Chaire industrielle

ACTE MBSE
Airbus – Université de Lorraine

Call for applications to a PhD thesis subject:

Executable Model-Based System Requirements Engineering (eMBRE) for early System requirements Validation and Design Verification (V&V)

Context of the PhD work

Airbus and Université de Lorraine are two major actors in the development of practices and knowledge and in training in the field of Model-Based Systems Engineering (MBSE). They are joining their efforts to create a synergy of complementary expertise, building on fruitful past collaborations in research and teaching in MBSE.

This thesis work will be a contribution to an industrial chair. This chair involves Airbus, and two research laboratories, CRAN UMR CNRS and ERPI, from Université de Lorraine. Its main objective is to develop and experiment an Actionable Collaborative Trustworthy Executable (ACTE) MBSE framework, for early systems requirements validation and design verification and for the co-engineering of the main system and its manufacturing (or industrial) system.

Context and industrial problems

Recently, the air transport market has changed significantly, due to a high variation in demand caused by the COVID crisis and due to the emergence on the market of new low-cost airlines. These changes require aircraft manufacturers to reduce the ramp-up time, lower their production costs, reduce the time to market for their products... Hence aircraft manufacturers must review their approach for the engineering of their System of Interest (SoI, e.g. aircraft) as well as for the engineering of their key enabling systems (manufacturing (or industrial), support & services) to meet the previous goals, to achieve a global performance in terms of availability, safety and security, etc. and to maintain this performance during all their long life-cycle (more than 30 years). To keep their competitive advantage, companies will have to develop early capabilities based on digital technologies to (re)specify, (re)design, verify and validate manufacturable and operable complex systems, in a context of deeper collaborations with multiple stakeholders, within the aircraft manufacturers and its extended enterprise.

Systems engineers use many kinds of models to represent different views of the system (operational, logical, physical, behavioral, …) and to verify the system behavior and the satisfaction of requirements such as availability, safety, mass, or power consumption... The SoI design is currently based on a descriptive MBSE approach while keeping requirement descriptions mainly textual. This current approach suffers from incompleteness, incoherence and incorrectness of the requirements and prevents them from being a robust verification reference for the system design and its implementation [1]. Model-Based Systems Engineering (MBSE) is "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" [2]. The digital transformation of development and these MBSE principles open new opportunities [3][1] to support the development of performant, safe, manufacturable and operable complex systems with an executable MBSE (eMBSE) approach grounded on a Modeling & Simulation approach supporting System Engineering goals.

Scientific issue

To reduce time to market, designers need models and methods to perform early and collaborative Validation and Verification (V&V) respectively of system requirements and architectures [4], to detect specification and design errors and to avoid late and costly modifications during the ground & flight test phase or even worse when the system is in operation. This approach ensures that system requirements at all levels and system design are trustworthy from the beginning. The system requirement validation process aims to ensure the right system was built. The design verification process aims to ensure the system was built right [5]. SE processes include requirements engineering based on the traceability of system requirements through the different system layers [6]. A text-based description is an ambiguous way for capturing and communicating system requirements, it leads system development teams to exchange incomplete, incoherent and incorrect descriptions of system requirements whereas executable model-based system requirements engineering (eMBRE) coupled with executable Concept of Operations open the opportunity to system requirements V&V: formally with proof-checking and factually with simulations reviewed with stakeholders. In addition, this formal requirement paradigm will potentially provide, through complexity and network theory, very early in the development some metrics on the complexity of the system to be developed [7][8][9][10][11]. In addition, Game theory, applied to formal requirements could provide interesting capability for pareto optimality analysis fostering multi objectives/SOI perspectives convergence process. "Executable" means that the model enables to support proof-checking for formal system requirements validation and simulable for factual system requirements validation [12]. Micouin proposed the Property-Based Requirements (PBR) theory [13] that describes the external relations of the system with its environment as cause-effect assertion requirements that may be validated formally and factually. To support the PBR theory, Micouin introduced PMM (Property Model Methodology) [14] aiming to propose an integrated end2end modeling & simulation method supporting top-down zigzagging steps for system specification validation & design verification. These models, methods and tools are the first steps towards an eMBRE framework and the study of its influence on the required evolution of MBSE activities and its impact on the expected development performance. The evaluation of these approaches mainly address the System of Interest (SoI) and has not yet been studied neither the coupling with the key enabling systems, nor the product variety due to customization. They support system requirements validation with different formalisms (e.g. causes/effects Boolean function, ontology-based description) but do not represent directly target setting requirements such as A/C range, availability level... However, it is interesting to investigate how they can support the validation of these target requirements. In conclusion, to facilitate the collaborative development and the early V&V of complex systems, the challenge is to explore further eMBRE methods driven by SE goals and to demonstrate how it can effectively introduce a paradigm shift in system development performance through formal proofs and modeling & simulation means for each coupled system (SoI, manufacturing system and support & services system).

