COST IC1404 WG4

Y1 and Y2 Technical Report WG4.3

CPS profile - Pilot Assessment

2016

Authors

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Document History

Version	Date	Who	What
V0.1	10/11/2016	VA	Document Created
V0.2	16/12/2016	MG	Added survey report
V0.3	20/12/2016	VA	Added screenshots
v0.4	29/12/2016	PC	Corrections and formatting

Introduction

Within the scope of the COST Action IC1404 MPM4CPS, we conducted a survey among the members in order to identify and classify the competencies, which they recognize as indispensable and most relevant related to particular areas of CPS, therefore applicable in academic education programs.

Methodology

The survey was presented in the form of an online questionnaire and answered by the participants in the MPM4CPS Workshop held in Gdansk in September 2016. The participants were asked to provide some personal background information, including:

- Whether they members of the MPM4CPS network, or guests participating in the meeting
- What their professional activity is (industry, education, research, or other)
- Whether they had previous, or current experience with industrial CPS projects
- An open question on participants' background and expertise

Ranking of MPM4CPS topics

The survey included a set of questions where participants were asked to rate, according to their perception, the relevance of each of the following topics for MPM4CPS, using a Likert scale from 1 (not relevant) to 5 (very relevant). The distance between each scale point is assumed equal, and 3 represents the neutral value in this scale. The survey items were as follows:

- Multi-Paradigm Modeling (MPM)
    - Multi-Formalism
    - Multi-Processes
    - Multi-Approximation
    - Multi-Abstraction
- Application Domains
    - Automotive Industry
    - Avionics Industry
    - Home Automation
    - Smart Cities
    - Astrophysics or High-Energy Particle Physics Detectors
- Cyber-Physical Systems (CPS)
    - Hybrid Systems
    - Combination of Domains
- Design and Simulation
    - Control Theory
        - Mechatronics
            - Fluids
            - Bio-Systems
            - Robotics

        - Tools and Languages
            - Pure Numerical
                - SPSS
                - SimaPro
                - Monte Carlo
                - Real-Time Physics Engines
            - Agents-Based
        - Industrial Design
            - Matlab
            - Modelica
            - Simulink
            - Other
- Software Engineering
    - Application Domains
    - DSL foundations
    - Verification
        - Automated test generation
        - Formal Analysis
        - Usability
    - Validation
        - Empirical Analysis

The actual Questionnaire used is presented in Appendix I.

Elicitation of Post-graduate courses

In the scope of the questionnaire, the respondents were also asked to report existing on post-graduate course offerings available either at their institutions, or at other institutions they were working with.

The analysis of the results reported in Appendix II reveals that the respondents contributed with a small set of items.

Respondent profile

There were a total of 20 respondents to the questionnaire. Of those, 18 are members of the COST IC1404 MPM4CPS network, while 2 were guests participating in the Gdansk meeting (Fig. 1)

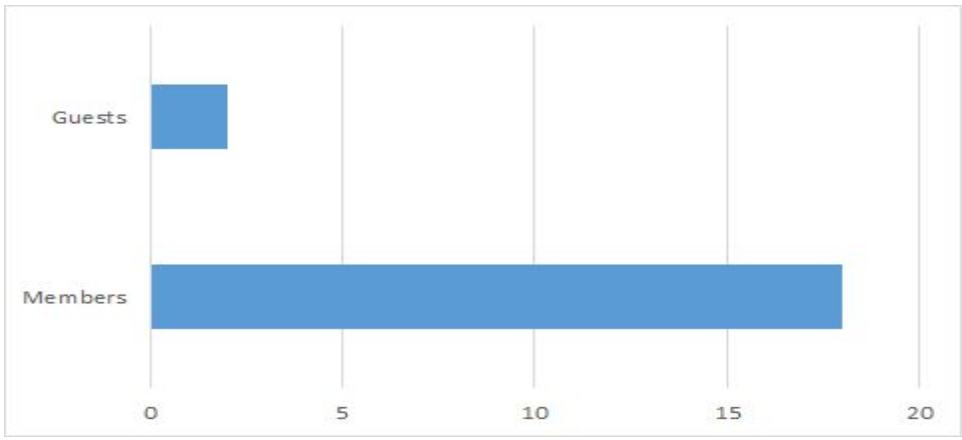


Fig. 1 - Survey participants status concerning IC1404

Concerning the professional background, 16 of the respondents are researchers, 13 educators, and 2 come from industry (Fig. 1). Note that the categories are not exclusive: several of the researchers are educators, as well (i.e. they are Faculty members).

