INSIGHT

This Issue's Feature:

AFIS Doctoral Symposium: New Challenges and Advances in MBSE in French Universities

DECEMBER 2017
VOLUME 20 / ISSUE 4

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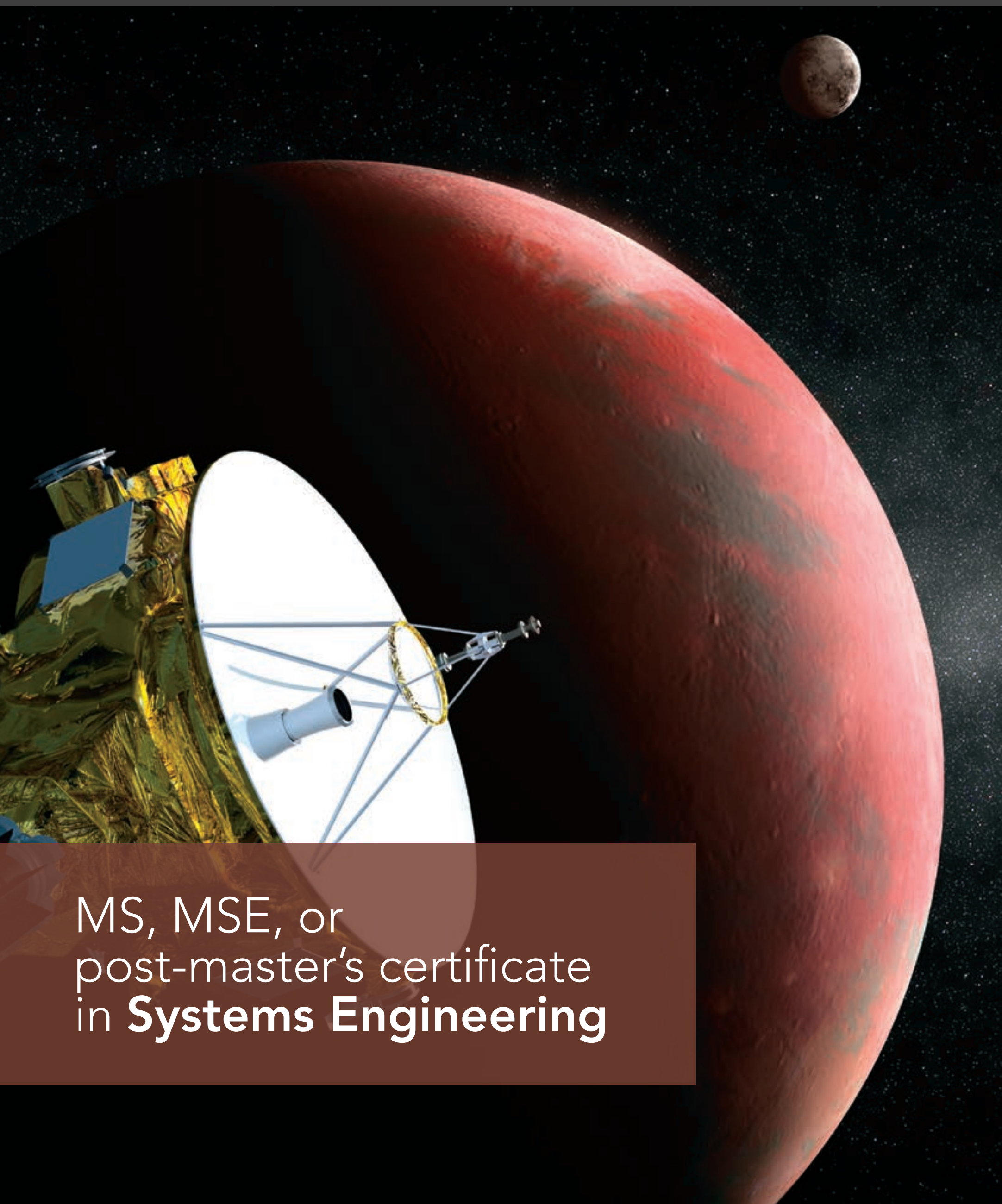

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Inside this issue

About This Publication

INFORMATION ABOUT INCOSE

INCOSE's membership extends to over 10, 000 individual members and almost 100 corporations, government entities, and academic institutions. Its mission is to share, promote, and advance the best of systems engineering from across the globe for the benefit of humanity and the planet. INCOSE charters chapters worldwide, includes a corporate advisory board, and is led by elected officers and directors.

For more information, click here:
The International Council on Systems Engineering
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OVERVIEW

INSIGHT is the magazine of the International Council on Systems Engineering. It is published four times per year and features informative articles dedicated to advancing the state of practice in systems engineering and to close the gap with the state of the art. ***INSIGHT*** delivers practical information on current hot topics, implementations, and best practices, written in applications-driven style. There is an emphasis on practical applications, tutorials, guides, and case studies that result in successful outcomes. Explicitly identified opinion pieces, book reviews, and technology roadmapping complement articles to stimulate advancing the state of practice. ***INSIGHT*** is dedicated to advancing the INCOSE objectives of impactful products and accelerating the transformation of systems engineering to a model-based discipline.
Topics to be covered include resilient systems, model-based systems engineering, commercial-driven transformational systems engineering, natural systems, agile security, systems of systems, and cyber-physical systems across disciplines and domains of interest to the constituent groups in the systems engineering community: industry, government, and academia. Advances in practice often come from lateral connections of information dissemination across disciplines and domains. ***INSIGHT*** will track advances in the state of the art with follow-up, practically written articles to more rapidly disseminate knowledge to stimulate practice throughout the community.

ARTICLE SUBMISSION

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Publication Schedule. ***INSIGHT*** is published four times per year. Issue and article submission deadlines are as follows:

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- June 2017 issue – 5 April
- September 2017 issue – 5 July
- December 2017 issue – 5 September

For further information on submissions and issue themes, visit the INCOSE website: www.incose.org

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INSIGHT reaches over 10, 000 individual members and uncounted employees and students of almost 100 CAB organizations worldwide. Readership includes engineers, manufacturers/purchasers, scientists, research & development processionals, presidents and CEOs, students and other professionals in systems engineering.

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FROM THE EDITOR-IN-CHIEF

William Miller, insight@incose.org

Welcome to the December 2017 issue of *INSIGHT* published in cooperation with John Wiley & Sons as a magazine for systems engineering practitioners. *INSIGHT*'s mission is to provide informative articles on advancing the state of the practice of systems engineering. The intent is to accelerate the dissemination of knowledge to close the gap between the state of practice and the state of the art as captured in *Systems Engineering*, the Journal of INCOSE, also published by Wiley.

The focus of the December issue of *INSIGHT* is the French Chapter of INCOSE, Association Française d'Ingénierie Système (AFIS) Doctoral Symposium: New challenges and Advances in MBSE within French Universities. This is our fifth issue devoted to doctoral research in France. The previous issues were July 2008 (Volume 11, Issue 3), December 2011 (Volume 14, Issue 4), December 2013 (Volume 16, Issue 4), and December 2015 (Volume 18, Issue 4). Theme editors selected the chosen articles after peer reviews from a larger set of doctoral presentations in collaboration with French universities and industry.

Articles from theme editors Mario Lezoche and Hervé Panetto, and other authors address the following topics:

1. Theme Editorial
2. Is There Any Agility in Systems Engineering?
3. Assessing Interoperability Requirements in Networked Enterprises: A Model-Based System Engineering Approach
4. Management of the Design Process: Human Resource Allocation in Factories of the Future
5. Complex System Tacit Knowledge Extraction Through a Formal Method
6. ProCASEE: An Innovative Solution for Systems Engineering Education
7. Towards Model-Based Systems Engineering (MBSE) Patterns to Efficiently Reuse Know-How
8. Configuring Processes Variants Through Semantic Reasoning in Systems Engineering
9. A Framework to Improve Performance Measurement in Engineering Projects.

The theme editors also submitted an additional article featuring a robot competition between students from French and German universities:

10. The First RobAFIS-RobSE International Student Competition in Systems Engineering

The first issue of *INSIGHT* in 2018 will include survey results of INCOSE Fellows on their recommendations for systems engineering research. We look forward to addressing identified research needs and leveraging the ongoing INCOSE systems engineering transformation as an enabler to the *systems engineering of the future*.

We thank you, our readers, for both your laudatory and constructive feedback in 2017. I thank assistant editor Lisa Hoverman, Chuck Eng for layout and design, our theme editors in 2017, associate director for INCOSE publications Ken Zemrowski, Holly Witte in the publications office, and the staff at Wiley. ■

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Editorial of *INSIGHT* Special Feature

AFIS Doctoral Symposium: New Challenges and Advances in MBSE in French Universities

Mario Lezoche, mario.lezoche@univ-lorraine.fr and **Hervé Panetto,** herve.panetto@univ-lorraine.fr

This special issue of *INSIGHT* includes the main contributions presented in workshops held during the Systems Engineering Academia-Industry Forum. The aim of this issue is to provide an overview of French research in the domain of systems engineering.

AFIS (Association Française d'Ingénierie Système), the French chapter of INCOSE, organizes the Systems Engineering Academia-Industry Forum; French universities support it as a regular series, usually held every two years.

This forum provides the opportunity for both academics and those in industry to debate:

- Education in systems engineering and developing competencies in systems engineering for engineering professions, and
- Developing and promoting research in systems engineering.

Thus, workshops and plenary lectures held during the forum cover the theme of education, research, and practices of systems engineering.

In December 2016, the sixth edition of the forum occurred in Toulouse, FR with the support of the University of Toulouse and the Laboratory of Analysis and Architecture of Systems (LAAS). This edition covered the important subject of "Innovation" divided into 11 topics:

- Model-based systems engineering,
- Agility in systems engineering,
- Resilience and allocation of requirements,
- Cyber-physical systems and systems engineering: the challenge,
- Risk management; the place of humans in our systems,
- Research activities in systems engineering,
- Innovation and systems engineering,
- Architecture and allocation of requirements,
- Pedagogies and systems engineering: challenges and issues,
- ROBAFIS challenge organized by AFIS that promotes project-based collaborative learning in systems engineering, and a
- Doctoral program in systems engineering as a challenge for research in French universities.

The last topic gave rise to a specific workshop, the doctoral seminar, offering the opportunity for doctoral students to present and to discuss their doctoral works concerning systems engineering, with academics and industrials.

For this issue of *INSIGHT*, doctoral students and their supervisors received an invitation to submit an extended version of their presentations as papers in order to emphasize the research aspects of systems engineering in France. We selected eight papers for inclusion in this *INSIGHT* edition in order to promote research contributions for model-based system engineering approaches.

The challenges and advances for the discipline of systems engineering in the domain of knowledge extraction and reuse, the possibility to apply agility methods to assess interoperability to define a problem, or better an opportunity, needs to be co-specified by systems engineering as a coherent collaborative whole. The interest for this systemic vision in both engineering, education and research, has been underlined by the international community of systems engineering (BKCASE Editorial Board 2015).

The first paper, *Is There Any Agility in Systems Engineering*, authored by Diego Armando Díaz Vargas, Claude Baron, Philippe Esteban, and Citlalih Yollohtli Alejandra Gutierrez Estrada makes a first contribution to discuss agility in systems engineering. It states that introducing agility in systems engineering could reduce development cycles and ensure control of the system. The paper proposes a method to evaluate if systems engineering standards such as the ISO/IEC 15288 could be compliant with any principles of agility as defined by the Agile manifesto. However, many issues remain. The first and the most relevant one is to clearly define agility: does it refer to the system architecture or to the management of systems engineering development processes? More work must be done in cooperation with companies using Agile on the subject. A working group at the French national level has been set up to consider these issues (CTM MIS, 2017).

The concept of *Assessing Interoperability Requirements in Networked Enterprises: A Model-Based System Engineering Approach* realized by Gabriel Leal, Wided Guédria, and Hervé Panetto depicts the interoperability as a crucial requirement in the networked enterprise (NE) context. The authors argue that the interoperability assessment is relevant for verifying such requirements and for identifying potential impacts that may hinder the network functioning. The paper also proposes representing a network of enterprises as a System of Systems (SoS). This is important to identify the characteristics of a SoS that are suitable for representing interoperability requirements related to a NE. Once they identify the requirements, the authors formalize them for determining their interdependencies.

Beyond the paradigm of *Management of the Design Process: Human Resource Allocation in Factories of the Future* there is the concept of Industry 4.0-factories have to cope with the need of rapid product development, flexible production as well as complete environments with the technology of IOT (internet of things). Thus, the authors, Guangying Jin, Séverine Sperandio, and Philippe Girard, understand that the success of large projects – including design process – does not depend only on the expertise of the people involved in the various project tasks, but also quite importantly on how effectively they collaborate, communicate, and work together in teams. The scientific work presents a methodology about the efficiency of collaboration between candidate actors through the calculation of the group interactions gap of the different combination of the actors.

Following another conceptual path, but remaining inside the same need to optimize the knowledge implicitly held by the models: *Complex System Tacit Knowledge Extraction Through A Formal Method* presents how to extract the knowledge from systems using relational concept analysis. The authors, Mickael Wijnberg, Mario Lezoche, Blondin Alexandre Massé, Petko Valtchev, and Hervé Panetto applied the results on real neurological data. The use case shows the potential of relational concept analysis as an accurate technique to process system interoperability of heterogeneous data.

In their paper Mohammed Bougaa, Stefan Bornhofen, and Alain Rivière, propose *ProCASEE: An Innovative Solution for Systems Engineering Education*. The proposed solution, ProCASEE, is for systems engineering education (an approach with its supporting web-based platform). It is based on the recommendations of academic and industrial communities. It is centered on the use of systems engineering standardized processes and at the same time, very adaptive to the learning context. The authors' proposal provides the ability to make the learning scenarios driven by the acquired or to-be-taught systems engineering competencies. The students using the ProCASEE solution will be able to engineer a requested system in a distant and collaborative way, but also to engineer it the right way. The solution aims to ease the learning at the same time while teaching the fundamental principles and processes of systems engineering, along with communication, team management, collaboration, and related soft skills. On the other hand, educators will be able to better manage their learning scenarios, training resources, and the expected outcomes. Last, educators and students' organizations (universities and colleges) using this solution will be able to manage and normalize the competencies to be acquired by their future systems engineers at every level.

Following the idea of knowledge extraction and reuse Quentin Wu, David Gouyon, Pascal Hubert, and Éric Levrat present in their paper, *Towards Model-Based Systems Engineering (MBSE) Patterns to Efficiently Reuse Know-How*, three approaches for developing efficient "knowledge reuse" in order to reduce costs, time, and facilitate innovation during engineering phases. The coupled approach between MBSE and "knowledge reuse" shows promising outlook especially concerning the concept of patterns which appears to be a possible part to the answer regarding the growing complexity of systems, as it is generic and does not follow a unique method.

In the same vein of optimization and knowledge extraction the *Approach to Select a Process Variant Using Process Mining: An Application in Healthcare*, authored by Silvana Pereira Detro, Edoardo Portela, Eduardo Loures Rocha, Hervé Panetto, and Mario Lezoche, intends to propose a framework for discovery of process variants from an event log. The framework is composed of three steps consisting in: extracting a process model from an event log, discovering variation points and rules for the selection of the alternative available, and applying the questionnaire-model approach in configuring process variants. Decision-point analysis application discovered the variation points, the alternatives available for the variation points, and the rules for the selection of alternatives. The discovery of process variants from the log enables improving process variants by correcting deviations, anticipating problems, and more. In addition, implicit knowledge can be captured, thus enabling enrichment of the process variants. The authors intend to propose a framework to manage process variants through ontologies enabling configuration of the most suitable, requirements-driven process model and ensuring accuracy of the configurable process model, respecting syntax and semantic aspects. Enriching business processes with semantics improves the representation of said processes and permits automation of different tasks such as modelling, configuration, evolution, and promotes more flexible and adaptive solutions.

Finally, Li Zheng, Claude Baron, Philippe Esteban, Rui Xue, and Qiang Zhang, developed A *Framework to Improve Performance Measurement in Engineering Projects*. The paper addresses the measurement of engineering project performance and its balanced utilization between lagging and leading indicators to ensure the project is in a healthy status. It provides a framework that associates leading indicators used in systems engineering with the project management processes described in the PMBoK knowledge areas. This contributes to improved performance measurement in engineering projects, thus resulting in a better monitoring and finally a better performance of these projects.

To add value to this *INSIGHT* issue, the editors chose to include a paper related to the important issues that the RobAFIS-RobSE challenge brings to the education of systems engineering. In the paper, *The First RobAFIS-RobSE International Student Competition in Systems Engineering*, Jean-Claude Tucoulou and David Gouyon describe how French and German students (master degree in complex systems engineering of the University of Lorraine in Nancy, and master degree in systems engineering of the Applied Sciences University of Munich) took part in an international challenge in systems engineering, initiated in October 2016, culminating in March 2017. The student teams designed, assembled, and validated a robot using systems engineering. The same requirements document approved by AFIS and GfSE (French and German chapters of INCOSE) went to the competitors.

