Preface to the 3rd Multi-Paradigm Modeling for Cyber-Physical Systems (MPM4CPS 2021)

Moussa Amrani
Université de Namur
Namur, Belgium
Moussa.Amrani@unamur.be

Dominique Blouin
Télécom Paris
Paris, France
dominique.blouin@telecom-paris.fr

Moharram Challenger
University of Antwerp/Flanders Make
Antwerp, Belgium
Moharram.Challenger@uantwerpen.be

Julien Deantoni
Université Cote d'Azur - Sophia Antipolis
Nice, France
julien.deantoni@univ-cotedazur.fr

Robert Heinrich
Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany
Robert.Heinrich@kit.edu

Manuel Wimmer
Johannes Kepler University Linz
Linz, Austria
manuel.wimmer@jku.at

***Abstract*—Multi-Paradigm Modelling (MPM) offers a foundational framework for connecting several engineering disciplines in a comprehensive and consistent way which is of particular importance for Cyber-Physical Systems (CPS). The MPM4CPS Workshop acts as a continuation of the successful MPM Workshop series hosted at the MODELS, but focuses on the application of the MPM approach to CPSs. The workshop aims at further advancing the state-of-the-art as well as identifying future research lines by bringing together international experts from academia and industry.**

***Index Terms*—Multi-Paradigm Modeling, Model-Driven Engineering, Cyber-Physical Systems**

I. Introduction

Cyber-Physical Systems (CPSs) are engineered systems, emerging from the networking of multi-physical processes (mechanical, electrical, biochemical, etc.) and computational processes (control, signal processing, reasoning, planning, etc.) that interact with highly uncertain environments (including human actors) in a socio-economic context [1]. Engineering such complex systems requires the contribution of experts from different domains and disciplines to solve challenges in their own field, but also to collaborate to make all parts in the overall system work together [1]. Single modelling paradigms rarely cover all aspects of a CPS, raising an heterogeneity and complexity in models that only multiple, carefully chosen paradigms targeted to each aspect of interest may be able to manage in order to describe the entire system.

Currently, there is a crucial need for building an unifying theory, accompanied by system design methods centred around explicitly modelling all relevant dimensions of CPSs, to support the various activities (design, analyse, reason, predict, calibrate, explore, deploy, among others) necessary in such a multi-disciplinary domain such as CPS engineering.

Multi-Paradigm Modelling (MPM) offers a foundational framework for connecting several engineering disciplines in a consistent and comprehensive way. The inherent complexity of CPS is managed by specifying each aspect of the system at the most appropriate level of abstraction, and allows for the modelling of different views on the system, each expressed in appropriate modelling formalisms [2]. To support this modeling paradigm, MPM provides processes and tools for combining, coupling, integrating, and synchronizing these views which describe one system from different perspectives.

The MPM4CPS Workshop acts as a continuation of the successful MPM Workshop series hosted at the MODELS Conference from 2006 until 2015. However, MPM4CPS focuses on the application of MPM to CPSs. MPM4CPS aims at further advancing the state-of-the-art as well as identifying future research lines by bringing together international experts from academia and industry.

The first edition of the Workshop on Multi-Paradigm Modeling for Cyber-Physical Systems (MPM4CPS) was held on September 15, 2019 in Munich, Germany, as part of the satellite events of the IEEE/ACM 22th International Conference on Model-Driven Engineering Languages and Systems (MODELS 2019) [3]. The second edition, also held at MODELS in 2020, occured virtually due to COVID pandemic crisis.

II. Summary of the workshop

For this third edition, we innovated and proposed two original tracks: *exemplars*, i.e. typical yet relatively tractable use cases of CPS systems demonstrating typical activities required in CPS engineering, and explicitly detailing the underlying formalisms, languages and tools deployed to support such activities, all expressed in a similar way to enable comparison and extract CPS Engineering common practices and design patterns; and *process-oriented use cases* with an explicit modelling of both the underlying formalisms, but also the various transformations at play, that all support the use cases development processes. As usual, we accepted "regular" *research papers* in two formats (long papers for mature results; and short papers for work in progress and early experimentations).

We received six papers that we all accepted for publication in the proceedings, and for presentation at the workshop. These papers represent a good mix falling in each tracks we proposed for the workshop: we received two exemplar descriptions; one

process-oriented use case, and three research papers, as listed below:

Reasearch Papers

- *Knowledge Base Development and Application Processes applied on Product-Assembly Co-design*, by Bert Van Acker, Joachim Denil, Alexander De Cock, Hans Vangheluwe and Moharram Challenger;
- *On the Need for Multi-Level ADS Scenarios* by Stefan Klikovits and Paolo Arcaini;
- *Supporting the Engineering of Multi-Fidelity Simulation Units With Simulation Goals*, by João Cambeiro, Julien Deantoni and Vasco Amaral.