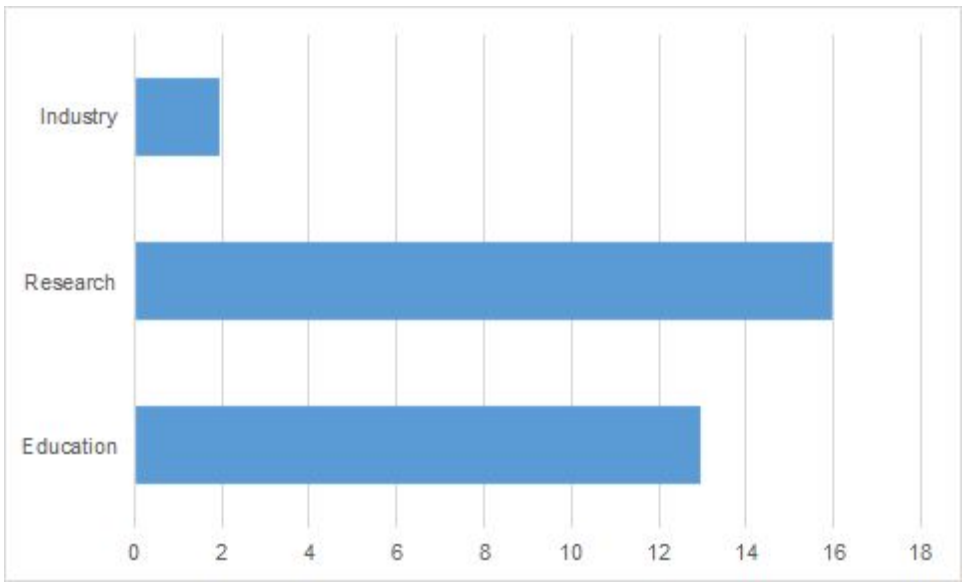


Fig. 2 - What is the professional background of the respondents?

We also wanted to know the extent to which the respondents had prior experience with CPS industrial projects. 40% of our respondents participate, or have participated in industry projects on CPS (Fig. 3).

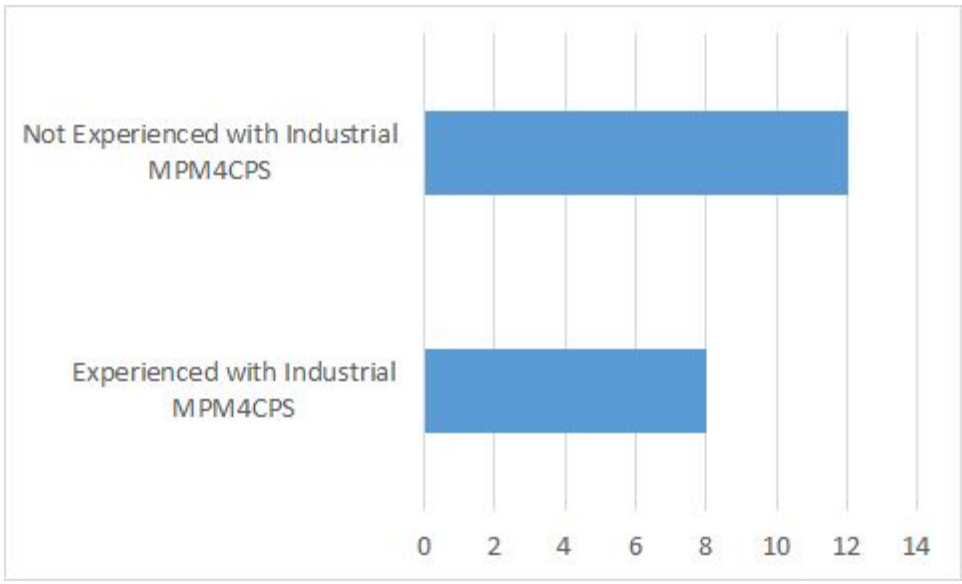


Fig. 3 - Do the respondents have experience with MPM4CPS projects in an industrial context?

Concerning expertise, the participants in our survey identified their expertise into 30 different categories (Fig. 4). The most frequently identified expertise subject was Software Engineering (6 out of 20 respondents), followed by Computer Science (4), Electrical Engineering (2), Formal Methods (2), Modeling (2), and several other areas of expertise with only one single occurrence in our sample. Overall, we observe a predominance of respondents with a background of software systems development, as well as a diverse spectrum of expertise.