All these contributions are valuable material for the systems engineering research and education foci of INCOSE and for future works.

We are grateful to the authors for their impressive contribution and to the reviewers for their valuable assistance to the scientific relevance of this issue of *INSIGHT*. ■

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Dr. Mario Lezoche is an associate professor at University of Lorraine, more specifically at IUT Hubert Curien of Epinal where he teaches object-oriented software engineering, base knowledge systems, and database development. He is a researcher at CRAN (Research Centre for Automatic Control of Nancy) joint research unit with CNRS. He graduated at Roma TRE University (Italy) in computer science engineering. He has experience in semantic web research and in models and semantics for systems interoperability. He is moreover a regular reviewer for international journals (EIS, FGCS, CII, IJPR). He is presently working on a conceptualisation approach and the use of lattice theory through the formal concept analysis method and relational concept analysis for enterprise information systems interoperability and knowledge extraction from generic systems.

Dr. Hervé Panetto is a professor of enterprise information systems at the University of Lorraine, TELECOM Nancy. He conducts research at the Research Centre for Automatic Control (CRAN), joint research unit with CNRS, where he is managing a project on the use of ontology for formalising models related to the interoperability of production information systems. He has been involved in European projects including IMS FP5-IST Smart-fm project (awarded by IMS) and the FP6 INTEROP NoE. He is author or co-author of more than 150 papers in the field of automation and systems engineering, enterprise modelling and enterprise systems integration, and interoperability. After being chair of the IFAC TC5.3 "Enterprise Integration and Networking", he is currently chair of the IFAC Coordinating Committee 5 on manufacturing and logistics. He received the IFAC France Award in 2013, the INCOSE 2015 outstanding service award, and the IFAC 2017 outstanding service award. He is general co-chair of the OTM Federated Conferences. He is member of the editorial board of the Annual Reviews in Control, Computers in Industry, the international Journal on Universal Computer Science, the scientific journal Facta Universitatis, and series Mechanical Engineering. He is also an associate editor of the international Journal of Intelligent Manufacturing (JIM), and both the Springer Taylor & Francis publications of the Enterprise Information Systems (EIS) journal.

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Is There Any Agility in Systems Engineering?

Diego Armando Díaz Vargas, dadiazva@laas.fr; **Claude Baron,** claude.baron@laas.fr; **Philippe Esteban,** philippe.esteban@laas.fr; and **Citlalih Yollohtli Alejandra Gutierrez Estrada,** citlaligh@yahoo.com

ABSTRACT

Industry employs agile methods more widely, mainly in software development companies. This paper tackles the point of transferring agile methods from software to systems engineering, which raises several questions: Is the transfer immediate, and if not, what are the difficulties? Does the agility refer to the product, the processes, or the project? Do systems engineering standards promote or suggest a kind of agility? Among this panel of questions, a first natural step consists of analyzing if systems engineering standards and guides already include agility in the practices they recommend and what kind of agility. The paper thus focuses on the analysis of one of the most famous current systems engineering standards, the ISO/IEC/IEEE 15288 (2015), with the goal to detect any explicit or implicit reference to agility in this document.

Agile methods are beginning to spread in industry; these methods are mainly used in companies whose business is software development. Fields like systems engineering are contemplating these methods to manage the systems engineering technical processes and to lead projects in complex systems development, but some issues must be overcome before implementing such approaches in this domain. Agile methods really emerged with the dissemination of the Agile Manifesto in 2001; however, this document does not give any formal definition of the agile concept, and is clearly focused on software engineering. This paper thus tackles the point of transferring agile methods from software to systems engineering, that includes several questions: Is the transfer immediate? What are the difficulties? Does the agility refer to the product, the processes, or the project? Do systems engineering standards already implicitly consider a kind of agility? Among this panel of questions, a first natural step consists in asking if systems engineering standards and guides would already include any form of agility in the practices they recommend? This paper focuses on the analysis of one of the most famous current systems engineering standards, the ISO/IEC/IEEE 15288 (2015), with the goal to detect any explicit or implicit reference to agility in this document.

INTRODUCTION

Companies continuously need to improve their practices and performance, thus using efficient methods and tools to design and deliver innovative products and services and to decrease the time to market. Agile management is becoming very popular in industry; the attention of customers is caught and retained by providing them fast services. Agile methods are well developed in software engineering; they are based on teamwork, customer collaboration, iterative development, process, and technology adaptable to change (Highsmith 2007). Their success in the field of software development became very popular and other domains are now beginning to try implementing these methods. Even if introducing agility in systems engineering makes sense, companies have not yet deployed such methods. Why? Is it due to the lack of methods? Are the most popular agile methods used in software engineering such as scrum not well adapted to systems engineering applications? Why then? Is it the lack of tools? One of the reasons could be because systems engineering must comply with strict standards. These documents for instance recommend having a full list of precise requirements before doing the design, while agile methods recommend being in constant interaction with the customer to iteratively define the requirements (Meyer 2014). Another example is that in the agile approach, building a design upfront is a waste of time because we do not know what will work and will not, what for the moment is not complaint with systems engineering standards recommendations. The agile recommendation is to build the system iteratively instead of having a design stage (Meyer 2014). Characterizing agility, according to its definition in the Agile Manifesto (2016), by analyzing how the most currently used methods implement agility in software engineering to better identify the difficulties to overcome to transfer practices to systems engineering is a path we authors intend to follow. However, before, the first question to answer is to analyze whether introducing agility in systems engineering would be a problem? A first step towards this goal consists in considering systems engineering standards to analyze whether they already include or are compatible with agile practices. This is the subject of this paper, which begins with the analysis of the most famous current systems engineering standard, the ISO/IEC/IEEE 15288 (2015). Section 2 introduces the background on the notion of agility and on systems engineering standards. Section 3 analyzes the ISO/IEC/IEEE 15288 (2015) standard to detect any explicit or implicit mention to agility as defined by the Agile Manifesto. Section 4 concludes and opens to future works.

BACKGROUND

This section first defines the notion of agility then presents the ISO/IEC/IEEE 15288 (2015) systems engineering standard and processes.

1. *About agility and agile systems engineering.*

Agility is defined by the Cambridge dictionary (2007) as the 'ability to move quickly and easily.' The term agile appeared with a movement born in the early 1990s. In 1992, Texas Instruments and General Motors founded the Agile Manufacturing Enterprise Forum to identify the nature of agile solutions by organizing collaborative workshop groups (Hoda and Murugesan 2016). In 2001, a meeting of prominent developers from IT and software engineering produced the Manifesto for Agile Software Development, which first defined the principles of agile methods. The Agile Manifesto is the source of the states, values and principles of the agile movement. It formalized techniques developed in the 1990s (Agile Manifesto 2016). It relies on 4 values: individuals and interactions over processes and tools, working software over comprehensive documentation, customer collaboration over contract negotiation, responding to change over following a plan. It enumerates 12 principles: P1 – Satisfy the customer, P2 – Welcome changing requirements even late, P3 – Deliver working software frequently, P4 – Business teams and developers working together, P5 – Motivating individuals, P6 – Face-to-face communication, P7 – Measure progress on software performance, P8 – Promote sustainable development, P9 – Technical excellence, P10 – Simplicity, P11 – Self-organization teams, P12 – Dynamical adjustments of work (adapted from Agile Manifesto, 2016). In synthesis, the Agile Manifesto focuses on teamwork closely involving the customer; agility relies in an iterative and incremental development, resulting in frequent and fast releases (Uskov, Krishnaiah, Kondamudi, and Singh 2016). The notion of agility now is widely spread and practiced in software engineering. However, it is not in systems engineering. Some references to agility in systems engineering can be found in literature, but note that a particular attention must be given to the terminology. Indeed, in literature can be found two different mentions to agility in systems engineering, both called "agile systems engineering." However, meanings are completely different and can confuse the reader. "Agile - systems engineering" (applying the agile approach to systems engineering processes management) should not be confused with "agile systems - engineering" (the engineering of agile systems, agile meaning here modular and re-configurable). Agile systems - engineering answer to the need for improved response (Parveen and Munir 2015) to facilitate the learning organization in the context of enterprises, many businesses "see agility as a deliverable of the business (Kemp, Evans, et al. 2016). Interestingly, agile-systems engineering is a response to trends towards connectivity, rapid requirements change, decreasing cycle-times, and more, exposing weaknesses in traditional methods of systems engineering which are sometimes perceived as "hold-overs" from the 50-60's (Turner 2015). In this paper, mentions to agility in systems engineering refer to the first meaning, managing systems engineering processes according to agile principles.

2. *The ISO/IEC/IEEE 15288 (2015) standard.*

The ISO/IEC/IEEE 15288 (2105) is a systems engineering international standard covering processes and life cycle stages. It establishes a common framework of process descriptions for describing the life cycle of human-made systems. It also provides processes that support the definition, control, and improvement of the system life cycle processes used within an organization or a project (ISO/IEC/IEEE 15288, 2015).

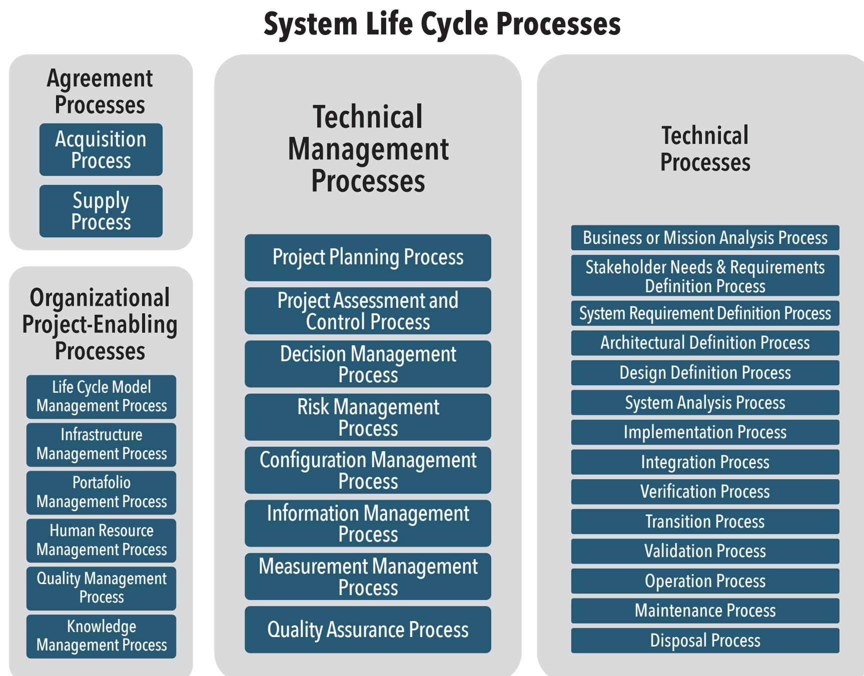

Figure 1. ISO/IEC/IEEE 15288 System Life Cycle Processes (ISO/IEC/IEEE 15288, 2015)

ACTIVITY 1 (A1) DEFINE THE PROJECT

- Task 1: Identify the project objectives and constraints.
- Task 2: Define the project scope as established in the agreement.
- Task 3: Define and maintain a life cycle model.
- Task 4: Establish a work breakdown structure.
- Task 5: Define and maintain the processes.

ACTIVITY 2 (A2) PLAN PROJECT AND TECHNICAL MANAGEMENT

- Task 1: Define and maintain a project schedule.
- Task 2: Define achievement criteria for the decision gates.
- Task 3: Define the costs and plan a budget
- Task 4: Define roles, responsibilities, accountabilities, and authorities.
- Task 5: Define the infrastructure and services required.
- Task 6: Plan the acquisition of materials and enabling system services.
- Task 7: Generate and communicate a plan for project and technical management.

ACTIVITY 3 (A3) ACTIVATE THE PROJECT

- Task 1: Obtain authorization for the project.
- Task 2: Submit requests and obtain commitments for necessary resources.
- Task 3: Implement project plans.

Figure 2. Activities and tasks of the project planning process (ISO/IEC/IEEE 15288, 2015)

This way, the standard is broken down into four groups of processes: agreement processes, organizational project-enabling processes, technical management processes, and technical processes (Figure 1). The group "technical management processes" concerns managing the resources and assets allocated by the organization management; it relates to planning (cost, timescales, achievements), to the checking of actions and to the identification and selection of corrective actions if needed. Therefore, its scope covers part of project management scope, that also includes planning and controlling resources to achieve project goals (ISO/IEC/IEEE 15288, 2015). Thus, if there were any notion of agility in the ISO/IEC/IEEE 15288 (2015) standard it would be in the technical management processes group. The next section focuses the analysis on this process group.

3. *Analysis of ISO/IEC/IEEE 15288 (2015) technical management processes with respect to agility*

This section analyzes the technical management processes group of ISO/IEC/IEEE 15288 (2015) to search for any implicit or explicit mention of agility as defined before. Technical management processes includes 8 processes that are used to establish and perform (ISO/IEC/IEEE 15288, 2015): project planning, project assessment and control, decision management, risk management, configuration management, information management, measurement management, quality assurance (Figure 1). Processes have attributes: title, purpose (describes the goals of performing the process), outcomes (express the observable results expected from the successful performance of the process), activities (sets of cohesive tasks), and tasks (requirements, recommendations or actions intended to support the achievement of the outcomes) (ISO/IEC/IEEE 15288, 2015). To detect agility in the standard, the analysis must stand at the task level. The method thus consists in exhaustively analyzing the tasks related to the activities of the technical management processes and to check with the 12 principles from the Agile Manifesto if any agility can be found. To illustrate the approach, this paper applies it to the 'project planning' process.

The project planning process has three activities: define the project, plan the project and technical management, and activate the project. Each activity includes several tasks (Figure 2). Figure 3 shows the results of the analysis. P8 and P9 are the most referred to principles among all the tasks from the project planning process; P11 is never referred to in the project planning process.

Following the same method, analysis can be extended to the seven remaining technical management processes. Figure 4 shows the results. Agile principles are not present in risk management process; P4 (business teams and developers working together) is one the most referred principles among all the processes of technical management processes and P11 (self-organization teams) is referenced only once. In proportion, the two main referred principles are P4 (business teams and developers working together) and P6 (face-to-face communication).

ISO/IEC 15288 Project Planning Process		12 Principles of Agile Manifesto											
ACTIVITIES	**TASKS**	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
A1	*Task 1*	*			*				*	*			
	Task 2			*					*	*			
	Task 3	*								*			
	Task 4	*	*										
	Task 5	*			*				*				
A2	*Task 1*		*	*		*	*		*	*			*
	Task 2		*	*		*			*	*	*		*
	Task 3	*			*	*	*	*	*		*		*
	Task 4								*				
	Task 5					*				*	*		
	Task 6												
	Task 7			*			*						*
A3	*Task 1*	*											
	Task 2		*				*						*
	Task 3							*		*			

Figure 3. References to agile principles in the tasks related to the project planning process

Process	Number of Activities	Number of Tasks	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Project Planning Process	3	15	40%	27%	27%	20%	27%	27%	13%	47%	47%	20%	0%	33%
Project Assessment and Control	3	16	56%	38%	19%	75%	38%	38%	0%	31%	75%	6%	13%	56%
Decision Management	3	10	20%	60%	0%	60%	10%	70%	0%	0%	30%	10%	0%	0%
Risk Management	5	16												
Configuration Management	6	21	0%	38%	5%	57%	5%	48%	5%	14%	10%	0%	0%	14%
Information Management	2	10	0%	0%	0%	70%	100%	0%	0%	0%	0%	0%	0%	0%
Measurement	2	11	0%	0%	0%	36%	0%	45%	0%	0%	0%	0%	0%	0%
Quality Assurance	5	17	0%	6%	6%	0%	0%	6%	0%	6%	0%	0%	0%	12%
	Total of presence		3	5	4	6	5	6	2	4	4	3	1	4

Figure 4. References to agile principles in technical management processes

CONCLUSION

This paper makes a first contribution to discuss agility in systems engineering. Indeed, introducing agility in systems engineering could help reduce development cycles and ensure control of the system. The paper proposes a method to evaluate if systems engineering standards such as the ISO/IEC/IEEE 15288 (2015) could be compliant with any principles of agility defined by the Agile Manifesto.

