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Towards an adaptive model for collaborative simulation: from system design to lessons learned. A use case from Aircraft industry

Laura Roa Castro; Julie Stal-Le Cardinal; Martine Callot

Abstract

Over the last few years, vehicle industry has been looking for a better preparation of test and certification phases of their complex products. In this context, Modelling and Simulation (M&S) technics have grown in importance for these companies. Since M&S technics are growing on, the number of people performing those technics have risen exponentially, making their teams work harder to accomplish the simulation objectives. Different alternatives supporting collaborative simulation have been proposed. Nevertheless, most of those alternatives deal only with Information and Technical (IT) problems. This paper proposes the considered solutions, based on a use case from aircraft industry, aiming at develop an adaptive model for collaborative simulation. The results include a holistic view of collaborative problems in simulation processes, distinguished between three different phases: initialization, collaboration and return of experience. In addition, the model combines also three main parts for a successful collaboration: the actors, the process and the objects to exchange. The adaptive model developed gives a clear idea of dynamic interactions between the different phases. Future work will consider a cooperative model based on game theory in order to establish the actors behavior model

Keywords: Collaborative simulation; actor based approach; simulation model exchange

1. Introduction

Nowadays, vehicle industry is highly interested in Modelling and Simulation technics (M&S). Today, it is very common to see M&S approaches to be part of their business models [1], [2]. Those technics require a new organization through the company, but they imply, among others, that the industry makes a better preparation of their tests and certification phases, increasing the global efficiency of the product development.

Although the companies make a remarkable effort trying to develop their products using the same digital mockup, as a collaborative initiative, during the whole design process [3] [4], important collaborative problems still exist in this new organization. Several research are focused in some aspects of the collaborative problem in a M&S context, such as: models synchronization, models interfaces [5], models quality or even platforms for models sharing. Nevertheless, none work containing a holistic view of the collaborative problem has been proposed.

In a previous work [6], a systemic approach was proposed, defining four main dimensions aiming at a successful performance of a collaborative simulation. In order to compare the proposed dimensions to the real industry needs, this paper presents an analysis done in cooperation with Airbus Group Industry resulting in a proposal of the considered solutions for an adaptive model aiming at managing collaborative simulation. Section one presents the current state of the art and the industrial problem, section two presents the methodology used for the analysis and section three presents the results.

2. State of the Art and Industrial problem

The research on collaborative M&S suggest three main work axes: the first one concerns a technology component and it is mostly addressed to interfaces, tools interoperability and integration problems on M&S field. The second one is related to sharing, monitoring and visualization capabilities and the third one is focus on the lifecycle product development problem.

Wang et al. [7] treat the problems related to availability of information, tool integration as a modular approach and multi-client access. In Corunua et al. [8] Interoperability is considered a major factor conditioning the success of deployment. The Data exchange problem has been treated in several works as well. Patzák et al. [9] propose a solution supporting the exchange between codes (different discretization technics and specific field transfer operators). While Zhaia et al. [10] work aims at supporting data exchange by adopting an external/internal units system. Patzak et al and Portegies Zwart et al. [9], [11] also tackle Modularity Problem by building their frameworks from separate components or modules. Finally, many works in the literature are also related to FMI and FMU approach. As an example Bertsch et al. present a standardization for model interfaces [12].

Most part of the works regarding sharing, monitoring and visualization capabilities treat the remote work problem and the understanding between specialists problem. Yasuaki et al. [13] aims at assisting simulation studies in which collaborators are spread on geographically different places. Using a trigger method the process consists in transmitting a request for up-date processing (from the client) to ongoing simulation. The work done by Dong et al. [7] and by Walker and Chapra [8] is more focused on a common understanding of one concept from different users avoiding the misconception is essential to prevent correction on validation phase.

Finally, Lifecycle Product development problem [14] characterizes collaborative engineering as a shared timeframe delivering an iDMU for all (Industrial Digital Mockup). For their part, Jordan and Schmitz [15] propose a library for scalable modelling of aircraft environmental control systems. This library avoids rebuilding simulation models on different phases during the design process.

