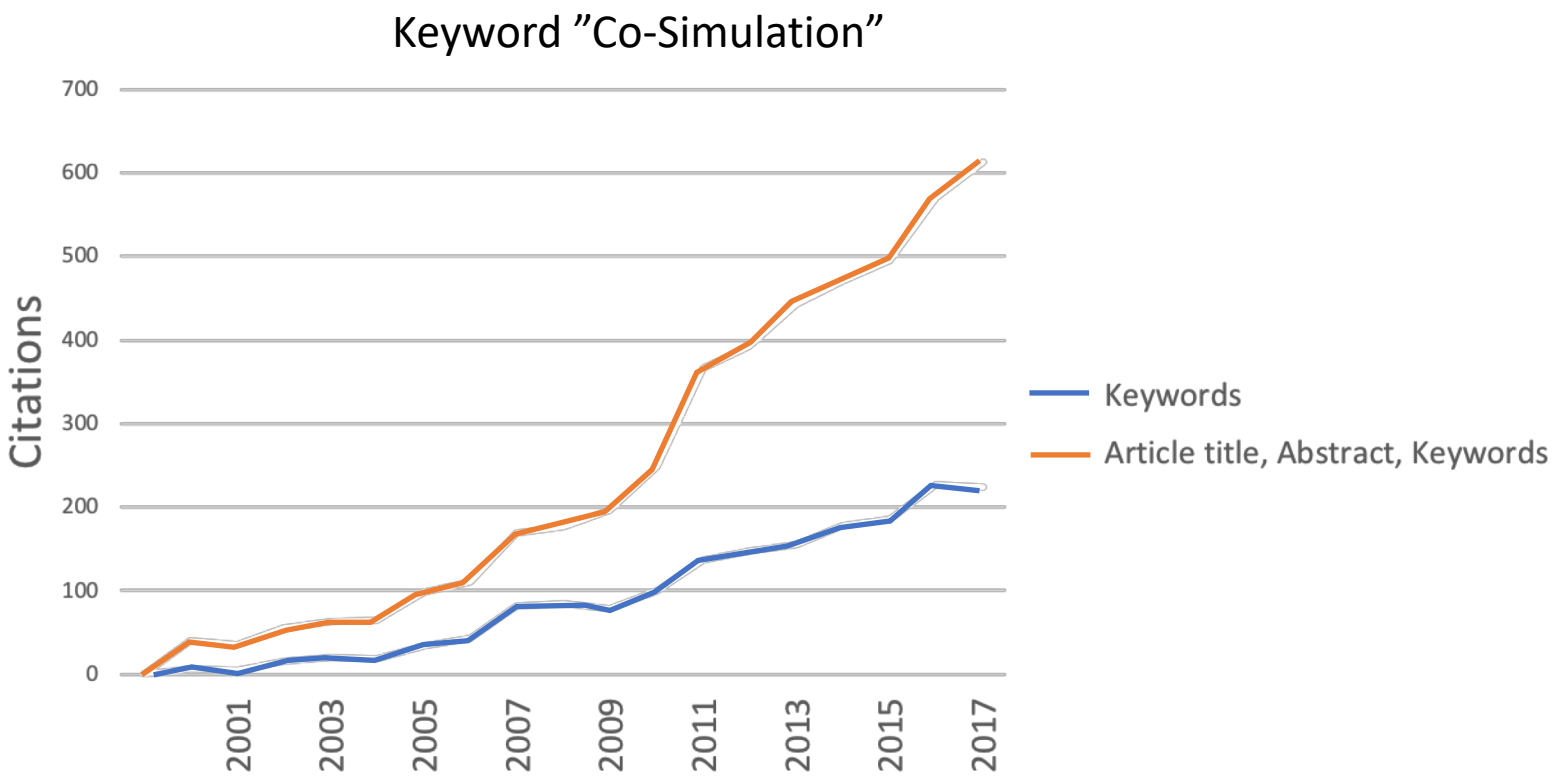
- Software development
- Mobility
- Energy Systems
- System engineering
- Railways