It concludes that some of the technical management processes could be aligned

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with the agile principles. However, many issues remain. The first one is to clearly define agility: does it refer to the system architecture or to the management of systems engineering development processes? What really could be the benefits from introducing agility in systems engineering? At what level? What really are the issues for companies? Are they technical or organizational ones? Could agility be introduced in the development of software parts of complex systems while other parts remain developed with a more traditional approach? More work in cooperation with companies on the subject must be done. A working group at the French national level has formed to consider these issues (CTM MIS 2017). ■

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Assessing Interoperability Requirements in Networked Enterprises: A Model-Based System Engineering Approach

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ABSTRACT
When two or more systems work together, it is crucial to verify interoperability. Systems engineers should be working to continuously improve the ability to interoperate for maintaining a sustainable and efficient collaboration among the networked systems. Systems could benefit from the use of interoperability assessments for identifying their strengths and weakness as well as their compatibility with potential collaborative peer systems. However, the current assessment approaches do not explicitly define the interoperability requirements and their interdependencies. Acknowledging the different requirement dependencies supports the identification of impacts on the overall system, for example implications within a network caused by changes in the collaboration strategy or the introduction of a new information technology tool. Thus, based on model-based systems engineering, this paper defines a networked enterprise as a system of systems (SoS) and proposes to use the SoS characteristics for identifying interoperability requirements and their dependencies. Further, we formalise and utilise inputs for an assessment tool.

In the fast-changing environment that we live in, enterprises need to work collaboratively with other companies to remain competitive. The businesses that are progressively collaborating with others are becoming the so-called networked enterprise (NE) (Jagdev et al. 2001), (Camarinha-Matos and Afsarmanesh 2005). In this context, communication and collaboration problems can impact the performance and the outcomes of the network drastically. Hence, to avoid these kinds of problems, enterprises should share their core competencies and improve their interoperability (IEEE 1990) that is, the ability of systems to exchange and share information and functionalities and use them in a meaningful manner. The interoperability *per se* happens when two enterprise systems (humans, software, or others) belonging to the members of the network, successfully interoperate with each other. Thus, the ability to interoperate is a crucial requirement to be verified when enterprises are creating or maintaining collaborative relationships.

For improving their interoperability, companies could benefit from the use of interoperability assessment approaches. One of the first steps of this kind of assessment is the analysis of the system's AS-IS situation considering the different areas of interoperability (ISO 2015) and their requirements. However, based on the comparative studies (Ford 2007), (Rezaei et al. 2014), we identified that the majority of existing assessment approaches are dealing with a particular area of interoperability. Hence, we raise the following question: "*How can we assess the interoperability, when dealing with different areas of interoperability, in the NE context?*" For answering this question, we argue that the use of a holistic assessment approach based on interoperability requirements dependencies could be fit. Hence, we consider that knowing the requirements' dependencies among the different areas, one may identify the potential positive impacts if a requirement is fulfilled, or negative impacts if not.

Therefore, this article aims at identifying and classifying the interoperability requirements and their dependencies. To do so, we propose to apply a model-based system engineering (MBSE) approach to designing a NE as a system of systems (SoS). The MBSE is the formalised application of modelling to support system requirements, design, analysis, and verification and validation activities (INCOSE 2007). This allows us to identify the SoS characteristics that can be associated with the NE concept and that can be "translated" into requirements. It is worth noting that the contribution of this article is part of ongoing research work for developing an interoperability assessment approach supported by a semi-automated tool. The identified requirements will be the inputs of the aforementioned approach.

Thus, in a preliminary work (Leal et al. 2016), we hypothesised that a *NE can be seen as a system-of-systems* composed of at least two autonomous systems (enterprises) that collaborate during a period of time to reach a shared objective, where interoperability requirements should be met for ensuring the network functioning. This hypothesis is raised based on the SoS definition proposed by Krygiel (1999): a SoS is an interoperating collection of component systems that produce results unachievable by the particular systems alone (Krygiel 1999), where component systems are themselves typically heterogeneous, inter-disciplinary and distributed systems (INCOSE 2011).

In more recent years, Morel et al. (2007) focus on the interoperation complexity between existing enterprises and components systems architected as a SoS-like. The authors propose a paradigm for system-of-systems design, where a SoS is a loosely coupled system, which is the result of the aggregation of other loosely coupled systems. Such systems are engineered, based on the requirements provided by the client (for example: the entity that requested the system). Further, the ontology for enterprise interoperability (OoEI), (Naudet et al. 2010) formally describes the main components of a system, regarding the interoperability domain. In Guédria and Naudet (2014) they enriched the OoEI with "enterprise as a system" concepts for identifying more precisely the relations between the interoperability and the enterprise systems. Based on the studied SoS concepts, we enriched the proposed model in (Leal et al. 2016). An overview of the mentioned model is illustrated in Figure 1.

In Figure 1, the ***abstract system*** concept is introduced to represent the generic form of a system. Further, a ***networked enterprise*** is seen as a ***system-of-systems*** which is an aggregation of ***enterprises***, which are themselves an aggregation of ***enterprise components***. Moreover, we observe that ***system-of-systems, interoperable system, enterprises, enterprise components*** and systems to be built (for example: ***engineering systems*** and ***interoperable system to build***) are subclasses of the ***engineered system*** concept. An ***engineered system*** has a ***model*** defining it. An ***engineered system*** also has a ***life cycle***, which goes from its creation to its decomposition, undergoing through operation and transformations. It is important to note that systems belonging to a ***system-of-systems*** have different life cycles (INCOSE 2011). Each system has a ***function***, which in the enterprise context is a set of business activities for achieving ***objectives***. For realising these functions, a set of ***requirements***, including ***interoperability requirements*** must be satisfied. We argue that such requirements can be associated with SoS characteristics and the areas of interoperability.

Regarding the SoS characteristics, Auzelle (2009) summarised six characteristics that can be used in the NE context, which are: the *autonomy, belonging, connectivity, diversity, emergence,* and *evolution*. The OoEI also pointed out characteristics of an interoperable system that are: *stability, openness*, and *adaptability*. Thus, correlating these characteristics to the NE concept, we have the following: (i) the network is an *open system* where its members are capable of interacting with the network's environment; (ii) the network systems have *autonomy* – the capability of the enterprises to fulfil their objectives without depending on the other network's systems; (iii) the enterprises have the sense of *belonging* – the choice to be part of the network, on a cost/benefits basis, for fulfilling their and the network's objectives; (iv) the companies are *connected* namely the capability of systems to connect with other systems through their interfaces, despite their differences; (v) the network supports the *diversity* of systems, thus providing a variety of functionalities; (vi) the network has the sense of *emergence* – the capacity to quickly detect and destroy unintended behaviours; (vii) the network supports *evolution*, in other words, the capability of SoS to adapt themselves to environment changes for ensuring their missions and objectives. Finally, (viii) a network has *stability*, the capability to remain stable despite any change.

Regarding the areas of interoperability, they are classified according to the interoperability aspects (conceptual, organisational, and technical) (ISO 2011), (European Commission 2017) and interoperability concerns (business, process, service and data) (ISO 2011). Based on this classification, we investigated the different existing interoperability assessment approaches and the used evaluation criteria (which can be seen as requirements). Among the studied approaches, the maturity model for enterprise interoperability (MMEI) (ISO 2015) is the only one explicitly organising and describing the evaluation criteria according to the areas of interoperability. Thus, for now, we are considering mainly the 48 requirements from MMEI.

The next steps are (i) the categorization of the requirements using the SoS characteristics and (ii) their formalisation. The formalisation is done to avoid misinterpretation and to serve as inputs for automated verification techniques. To do so, we apply the formalisation process proposed by Peres et al. (2012). Formalising the requirements, we identify the same atomic requirements that are used by different formulas. Therefore, combining the enterprise systems relations and the requirements similarities, we can define the dependencies of the interoperability requirements. Figure 2(a) shows the formalised requirement DT1. This requirement is related to the *connectivity* characteristic, and it refers to the *data* concern and the *technical* aspect. Figure 2(b) illustrates the same requirement and its interdependencies. The DC1.12 requirement in Figure 2(b) belongs to the *data-conceptual* area of interoperability, and the BT1 belongs to the *business-technical* area.

DT1 aims at making different devices connectable for allowing data exchange. In order to fulfil this requirement, a set of atomic requirements should be met first. For example, when a requirement "A" refines a

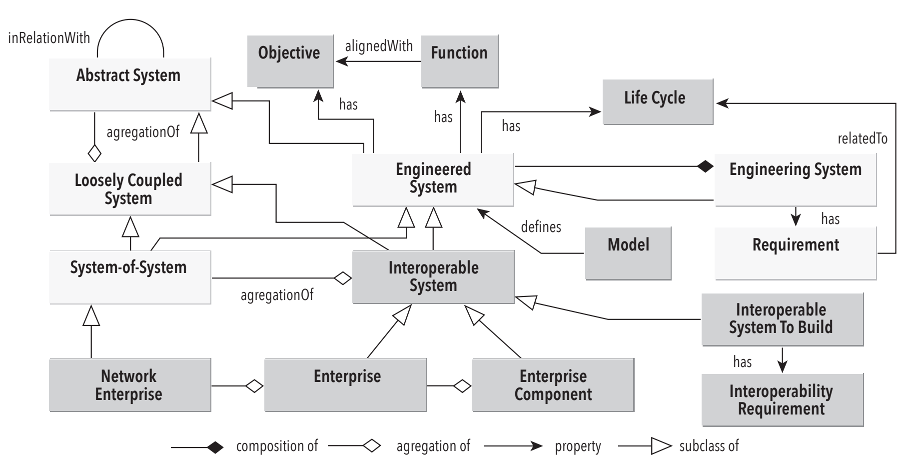
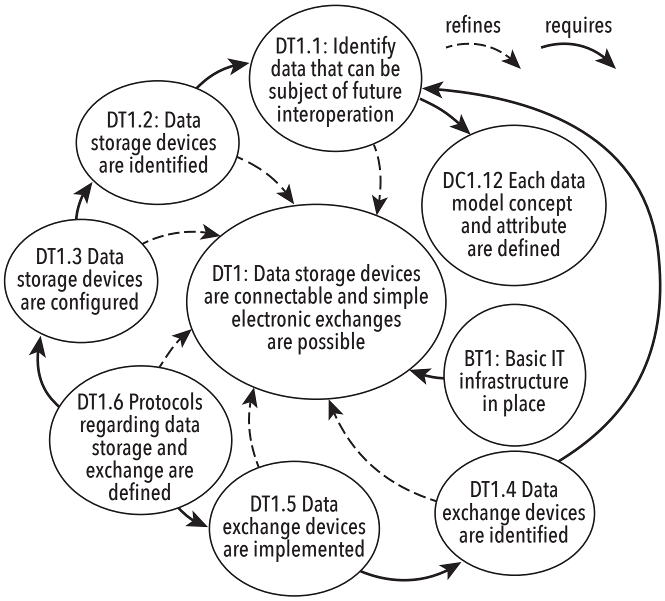


Figure 1. An overview of the networked enterprise meta-model. The white concepts depict the concepts from SoS related works, and the grey ones represent the concepts from the (Leal et al. 2016)

SoS characteristic	Connectivity
Requirement	DT1. Data storage devices are connectable and simple electronic exchange are possible
Atomic Requirement	DT1.1 Identify data that can be subject of future interoperation DT1.2 Data storage devices are identified DT1.3 Data storage devices are configured DT1.4 Data exchange devices are identified DT1.5 Data exchange devices are implemented DT1.6 Protocols regarding data storage and exchange are defined
Formalization	DT1. 1 ∪ ((DT1.2 ∪ DT1.3) ∧ (DT1.4 ∪ DT1.5))) ∪ DT1.6

∧ = AND/∪ = Holds UNTIL

(a)



(b)

Figure 2. (a) Example of a formalised requirement. (b) Example of requirement dependencies

requirement "B", it means that the requirement "A" is an atomic requirement of "B". Otherwise, requirements may only *require* another without being an atomic requirement, or may not have any dependency.

As a conclusion, the presented research work depicts the interoperability as a crucial requirement in the NE context. Hence, we argue that the interoperability assessment is relevant for verifying such requirements and for identifying potential impacts that may hinder the network functioning. Such assessment is also relevant for proposing improvements for reducing negative impacts caused by the non-fulfilment of requirements. Moreover, we propose it to represent a network of enterprises as a SoS. It aims at identifying characteristics of a SoS that are suitable for representing interoperability requirements related to a NE. We used knowledge extracted from existing assessment approaches for the identification of requirements. Once we identified the requirements, we formalised them for determining their interdependencies. As future work, we intend, first, to finalise the formalisation of interoperability requirement and their interdependencies. Then, we will consider the formalised requirements as inputs for the assessment tool. ■

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Management of the Design Process: Human Resource Allocation in Factories of the Future

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ABSTRACT

Currently, many new challenges, such as multiplication of data and information, mass customization, global cooperation, and scarcity of resources, shape the relationships among different actors. Therefore, when managers have several projects to schedule, human resources allocation becomes much more complex to grasp. The work in this paper is to propose a human resources allocation methodology in design process to cope with the adaption of the Product-Process-Organization (P-P-O) model for the factory of the future. According to the new concept in the Industry 4.0, future human resource organization structure will be the horizontal and point-to-point structures. Therefore, this paper discusses the related concepts regarding human resource horizontal ability and project urgency level.

In the modern economy, the challenge of resource allocation is a fundamental feature of corporate strategy (Levinthal 2016). For the challenge in the company, the multi-projects resource allocation problem can be seen as one of the most important challenges. In literature for multi-project management in the corporate setting the primary theme is the issue of allocation of resources between simultaneous projects (Engwall and Jerbrant 2003; Hendriks et al. 1999). The main challenge of managing a multi-project environment is the allocation of scarce human resources over the projects in execution (Ponsteen and Kusters 2015).

The design process corresponds to the place where the knowledge is created and used by the actors to develop the product (Robin and Girard 2010). The P-P-O (product-process-organization) model (Robin and Girard 2010) is a model to describe the design system. The P-P-O model not only integrates elements linked with the product, process, and organization but also takes into account clearly the human aspects (Robin et al. 2007). Because on the one hand, increases of global competitive pressure and product development process complexity, and, on the other hand, decreasing product development life cycle, design actors in the P-P-O model must collaborate more and more closely to enhance design efficiency (Robin et al. 2007). Therefore, how to effectively allocate resources is key to complex multiple product design project planning (Wu and Ji 2016). Meanwhile, the resource allocation problem is very important to the P-P-O model to adapt the future collaborative organization relationship. The main objective of this research is to approach the multi-project human resources allocation problem for future resource organization structure. Therefore, we propose a human resource allocation methodology to allow the P-P-O system to adapt to the factory of the future.

The efficiency of resource allocation to some extent is affected by resource organization (Wu and Ji 2016). Traditionally, the relationships among actors in an industrial design process take place according to a hierarchical structure. However, in today's global and Internet-driven economy, the rapid movement of people and goods across borders means the traditional hierarchical organizational structure can slow down functions in a company (Russell 2005). In contrast, it may depend on the concept of Industry 4.0 (Lee et al. 2015), Factory of The Future (Factory 2015), and peer-to-peer networks (Subramanian et al. 2005), the hierarchical structure will change to the horizontal integration through the Internet of Things (IoT) (Figure 1).