In the other hand, aeronautical industry has proposed several initiatives concerning the model exchange problem such as CRESCENDO project (Collaborative and Robust Engineering using Simulation

Capability Enabling Next Design Optimization), FEDEP or ProSTEP. Airbus Group industry made part of some of those projects, consequently, some of their results are based on Airbus procedures (AP). This paper pays specially attention on AP2633: Airbus Procedure for Integration and Exchange of Simulation Models. This procedure is a guideline supporting the models exchange between partners with a breakdown structure based on roles and responsibilities, process and model description.

3. Methodology

Based on a previous systemic study [6] and taking into account an extensive state of the art where collaboration features and collaborative M&S features were identified [18], our research has been led by an action-research methodology. A complete view of the methodology is presented in Figure 1.

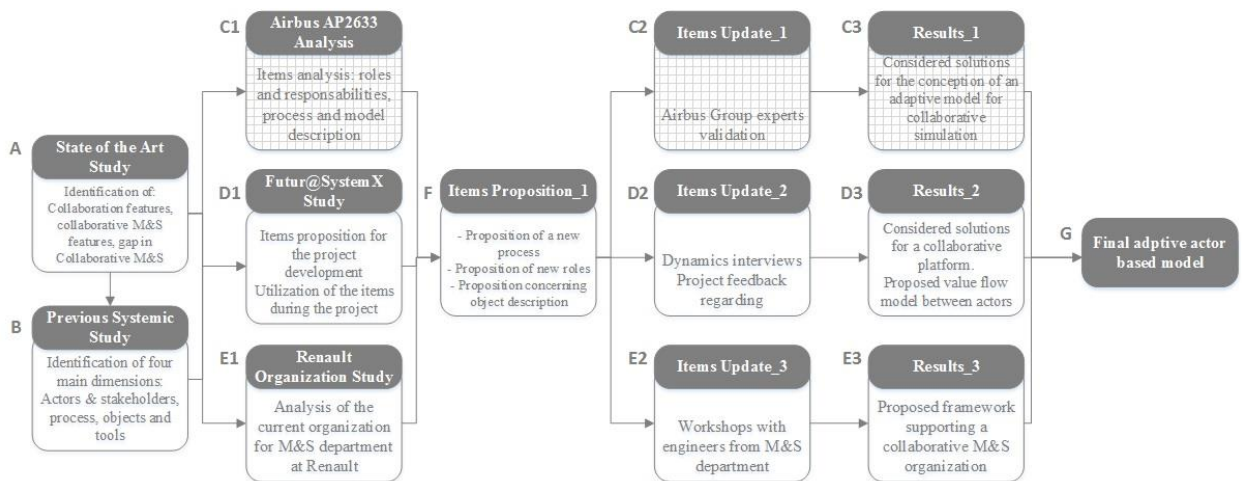


Figure 1: Proposed framework for an action-research Methodology: filled square are the steps presented in this paper

Boxes A and B in Figure 1 represent previous studies. The state of the art study [18], represented in the box B, supports the Systemic study [6], represented in box A. From the systemic study, four main dimensions aiming at a successful performance of a collaborative simulation were identified: the actors and stakeholders of the simulation, the objects to be exchanged, the process under which the objects will be exchanged and the tools supporting the whole.

After these study, three research were carried out. First, an analysis of the Airbus Procedure 2633 was realized (box C1). This analysis was driven by the items of the breakdown structure of the procedure: roles and responsibilities, process and model description. The analysis suggested an improvement concerning the three items.

Second, a list of items based on the results of axis A and B was proposed for the proceedings of a project at the Research Institute of Technology (Box D1). Third, an analysis of the current organization for M&S department at Renault was done based on the systemic approach (Box E1). These analysis apply the identified axis in the vehicle industry.

