CO-SIMULATION – AN EMPIRICAL SURVEY: APPLICATIONS, RECENT DEVELOPMENTS AND FUTURE CHALLENGES

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Keywords: Co-Simulation; Computer Modelling; Numerical Simulation; Expert Interviews

1. INTRODUCTION

In recent decades, simulation-driven development has increasingly become established as a central method in industry and academia. This is leveraged by computational advances, like the recent emergence of equation-based modelling languages, which offers new possibilities compared to block diagram modelling using imperative programming languages. Classically, systems are modelled in a single tool, which is referred to as monolithic approaches. With the increased complexity of systems and the need for linking several domains in one model, monolithic approaches have restrictions: Sometimes it is not possible to simulate a complex system in a single tool, but even if it is possible, very often there are more suitable tools available for different subsystems. Ideally, every subsystem is modelled in a tool that meets the particular requirements for the domain and the structure of the model. Thus, the need for coupling different tools is a pragmatic one. Co-simulation is an approach to enable a simulation of complex single or multi-domain systems that consists at least two subsystems (modelled in different tools) which solve coupled (algebraic) differential systems of equations (Gomes et al. 2017).

An overview of co-simulation approaches and tools, research challenges, and research opportunities are presented, e.g. in the references (Trcka 2008; Atam 2017; Mathias et al. 2015; Gomes et al. 2017). The proposed empirical survey aims to merge different views of heterogeneous communities which are working in the field of co-simulation, on the state of the art, research gaps and future challenges.

2. METHOD

As a methodological foundation of the empirical survey, the Delphi method will be adopted. The Delphi method is a forecasting technique that bases on the collection and compilation of expert knowledge from a panel of experts in a multi-stage process (Dalkey & Helmer 1963; Hsu & Sandford 2007). It fosters group communication which is intended to deal with complex problems, particularly for the case where there is insufficient knowledge, lack of historical data, or lack of agreement found within the studied field (Okoli & Pawlowski 2004). The Delphi method is also conceived to be useful particularly for solving interdisciplinary research problems in a heterogeneous environment (Stern et al. 2012). Moreover, it enables determining probable future scenarios.

We aim at integrating 15-30 experts in our Delphi study, because despite the lack of a mandatory minimum requirement, for instance (Clayton 1997) states that 15-30 participants are adequate for studies involving experts with a homogenous expertise background. For selecting the sample of participants, a Knowledge Resource Nomination Worksheet (KRNW) will be used as a guideline (Delbecq et al. 1986; Okoli & Pawlowski 2004).

The Delphi study will form two rounds. The first round will comprise a mix of open-ended and closed-ended questions. The second round will only include closed-ended questions that will be formulated based on the results of the first round. In addition to these standard questions, an additional quantitative analysis of the strengths, weaknesses, opportunities and threats (SWOT) of co-simulation utilizing the Analytic Hierarchy Process (AHP) will be conducted.

The SWOT-AHP method was introduced by (Kurttila et al. 2000) to increase the effectiveness of a primary SWOT analysis as a decision-making tool (Reinsberger et al. 2015). In this study, the SWOT-AHP method is utilized to enrich the results of the Delphi study by providing an additional and new perspective on the current state of co-simulation.

3. EXPERT INTERVIEWS

The questionnaire for the first round of the Delphi study consisted of four parts: (i) the roots of co-simulation. This includes questions about different origins for co-simulation, concepts, wording and scientific and industrial communities. (ii) Theoretical questions. Included are questions regarding the state-of-the-art, research gaps and open issues within continuous, discrete and hybrid co-simulation. (iii) Functional Mock-Up Interface (FMI). Since FMI is already widely used and it is a promising candidate to become the standard for industry and academia, a section with specific FMI related questions was designed. (iv) Questions related to an overall SWOT-AHP analysis of co-simulation.

At this stage of the survey, the first round of interviews and the expert selection for the second round have both been completed; more than 40 experts have already committed to participate in the second round.

4. PRELIMINARY RESULTS

In the first round of interviews, experts had to select three factors for the categories “Strengths”, “Weaknesses”, “Opportunities” and “Threats”. In the following, we present the results for the pre-selection of SWOT factors in hierarchical order.

Strengths: (i) Every sub-system can be implemented in a tool that meets the particular requirements for the domain, the structure of the model and the simulation algorithm; (ii) cross-company cooperation is supported (e.g., suppliers and system integrators can exchange virtual "trial components" before signing contracts); (iii) every sub-system can be implemented in a tool that meets the particular requirements for the domain, the structure of the model and the simulation algorithm.

Weaknesses: (i) Computational performance of co-simulation compared to monolithic simulation; (ii) robustness of co-simulation compared to Monolithic simulation; (iii) licenses for all programs are required to couple different simulation programs.

Opportunities: (i) Growing co-simulation community / growing industrial adoption; (ii) better communication between theoretical/numerical part, implementation and application/industry; (iii) user-friendly tools (pre-defined master algorithms, integrated error estimation, sophisticated analysis to determine best parameterization of solvers and master algorithm).

Threats: (i) Insufficient knowledge/information of users in co-simulation may lead to improper use (e.g. wrong or missing error estimation, stability issues etc.); (ii) lack of exchange/cooperation between theoretical/numerical part, implementation and application/industry; (iii) incompatibility of different standards and co-simulation approaches.

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