In the concept of Industry 4.0, factories have to cope with the need of rapid product development, flexible production, as well as complete environments (Brettel et al. 2014) with the technology of IoT. In Figure 1 left part, the relationship among the different parts (business partners, suppliers, employees, customers, and so on) is the collaboration and point-to-point structure without any kind of boundaries and intermediary. In Figure 1, for instance, it is possible to employ external designers (employees will no longer be the company internal designers), and the suppliers can directly connect with the customers with-

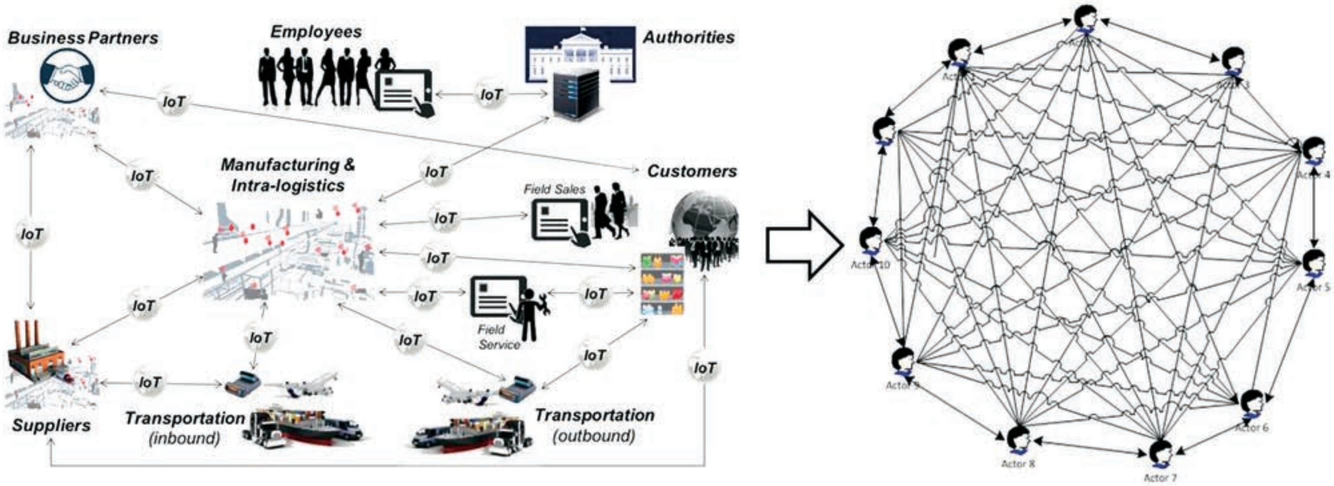


Figure 1. Internet of things as part of the future horizontal organization structure (Schoenthaler et al. 2015)

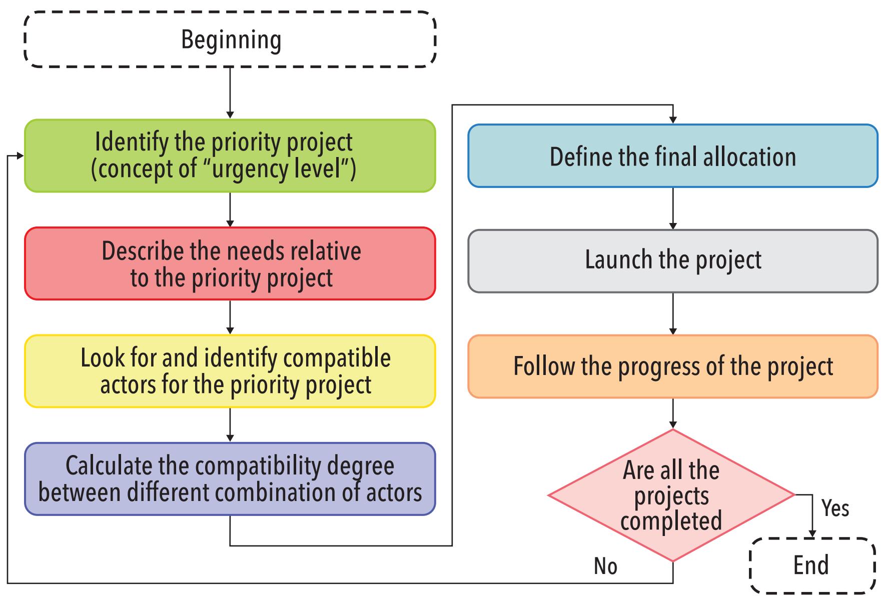


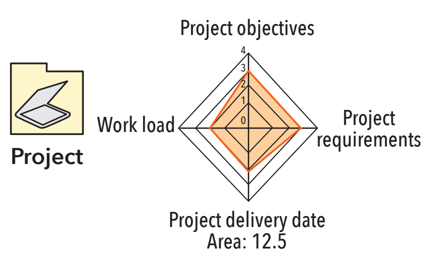
Figure 2. Methodology for human resource allocation

out the intermediary of the manufacturing company. Hence, according to the new concept in the Industry 4.0, future resource organization structure will be the horizontal and point-to-point structures (Figure 1 right part). From here, we can understand that the success of large projects – including design process – does not depend only on the expertise of the people involved in the various project tasks, but also quite importantly on how effectively they collaborate, communicate, and work together in teams (Karageorgos et al. 2015).

The whole process of human resources allocation in this paper can be seen in Figure 2.

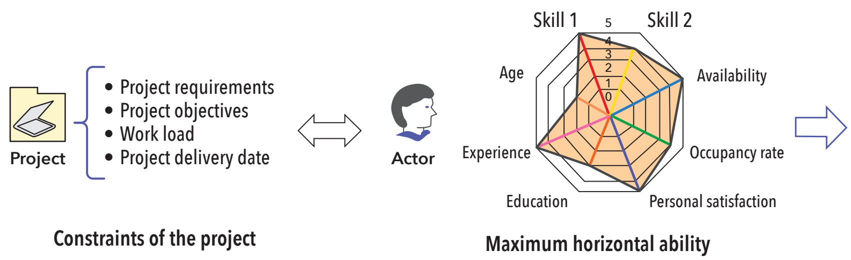
First, it is necessary to identify the priority project, when several projects are scheduled, in order to promptly, solve the human resource allocation problem of this project. Here, the urgency of the project can be divided in 4 levels (Figure 3) with the detailed description.

In the Figure 3 left part, we can find that the strength of every constraint can



Critical – 4	18 < Area ≤ 32	Objectives	Objective brings extremely high profits.
		Requirements	Failure of Project requirements will cause Critical damage to the company.
		Delivery Date	Project delivery date is extremely urgent.
		Work load	Huge work load.
Important – 3	8 < Area ≤ 18	Objectives	Objective brings a lot of profits.
		Requirements	Failure of Project requirements will cause certain degree of damage to the company.
		Delivery Date	Project delivery date is urgent.
		Work load	Big work load.
Normal – 2	2 < Area ≤ 8	Objectives	Objective brings some profits.
		Requirements	Failure of Project requirements will cause normal damage to the company.
		Delivery Date	Project delivery date is not urgent.
		Work load	"Normal" work load.
Low – 1	Area ≤ 2	Objectives	Objective brings a little profit.
		Requirements	Failure of Project requirements will cause light damage to the company.
		Delivery Date	Project delivery date is very late.
		Work load	Little work load.

Figure 3. Different urgency levels for project



Level	Horizontal Ability
Critical–4	At min 80% of the maximum horizontal ability
Important–3	At min 60% of the maximum horizontal ability
Normal–2	At min 40% of the maximum horizontal ability
Low-1	At min 20% of the maximum horizontal ability

Figure 4. Relationship between project urgency and horizontal ability of actor

be divided as 4 levels (from the light to the strongest with 0 to 4), and the area value of the orange graph is 12.5 (0.5 × 3 × 3sin90° + 0.5 × 3 × 2sin90° + 0.5 × 2 × 2sin90° + 0.5 × 2 × 3 sin90°). Here, the area means the strength of the urgency for this project. Meanwhile, the right part table of Figure 3 describes constraints' levels depending on 4 aspects (project requirements failure, profits of objective, project delivery date, and work load). In this figure, the urgency level for the project in the left part of Figure 3 belongs in the "Important level" ($8 < 12.5 \leq 18$) in the table on the right.

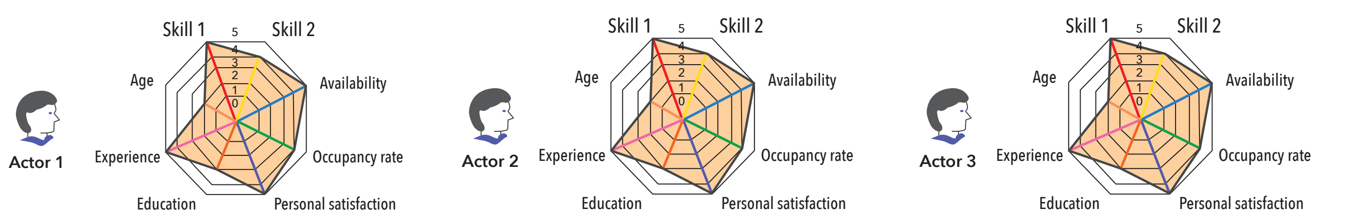
After we identify the priority of the projects, we can look for compatible actors for the priority project according to the relationships between actor and project (Figure 4).

The horizontal abilities in the Figure 4 (maximum horizontal ability) include all factors that can affect more or less quality and time delay of the project. In the future, when the project manager wants to select and allocate the candidate actors to different projects, they are not only considering the skills for employees but also thinking about horizontal abilities (Emiliano 2015). The maximum horizontal ability in Figure 4 means the candidate maximum capacity that can be reached under project needs. Here, we can use the skills acquisition model of Dreyfus (2004) to define the five levels (from novice actor to the expert) to the horizontal ability and use the pairwise comparison method in the AHP (analytic hierarchy process) (Saaty 2013) methodology to define the weight of all properties. From the table in the Figure 4 right part, different levels of urgency area relate to the project required different candidate horizontal ability areas.

Afterward, we have to calculate the compatibility degree between different combination of actors, so we will calculate the group interactions and personal relationships gap (Figure 5) for every different combination of actors. The main target of this step is to find the most efficient collaboration team actors to increase the project completion speed and quality.

In the Figure 5, the total gap of group interactions and personal relationships (TAVG) is 4.667 (0.667 + 1.333 + 2 + 0 + 0 + 0 + 0.667 + 0). The AG in the Figure 5 means the average gap for all the actors' horizontal properties gap in one candidate group. For the calculation of AG, such as the AG for Skill 1, we can understand that the gap between Actor 1 and Actor 2 is 1 (5 – 4), gap between Actor 2 and Actor 3 is 1 (5 – 4), and gap between Actor 1 and Actor 3 is 0 (5 – 5). Hence, the AG for Actor 1, Actor 2 and Actor 3 is 0.667 ((1 + 1 + 0) ÷ 3). After that, we need to calculate all the combination of candidate group actors, and select the lowest group interactions and personal relationships gap to define the final actors to the project. At the final, we will launch and follow the progress of the project. Finally, we need to check if all the projects have finished. If they are not finished, we need to return to the step to "check the priority of project." Otherwise, all the processes will be finished.

In conclusion, the presented methodology approaches the problem of human resource allocation for the future organization structure. In the methodology, we consider the efficiency of collaboration between candidate actors through the calculation of the group interactions gap of the different combination of the actors. From here, we can integrate all the resulting information into the P-P-O model, and let it adapt to the factory of the future. ■



Group interactions and personal relationships	Skill 1	Skill 2	Availability	Occupancy Rate	Personal Satisfaction	Education	Experience	Age	TAVG
Actor 1	5	4	4	3	3	2	5	1	
Actor 2	4	2	2	3	3	2	4	1	
Actor 3	5	2	5	3	3	2	5	1	
AG	0.667	1.333	2	0	0	0	0.667	0	4.667

Figure 5. Calculation process for group interactions and personal relationships gap

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Complex System Tacit Knowledge Extraction Through a Formal Method

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ABSTRACT

A complex system integrates multiple sub-systems and contains both knowledge in each sub-system and in their connections. This paper aims to present the relational concept analysis as a method to extract "connection" knowledge as much as the sub-system contained knowledge. A use case from neurology to validate the approach is introduced. A brain is a system that can be studied through different clinical examinations, therefore each clinical examination can be considered as a sub-system.

A complex system, integrates multiple sub-systems (Carney, Fisher, and Place 2005). Each sub-system contains some form of domain knowledge but the main difference that can be seen between a complex system and a set of simple systems is that the knowledge the complex system presents is larger than the sum of the knowledge that each sub-system contains (Billaud, Daclin, and Chapurlat 2015). In both cases, each sub-system is made of elements that are exploitable together, but two different sub-systems have information that cannot be used in concert. Therefore, the tacit knowledge, the knowledge contained in the interaction between the sub-systems, is usually harder to extract than the knowledge contained in the sub-systems. (Yahia, Lezoche, Aubry, and Panetto 2011).

In "simple cases," the sub-system presents as a formal context, a cross-table of objects and their attributes, and the links between the diverse sub-systems can be represented as relational context, a cross-table containing the objects of two sub-systems, and modeling if two objects are in relation. In this paper, we aim to present the process to extract knowledge from such a model of complex systems. We will show how to apply it to a use case of real data from the neurology domain.

CARS	electrical (elec.)	powerful (pow.)	compact (comp.)	cheap (ch.)
TWINGO			⊗	⊗
TESLA 3	⊗	⊗		
ZOÉ	⊗		⊗	
FIAT 500		⊗	⊗	⊗

Figure 1. Table of concepts and properties

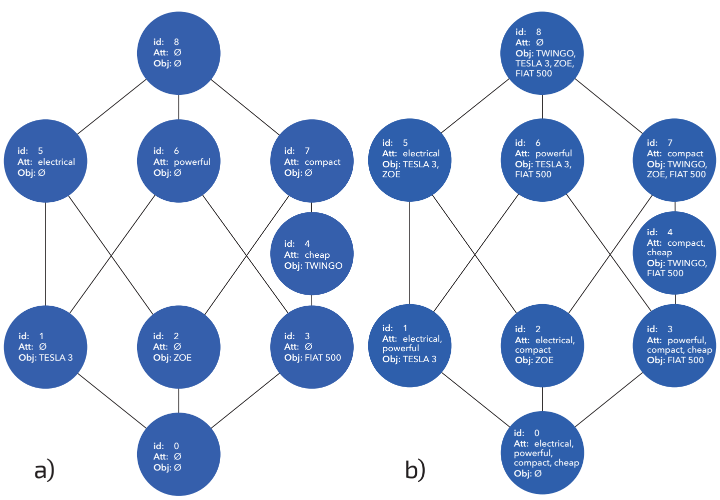


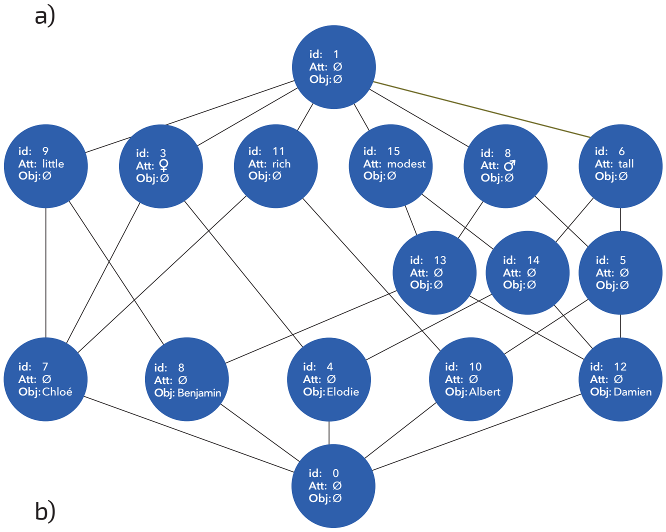
Figure 2. a) Concept lattice in normal shape, b) Concept lattice in compressed shape

THE TECHNIQUE

A formal context (a sub-system) can be presented as a cross-table like the one in Figure 1. It lists a set of cars and their characteristics; a simple cross means that the specific car presents the characteristic. Through a technique called formal concept analysis (Wille 1992) (Szathmary, Valtchev, Napoli, Godin, Boc, and Makarenkov 2014) (Ganter and Will, 2012) (Carpineto and Romano 2004), that presents all the possible clusters from such a context, a lattice of the clusters (called concepts) is generated. For any node (a cluster) you can extract knowledge through the dependency between the attributes and the objects. In each node, as in Figure 2a, all the objects present every attribute, and no other object in the table presents all the attributes of the concept. The node gives us the information that TWINGO and FIAT 500 are

person	♂	♀	tall	little	rich	modest
Albert	X		X		X	
Benjamin	X			X		X
Chloé		X		X	X	
Damien	X		X			X
Elodie		X	X			X

a)



b)

Figure 3. A new context: a) table representation, b) concept lattice representation

all compact and cheap, and that no other car in the table is both compact and cheap.

The lattice can also be presented in a compressed form (each attribute or object is presented only once but can be deduced from the shape of the lattice) as in Figure 2b.

For each node, knowledge from relation of attributes can be extracted: the attributes of the compressed node imply the other attributes in its extended version. Node 4 gives that if a car is cheap, then it is compact. These two aspects present how to extract knowledge from a formal context, in other words a simple system.

In the case of a complex system, we will be presented with multiple formal contexts and relations between these contexts. The

BUY	TWINGO	TESLA 3	ZOÉ	FIAT 500
Albert		X		
Benjamin	X			
Chloé		X		X
Damien			X	
Elodie			X	

Figure 4. Relations between the two contexts

formal concept analysis can handle each formal context separately but it is not designed to take care of the relations between them. An extension to the paradigm is proposed: the relational concept analysis (RCA) (Rouane-Hacene 2007) (Rouane-Hacene 2013). We grant the previous example with a second formal context that can be found in the Figure 3. The formal concept analysis will design the following lattice.

Added to that, the system is provided with a relation table, the one found in the Figure 4.

The scientific question is how to use that information to extract knowledge? RCA uses the relation table to enrich each lattice through the information contained in the other one. The main principle is linking the objects from the two tables and iterating the procedure until all the concepts are taken into account. If we have a context A with its lattice A and a context B with its lattice B plus the relation table linking objects of A to objects of B, an iteration is made from A to B then from B to A. In the iteration from A to B one column is added to the context A for each node in lattice B, the cross in the column depends on the operation applied to the relational context. It gives enriched contexts such as the one in Figure 5. Then, since the contexts are updated, the lattice needs to be updated too and it processes again until a fixed point is reached (its existence is guaranteed). Each lattice now contains more information.