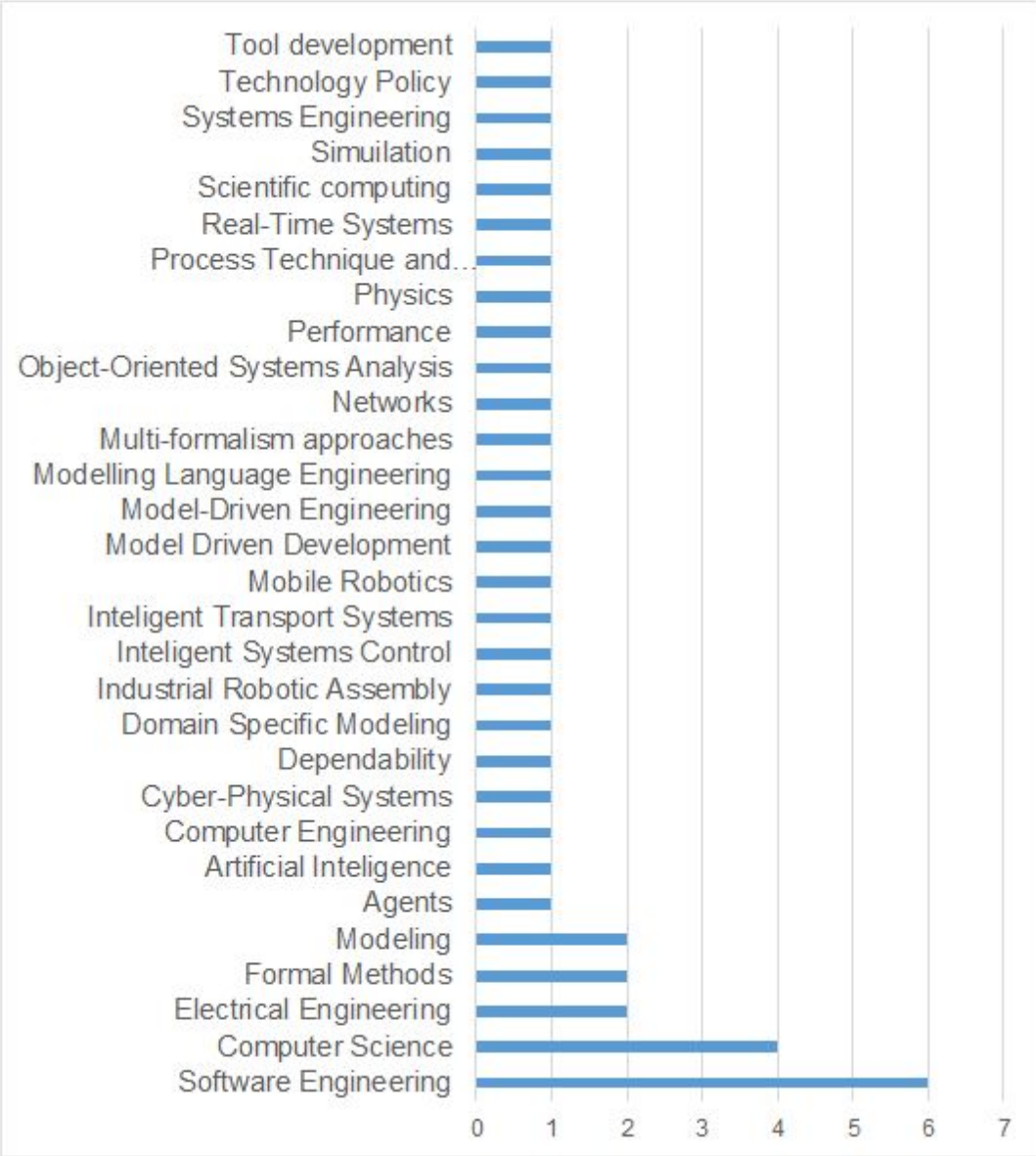


Fig. 4 - Self-reported expertise

Results

In this section we analyze the responses of our participants concerning their answers on the adequacy of each topic for the MPM4CPS curriculum. We first present an overview of descriptive statistics (the mean scores for the classification of relevance, for each category). Then, as we were interested in determining the extent to which there was a significant difference in the obtained scores we tested whether the found differences were statistically significant. Our null hypothesis was that all topics were similarly relevant. The alternative was that some of them were significantly more, or less, relevant for the MPM4CPS curriculum.

Analysis

We analyze the results with two different degrees of granularity. At a higher abstraction level (first level topics, in the list of potential MPM4CPS subjects proposed in survey structure) we have an overview of the most relevant broad topics (Fig. 5, and Table 1). The sub-topics directly concerning CPS have a mode of 5 (very relevant). Sub-topics concerning MPM, Application Domains and Software Engineering were considered relevant, with a mode of 4. Finally, design and simulation have a mode of 3 (the neutral value in the used Likert scale), with the vast majority of answers provided between either 3 (the mode) or "relevant". Among the surveyed topics, these were the ones receiving lower rankings.

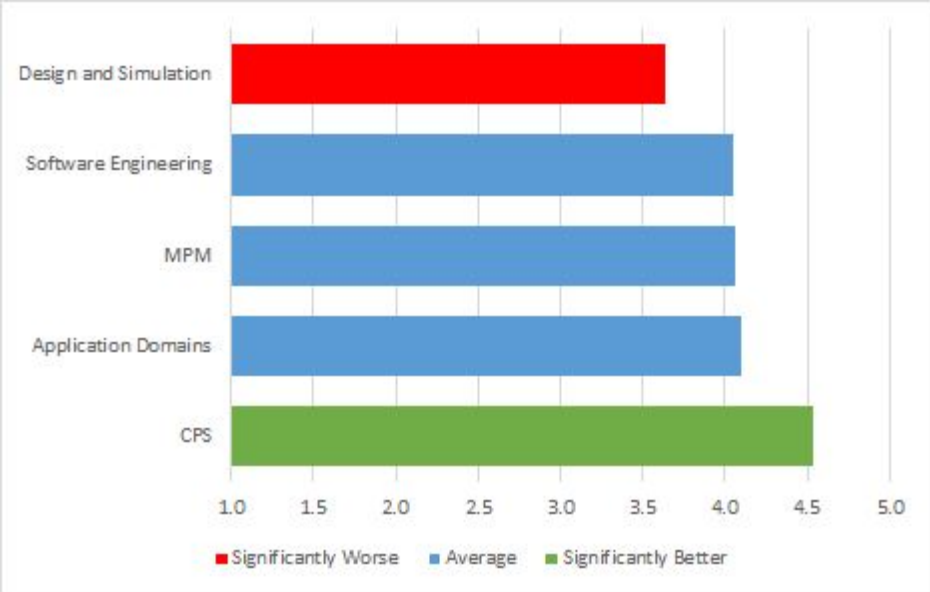


Fig. 5 - Distribution of answers by High level MPM4CPS topic perception

For testing our hypothesis, we used the Welch t test, instead of the t test, as it is robust to deviations from the normal distribution, different sample sizes and different variance in the samples.

There was a statistically significant difference (see Table 1) between the mean score obtained in the different topics, $t(4) = 11.577$, $p = 0.000$. Post-hoc Games-Howell tests allowed further identifying those differences. The most differentiated topics were CPS and Design and Simulation. The CPS topic ($M = 4.5385$, $SD = 0.71987$) had statistically significantly higher scores, when contrasted with each of the remaining high-level topics. In contrast, there was a statistically significant difference between the mean score obtained by the Design and Simulation topic ($M = 3.376$, $SD = 1.09117$) and all the remaining topics.

