

A Qualitative Study on SysML Based on Perceived Views from Industry Professionals

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Abstract. SysML is a UML profile, proposed more than 15 years ago, as a systems modeling language supporting specification, design, development, verification and validation of a variety of complex systems and systems of systems which include elements such as processes, information, people, software and hardware. In the past years, SysML has been used in industry to support the development of systems in many domains. SysML shares diagrams and other constructions and elements with UML, which, at least in theory, makes it easy to learn for those who are already familiar with UML diagrams. However, there are few researches on the evaluation of what professionals in industry who are effectively using SysML in their daily tasks think about the language. This paper brings new reflections of a survey on what professionals think about SysML when used in practice. The survey received responses from 344 professionals from 38 different countries. 163 participants left their written general comments on SysML. After reading each one of the comments from the participants, these comments were divided into positive or negative for the language. In view of this, 70 responses were categorized as positive and 72 as negative. Based on this categorization of comments, we performed a qualitative analysis of the positive and negative responses, and then proposed a cloud word for each type of statement.

Keywords: SysML · Qualitative study

1 Introduction

SysML is a modeling language derived from UML to be applied to a variety of systems, supporting activities of specification, design, development, verification and validation. In the past years, SysML has been used in academia and industry to support the development of systems in many domains, including railway transportation [13], energy [8], automotive [10], and many others [25].

As a UML profile, SysML shares diagrams and other constructions and elements with UML, which, at least in theory, makes the language easy to learn for those who are already familiar with UML diagrams. There are studies on using UML and SysML together to solve a variety of problems [9,14,22]. However,

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there are few researches on the evaluation of what professionals in industry, who are effectively using SysML in their daily tasks, think about the language [4]. For instance, it would be interesting to know if SysML is really easier to use, understand and manage than UML, as first proposed by its creators [18]. In addition, research on drawbacks and weakness of SysML are rarely studied in practice, in systems engineering projects in industry, as most often industrial companies are not interested in publishing their results in detail.

From an industrial perspective, many aspects on the Verification and Validation of SysML models are presented in [4]. Verification and Validation activities accelerate the system development process with less time consumed on testing and system validation, which, in the end, improves the final quality of products and processes developed in industry [4]. However, these results are still incipient, and further analysis in industry are necessary.

Companies that are willing to use SysML in their projects in the near future may be interested in knowing what other professionals think about SysML in practice. Knowing what SysML really looks like for those who are responsible to design real products and systems in industry is an important issue, and can provide confidence for those who are thinking about investing resources for introducing SysML as a modeling language in their software and systems development processes. One can not neglect that industrial companies are interested in final results and not only academic research, in quality of products and processes and short time to market. Therefore, this paper describes positive and negative answers about SysML extracted from a survey from practitioners who work in their daily activities with SysML.

This paper brings new reflections of a survey on what professionals think about SysML when used in practice. The survey received written comments about what those professionals think about SysML. A total of 163 participants professionals from 38 different countries left their written general comments on SysML. After reading each one of the comments from the participants, these comments were divided into positive or negative for the language. In view of this, 70 responses were categorized as positive and 72 as negative. Based on this categorization of comments, we performed a qualitative analysis of the positive and negative responses, and then proposed a cloud word for each type of statement.

2 Basics on SysML

The Systems Modeling Language (SysML) is a standard from the Object Management Group (OMG) proposed more than 15 years ago. It is an extended subset of UML that provides a graphical modeling language for designing complex systems, considering software, people, processes, hardware parts and other systems elements. The current version of the OMG SysML specification is SysML version 1.6.

SysML supports the specification, analysis, design, verification, and validation of a broad range of systems, allowing one to model from different perspec-

tives, such as behavior, structure or requirement [16]. According to the International Standard Document of the Systems Modeling Language [18], SysML diagrams contain elements named concrete syntax, which represents elements of the model such as activities, blocks and associations.

Different from UML, SysML involves modeling blocks instead of modeling classes, accordingly providing a vocabulary that is more suitable for Systems Engineering than considering only its software counterpart [15]. However, the compatibility between these two languages can facilitate the integration of the disciplines of Software Engineering and Systems [24].

SysML offers new language elements in relation to UML, such as value types, quantity types, as well as the opportunity to describe the functionality of continuous systems [3]. The fact that SysML establishes well-integrated architectural descriptions [12], makes it possible to define and visualize the complexity of a system from different, well-defined and restricted points of view, without losing sight of the complete whole or the need for details.