This information deals with the other contexts by using the same rules extraction process used in a lattice generated through formal concept analysis. New knowledge is discovered such as tall people buy electric cars, knowledge that could not have been

person	♂	♀	tall	little	rich	modest	∃buy : c0	∃buy : c1	∃buy : c2	∃buy : c3	∃buy : c4	∃buy : c5	∃buy : c6	∃buy : c7	∃buy : c8
Albert	X		X		X			X				X	X		X
Benjamin	X			X		X					X			X	X
Chloé		X		X	X			X		X	X	X	X	X	X
Damien	X		X			X			X			X		X	X
Elodie		X	X			X			X			X		X	X

Figure 5. Enriched context

found with the separate exploitation of the two formal contexts. We now want to illustrate a use case of the method in a real data application.

USE CASE FROM NEUROLOGY

The use case we chose to use to validate the method comes from neurology. The brain conveys information through electric signals, which can be evaluated through an Electroencephalography (EEG), a clinical examination that consists in recording the electrical signal with captors put on the head. This examination induces an excellent time precision but is not perfectively accurate for the spatial information. When a part of the brain (called cortical area) is activated and emits an electrical signal, this area receives oxygen through blood, and this oxygenated blood has

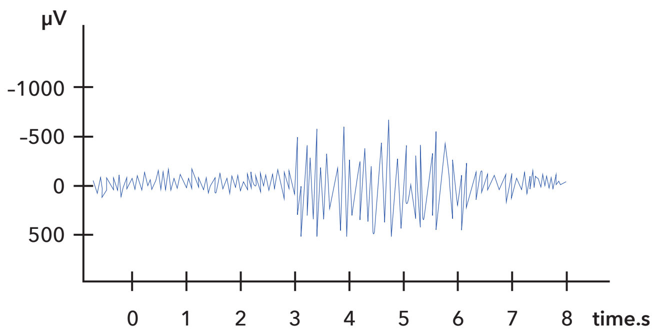


Figure 6. Sleep spindle signal

a different magnetism that can be tracked through functional magnetic resonance imaging (fMRI). This clinical examination, contrary to electroencephalography is spatially accurate, but because the blood flow is slow compared to electrical signal, the temporal aspect is not precise. In our study, the focus is made on a particular signal the brain emits while one is asleep: the sleep spindle. Through encephalography, it can be seen as a punctual (in the temporal aspect) excitation that occurs periodically within the sleep. The signal has the shape shown in Figure 6 (Gath and Bar-On 1983) (Gath and Bar-On 1980). The hypothesis from the neurologists is that there is a correlation between the areas that presents the strongest signal from the spindle and the most represented frequencies in it (that can be extracted through a Fourier transformation). Through a process of knowledge extraction via relational concept analysis, we want to exploit the temporal precision of electroencephalography in concert with the fMRI spatial precision in order to assert or reject such hypothesis.

THE PROCESS

Due to the constraints of length, we present as a result the engineering process for knowledge discovery (Figure 7). First are the raw data that are preprocessed to extract the signal values and then digitized to give relevant cross-tables. One formal context compiles the results of EEG, another one compiles the information for fRMI and relational contexts are made to link the formal contexts. These relations define which electroencephalogram captor covers which cortical area, and links electric signal to blood oxygenation response. Then an RCA method is applied to generate the lattices before we analyze the association rules that can be

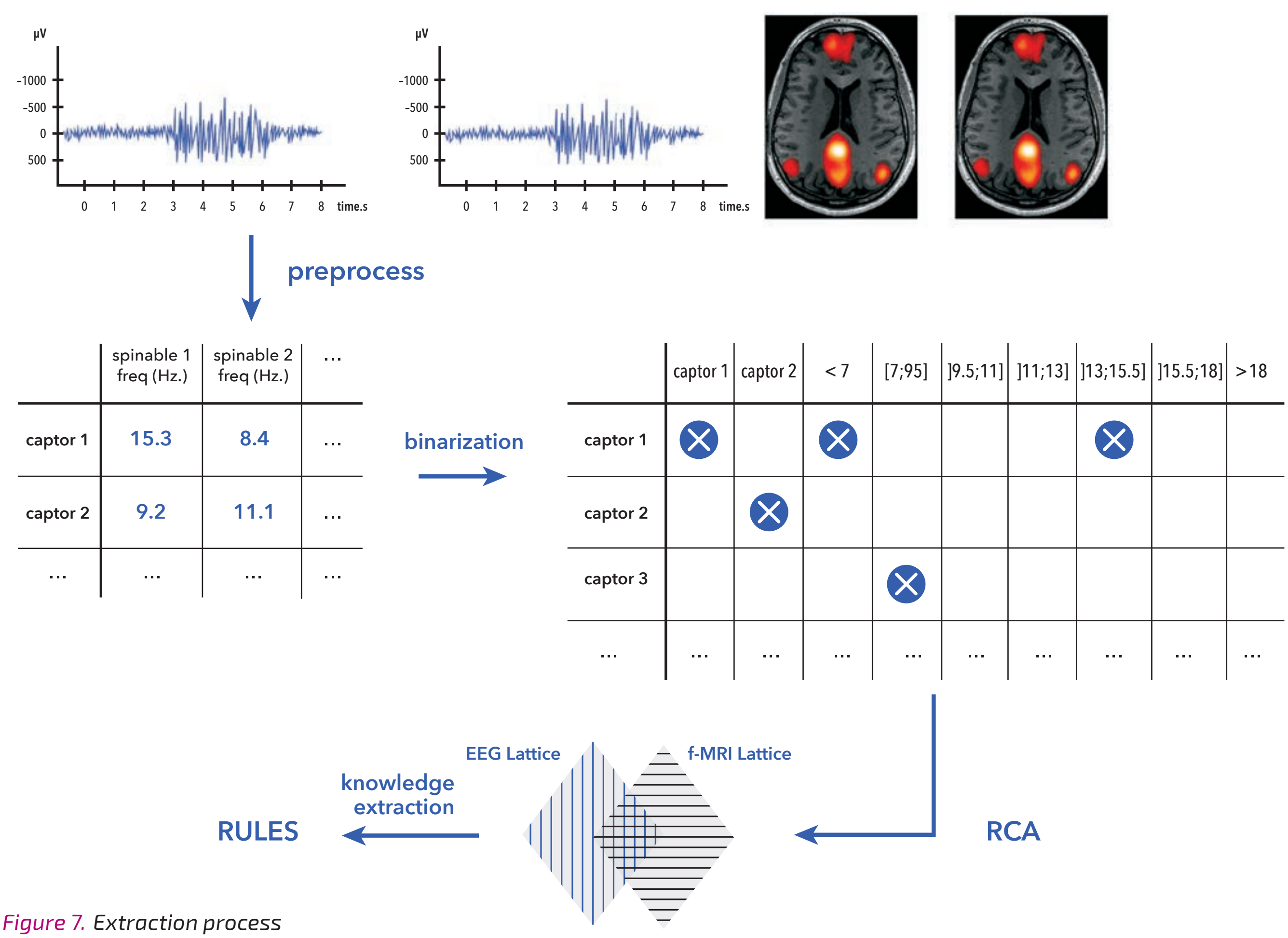


Figure 7. Extraction process

extracted. Through this process we aim to discover first relations in the form « If cortical area A presents a sleep spindle with frequencies in the range [r1; r2] then we also have area B that presents a spindle with frequencies in the range [r3; r4] ».

CONCLUSION

We applied the knowledge extraction method using relational concept analysis to a toy example and the results showed the potential of relational concept analysis as an accurate technique to process interoperability of heterogeneous neurology data. ■

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ProCASEE: An Innovative Solution for Systems Engineering Education

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ABSTRACT
Teaching systems engineering is a very challenging task where the complexity of the engineered systems must be considered together with systems engineering complexity itself. This article illustrates a solution that can help train systems engineers with different levels of expertise, and that should be easily transmissible from a university to another, and from a specific engineering discipline to another. The article deals with both the proposed pedagogical approach, for systems engineering education, and its supporting web-based platform, called ProCASEE. The proposed approach is based on the recommendations of academic and industrial communities. It is centered on the use of systems engineering standardized processes and at the same time very adaptive the learning context. Our proposal also provides the ability to make the learning scenarios driven by the acquired or to-be-acquired systems engineering competencies.

Dealing with the complex systems of today requires highly qualified systems engineers. In fact, systems engineering education is as much about skills and processes, as it is about knowledge transfer. This makes teaching systems engineering a very challenging task where the complexity of the engineered systems must be considered together with systems engineering complexity itself. There is no common formal learning path for this discipline (if we consider it as such). During the last few years, we worked on a solution that can produce systems engineers with different levels of expertise, and that should be easily transferable from one university to another, and from a specific engineering discipline to another. We tried to consider some basic questions such as: what pedagogical model should be used? What role technology and educators should play in a perfect systems engineering educational environment? Which tools should be used?

We ended up proposing a novel solution, called process centered approach for systems engineering education (ProCASEE), for systems engineering education (an approach with its supporting web-based platform). The proposed approach is based on the recommendations of academic and industrial communities. It is centered on the use of systems engineering standardized processes and at the same time very adaptive to the unique learning context. Our proposal also provides the ability to adapt the learning scenarios driven by the acquired company/department/college or to-be-taught systems engineering competencies. The proposed supporting platform is a web-based platform that has been developed to support this novel approach within a distant project-based learning (PBL) environment.

THE PROPOSED APPROACH, A HEART AND A SPIRIT

ProCASEE is based on two fundamental principles; the first one is the adoption ***of systems engineering standardized processes***, which represent ***the heart of the proposition***. Second is the ***competency management system*** and its benefits for defining systems life cycle models fitting the learning goals and for managing students' acquired and/or to be acquired competencies. This represents ***the spirit of the proposition***.

The three main roles when using ProCASEE consists of:

- For the organization (learning institution), preparing the framework for educators and students, and defining the competency model to be followed.
- Educators create learning projects, learning scenarios, assign them to teams of distant students, assisting them in engineering the requested system, and assessing them.
- Students in their turn, work as a team to engineer the requested system, while learning and practicing the fundamental principles of systems engineering as conveyed by the used systems engineering processes that form the learning scenario.

Creating a new project goes through several stages. The educator defines the project title and description, as well as the life cycle model that will be followed by students, based on standardized systems engineering processes. For this purpose, the educator selects and tailors if necessary, a number of processes from the processes database, while documenting them. If a specific process does not exist in the database, it can be added using the processes management system. Finally, the educator specifies the resources and tools to be used by students. Note that, as illustrated by Figure 1, the system life cycle model can be defined in to ways, the manual one and the semi-automatic one. The manual method consists of an educator selecting which processes to include, while tailoring them

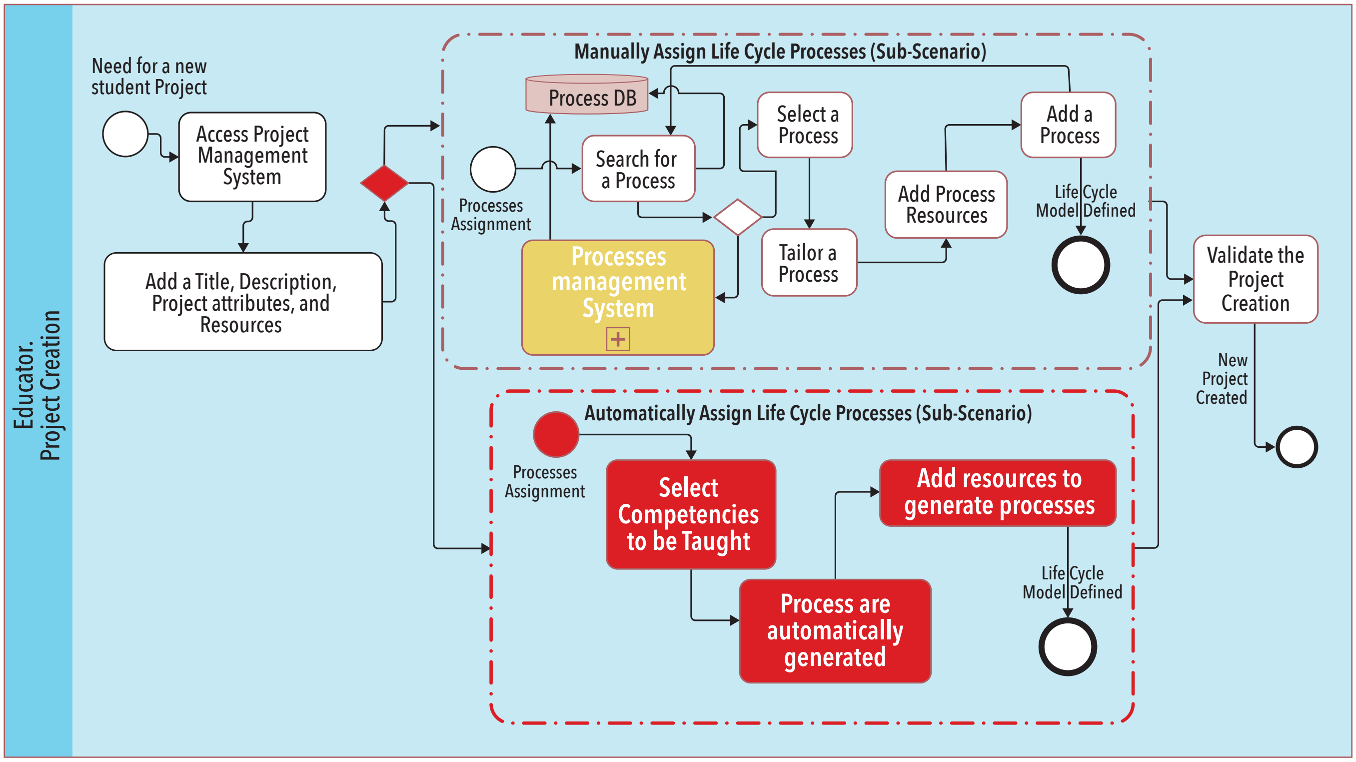

Figure 1. Project and its system life cycle model definition within the learning scenario

or not. The semi-automatic one consists of the educator selecting, from the adopted competency model, the competencies to be taught, and the processes that will be followed will be automatically generated based on an existing links between competencies elements and processes activities. We refer to it as semi-automatic, because the educator can go further and tailor the automatically generated processes and/or adding/removing other processes. Systems engineering competencies management elements are the red colored parts of Figure 1. Note that this is an independent component, so the organization and educators using the solution may decide to use or not the competencies management system, and so to use or not a systems engineering competency model.

Once a project is created and assigned to a team of students, students may start engineering the requested system. The systems engineering is done by students executing the different tasks and activities using appropriate tools and methodologies, and reporting the results of each task to the right place of the shared workspace (illustrated by Figure 2). All along the engineering scenario, the educator or an assigned industrial expert, can see in real time what students already performed as tasks, and can assist them by putting remarks and recommendations beside each task. At the end of the project, the educator can assesses each task directly within the team shared workspace, in order to get a summary of the results and process assessment data in the teams' assessment space, within the ProCASEE environment.

THE SUPPORTING WEB-BASED FRAMEWORK

Figure 2 illustrates the ProCASEE supporting platform from a student's perspective. As shown, when a student enters into a project they are a part of, they can see the details of the project, that is they see the requested system, can download the project description file, see their teammates, consult the processes assigned to the project, and the number of already uploaded results, in addition to a direct access to the most important two additional components of the shared workspace:

The system structure:

This component allows students to define the structural architecture of the system, as a set of sub-systems, and system-elements. By doing that, shared workspaces are automatically generated for each of them, so that students will be able to perform the different tasks and processes, not only on the system itself, but also, independently on each sub-system and system-element.

The life cycle model:

The life cycle model allows students to navigate the different stages, processes, activities, and tasks. They will be able then to notice what to do, and how to perform each task and report its results to the right places. This will also allow them to notice the recommendations of their educator or industrial tutor regarding each performed task, in addition to the assessment results of each performed task.