Examplars

- *Developing a Physical and Digital Twin: An Example Process Model*, by Hao Feng, Cláudio Gomes, Michael Sandberg, Casper Thule, Kenneth Lausdahl and Peter Gorm Larsen;
- *Modeling the Engineering Process of an Agent-based Production System: An Exemplar Study*, by Burak Karaduman, Istvan David and Moharram Challenger.

Process-Oriented Use Cases

- *FTG+PM for the Model-Driven Development of Wireless Sensor Network based IoT Systems*, by Burak Karaduman, Sadaf Mustafiz and Moharram Challenger.

Due to the organisation constraints related to the COVID situation, we rely on a virtual meeting, we opted to host a keynote presentation and three sessions corresponding to the tracks above. We hope that the next edition will happen during a physical meeting to foster long-waited discussions. We also already plan to attract exemplars and process-oriented use cases descriptions during the next edition(s) to collect enough samples to study possible patterns of CPS Engineering practices.

III. Acknowledgement

We would like to thank the MODELS 2021 organization for giving us the opportunity to organize this workshop, especially to the workshops chairs Xiaoxing Ma (Nanjing University) and Huseyin Ergin (Ball State University) as well as the proceedings chair Seung Yeob Shin (Univeristy of Luxembourg), who were always helpful and supportive. Many thanks to all those who submitted papers, and particularly to the presenters of the accepted papers. Last but not least, our thanks go to the reviewers and the members of the Program Committee and Steering Committee, for their timely and accurate reviews (during a well-deserved vacation period) and for their help and suggestions for improving the selected papers.

IV. Steering Committee

- Hans Vangheluwe (University of Antwerp – Flanders Make, Belgium)
- Pieter J. Mosterman (MathWorks, USA)
- Jeff Gray (University of Alabama, USA)
- Vasco Amaral (Universidade Nova de Lisboa, Portugal)

V. Workshop Program Committee

- Shaukat Ali, Simula Research Laboratory, Norway
- Soumyadip Bandyopadhyay, BITS, India
- Ankica Barisic, Universidade Nova de Lisboa, Portugal
- Frédéric Boulanger, CentraleSupélec, France
- Loli Burgueño, Open University of Catalonia, Spain
- Antonio Cicchetti, Mälardalen University, Sweden
- Federico Ciccozzi, Mälardalen University, Sweden
- Andrea D'Ambrogio, University of Roma TorVergata, Italy
- Ferhat Erata, Yale University, USA
- Raheleh Eslampanah, University of Antwerp, Belgium
- Holger Giese, Hasso Plattner Institute, University of Potsdam, Germany
- Mauro Iacono, Università degli Studi della Campania "Luigi Vanvitelli", Italy
- Gabor Karsai, Vanderbilt University, USA
- Stefan Klikovits, National Institute of Informatics, Japan
- Thomas Kuehne, Victoria University of Wellington, New Zealand
- Hana Mkaouar, Recdad, Tunisia
- Letitia Li, BAE Systems, USA
- Ivan Ruchkin, University of Pennsylvania, USA
- Bran Selic, Malina Software Corp., USA
- Eugene Syriani, University of Montreal, Canada
- Antonio Vallecillo, Universidad de Málaga, Spain
- Clark Verbrugge, McGill University, Canada
- Andreas Wortmann, University of Stuttgart, Germany

References

[1] M. Amrani, D. Blouin, R. Heinrich, A. Rensink, H. Vangheluwe, and A. Wortmann, "Multi-paradigm modelling for cyber-physical systems: a descriptive framework," *Softw. Syst. Model.*, vol. 20, no. 3, pp. 611–639, 2021. [Online]. Available: https://doi.org/10.1007/s10270-021-00876-z

[2] P. J. Mosterman and H. Vangheluwe, "Computer automated multi-paradigm modeling: An introduction," *Simul.*, vol. 80, no. 9, pp. 433–450, 2004. [Online]. Available: https://doi.org/10.1177/0037549704050532

[3] S. V. Mierlo, E. Syriani, D. Blouin, M. Amrani, J. DeAntoni, and M. Wimmer, "Preface to the 1st Multi-Paradigm Modeling for Cyber-Physical Systems (MPM4CPS 2019)," in *22nd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion, MODELS Companion*. IEEE, 2019, pp. 417–418. [Online]. Available: https://doi.org/10.1109/MODELS-C.2019.00066