SysML provides 9 diagrams, 4 of them are similar with others from UML: Use Case, Sequence, State Machine and Package Diagram. Another 3 diagrams are modified to be consistent with the SysML extensions, they are Activity, Block Definition and Internal Block diagrams. Finally, 2 SysML diagrams are new in relation to UML, the Requirements and the Parameter Diagrams [18].

SysML consists of four pillars [26]: Structure, Behavior, Requirements and Parametric Diagram, which allow several views of the system design. The system structure view mainly describes the system hierarchy (Block Definition diagram) and the interconnections between its parts (Internal Block diagram). The Package diagram, which is used to organize a model, also belongs to the structure view. The Parametric diagram provides system property values, such as performance and reliability.

Behavior diagrams declare the sequence of events and activities that a system performs, which includes Use Case diagram, Activity diagram, Sequence diagram and State Machine diagram. Behavior diagrams integrate the specification and design model with engineering analysis models. The Requirements diagram captures requirements hierarchies and allows them to be linked to other parts of the model.

Relevant activities within the life cycle of the system in which SysML can be used are Communication with stakeholders, which can be performed through the Use Case and Requirements diagrams, where the requirements can be graphically visualized.

The effective use of SysML improves the knowledge of the system, through the application of visual models, facilitating the understanding and definition of patterns. Model execution and verification, which are made possible through transformations of semi-formal SysML diagrams (Sequence, State Machine, Activity Diagrams) to a formal model, mainly assisting in the discovery of design problems. SysML models are useful to document design decisions, which facilitates future maintenance to the system. Considering that changes in a system become necessary, the language becomes useful to meet such changes and even carry out the reengineering of legacy systems.

3 Motivation

Studies found in the literature about SysML bring in their discussions and considerations points considered as positive and negative for the language. However, most of these studies are specific to a domain, or only consider toy examples, or even do not evaluate SysML as a modeling language in their examples.

In [12], the authors claim that well-defined modeling languages such as SysML can increase the ability to assess systems engineering in general and thus provide support in a more accurate way of verifying its value. In addition, they consider that the maturity and breadth of SysML applications are still limited, even though the trend indicates the continuity for its increasing use.

As SysML diagrams do not follow strict formal semantics [2], the accuracy of the description of SysML models cannot be easily verified. Thus, at least two approaches can be followed here. First one is the formalization of SysML [1]. Second, is the combination and/or transformation of SysML diagrams to formal methods [19,20]. Both approaches have been followed by some researchers, but still need further evaluation.

In [6], the authors stated that, through a SysML profile, it is possible to have greater traceability and integration, in addition to greater consistency between safety information and system design information and can assist in communicating this information to interested parties.

As SysML is a language and not a methodology, it is expected that SysML can be incorporated into an organization's development process without much difficulty [24]. In addition, the authors point out as a facilitator the fact that SysML is based on UML, which is a popularly known and used language.

Although SysML is well established as a modeling language for designing, analyzing and verifying complex systems, many researchers customize the language for their purposes and therefore define their own profiles, since SysML seems still too generic for some domain-specific tasks. Nevertheless, SysML lacks operational semantics, although some approaches aim to bridge this gap by combining SysML with formal methods [11,27].

4 Methodology

The results of this research were obtained through a survey which main objective was to seek quantitative and qualitative information on the use of SysML all around the world. The survey was conducted online, through Google Forms, and was available between the months of November 2020 and February 2021.

To reach the largest possible number of SysML users, we first performed a search through Google Scholar to identify the 100 most relevant works in this research field. Therefore, after removing the repetitions, a survey was sent by email to each one of the authors of these articles. For another source of data, the questionnaire was published in groups of the social network LinkedIn which are related to SysML. The most important considered groups were INCOSE, SysML User Group and Systems Engineers.

The survey was also sent by direct message to professionals who present among the skills of their LinkedIn profile the term "SysML". In the message sent, we included the request for participants to invite other professionals from their network of friends and acquaintances, thus aiming to reach a new and larger network of invited people. That technique is known as Snowball Sampling [5].

Participants were asked to leave, in a non-mandatory way, a general comment on SysML. The comment sought to identify, from the point of view of industry professionals, what are their motivations for using SysML, expectations about SysML's future, in addition to the flaws and benefits perceived by them when using SysML.

5 Categorization of the Survey

The survey received responses from 344 professionals from 38 different countries. 163 participants left their written general comments on SysML. After reading each one of the comments from the participants, these comments were divided into positive or negative for the language. In view of this, 70 responses were categorized as positive and 72 as negative. Another 45 responses were discarded because they did not contain relevant information to the research. Based on this categorization of comments, we performed a qualitative analysis of the positive and negative responses.