THE USE CASE OF PROCASEE:

We experimented using ProCASEE during an introductory course to systems engineering at Paris Mechanical Engineering School (Supméca) as a doctoral training for PhD students. PhD students from different doctoral schools at UPSaclay (Paris Saclay University) were invited. We had nine students participating. The goal of the training course was to introduce students to the discipline of systems engineering, and to deepen their knowledge in three selected topics of systems engineering: the stakeholder needs and requirements definition, the systems requirements definition, and the systems architecture definition. This basis for this course was systems engineering principles and processes from the ISO/IEC/IEEE 15288. The course organization was theoretical and practical sessions: during the theoretical sessions the educator explained systems engineering fundamental principles and presented the three ISO/IEC/IEEE 15288 processes in relation to the previous three selected topics, while describing their activities and the expected outcomes from their execution. During the prac-

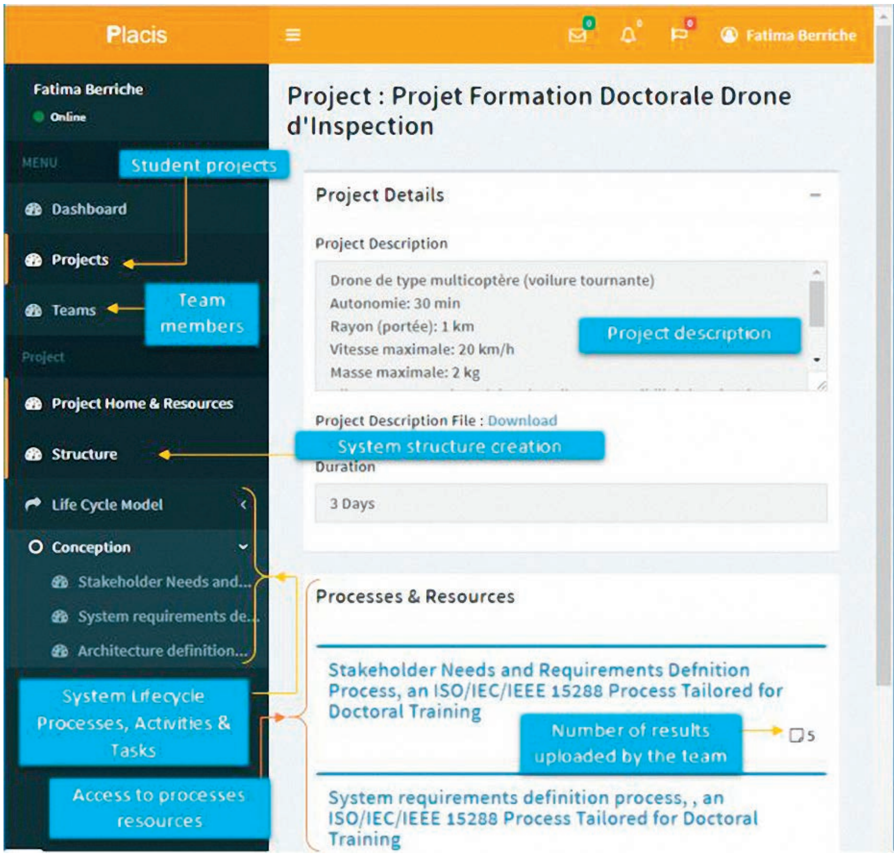

Figure 2. Student collaborative virtual environment – "the students shared workspace"

tical sessions, students worked in teams, the objective of the practical sessions was to engineer the requested systems, while considering its life cycle model as defined by the educator, and executing the corresponding processes. This part of the course required use of ProCASEE, and at the end students took part in a survey. The survey results showed a high rate of acceptance of ProCASEE and its features, as a new way of learning systems engineering, and also demonstrated good systems engineering knowledge acquisition results.

The competencies management system

To demonstrate how a competency model can be used jointly with systems engineering processes, we successfully integrated a tailored competency model with a systems engineering standardized processes. We started by defining and integrating the tailored competency model that contains a set of NASA competency areas, along with their competencies and competencies elements within our solution, the selected competencies are the 17 competencies (four competency areas) related to systems engineering technical processes and professional and leadership skills. We also added one competency, which is the "knowledge capture and transfer." After, we deployed all activities of the system definition and realization (SR) process of the ISO 29110 standard. As you might note, we choose the 29110 standard to demonstrate the concept of competencies management at this stage, while we used the 15288 standardized processes for our doctoral course. The first reason for that is to demonstrate that the proposed solution can be used with different standards, and second, to demonstrate that it can be used with the entire life cycle processes of the 29100 standard, or with only some selected processes from the 15288 standard. Finally, we added to each defined process activity, one or more competency elements from the adopted (tailored) competency model, and which are susceptible to be acquired by the user performing the activity, totalizing the number of 6 processes (that represents the activities of the SR process) and 34 activities, in addition to one additional process that models what students do within the platform.

CONCLUSION

Students using this solution will be able to engineer a requested system in a distant and collaborative way, and to engineer it the right way. The solution aims to ease the learning at the same time of fundamental principles and processes of systems engineering, along with communication, team management, collaboration, and related soft skills. On the other hand, educators will be able to better manage their learning scenarios, training resources, and the expected outcomes. Last, educators and students' organizations (universities and colleges) using this solution will be able to manage and normalize the competencies to be acquired by their future systems engineers at every level

We consider that ProCASEE may have high potential to be used as a support to project based learning experiences in general, in other domains than systems engineering, as it responds to most of PBL challenges cited in Dym et al, 2005. In this context, organizations can replace the competency model by those of their own discipline, and educators can model their learning projects as a set of processes and activities. Once deployed on the cloud, and once efficient assessment methods are operational, we think that this solution will have great potential to become the next Open edX for Project Based Learning experiences. Open edX is open-source platform software, used to provide Massive Open Online Courses –MOOC- services. It can even be used as a part of existing solutions such as "Edx.org" or "Coursera.org," to add PBL experiences to their theoretical courses. Next, we will be working on some additional subjects to go further in improving ProCASEE, namely, we will be working on proposing effective assessment methods, integrating systems engineering roles, introducing a sample project by educators to guide students, a 3D virtual design review component, an artificial intelligence engine integration… and more.

For additional information about ProCASEE, its background and related work, we invite you to check the recently published article by the American Society of Systems Engineering (ASEE) dealing with this proposition (Bougaa, Bornhofen, Rivière, and Tucoulou 2017). More detailed information, especially on the subject of systems engineering education is available in Mohammed Bougaa's thesis report that will be shortly available on the website www.theses.fr. ■

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Towards Model-Based Systems Engineering (MBSE) Patterns to Efficiently Reuse Know-How

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ABSTRACT

Know-how reuse is an approach that has been always used by engineers to take advantage of their accumulated knowledge and practices. But, the difficulty to formalize and reuse expert know-how is increasing alongside the complexity of systems. To deal with this challenge, this paper aims to open the way to new approaches of know-how reuse, in order to improve engineering activities. For that purpose, it explores the capabilities of three reuse approaches (commercial off-the-shelf (COTS), set-based design, and patterns), and their ability to be linked with a model-based systems engineering (MBSE) framework.

INTRODUCTION

Engineers from all domains have always used their accumulated knowledge in order to develop new systems and reduce engineering phases during the life cycle of a project. But, facing the increasing complexity of systems, difficulties emerge to formalize expert know-how, making it laborious to reuse (or at a great cost of energy, time, and money). To deal with this complexity, MBSE has been introduced to shift the document-centric approach practiced by engineers towards a model-centric approach, that "integrates system requirements, design, analysis, and verification models to address multiple aspects of the system in a cohesive manner" (Friedenthal, Moore, and Steiner 2008). One consequence of this formalized application of modeling is opening the way to search new forms of expressible and reusable know-how to improve engineering activities. To face this reuse challenge, this short article presents three approaches: commercial off-the-shelf (COTS), set-based design, and patterns.

STATE OF THE ART OF KNOWLEDGE REUSE

These approaches belong to the process of "knowledge transfer" which consists of two sub-processes defined by Majchrzak, Cooper, and Neece (2004). The process by which one captures an entity's knowledge is called "knowledge sharing," and the process by which one is able to locate and to use the captured knowledge somewhere else, is called "knowledge reuse." This paper focuses on the latter and presents three approaches that seem most likely to improve engineering activities.

The COTS approach can be seen as a "divide and conquer" design paradigm, as it introduces the notion of modularity at the software and hardware level of systems. It consists in breaking down a problem into solvable sub-problems by already existing components. Consequently, Hedman and Andersson (2014) pointed out that COTS may be selected and implemented for technical (less development time), business and organizational (reduce overall system development costs), and strategic reasons (access a technology that cannot be developed internally). However, in systemic thinking, the "whole" is greater than the sum of its "parts." For this reason, the advantages of COTS are accompanied by integration issues, early identified by Boehm and Abts (1999) which are: functionality and performance (what it is expected to do), interoperability (no standards exist), product evolution (risk of no longer meeting the need), and vendor behavior (false promises). Beyond these concerns, it appears that the key to use COTS is the need for an efficient selection method, which understands companies' needs and situations to improve integration. This is a critical point when trying to start an MBSE project, as stakes are high in terms of both time and budget. Thus COTS-based tools in the market do not provide the same usability, functionality, interoperability, technical support, and more as internally developed tools. That is why Friedland, Malone, and Herrold (2016) are customizing their own MBSE tools based on a COTS product in order to answer their needs.

The "set-based design" approach consists in a paradigm shift for industries. Currently, Kennedy, Sobek, and Kennedy (2014) describe a fumbling situation where companies spend a long time to build their products, and test it at the end of the development process. What often occurs is that rework is needed, which requires them to take more time to develop a new version of the product to test. Sobek, Ward, and Liker (1999) called this paradigm "point-based design," as the development team is moving from one "point" solution to another one more mature and closer to the customer needs. Kennedy, Sobek, and Kennedy (2014) emphasize the fact that an inversion of the paradigm is needed, and from their point of view, it is feasible by transferring the load toward the "front" phases of engineering activities. This implies that the development team innovate with small tests that can help them define and challenge the limit of a technology earlier on in order to establish a *set* of possible designs. They can then build the system thanks to all the knowledge accumulated from these maturation activities. That is the reason why "point-based design" can be seen as a "document-based design" as requirement and specifications have been managed with documents and natural language, resulting in many iterations. As a result, "set-based design" and MBSE approaches aim at the same goals, which are reducing rework and improving decision-making. However, even if models support the decision maker by presenting just the information needed, it still needs to be improved (Russell 2012). That is why this paradigm shift complements modeling approaches with decision-making by systematically accumulating knowledge and defining a set of possible designs (by maturation) before making key decisions.

The third approach is based on the concept of "pattern", described for the first time in architecture by Alexander, Ishikawa, and Silverstein (1977), then promoted in software engineering by Gamma et al. (1993) and Bushmann, Meunier, and Rohnert (1996). In the field of systems engineering, Barter (1998) and Haskins (2003), were the first to introduce pattern and pattern language for capturing the engineering knowledge. (Pfister et al. 2012) adapted the concept to functional architecture design and describe patterns with an enhanced function flow block diagram (eFFBD), which is translatable into SysML, allowing a bridge with MBSE. However, other works are trying to link MBSE and patterns. Schindel (2005) based his work on the hypothesis that systems engineering should be a merge of prose and diagrams in order to create a formal model. He sees "patterns as re-usable models" and applies it to requirements and design. This modelling framework led to an INCOSE working group called MBSE Patterns (pattern-based systems engineering) to examine where patterns can be configured or specialized into product lines or into product systems. At a high-level, they constitute a generic system model that can be customized for an enterprise's needs, configuration, use, so that engineers can benefit from the concepts of MBSE without being an expert of modeling methodologies.

In this section, three approaches have been presented, and possible links with MBSE have been considered.

DISCUSSION

From the three approaches presented in the previous section, arguments regarding "knowledge reuse" have not been discussed even if bridges with MBSE have been made explicit. As "knowledge reuse" is one key element when engineers seek to reduce rework and system development costs, these goals raise issues concerning knowledge management to perform efficient reuse. This discussion focuses on the pattern approach, as its configurability property and its capacity to combine with MBSE is more likely to help in the search for new forms of expressible and reusable knowledge.

The engineering artefact on which a pattern is applied may be the system of interest (SOI) or systems engineering activities (SEA) – such as requirements engineering, functional architecture design, and physical architecture design – whose aim is to produce a model of the SOI (Pfister et al. 2012). Both should be addressed in order to propose a broad approach for generic patterns based on MBSE methodology. But, to keep consistency between patterns – as they do not target the same objectives – they must not be mixed: one pattern addresses only one aspect (SOI or SEA). For example, COTS addresses a solution for the SOI, thus it may be possible to apply the same criteria in order to build SOI patterns, but a particular attention must be paid concerning the pattern's configurability contrary to COTS. Another example would be to address a pattern concerning "set-based design" as a SEA pattern, but this would need to correctly address the principle of this approach in MBSE, which means identifying the level of abstraction or how to model it.

Beyond these aspects, a very important dimension appears when trying to practice "knowledge reuse" for innovation. Indeed, reuse cannot be applied like a copy and paste process as it also should facilitate innovation by allowing engineers to create new ideas from expressed knowledge. It is true that many capitalize on experience when a solution is known and frequently used in the field. But, this would mean missing the separation of "knowledge reuse" detailed by (Majchrzak, Cooper, and Neece 2004) in two processes: one for replication, and the other for innovation. They identified a six-stage process, which is more likely to foster innovation in the specific context of the Jet Propulsion Laboratory (JPL). But what drives JPL can possibly drive other institutions, thus it seems possible to build a SEA pattern concerning innovation. And as it appears that the process can be defined by use cases and scenarios (depending on the actors), and a functional flow, an MBSE approach can be considered.

To go further, a process of knowledge reuse combined with an MBSE approach that follows lean (McManus, Haggerty, and Murman 2005) or frugal (Weigl, Wang, and Sepahvand 2012) philosophies seems to make sense. Indeed, one issue that appears when applying MBSE concerns the level of abstraction a model is addressing. These ways of thinking can help engineers to find the level of modeling that is complete enough to provide the right information for the right stakeholders.

What emerges from this discussion, is the need to practice reuse in a smart way, in order to benefit from engineers feedback for improving engineering phases, while enabling innovation and bridges towards MBSE.

CONCLUSION

The three approaches presented in this article raise many issues, which must drive stakeholders to develop efficient "knowledge reuse" in order to reduce costs, time, and facilitate innovation during engineering phases. The coupled approach between MBSE and "knowledge reuse" shows a promising outlook, especially concerning the concept of pattern, which appears to be a possible part to the answer regarding the growing complexity of systems, as it is generic and does not follow a unique method. ■

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SPECIAL FEATURE
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Configuring Process Variants Through Semantic Reasoning in Systems Engineering

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ABSTRACT

When dealing with processes, engineering systems need to be able to deal with the existence of many versions of the same process, known as variants. Each process variant aims to represent a specific business context but, due to some differences in the activities, resources, and control flow, they may differ in their logic. As result, the concept of a customizable process model has emerged. A process model can be customized by representing the process family in one single model deriving a variant through transformations in this single model. However, the process customization is not a trivial-task. It must be ensured that the variant is correct. Besides, the resulting variant must respect all requirements related to the application context and internal and external regulations, among others. In addition, recommendations and guidance should be provided during the customization. In this context, this research aims to propose a framework for customizing variants according to the user's requirements. The customization is achieved by reasoning in an ontology based on the rules for selecting a variant, in the internal/external regulations, and on expert knowledge.

INTRODUCTION

Healthcare is a dynamic environment with complex, non-trivial, lengthy, diverse, and flexible clinical processes (Rebuge & Ferreira 2012). This kind of environment has several contexts differing in activities, resources, control flow, and data. For example, two patients with ischemic stroke can be treated differently according to the symptoms displayed, their response to the treatment, the expert knowledge, among others. Additionally, medical treatment must comply with the respective clinical guidelines, which are statements that include recommendations to improve the quality of care, limit unjustified practice variations, and reduce healthcare costs (Kaymak, Mans, van de Steeg & Dierks 2012). In these environments, dealing with the concept of variability is required. Business process variability is the ability of a process to adapt to changes in the environment or to its requirements. Thus, an artefact can undergo configuration, customisation, or change for use in a specific domain. The different versions of the same process model are known as process variants (Valença, Alves, Alves & Niu 2013). Process variants reflect the awareness of process constraints and requirements which provide valuable insight into work practices, help externalize previously tacit knowledge, and provide valuable feedback for subsequent process design, improvement, and evolution (Mahmod & Chiew 2012).

One challenge is to design a basic process model that can serve as reference for configuring a family of related process models. Another challenge is to design, model, and structure the adjustments that may be applied to configure the different process variants to this basic process model (Hallerbach, Bauer & Reichert, 2010). Soundness and evolution are also challenges. The need for evolution happens when there is a need to introduce new variation points and/or new variants, and may refer to a single process variant or to an entire process family (Reichert & Weber, 2012).

This paper aims to discover process variants from an event log related to acute ischemic stroke treatment, through the decision point analysis, a process mining tool. By identifying the process variants and their characteristics, the process model can be correctly individualized by meeting the requirements of the context of application. In addition, given that process variants are extracted from the event log, they reflect what happened during the treatment applied to the patient, enabling acting more effectively in correcting or improving process variants.