A first items proposition based on the work done on C1, D1 and E1 was suggested (box F). The proposal contains new actors, different description of the process and an improvement of the description of the object.

The validation of the proposition (box F) was split also in three ways. First, in order to validate the results two meetings were scheduled with two experts in simulation from Airbus Group (box C2). After analysis, the results were considered solutions for the conception of an adaptive model for collaborative simulation. Second, the proposed items were employed in a project where four people exchanged models playing the proposed roles and process (box D2). This project took place at the Research Institute of Technology IRT SystemX. At the end of the project, four dynamic interviews were organized aiming at understanding the collaborative interactions in a real Use Case. The results of this part, consider solutions for a collaborative platform and propositions for a value flow model between actors (D3). Third, seven workshops with engineers from M&S department at Renault were organized in order to establish a collaborative framework for M&S activities (box E2). The results introduce a supporting a collaborative M&S organization (E3). This paper mainly focus in the industrial validation of the considered solutions aiming at develop an adaptive model for collaborative simulation (boxes C1, C2, C3 in Figure 1). The results are presented in Table 2. This table contains the representation of the considered solutions aiming at develop an adaptive model for collaborative simulation, regarding the dimensions identified on systemic study, [6] validated with the analysis described in boxes C1, D1 and E1.

4. Aircraft Industry case

In order to validate the interest of our adaptive model for collaborative simulation in the aeronautical industry, the work follows the break down structure of the AP2633. The previous work [6], were an identification of four main dimensions of the collaborative simulation was done, takes into account the AP2633 structure, and is completely compatible. In this way, subsection presented below concerns the experts points of view regarding process, actors and objects to exchange.

4.1. The Process

Although the AP2633 has been designed for the extended enterprise context, the process for the model exchange presented does not make any difference between the extended enterprise situation and the proper enterprise context. The process stays general and is defined for being adapted to different situations. Several other Airbus Procedures (AP) are associated to this main standard. Some of those associated AP implement the standard in a proper context. However, the collaborative process is not mapped out between the AP2633 and the other associated Airbus Procedures. In consequence, it results very difficult to monitor the process and to know the adhesion of the process in the organization. Without this information, the adaptation of the process seems problematic.

4.2. The Actors

A clear and generic definition of the roles and responsibilities is proposed in the AP2633. Nonetheless, 6 problems have been identified during the meetings with the experts:

- Even if the roles are well defined, their implementation is still difficult
- Since every level of the organization responds to specific constraints, the global coherence between the constraints and the actors is still laborious to reach.
- The understanding of simulation objectives remains tough due to none shared vision of the main simulation aims.
- Some situations, needing arbitration are still not well defined.

- The synchronisation of the models, at functional level, is a complicated situation. Some means have been developed aiming at bring some help at this level.
- For the complex simulation, in a large scale, the models coupling situation and the traceability problem became hard to handle.

Another interest aspect identified was the characterization of the collaborative simulation in function of the phases in the product development process. Unavoidable and flexible constraints are presented in Table 1. Each group of phases characterizes a kind of collaboration. As Airbus Group Innovation uses V cycle as its model reference for the product development phases, we use it as well for the representation in Table 1. The V cycle model aims at understanding the development process through a graphical representation of a specification axis and a testing axis. In the phases corresponding to the left side of the V cycle, simulation practices correspond to small applications. A co-simulation between two systems is an example of the nature of simulations at this stage. A reduce quantity of people are concerned (approximately twenty people). In these development phases, constraints regarding the budget and the planning are flexible, in consequence they are easier to handle. By contrast, the constraints against the functional definitions are harder to handle because of the maturity of the concepts. In addition, technical constraints concerning the reuse degree of the simulation come across some difficulties to find the best trade-off between the actors.

In the other hand, for the right side phases of to the V cycle, simulation practices correspond to entire Aircraft scale. For simulations at this scale, between one and two hundred people are involved for about twenty or thirty different simulation applications. At this point, the constraints related to the budget, planning and technical resources are practically frozen, as a result, they are almost unavoidable. However, as the functional constraints are well defined and the concepts are well known, their manipulation is easier. It makes functional definition constraints more flexible in front of some modifications.