Research objectives and action plan

In ISO 15288 and ARP4754A standards, capturing complete, coherent and correct requirements is a key process. Our objective is to **propose and experiment models and methods to support a collaborative and trustworthy eMBRE approach focused on the objectives of systems engineering** (capture requirements with executable and therefore validable requirement models; design executable and therefore verifiable solution models), that shall be consistent with other SE processes, applicable for the development of key enabling systems (manufacturing, support & services), and able to prevent specification and design errors and foster collaborative approaches either on the overall SoI problem or on solution spaces.

The action plan may be structured as follows:

- Perform a state-of-the-art concerning SE driven modeling & simulation methods and tools and complexity theory
- Define quality criteria to assess an eMBRE approach based on current AIRBUS programs pain points.
- Select use cases focused on the aircraft system and its manufacturing system. The two selection criteria will be the use case representativity and the compatibility with the thesis workload.
- Identify appropriate V&V oriented eMBRE methods (PBRs, boiler plates,..) according to a requirement typology (System cause-effect relation, target setting...) and analyze associated complementarity & gap amongst eMBRE methods
- Formalize interactions between executable CONOPS and eMBRE methods to get an early validation of the optimized problem space
- Run the use cases on the aircraft system (SoI) and adapted MBRE approaches. Deduce associated end2end ROI vs classical text-based requirement approaches (regarding previous quality criteria).
- Propose and justify the To-Be eMBRE method and learning path on the way to capture and model validable & simulable upper level requirement domains.

Particular attention will be paid to the ability of systems engineers to learn, use and accept such an innovative approach. Research has led to the development of advanced formal requirements engineering and model checking techniques, but these approaches are not always easily understandable and may be rejected if their associated benefits are not understood and/or the efforts for their application are perceived too complex.

The objective of this PhD work is to increase the systems engineering body of knowledge in executable model-based requirements engineering and to convince systems engineers to use model-based approaches, to train and coach them to these innovative practices.

References

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Partners : AIRBUS, Université de Lorraine (Laboratoire ERPI et Laboratoire CRAN UMR CNRS). The PhD student will be hired by the Université de Lorraine, for a 3-year period.

Location: mainly at AIRBUS, Toulouse, France. Travel fees to Nancy will be in charge of the laboratory.

Beginning date: November 2020

Funding: Industrial Chair between Airbus and Université de Lorraine. **Net salary: about 1800€.**

Applicant's profile. With a master degree in engineering or with an engineer degree. Will be appreciated knowledge in the field of: systems engineering, MBSE, requirements engineering, architecture, predicate logic (first-order logic).

Professional skills and motivation: autonomy, good writing in English, good interpersonal skills, motivation for action-research in aeronautics design offices.

Deadline for applications: October 30th, 2020

Date of answer to applicants: November 6th, 2020 (possibly after an interview and a recruitment exam)

Contacts and applications (CV and motivation letter should be sent by email with the object "eMBRE Thesis Application" to).

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