LITERATURE REVIEW

This research presents an approach to

identify the process variants from an event log by applying a process mining technique. Thus, this section starts by introducing approaches in process variability management. It is common in organizations to maintain repositories containing several process variants. This practice is a crucial task in maintaining competitiveness in business environments enabling the reuse of process models. The design of business process models from scratch is a time-consuming and costly task, besides process models usually vary over time, which makes this task even more challenging.

Process variants are the result of some transformation such as adding, deleting, or moving fragments in a customizable process model. Thus, the process variants pursue the same or similar objective, however, they may differ in their logic (La Rosa, van der Aalst, Dumas, and Milani 2017). There are two approaches to variability management: by extension or by restriction. The first approach refers to a customizable process model that contains all behaviour of all process variants. In this approach, the customization is achieved by restricting the behaviour of the customizable process model. In the second approach, the customizable process model represents the most common behaviour, or the behaviour that is shared by most process variants. For the customization, the behaviour needs to be extended to represent a particular situation (La Rosa, van der Aalst, Dumas, and Milani 2017).

Customizable process models of the extension type are configurable process models. The goal of configuring a process model is to adapt the model such that it fits the model user's individual needs better than the original process model. Thus, configuring a process model means restricting the behaviour depicted by an existing process model in such a way that it only allows for the desired behaviour of the model (Gottschalk 2009).

The process mining technique aims to promote understanding of process behaviour and, in this way, facilitate decision making in controlling and improving that behaviour. However, process mining can have different types of results, not being limited to the discovery of process models (Abraham & Junglas 2011). Event logs are the basis for process mining since they contain information about the instances processed in the systems, the activities executed for each instance, at what time the activities were executed and by whom, known respectively as timestamp and performer or resource. Event logs may store additional information about events as age, gender, and more (De Medeiros, Van der Aalst, & Pedrinaci 2008).

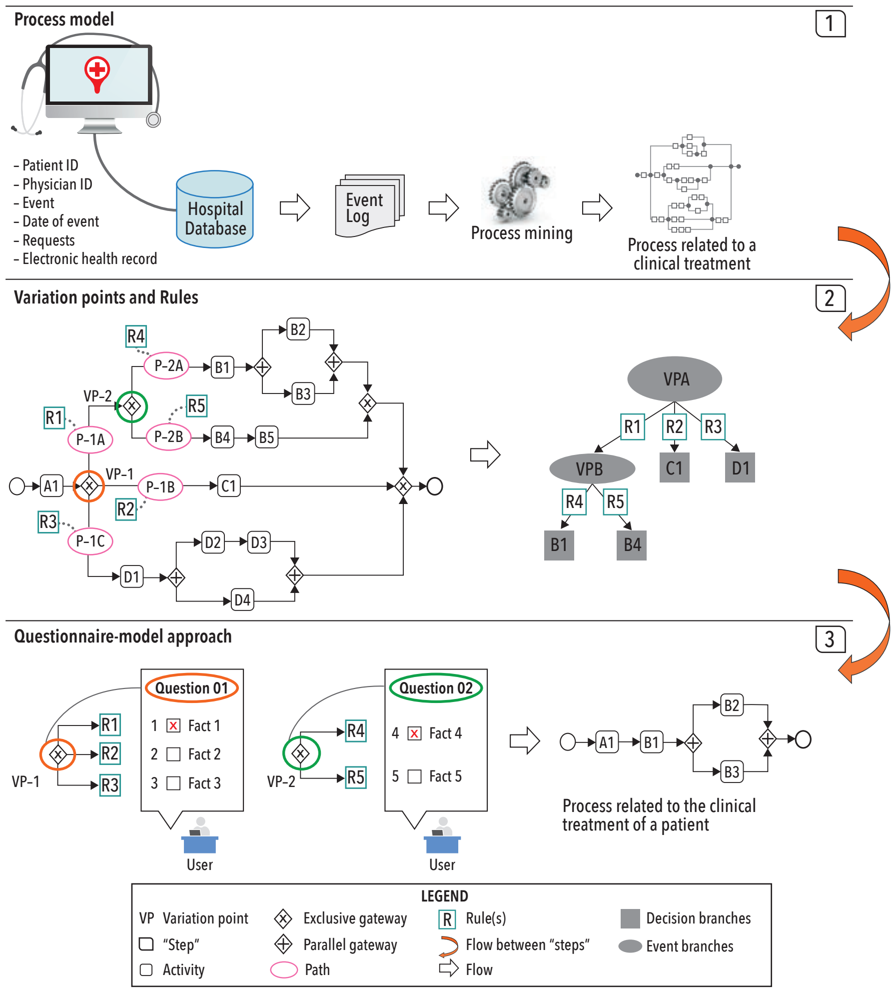

Figure 1. Framework for extracting process variants

At run-time, one can also observe the actual behaviour and use this as input for analysis.

In healthcare, the application of process mining can aid in analysis of patient treatment, enabling detection of deviations, thus minimizing medical errors and maximizing patient safety, as well as suggesting ways to enhance healthcare process effectiveness, efficiency, and user/patient satisfaction (Mans, van der Aalst & Vanwersch 2015).

FRAMEWORK FOR EXTRACTING PROCESS VARIANTS

The framework presented in the Figure 1, proposes the discovery of variation points, alternatives for the variation points, and the rules for choosing the available paths through the process mining technique. The framework also proposes to select a process variant by posing relevant questions to the user through the questionnaire-model approach.

The framework presented in Figure 1 contains three "steps." The first "Step" is in relation to discovering the process model from an event log, which contains all the process execution information. By analysing the process model, the variation points are discovered in "Step 2." Variation points refer to the points where, according to the context, the process may follow different paths. In the Figure 1, there are two variation points: the first variation point has three paths available, each one representing a different context. Each path has requirements, which are represented by rule(s) which define the selection of a path, ensuring that the configuration of a process variant respects context-specific requirements.

Thus, "Step 2" also aims to discover the rules related to each path and check its compliance in order to avoid configuring incorrect process variants. In this step, the decision tree concept is used to carry out a decision point analysis, for example, to find out which properties of a case might lead to taking certain paths in the process. In "Step 3," we propose to apply the questionnaire-model approach for process variant configuration. The questionnaire-model

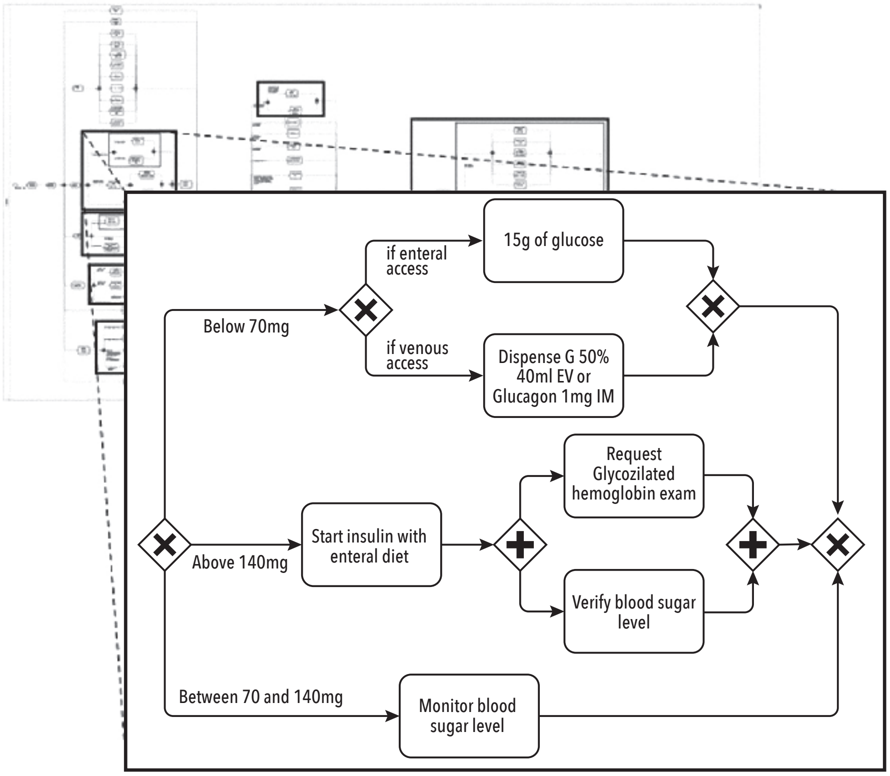

Figure 2. Variation points in the process model

approach (La Rosa, van der Aalst, Dumas, and Ter Hofstede 2009) guides the configuration process by posing relevant questions to users. Thus, by selecting an alternative in connection with a question, users define process variants. The steps related to the proposed framework are discussed in more detail in the next section.

DISCOVERING THE PROCESS MODEL

As presented in Figure 1, the first step refers to the discovery of the process model from an event log. We obtained an event log from a Brazilian hospital related to the treatment provided to the patients diagnosed with acute ischemic stroke. However, the event log is incomplete, not reflecting the complete treatment provided to the patient. The event log does not contain all the activities perform during the patient's treatment, all the sequences and some attributes are missing. As mentioned before, three aspects must be defined in configuring a process model: the variation points, such as the points where the process splits into alternatives branches (OR-split); the alternatives for each variation point; and the rules for the selecting the alternatives available. Thus, in order to discover these aspects, we applied the decision point analysis, which aims at the detection of data dependencies that affect the routing of a case. By applying decision point analysis in the event log, 10 variation points were discovered.

Figure 2 shows the variation points for activity 'Verify blood sugar levels'. The first one has three paths and the second has two paths. It is possible to note that the selection of a path in the first variation point relies on the blood sugar levels displayed by the patient. If the patient's blood sugar level is below 70 mg, one can follow two paths, represented by the second variation point. Therefore, one must examine the event log to establish the rules defining the selection of each path in connection with the different variation points.

In order to discover the rules, the decision point analyses the data attributes obtained for cases that followed the same path to check whether they share certain properties. The attributes to be analysed are the case attributes contained in the log, and we presume that all attributes written before the considered choice construct are relevant for the routing of the case at that point. By examining the resulting decision tree, logical expressions can be inferred which form the decision rules. The information about the dependency between the variation points is useful for the development of the next step, which refers to configuring process variants to meet specific end-user requirements. In this paper, we applied the questionnaire-model approach to support process variant configuration. The questionnaire model allows a configurable process model to be individualized by applying answers to questions about the respective deployment context. In this approach, each question refers to a variation point, and each domain fact corresponds to a Boolean variable representing a feature of the domain. Such a feature, in its turn, may either be enabled or disabled depending on the given application context. Thus, the link between configurable process models

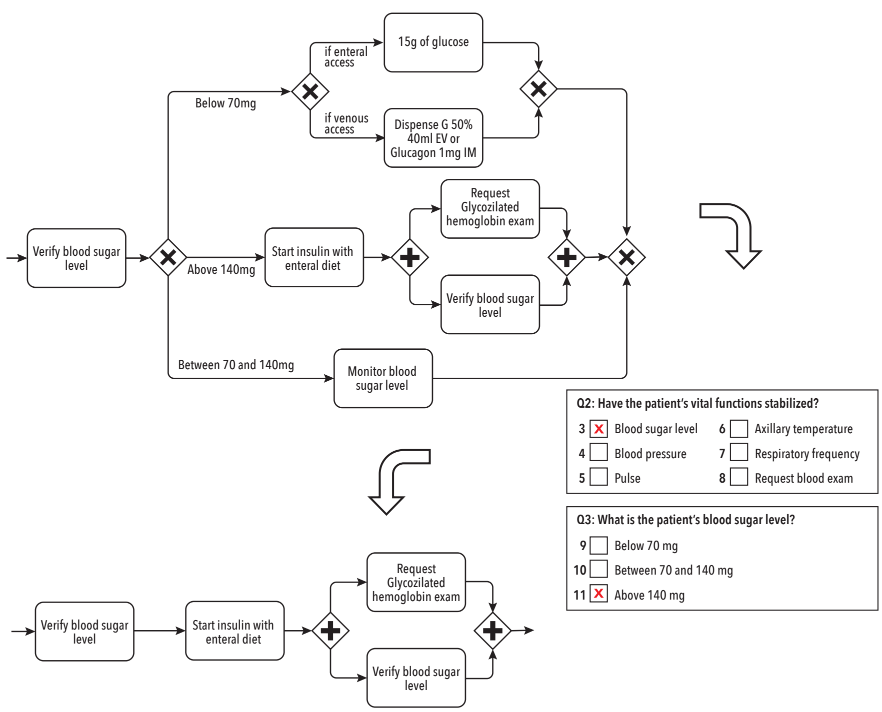

Figure 3. Selection of a process variant

and questionnaire models is achieved by mapping each process variant to a condition over the values of domain facts, such that when the condition holds, the specific variant is selected (La Rosa, van der Aalst, Dumas & Ter Hofstede, 2009). In the questionnaire-model approach, some facts are mandatory, which means the user when answering the questionnaire must explicitly set them. If a non-mandatory domain fact remains unset, the system will use the default value (Hallerbach, Bauer, and Reichert 2010). This approach also allows specifying the order of dependence on facts and questions. Figure 3 shows that the process variant arises by selecting alternatives in relation to the patient's symptoms. By selecting the blood sugar level in question 2, three paths become available. Then, by answering question 3, related to the patient's condition, the path selection occurs.

CONCLUSION

This paper intends to propose a framework for discovery of process variants from an event log. The framework is composed of three steps consisting in: extracting a process model from an event log, discover variation points and rules for the selection of the alternative available and apply the questionnaire-model approach in configuring process variants. As next step, we intended to propose a framework to manage process variants through ontologies enabling configuration of the most suitable, requirements-driven process model and ensuring accuracy of the configurable process model, respecting syntax and semantic aspects (Liao et al. 2015). ■

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A Framework to Improve Performance Measurement in Engineering Projects

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ABSTRACT

Performance measurement enables project managers to monitor the project progress and evaluate results. However, several issues remain, such as an unbalanced use of leading and lagging indicators. Lagging indicators are used to track how things are going. Leading indicators are used as precursors to the direction towards which things are going. The goal of this paper is to develop leading indicators to improve the measurement of projects performance. To address this issue, we consider the measurement processes and indicators in systems engineering measurement that promotes leading indicators. Our objective is to extend the performance measurement activities in the Project Management Body of Knowledge (PMBoK version 5) by adapting the good practices in systems engineering measurement resulting in the proposal of a framework. Thereby, systems engineering leading indicators can be applied to project performance measurement, thus providing project managers with a wider type of indicators and measurement techniques.

A wide range of methods and good practices exist for the measurement of projects performance. They help project managers effectively monitor the project progress and evaluate results. However, from a literature review, we noticed several remaining critical issues in measuring project performance, such as an unbalanced development of Key Performance Indicators types between lagging and leading indicators. Systems engineering measurement is a more recent discipline with practices and theories that appeared with the emergence of the systems engineering discipline; however, this discipline offers very deep developments, published in several standards and guides. In particular, systems engineering measurement not only manipulates lagging indicators, useful to track how things are going, but defines methods to promote leading indicators, used as precursors to the direction the engineering is going. Indeed, 18 leading indicators were recently proposed, validated, and finally engineered in a practical guidance. The overall objective of this paper is to improve project performance and success rate, one specific objective is to improve the measurement of project performance by enriching its leading indicators, on which decisions rely in project management. To reach this goal, we propose to refine and extend the performance measurement activities in the Project Management Body of Knowledge (PMBoK version 5) by considering systems engineering measurement. This paper thus considers transferring and adapting the good practices in systems engineering measurement such as described in systems engineering guides as well as the set of systems engineering leading indicators to the well-defined project management processes in PMBoK. To this effect, we propose a methodology resulting in a framework to explore this integration. This way, systems engineering leading indicators can be applied to project performance measurement, thus providing project managers with a wider set of leading indicators and straightforward measurement techniques.

1. INTRODUCTION

In the PMBoK, measurement of project performance is an assessment of the magnitude of variation from the original scope baseline. Project performance measurement is receiving wide focus from both academia and practitioners and some remarking results have been achieved, such as earned value project management, performance measurement of engineering projects (Atkinson 1999), or benchmarking project performance management. Even though these results have great contributions to the economic development and enterprise competitions, it seems that the basis of most studies is on the outcome measurement of project performance with a wide variety of lagging indicators, used to track how things are going and to be able to confirm that something is occurring or about to occur (Atkinson 1999; Zidane et al. 2015). Relatively few studies focus on prediction-based measurement of project performance with leading indicators that are performance drivers and provide early warning information (Guo and Yiu 2015; Kueng et al. 2001).

Conversely, systems engineering measurement is related to more recent practices and theories, which appeared with the emergence of the systems engineering discipline (Wilbur et al. 1995); however, systems engineering measurement offers very deep developments, published in several standards and guides (Roedler et al. 2010; Wilbur et al. 1995). In particular, it is also important to note that systems engineering measurement does not only use lagging measurement but defines methods to promote leading measurement recently (Rhodes et al. 2009); therefore indeed, as a result, 18 leading indicators were recently proposed, validated, and finally engineered in a practical guidance (Roedler et al. 2010).