Participants from the following 38 countries (Fig. 1): Argentina, Australia, Austria, Belgium, Brazil, Canada, China, Colombia, Czech Republic, England, France, Germany, Greece, India, Iran, Ireland, Italy, Japan, Luxembourg, Mexico, Norway, Pakistan, Poland, Portugal, Romania, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, The Netherlands, Tunisia, Turkey, United Kingdom and United States answered the survey.

The most common undergraduate degree among participants is Electrical or Electronic Engineering (29%), followed by Mechanical Engineering (14%) and Computer Science (9%). Computer Engineering (6%), Aerospace Engineering (6%) and Systems Engineering (5%), although to a lesser extent, were also mentioned.

Master's is the most popular academic degree, selected by 61% of the participants. Bachelor's and Doctor's degrees are also often mentioned, selected by 19%–17% of participants.

Most participants (34%) have at least 2 years of experience with SysML, while another 33% have 3 to 6 years of experience, 19% have 10+ years and 14% have 7 to 9 years of experience.

From the categorization of the survey responses, it is possible to identify common points in relation to the comments of professionals in the area in relation to SysML and, thus, perform a qualitative analysis of these data. Next, data will be presented by category, both positive or negative.

Europe	France	47
	Germany, United Kingdom	32
	The Netherlands	13
	England	11
	Spain	10
	Italy, Sweden	8
	Romania	6
	Poland	5
	Switzerland	4
	Portugal	2
	Austria, Belgium, Czech Republic, Greece, Ireland, Luxembourg, Norway	1
America	United States	41
	Brazil	22
	Canada	5
	Mexico	5
	Argentina	2
	Colombia	1
Asia	India	33
	Turkey	16
	Iran, Japan, South Corea	4
	Pakistan	3
	Singapore	2
	China, Saudi Arabia, Thailand	1
Oceania	Australia	11
Africa	South Africa, Tunisia	1

Fig. 1. Countries where the participants work.

5.1 Positive Comments

It is possible to identify, in most of the positive responses, statements about the usefulness and benefits of SysML. Most participants describe the language as powerful, detailed, consistent and broad.

Some of the interviewees point out the importance of SysML within the area of Systems Engineering. Modeling of systems architecture in SysML is pointed out by many as ideal. In addition, the Requirements Diagram also stands out for allowing requirements specification and traceability, enabling the identification of possible future design problems.

As for the modeling possibilities using SysML, most participants affirm that the language allows to model different types of systems, from software to hardware, which confirms SysML characteristics. It is also possible to model the system completely and in detail, covering the entire development life cycle and describing the system from different points of view.

Many of the comments describe the benefits of SysML in terms of team communication through the diagrams. It is reported among the participants that SysML is an unequivocal means for communication between stakeholders, in addition to facilitating the integration of new participants in the development



Fig. 2. Word cloud of positive comments.

team and allowing easy communication between professionals who have different functions.

Figure 2 depicts the word cloud for positive responses of the survey.

5.2 Negative Comments

Most of the participants highlighted the main negative point of SysML as its learning difficulty and complexity, especially for beginners and non-specialized people, with training in different areas of systems/software engineering. It was alleged that there is short experience in industry regarding to the language and that it requires a great amount of specific knowledge for its effective use, in addition to a steep learning curve.

Another highlight among the comments concerns the existing tools for modeling in SysML. Participants argue that the tools are expensive and difficult to use, in addition to having deficiencies such as the absence of design rules and support for analysis. There are still complaints about lack of updating in relation to the standard and lack of interchange of models between tools.

Simulation and validation of models in SysML were also criticized in some of the comments. Difficulties were identified in relation to the simulation and validation of the models. Respondents state that SysML's resources do not allow for the proper and efficient execution of these tasks. Some associate part of this difficulty also with limitations of the used tools.

For some participants, SysML diagrams can introduce many abstractions and complexity into a project, which are not needed. They also claim that a language such as SysML has an extensive and complicated set of rules to deal



Fig. 3. Word cloud of negative comments.

with and that the absence of a standardized modeling method has created many conflicting interpretations about the use of the language.

It is also noteworthy that many of SysML users are waiting for version 2.0. Some report that the expectation is that the new version will solve flaws and add improvements to the language, but some present concerns about migration to this new version.

Some other problems were pointed out to a lesser extent, such as difficulties with scalability, usability and traceability, flaws in parametric diagrams, lack of formality and adaptation to agile software models. In addition to impediments to its use in industry are the need for productivity and efficiency.

Figure 3 depicts the word cloud for negative responses of the survey.