Table 1 - High-level topics descriptive statistics

Topic	N	Mean	Std. Deviation
MPM	79	4.0633	1.02959
Application Domains	91	4.0989	1.17431
CPS	39	4.5385	0.71987
Design and Simulation	218	3.6376	1.09117
Software Engineering	109	4.0459	1.03981
Total	**536**	**3.9272**	**1.09388**

At a finer granularity level, we also observe differences in the distribution of the classifications provided by our participants to the finer-grained topics. Fig. 6 and Table 2 present a broken down view of the mean scores for the scores distributions, with the more detailed topics, i.e., those represented as leafs in the topics break down. Again, values closer to 5 represent the topics regarded as the best candidates, while values closer to 1 would represent the least relevant candidate topics to include. The different numbers of answers for some of the topics reflect that the answers were not mandatory, as not all participants were familiar enough with all the topics to feel comfortable in answering about each topic's adequacy.

Hybrid Systems was the highest ranked topic, while SPSS was the one obtaining the lowest scores.

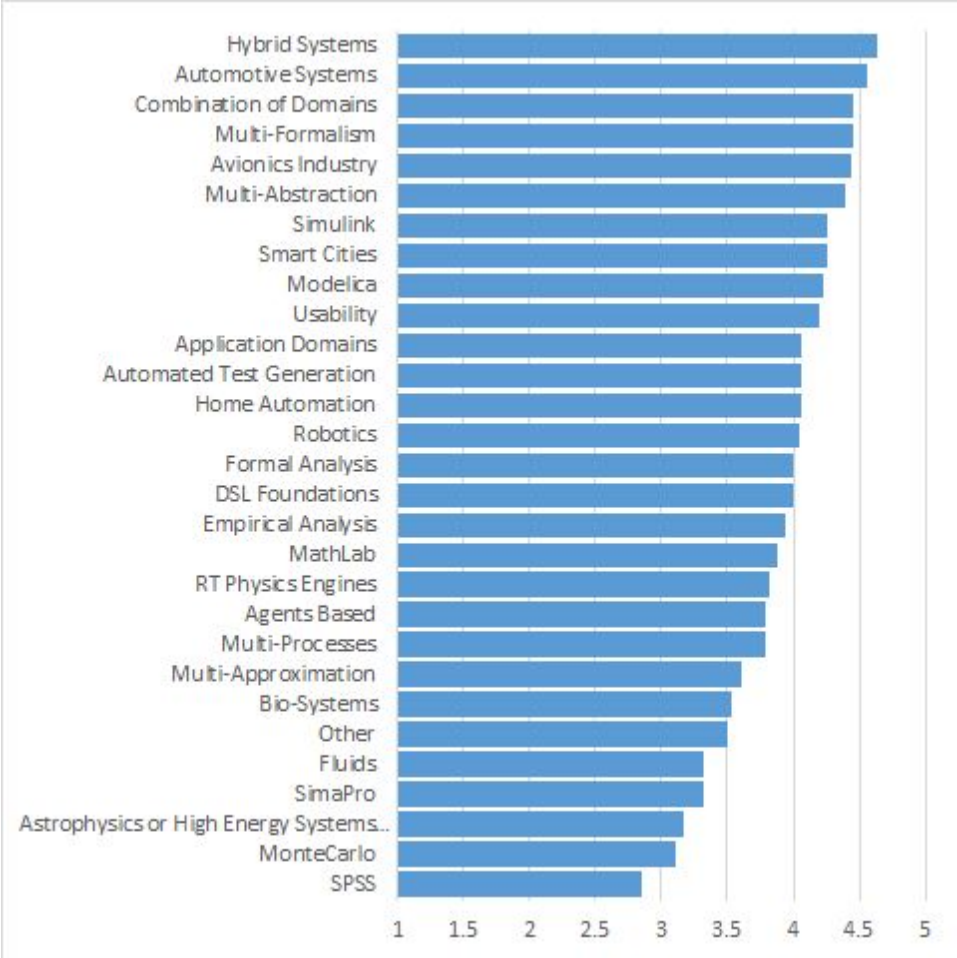


Fig. 6 - Distribution of answers by leaf topic

Table 2 - Fine-grained topics descriptive statistics

	N	Mean	Std. Deviation
SPSS	20	2.85	1.03999
MonteCarlo	18	3.1111	0.96338
Astrophysics or High Energy Systems Particle Physics Detectors	18	3.1667	1.38267
SimaPro	16	3.3125	1.01448
Fluids	19	3.3158	1.15723
Other	16	3.5	1.26491
Bio-Systems	19	3.5263	1.07333
Multi-Approximation	20	3.6	1.14248
Multi-Processes	19	3.7895	1.08418

Agents Based	19	3.7895	0.85498
RT Physics Engines	17	3.8235	0.80896
MathLab	17	3.8824	1.31731
Empirical Analysis	18	3.9444	0.9376
DSL Foundations	19	4	1.20185
Formal Analysis	19	4	1.1547
Robotics	20	4.05	0.88704
Home Automation	18	4.0556	1.34917
Automated Test Generation	17	4.0588	0.96635
Application Domains	16	4.0625	1.06262
Usability	20	4.2	1.00525
Modelica	18	4.2222	0.94281
Smart Cities	19	4.2632	0.93346
Simulink	19	4.2632	0.93346
Multi-Abstraction	20	4.4	0.75394
Avionics Industry	18	4.4444	0.85559
Multi-Formalism	20	4.45	0.88704
Combination of Domains	20	4.45	0.75915
Automotive Systems	18	4.5556	0.78382
Hybrid Systems	19	4.6316	0.68399
Total	**536**	**3.9272**	**1.09388**