The purpose of this paper, therefore, is to broaden the path of project performance measurement through applying the systems engineering leading indicators to project performance measurement based on a mapping mechanism we designed between the two disciplines.

2. RESEARCH BACKGROUND ON PROJECT PERFORMANCE AND SYSTEMS ENGINEERING MEASUREMENT

(1) *Research Background on the Measurement of Project Performance*

Generally, in the measurement of project performance (MPP), there are two types of indicators, lagging indicators and leading indicators. The characteristics of MPP evolution can be generated below:

- The history of MPP largely experienced the lagging indicators, however the concept of leading indicators is not yet in effective use.
- The most popular model for project management is earned value management (EVM), however only limited leading indicators are available.
- Perspectives for MPP are variable, not developed systematically, and the description of leading indicators differs according to the opinions of researchers.

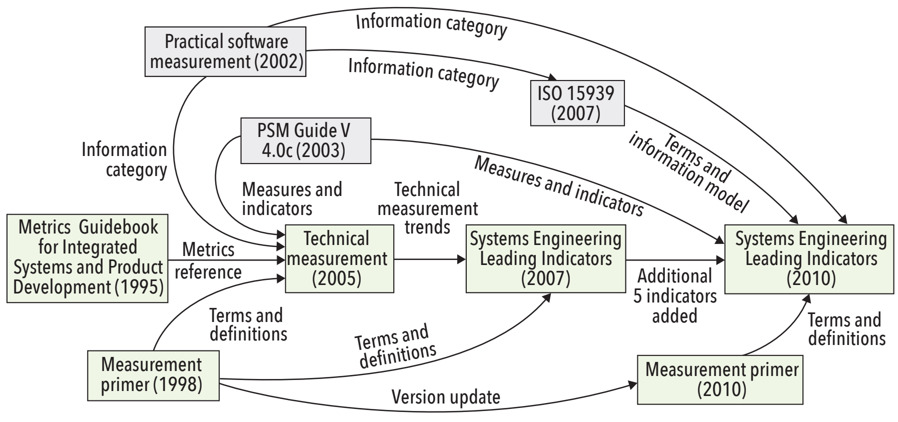

Figure 1. Overview on systems engineering measurement evolution

From the characteristics above, we can see that practitioners widely use lagging indicators, but not leading indicators. However, both types of indicators are important in providing project performance information. Thus, we propose building a balanced performance measurement system with both leading and lagging indicators. To do this, we used learnings from some advanced measurement practices from other measurement disciplines, specifically, systems engineering measurement. Systems engineering measurement (SEM) is experiencing a remarkable development with a shift from outcome measurement to predictive, which provided us with many available guides and standards for measurement, particularly around its advances in leading indicators. A mapping of the measurement methods from SEM to MPP is in section 3. Based on the mapping, we defined a further step to analyze the processes of transferring and adapting the good practices of SEM to "balance" the indicator types of MPP.

(2) *Research background on systems engineering measurement*

For effectively evaluating the health status of systems engineering in a program, many researchers and practitioners provide ideas for measuring and monitoring systems engineering processes (Xue et al., 2016). As a result, a series of formal guidebooks exist: the Metrics Guidebook for Integrated Systems and Product Development (Wilbur et al. 1995), the INCOSE Systems Engineering Measurement Primer (INCOSE Measurement Working Group, 2010), Technical Measurement (PSM and INCOSE 2005), and Systems Engineering Leading Indicators (Roedler et al., 2010).

From the development and characteristics of systems engineering measurement (SEM), some of its advantages could be summarized as following:

- The history of systems engineering measurement experience shifted from lagging indicators to the "balance" of both lagging and leading indicators, and both lagging and leading indicators constitute a systemic, effective, and balanced SEM.
- A set of systems engineering leading indicators (SELIs) developed based on the practices of systems engineering, align well with pre-existing measurement references, and the specification (rationale, decision insight, measure, and calculation) of leading indicators.

This short comparison of the advantages of SEM development and the shortcomings of MPP leads one to conclude that the application of SEM practices, by introducing the SELIs, into project management measurement can improve the MPP by balancing some of the lagging indicators.

3. PROPOSAL OF A FRAMEWORK TO IMPROVE PROJECT PERFORMANCE MEASUREMENT

Considering the history and evolution of both disciplines, we propose to transfer and adapt the good practices and indicators of systems engineering performance measurement to project performance measurement. To that end, we consider the 18 leading indicators proposed by INCOSE (Roedler et al., 2010) with the knowledge areas (KA) of the Project Management Book of Knowledge (PMBoK) to analyze if a mapping could be possible.

Each systems engineering leading indicator has its information category and leading insights. The information category specifies what categories are applicable for this leading indicator. The leading insights specify what specific insights the leading indicator may provide. Each knowledge area of PMBoK offers a set of processes, and each one of these process includes a list of inputs, tools and techniques, and outputs, from which information needs can be derived.

To make a mapping we proceeded in two steps. The first step consists in verifying

Table 1. The mapping of SELI per knowledge area of PMBoK version 5

10 Knowledge Areas PMBoK 5 / 18 systems engineering leading indicators	Project Integration Management	Project Scope Management	Project Time Management	Project Cost Management	Project Quality Management	Project Human Resource Management	Project Communication Management	Project Risk Management	Project Procurement Management	Project Stakeholder Management
Requirements trends		X			X					
System definition change backlog trend	X	X	X		X					
Interface trends		X								
Requirements validation trends		X			X					
Requirements verification trends		X			X					
Work product approval trends			X		X		X			
Review action closure trends			X		X					X
Technology maturity trends		X								
Risk exposure trends			X	X	X	X		X		
Risk treatment trends			X		X			X		
Systems engineering staffing & skills trends				X		X				
Process compliance trends										
Technical measurement trends		X			X					
Facility and equipment availability trends			X	X						
Defect/ error trends					X					
System affordability trends			X	X				X		
Architecture trends					X					X
Schedule and cost pressure			X	X				X		

whether systems engineering leading indicators can be usefully applied to knowledge areas. We take each SELI and evaluate its interest (analyzing the information category and leading insights) for each KA. This analysis results in a framework establishing a list of SELIs that can be associated to each KA to improve project performance measurement (see Table 1).

A second step consists in deepening the analysis by focusing on each knowledge area, by turn, in order to integrate each SELI identified in the list of useful indicators to this KA (first step) with the processes of the KA.

For example, we look at the project quality management knowledge area from Table 1, there are 11 SELIs mapped to it. But the assumed information need here is the quality of documentation. So the leading indicator—defect and error trend can be chosen to monitor the quality of documentation by tracking the defects of it. Once the SELI is chosen, we should further tailor it to satisfy the current project context. The tailored indicator includes: a base measure—number of defects found at each discovery stage, a derived measure—estimated number of latent defects, thresholds and outliers—range of acceptable values for defect discovery based on past project history. A defect discovery profile can thus be built based on the tailored indicator.

4. CONCLUSION

This paper addresses the measurement of engineering project performance and its balanced utilization between lagging and leading indicators to ensure the project in a healthy status. It provides a framework that associates leading indicators used in systems engineering with the project management processes described in the PMBoK knowledge areas. This contributes to improved performance measurement in engineering projects, thus resulting in a better monitoring and finally a better performance of these projects. ■

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In an effort to respond to ideas coming from a number of INCOSE members and Symposium participants, the Corporate Advisory Board, the Board of Directors, and Technical Operations, the 2018 Symposium will feature an opportunity for expanded participation in the program through designed presentations of material not intended to be the subject of more formal papers. The goal is to broaden participation and learning by opening the opportunity for innovative and challenging material that would not otherwise be available in other formats. This Call for Presentation Abstracts is the initial step in the proof of concept process in expanding the Symposium program to greater participation and engagement.

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a) a description of the presentation topic and approach,
b) a brief statement of the reason for submission of the topic as a presentation (not to exceed 100 words)
c) a biographical sketch of each presenter (50–100 words each).
d) a statement of the presenter's suggestion as to which of the two time formats described below

Presentations will be delivered in one of two formats: a 30-minute presentation with a 10-minute question and answer segment following, or a 15-minute presentation with a 5-minute Q&A segment following. Each submission should include the presenter's suggestion as to time format but presenters should be aware that the presentation will be assigned a format by the reviewers at the time of acceptance.

Each presentation abstract will be reviewed by at least 3 members of the INCOSE review team and judged on a range of parameters. Presentations will be competitively evaluated using:

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ABSTRACT
Since 2006, AFIS, the French Chapter of INCOSE, organizes a systems engineering student challenge every year called RobAFIS. In 2016, GfSE, the German Chapter of INCOSE, joined AFIS in the RobSE challenge. Both chapters organized a first common international systems engineering student challenge this year. For this challenge, French and German teams have competed with a same requirement document, applicable to a space exploration robot called Explorer II. Its global mission was to put waypoints (identification marks) on different points of a planet's surface considered as dangerous to allow vehicles of future missions to move securely. A final meeting occured in Pforzeim, Germany in March, 2017.

French and German students in systems engineering (master degree in Complex Systems Engineering at the University of Lorraine in Nancy, and master degree in Systems Engineering of the Applied Sciences, University of Munich) took part in an international robotics competition that started in October 2016, to design, assemble, and validate a robot using a systems engineering approach. The requirements document, approved and proposed by both the AFIS and GfSE (French and German chapters of INCOSE) went to the competitors in October, and the competition occurred in March 2017.

The judges found the development files written by each team to be of very good quality. The competition took place in Pforzheim, DE and included a phase of operational validation and a friendly competiton. The team from Nancy, FR participated in "RobAFIS 2016" and the team from Munich, DE participated in "RobSE 2016/2017." Both came with competition experience.

The robot design ensured three successive and different missions with a phase in autonomous mode, then a phase in teleoperation mode. The missions consisted of depositing a beacon on a black rectangle, then two beacons on black rounds, then three beacons on black squares. The teleoperation occured in a "blind" manner, thanks to an embedded video channel from a camera that was received and displayed in the control center.

The RobAFIS competition is in the 11th year in France, organized by the RobAFIS operations manager, and AFIS Vice President (VP) Jean-Claude Tucoulou. Usually an average of ten student teams from universities and schools of engineers meet each year (RobAFIS has 24 different organizations that competed in RobAFIS over the 11 years). Considering that this competition is so successfully organized, the German chapter of INCOSE (GfSE) created, with the support of AFIS, the RobSE competition in 2016 to bring this teaching challenge (with the principle of learning systems engineering through an actual project) to German organizations of higher education.

On February 3rd, 2017, the first RobAFIS-RobSE international student competition in systems engineering took place at the University of Pforzheim, located geographically halfway between Munich,DE and Nancy, FR. We sincerely thank Professor Dr. Hanno Weber for his warm welcome and the perfect organization of the day. A jury evaluated: (1) the development files prepared by the two teams, (2) the oral defense of their project by each team, and (3) the operational evaluations of the missions performed by the robot of each team.

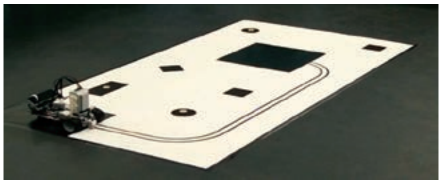

Figure 1. Operational environment for the 3 missions

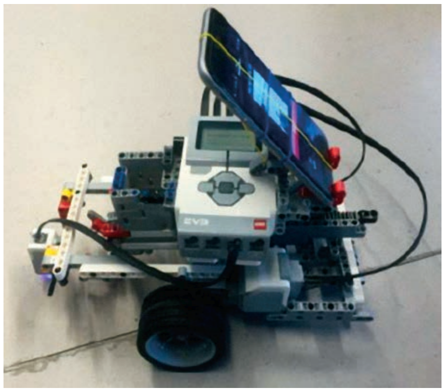

Figure 2. Robot built by the German team

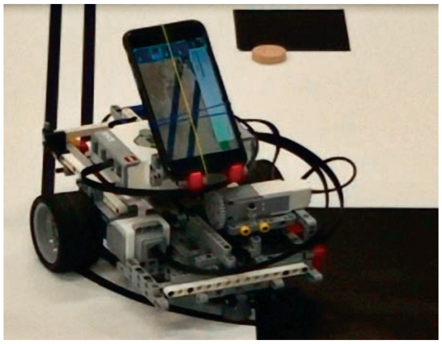

Figure 3. Robot after the deposit of a beacon

Figure 4. Teleoperator, Control Center, and Robot in autonomous mode (French robot)

The jury judged both teams' development files to be of very good quality; the teams developed slightly different approaches of design. The students of the master degree of the University of Lorraine took a comprehensive approach based on the system and its environment to seek solutions for each subsystem, by specifying the interfaces, before their assembly and verification. The students in systems engineering coming from the University of Munich designed the subsystems progressively by integrating them gradually; starting with the most critical subsystem, ensuring the displacement of the robot.

The numerous questions of the jury related to, for example, the choices of architectures, the specifications of the interfaces, the allocations of requirements to the subsystems or to the activities of verification and validation of the adopted solution. The two teams explained and defended their choices of the design and the organization of their project. The jury could sense all the motivation and the enthusiasm of both the German and French students, which was for their professors, great satisfaction!

The quality of the development files has to be put in comparison with the quality of the operational tests. The performance of the missions was very efficient for the two teams, Nancy succeeding in collecting 38 points/45 and Munich performing nearly without fault with 42/45, showing the very high level of this competition.

After the evaluation of the various phases of the competition, the jury did not succeed in choosing a best performer between the two teams, so the jury decided to declare the two teams as being *ex aequo* and both the winners of the RobAFIS-RobSE 2017 competition and strongly congratulated them for the high quality of their work.

The second objective of this day was to bring together professors coming from the University of Lorraine (Nancy), Dr Eric Levrat, Dr David Gouyon, from the University of Munich, Dr Claudio Zuccaro, from the University of Pforzheim, Dr Hanno Weber, as well as the vice-president Teaching–Research of AFIS, Dr Eric Bonjour from the University of Lorraine, and the President of the German chapter of INCOSE (GfSE), Sven-Olaf Schulze.

They exchanged ideas on their practices of the training of systems engineering and spoke of plans to develop possible co-operations. The professors planned to attend the INCOSE EMEA workshop in Mannheim, Germany, in September 2017 where they planned to take the opportunity to continue and further these exchanges.

Sven-Olaf Schulze and Eric Bonjour closed the RobAFIS-RobSE 2017 competition by thanking again the University of Pforzheim and Jean-Claude Tucoulou, Vice-president of AFIS and operations manager of RobAFIS, whose great involvement and long experience with the RobAFIS competition made the organization of this international competition possible. ■

ABOUT THE AUTHORS

Jean-Claude Tucoulou has had a fruitful working life in defense industry and in systems engineering. From 1974-1981, he was the head of the Weapon Systems Department. From 1978-1989, he worked with the Systems Development Department, responsible for methods and tools of systems engineering, and from 1981-1989, he served as head of this department. He was involved in the Systems Division, which is responsible for systems configuration management, from 1989-1998, and from 1999- 2007, he served as head of Career and Competence Management in the field of human resources management.

He has also been active in the French Chapter of INCOSE (AFIS). From 2000-2010, he served as the leader of the working group, Jobs, Competencies, and Training. From 2003-2010, he was the scientific head and then technical head of AFIS. He also served as operations manager of RobAFIS from 2007-2017, and he will be the vice president of AFIS from 2013-2019.

Eric Bonjour is a full professor specialized in systems engineering at the Université de Lorraine / Graduate School of Innovation and Industrial Systems Engineering (ENSGSI). His main research interests touch upon the fields of innovation, model-based systems engineering, and knowledge management. He supervised 9 PhD theses related to these topics. He is an associate editor of two journals, Journal of Intelligent Manufacturing and Knowledge-Based Systems. He served as a vice-chair of the French Chapter of INCOSE (AFIS), responsible for "Research – Training" topics (from 2012 to 2017). He published more than 80 papers for conferences, journals, and books. In 2015, he received the INCOSE Outstanding Service Award 2015. He served as the academic co-chair of the Program Committee of an international conference dedicated to systems engineering: CSD&M Paris, 2015.

David Gouyon is an associate professor at the University of Lorraine, FR, where he oversees a track in digital engineering of manufacturing systems, within a master degree on complex systems engineering. He has been a member of The Nancy Research Centre for Automatic Control (CRAN) since 2005. His research and teaching interests are model-based systems engineering and automation engineering. He is an active member of the French chapter of the International Council of Systems Engineering. David has been involved in the RobAfis student challenge as an evaluator since 2007.