

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

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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, occurred 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:

Research 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.

Exemplars

- *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-awaited 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

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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
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- Antonio Vallecillo, Universidad de Málaga, Spain
- Clark Verbrugge, McGill University, Canada
- Andreas Wortmann, University of Stuttgart, Germany

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