A Welch t test was performed on this finer-grained topics rankings, following the same rationale as for the coarse-grained topics. Unlike what happened for the coarse-grained topics, here there were no topics which obtained significantly higher (or lower) scores than all the others. Nevertheless, there were differences that were considered statistically significant $t(28) = 4.036$, $p = 0.000$. Post-hoc Games-Howell tests allowed further identifying those differences. Hybrid Systems had significantly better scores ($M = 4.6316$, $SD = 0.68399$) than Fluids ($M = 3.3158$, $SD = 1.15723$), SimaPro ($M = 3.3125$, $SD = 1.01448$), Monte Carlo ($M=3.1111$, $SD = 0.96338$), and SPSS ($M = 2.85$, $SD = 1.03999$), but not for Astrophysics or High Energy Systems Particle Physics Detectors ($M = 3.1667$, $SD = 1.38267$), although this particular topic had a mean classification lower than that of Fluids and SimaPro (in this particular case, the due to the higher value of the standard deviation). More generally, the top ranked topics had a distribution of classifications with a statistically significant difference when compared to Monte Carlo and SPSS.

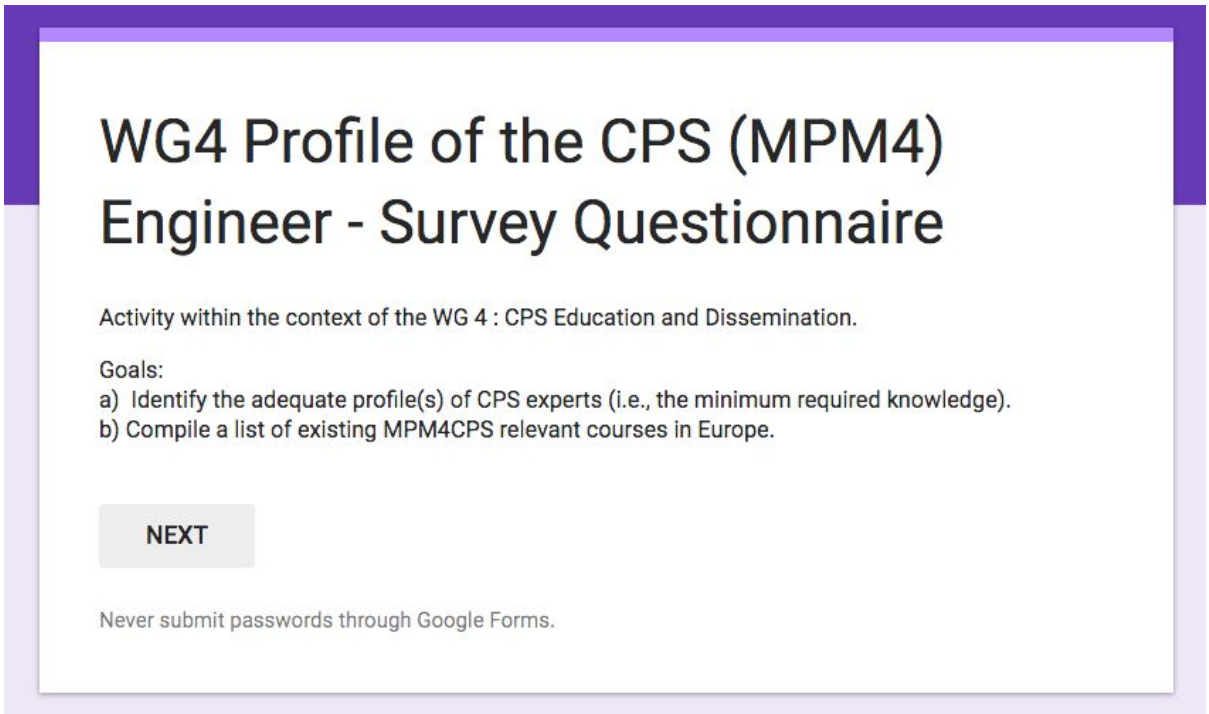
Discussion

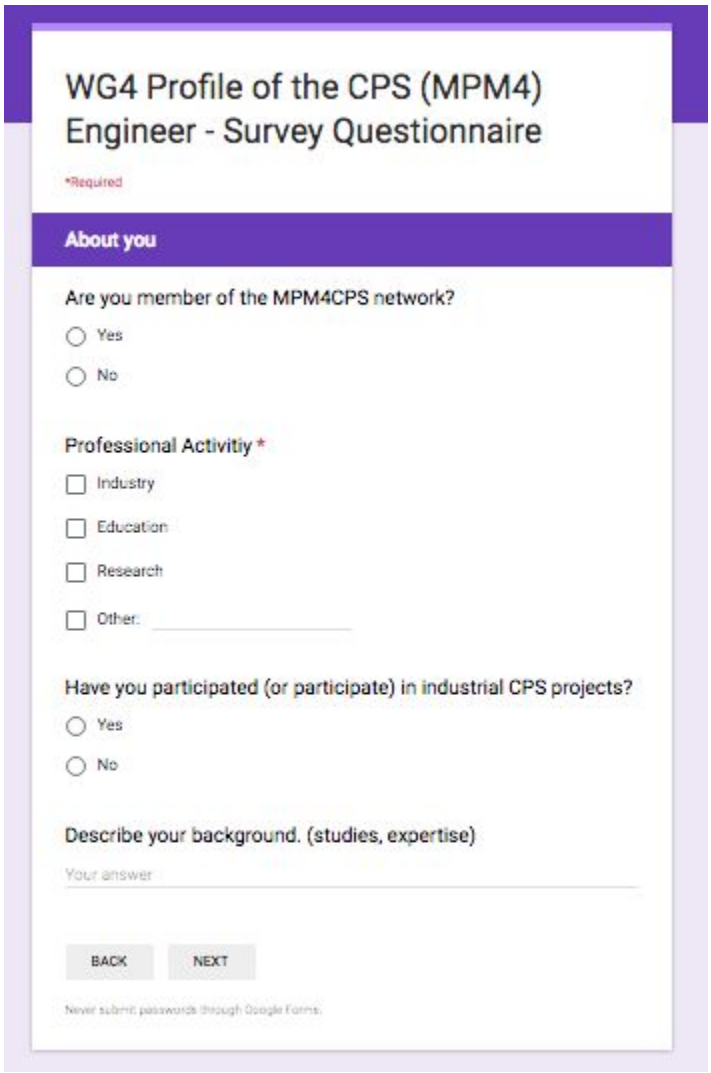