## Academia

- Software development
- Mathematics
- Automotive
- Energy related applications



# Results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Citations
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600
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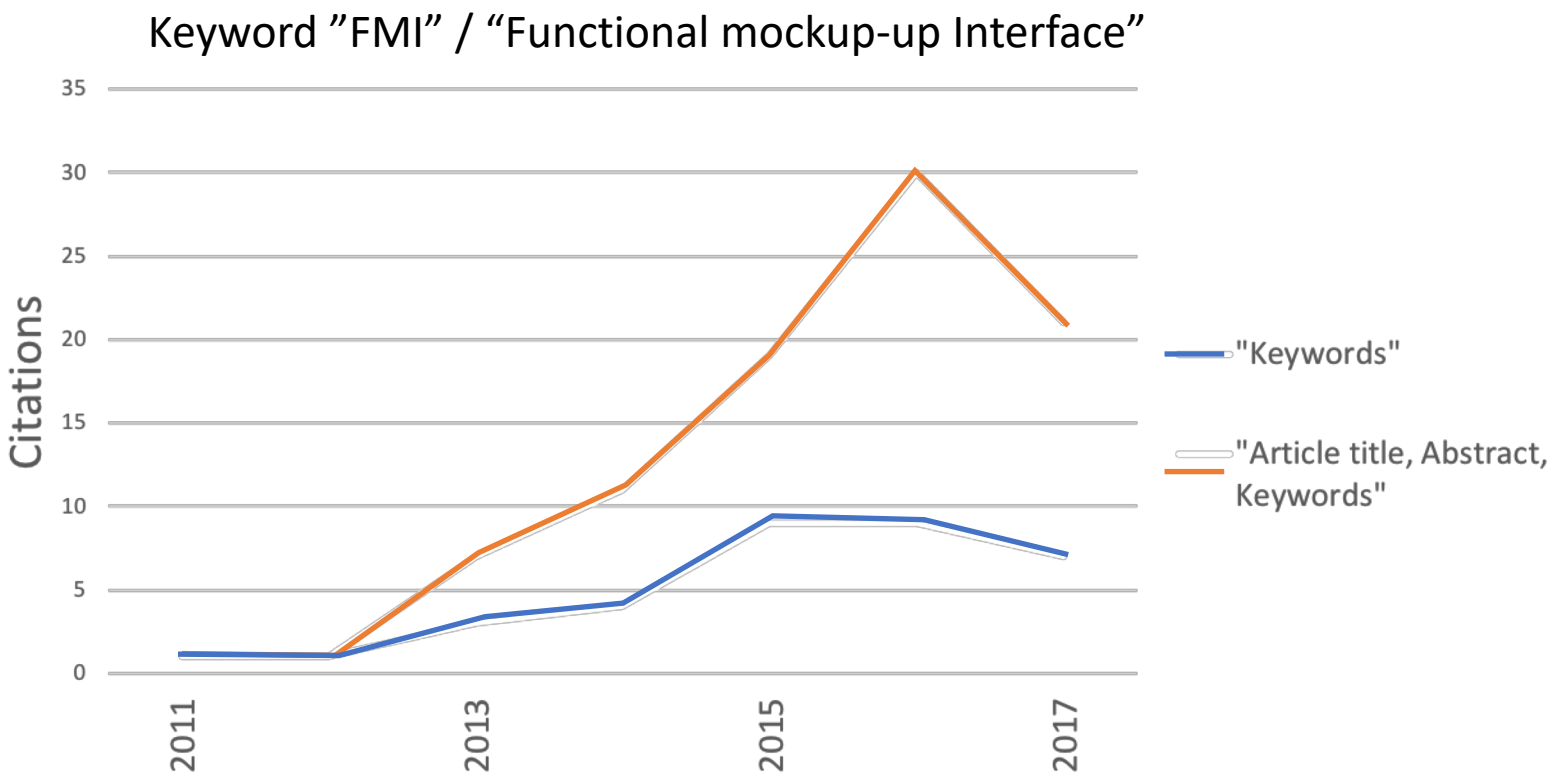
2017
Keywords
Article title, Abstract, Keywords


Keyword ”FMI” / “Functional mockup-up Interface”
Citations
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"Keywords"
"Article title, Abstract, Keywords"