6 Discussion

SysML has been increasingly used in academia and research environments in the past 15 years. A systematic mapping study on SysML was published recently, in which the authors present, among other results, the most prolific authors, most prominent conferences and scientific journals regarding the number of publications, most used SysML diagrams, and most common domains [29]. These results have mostly an academic focus.

Considering a systems life cycle, SysML has been considered as a modeling language for activities of Software/Systems Requirements Engineering [21–23] using both SysML Requirements and Use Cases diagrams, as well as for system design using SysML Block diagrams [28] and other behavioral diagrams [11]. SysML has also been considered as useful for Simulation [17]. There are even

attempts on using SysML together with other modeling languages, tools and processes [7,25].

This article carried out a qualitative analysis, through a survey, on what industry professionals think about SysML when used in practice. Through the collection and categorization of the comments received (positive and negative) it was possible to identify gaps and different perceptions about SysML.

Given the purpose of the language, the importance of SysML in the Systems Engineering area is recognized by the participants as ideal, and can be used to model different types of systems, in a complete and detailed way throughout the life cycle.

As an example, two comments considered positive are mentioned as follows.

"SysML is absolutely necessary to represent a system in all point of views. External analysis (needs architecture), functional architecture, logic architecture, and component architecture. This language is the most advanced I know to represent the way a system should work."

"SysML is one among the powerful languages existing to bring in the imagination of a systems engineer about the system and its corresponding interaction. It's more about the unfurl of the purpose of the system in accomplishing right goals and objectives, keeping in mind the perspective of not falling into the solution right away."

Because it is derived from UML, which is a widely known and used language, and shares some of its elements and diagrams, SysML is considered by many to be an easy-to-learn language, especially for users already familiar with UML. However, most comments were categorized as negative regarding this statement.

"Learning curve is too high for most engineers. Lack of standard frame work. Traceability between different stages of engineering as well as between different diagrams are a major concern."

"SysML is complex and hard to teach. To express simple concepts you often have to create lots of elements which is time consuming."

Therefore, further research should be performed on the subject of learning curve, effective use and every detail that can be considered when one wants to learn how to use SysML in a project. For future research, an evaluation can be performed on current books, tutorials, courses and so on.

Through the qualitative analysis carried out, it is possible to perceive that despite presenting great advantages in its use, SysML still presents some gaps that need to be studied and deepened so that the industry can expand its use and that more professionals recognize it as a valuable language.

There are even sentences with both positive and negative aspects. For instance, one individual wrote that "SysML as a modelling language is adequate to communicate the detailed system design though it is not easy to simulate a SysML model for quick validation. Maybe this is a flaw of the tools and not the language itself".

Sentences with positive and negative characterization are normal for SysML and also other modeling languages. It is common that, when using a modeling language for a project, one becomes an expert on the language. Thus, after an in

depth knowledge of concepts, stereotypes, models and diagrams, one can characterize the benefits of using a modeling language, and can even avoid known flaws. For instance, in the mentioned case, it is clear that simulating SysML models is considered an issue, and then other modeling languages can be considered for simulation.

7 Conclusion

SysML has been considered as a modeling language for developing systems in the past 15 years, in many domains, both in industry and academia. From its first studies and applications, the language increased in popularity and importance. Currently in its 1.6 version, there are many books, courses, tools and case studies on SysML. Thus, a study such as the one described in this paper is necessary, in which the industry professionals describe what they think about using SysML in practice. Future works should also deal with comparison of SysML with other modeling languages in the context of systems engineering development.

In this paper, after distribution of a survey for 344 individuals who use SysML in industry, we received 163 responses on general comments about the use of SysML in industry. After reading all these comments, 142 were selected and further characterized as 70 positive and 72 negative responses. Based on these comments, we performed a qualitative analysis of the positive and negative responses, and then proposed a cloud word for each type of statement. Some entries in the survey bring positive comments, as well as negative aspects of SysML. In this case, each comment is counted two times, one as positive and one as negative.

One important result is that SysML, as a general purpose modeling language for systems applications, is considered useful for some activities and less important/useful for other activities. This means that SysML, as a modeling language, presents flaws and benefits, and is not different from many other modeling languages proposed in the past 50 years, As a matter of fact, well-known negative aspects of SysML such as, for instance, lack of formality or high complexity of models, can be addressed, for instance, by creating extensions and formal profiles for the language, as well as integrating SysML with other modeling languages.

Further research should be performed on the subject of difficulty of using SysML in practice, including its learning curve, comparison to other modeling languages, effective use and every detail that can be considered when one wants to learn how to use SysML in a project.

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