Table 1: Characterization of the collaborative simulation in function of the phase

Phase	Example	People Involved	Applications	Conflicts	
				Unavoidable constrains	Flexible constraints
Left side phases of the V cycle	Co-Simulation Between two systems	20 approx.	Small	Functional definition Technical: reuse	Budgetary Planning
Right side phases of the V cycle	Aircraft	100-200 approx.	20-30 approx.	Budgetary Planning Technical: resources	Functional definitions

4.3. The Object

The AP2633 is focused on the description of the model to exchange. Other objects to exchange, related to this model, such as scenarios, hypothesis, etcetera, are not described in the procedure. Nevertheless, an internal document exists aiming at the description of these objects. This document describes the minimal information to be shared for any model exchange. The needs of all the model's users shall be described in this document. In practice, the description and the identification of the objects to be exchanged are still incomplete at the first time. A strong iterative mode is required to complete the description.

Another important point that was treated during the meetings was the change propagation procedure. Today, the identification of the links between the actors and the objects is still undone. This makes harder

the identification of the objects or the people concerned when a change is done. The simulation architect centralizes and distributes the information, but again, a strong iterative mode is required.

5. Results: Towards an adaptive model for collaborative simulation

The results are presented in Table 2. The current problems of the collaborative simulation presented in section four are synthesized under six axes in this table. The axes in the columns represent the collaboration phases [19]. Three main phases are identified: Initialize collaboration, collaboration and monitoring, and return of experience. The axes on lines represent the three dimensions of the collaboration: the process, the actors and the objects to exchange. At the crossing of collaboration phases and collaboration dimensions are presented:

- In regular font the problems to be solved
- In bold and italic font, the considered solutions aiming at the development of an adaptive model for collaborative simulation.

For each problem at least one considered solution has been proposed. The arrows in the table, represent the link between the problems and the considered solutions. Different problems could be solved by a same solution.

Table 2: Considered solutions aiming at develop an adaptive model for collaborative simulation

Axe/phase	Initialize Collaboration	Collaboration and Monitoring	Return on Experience and capitalization
Process			Create a faculty to adapt and to learn from the collaborative process
		<p>Plan to do an upgradeable platform based on the proposed process, where the user's actions could be summarized as he goes along.</p> <p>Consider an take into account the monitoring and REX</p>	
Actors		<p>Take into account the global constraints (at system architect level) and the local constraints (at trade level).</p> <p>Include an actor based model aiming at finding the best trade-off, making the constraints as compatible as possible.</p>	
		<p>Have a better vision of the trade-off key points, between the actors (system architect and simulation architect)</p>	
Objects	<p>Improve the model description and its environment through a data-configuration model where all the objects to exchange are identified and described as well as its links with the actors</p>	<p>Improve simulation objectives</p> <p>comprehension at model provider level</p> <p>Better define the objects and information to share during the collaboration phase.</p>	<p>Capitalize the simulation and its related objects</p>
			<p>Capitalize all the objects related to a simulation study together based on a data-configuration model</p>

6. Results and Future work

This paper proposes the considered solutions, based on a use case from aircraft industry, aiming at develop an adaptive model for collaborative simulation. In order to compare the proposed dimensions to the real industry needs, this paper presents an analysis done in cooperation with Airbus Group Industry resulting in a proposal of a holistic view of collaborative problems in simulation processes, distinguished between three different phases: initialization, collaboration and return of experience. In addition, the results combine also three main parts for a successful collaboration: the actors, the process and the objects to exchange giving a clear idea of dynamic interactions between the different phases.

The solutions proposed, will be used for the definition of an adaptive model for collaborative simulation, where the actors, objects and process are clearly defined as well as the links between them. Future work will consider a cooperative model based on game theory in order to establish the system behaviour model.

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