Overall, both for the coarse-grained and for the fine-grained topics, the vast majority of opinions ranged from very positive to neutral, with few exceptions. This should not be surprising, as the list of potential topics was created by identifying potential candidate topics. Even those topics receiving lower scores are often used in the context of projects involving CPS, although they were not perceived by our survey participants as core elements of the CPS expertise. This kind of ranking should be regarded as a relevant element when discussing a CPS curriculum, but not, at least in isolation, as a defining metric for including or excluding a particular topic from the CPS curriculum just because it happens to be above or below some given threshold.

Related Bibliography

Google forms: http://forms.google.com

Annex I: Used Formulaire





WG4 Profile of the CPS (MPM4) Engineer - Survey Questionnaire

*Required

About you

Are you member of the MPM4CPS network?

- Yes
- No

Professional Activitiy *

- Industry
- Education
- Research
- Other:

Have you participated (or participate) in industrial CPS projects?

- Yes
- No

Describe your background. (studies, expertise)

Your answer

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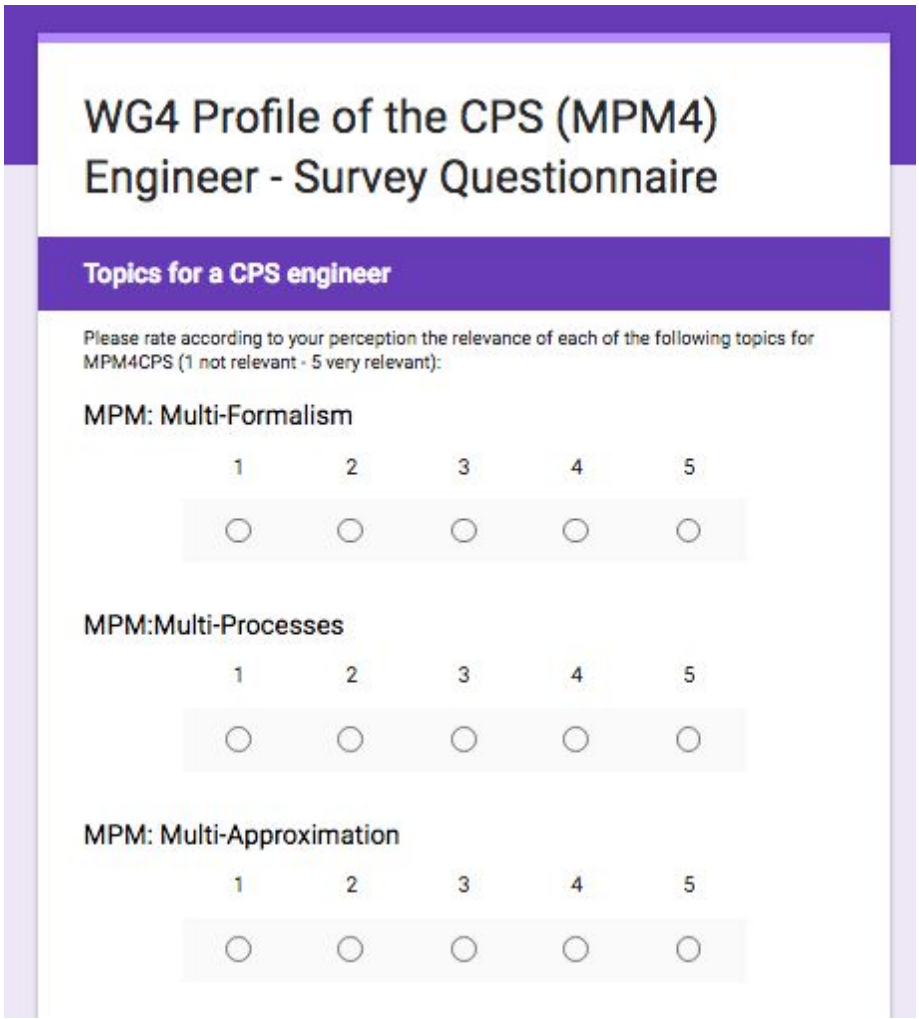


WG4 Profile of the CPS (MPM4) Engineer - Survey Questionnaire

Topics for a CPS engineer

Please rate according to your perception the relevance of each of the following topics for MPM4CPS (1 not relevant - 5 very relevant):