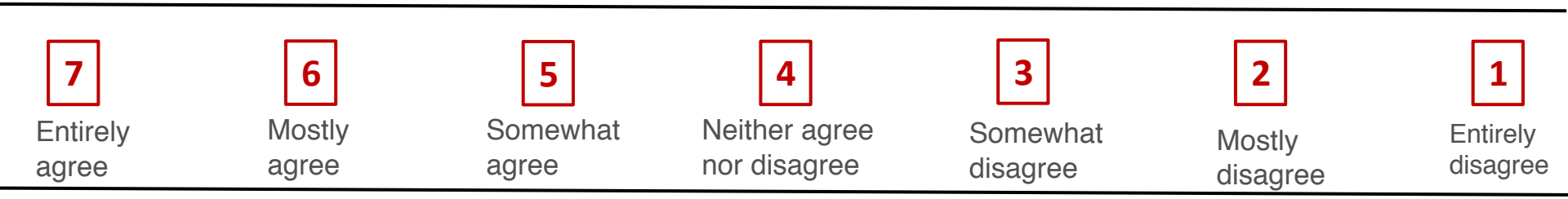
# Barriers for FMI

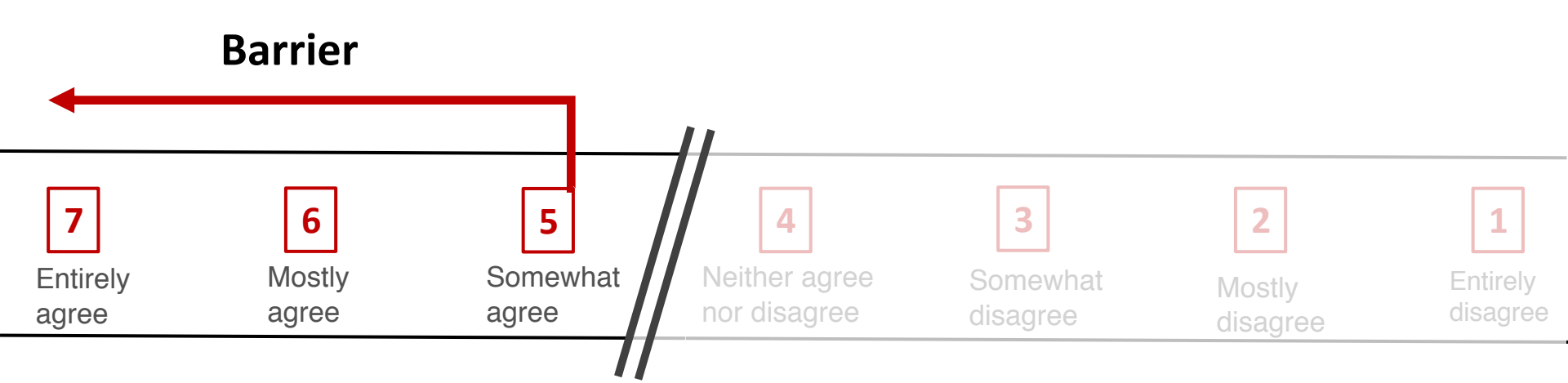
# FMI - Barriers

**In the first round of expert interviews, we identified the following barriers:**

- Limited support for discrete event co-simulation
- Limited support for hybrid co-simulation
- Certain requirements that would be widely needed by industry and academia are not supported
- No pre-implemented master algorithms

- Insufficient documentation and a lack of examples, tutorials, etc.
- Lack of transparency in features supported by FMI tools
- There is a lack of (scientific) community, forums, groups
- Not enough cooperation (theoretical, implementation, application/industry) in defining and developing the FMI standard
- It is difficult to implement FMU's (API, connecting/linking different subsystems)
- Simulations are slow compared to monolithic simulations
- There is a lack of tools that sufficiently support FMI
- Concerns of industry/academia regarding FMI and IP protection


7
Entirely agree
6
Mostly agree
5
Somewhat agree
4
Neither agree nor disagree
3
Somewhat disagree
2
Mostly disagree
1
Entirely disagree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7
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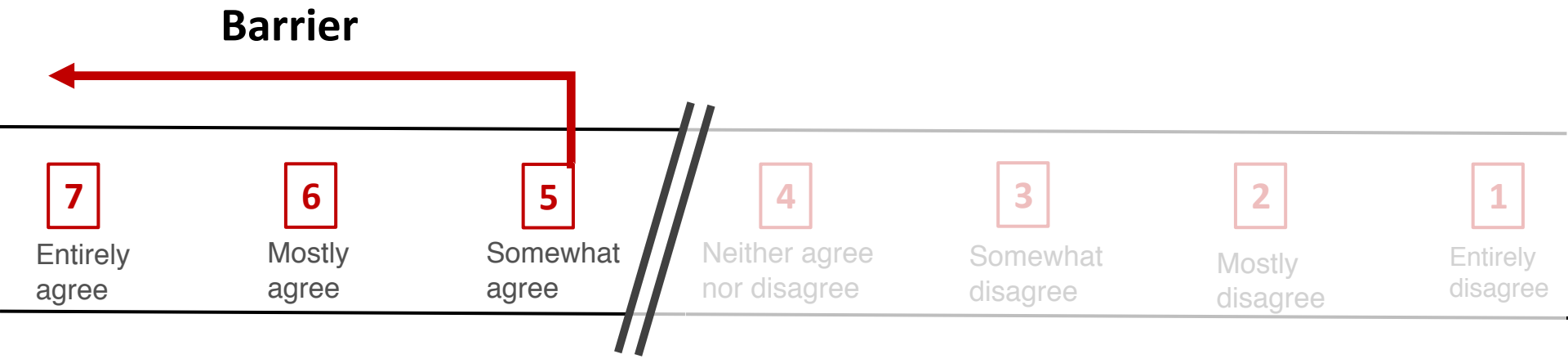


| Barrier | Interp. Median |
|---|---|
| FMI has limited support for discrete co-simulation and it is not easily applicable | 5.3 |
| The standard does not support certain requirements that would be widely needed by industry and academia | 5.3 |
| There is insufficient documentation and a lack of examples, tutorials, etc. | 5.2 |
| Lack of transparency in features supported by FMI tools | 5.0 |
| FMI has limited support for hybrid co-simulation and it is not easily applicable | 5.0 |

# Literature

[1] Schweiger, G., Gomes, C., Engel, G., Hafner, I., Schoeggl , J., Posch, A. & Nouidui, T. S. (2018). Functional Mockup-Interface : An empirical survey identifies research challenges and current barriers. In *American Modelica Conference 2018*.

[2] Schweiger, G., Gomec, C., Engel, G., Hafner, I., Schöggl, J., Posch. A. & Nouidui, T. S. (2018). Co- Simulation: An empirical survey identifies promising standards, current challenges and research needs. *Submitted*.