MPM: Multi-Formalism

1	2	3	4	5
○	○	○	○	○

MPM:Multi-Processes

1	2	3	4	5
○	○	○	○	○

MPM: Multi-Approximation

1	2	3	4	5
○	○	○	○	○

MPM: Multi-Abstraction

1	2	3	4	5
○	○	○	○	○

Application Domains: Automotive Industry

1	2	3	4	5
○	○	○	○	○

Application Domains: Avionics Industry

1	2	3	4	5
○	○	○	○	○

Application Domains: Home Automation

1	2	3	4	5
○	○	○	○	○

Application Domains: Smart Cities

1	2	3	4	5
○	○	○	○	○

Application Domains: Astrophysics or High-Energy Particle Physics Detectors

1	2	3	4	5
○	○	○	○	○

CPS: Hybrid Systems

1	2	3	4	5
○	○	○	○	○

CPS: Combination of Domains

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Control Theory:Mechatronics: Fluids

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Control Theory:Mechatronics: Bio-Systems

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Control Theory:Mechatronics: Robotics

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Tools&Languages:Pure Numerical:SPSS

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Tools&Languages:Pure Numerical:SimaPro

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Tools&Languages:Pure Numerical:MonteCarlo

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Tools&Languages:RT Physics Engines

1	2	3	4	5
○	○	○	○	○

Design&Simulation: Tools&Languages:Agents Based

1	2	3	4	5
○	○	○	○	○

Design&Simulation:Industrial Design:Mathlab

1	2	3	4	5
○	○	○	○	○

Design&Simulation:Industrial Design:Modelica

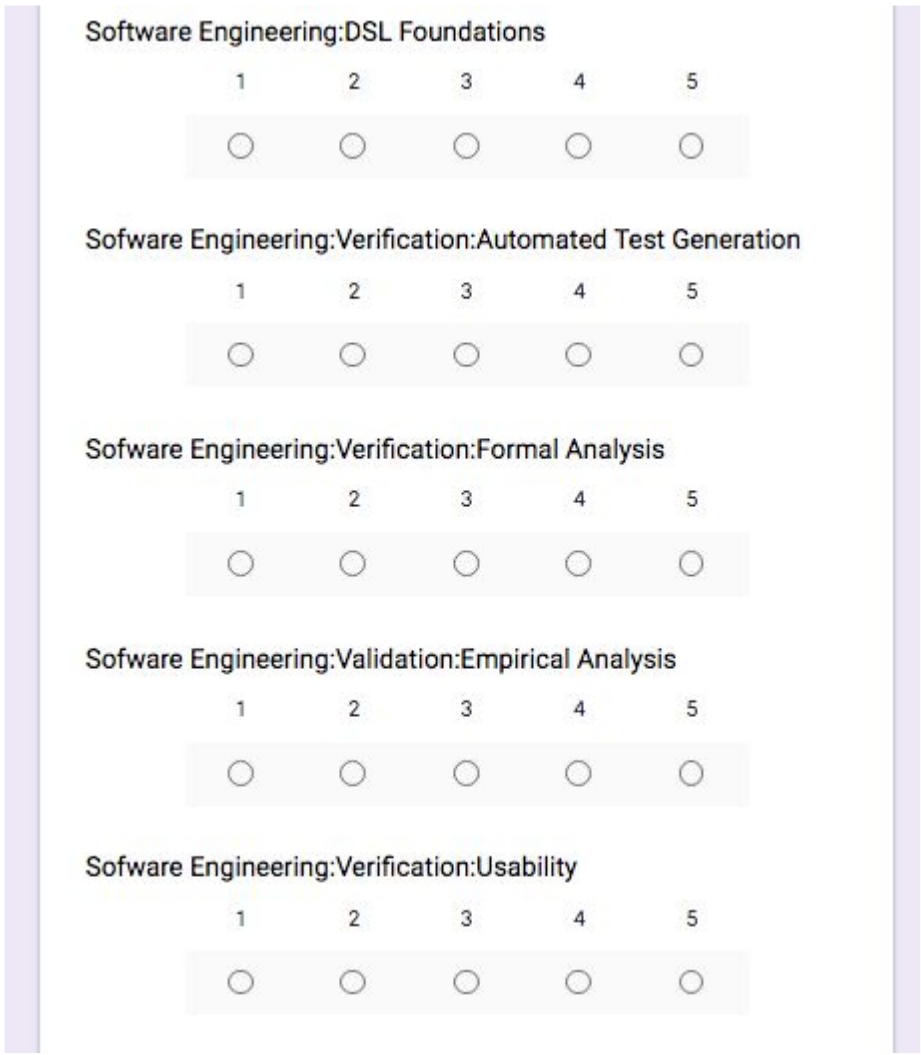
1	2	3	4	5
○	○	○	○	○

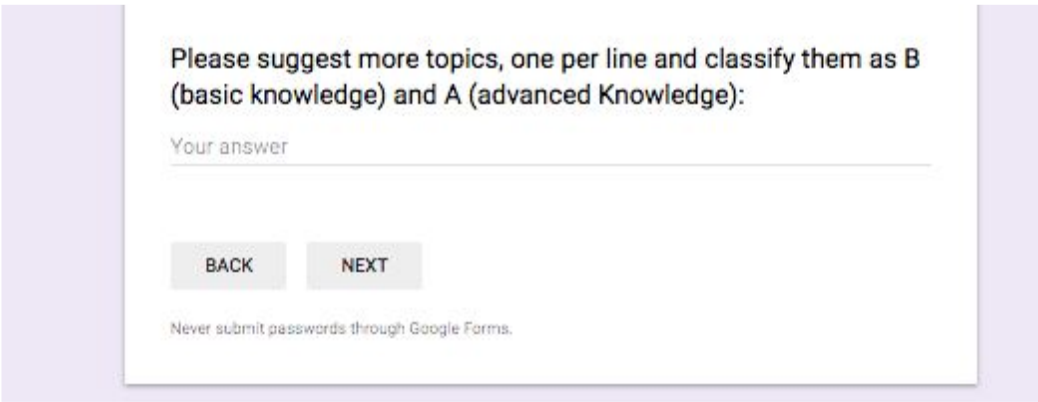
Design&Simulation:Industrial Design:Simulink

1	2	3	4	5
○	○	○	○	○

Design&Simulation:Industrial Design:Other

1	2	3	4	5
○	○	○	○	○


Software Engineering:DSL Foundations
1 2 3 4 5
Sofware Engineering:Verification:Automated Test Generation
1 2 3 4 5
Sofware Engineering:Verification:Formal Analysis
1 2 3 4 5
Sofware Engineering:Validation:Empirical Analysis
1 2 3 4 5
Sofware Engineering:Verification:Usability
1 2 3 4 5


Please suggest more topics, one per line and classify them as B (basic knowledge) and A (advanced Knowledge):
Your answer
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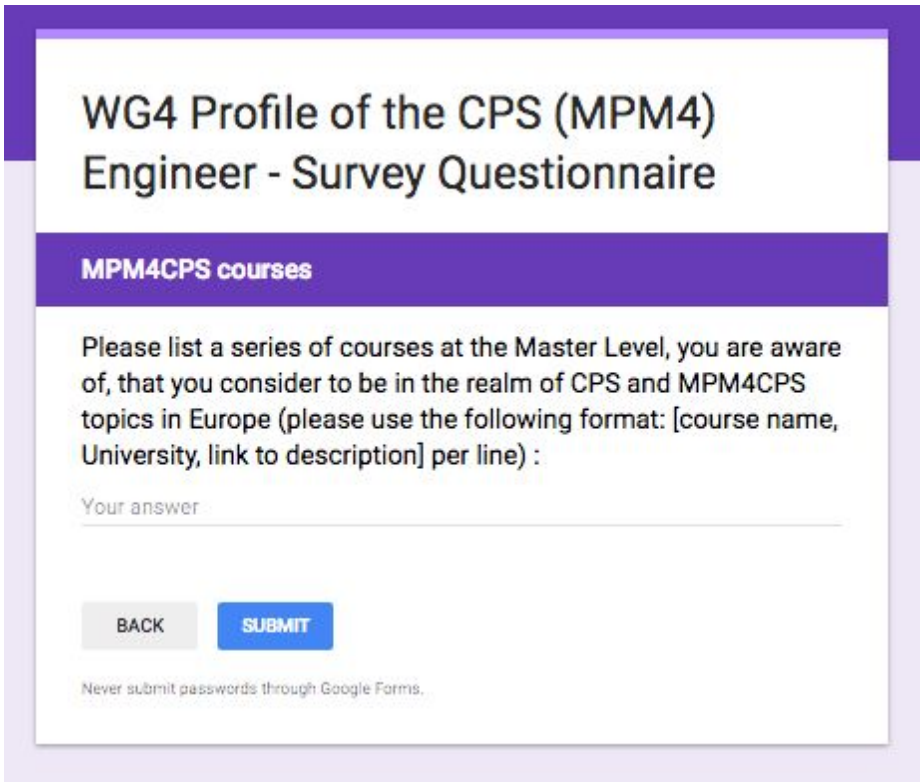

Annex II: List of reported course suggestions

Question: Please list a series of courses at the Master Level, you are aware of, that you consider to be in the realm of CPS and MPM4CPS topics in Europe (please use the following format: [course name, University, link to description] per line) :
Modelling of software-intensive systems, University of Antwerp, http://msdl.cs.mcgill.ca/people/hv/teaching/MoSIS/
Model-Driven Engineering, University of Antwerp, http://msdl.cs.mcgill.ca/people/hv/teaching/MSBDesign/
Object-Oriented System Analysis, Riga Technical University, http://wpweb-prod.rtu.lv/wp-content/uploads/sites/65/2016/04/Computer%20Systems%20Msc%202014/DPI502.pdf
Real-Time and Embedded Systems, University of Pennsylvania, https://www.seas.upenn.edu/~rahulm/teaching/index.html

Modellierung Verteilter Systeme TU München, https://wwwpretschner.in.tum.de/modellierung-verteilter-systeme-sose2016/
Automotive Software Engineering, TU München, https://wwwpretschner.in.tum.de/modellierung-verteilter-systeme-sose2016/
Systems Engineering, TU München https://wwwpretschner.in.tum.de/lehre/systems-engineering/
Distributed Big Data Processing, University of Zagreb Faculty of Electrical Engineering and Computing, http://www.fer.unizg.hr/en/course/dbdp
Mobile Software Agents, University of Zagreb Faculty of Electrical Engineering and Computing, http://www.fer.unizg.hr/en/course/msa_a
Distributed Contrl Systems, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
Fuzzy Systems, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
Intelligent Control Systems, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
Adaptive and Advanced Control, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
[Nonlinear Control Systems, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
Domain Specific Modeling and Languages, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering
Discrete Event Simulation, Uni. of Novi Sad, http://www.ftn.uns.ac.rs/123263546/computing-and-control-engineering