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ScienceDirect

Procedia CIRP 21 (2014) 27 – 33

www.elsevier.com/locate/procedia

24th CIRP Design Conference

Communication in multidisciplinary systems architecting

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Abstract

Systems architecting is multidisciplinary by nature. It is interesting to note that the methods and tools that are developed and presented in literature are mostly based on one or a very limited number of formalisms. This means that an often large part of the stakeholders involved in the architecting process are hindered in the understanding of, and contributing to the architecture.

The paper investigates the architecting process and complexity in combination with knowledge and knowledge creation. Communication is identified as essential. It thus follows that tools that base on one formalism limit this communication in a multidisciplinary setting. Based on experiences from architects, literature and the author, ingredients for successful multidisciplinary architecting are listed, and directions for future research in complex systems architecting are given, based on these ingredients.

Selection and peer-review under responsibility of the International Scientific Committee of "24th CIRP Design Conference" in the person of the Conference Chairs Giovanni Moroni and Tullio Tolio

Keywords: Complex systems architecting; Research; Communication

1. Introduction

Systems architecting is getting increasingly complicated due to a variety of reasons. On the one hand the number and complexity of product functions are increasing. The application area of the systems under design is becoming more complex, too. On the other hand, we observe the increasing number of stakeholders as well as their disciplines. Architecting is predominantly a non-deterministic search process, where the outcome cannot fully be anticipated. Although the goal of the architecting process *can* be clear (it is often not), the system that it will produce is difficult to foresee from the outset.

As systems architecting is in essence *multidisciplinary*, it is performed by people with diverse backgrounds. Partial solutions in different domains have to be weighed and balanced in order to find a fit among cost, performance, development effort, development time, risk and the application. In the early phase of the process, the basic structure is determined as the architecture of the system, as we will see in Section 2.

As the process continues, the final system is gradually worked out in a manner that can best be described by *successive approximation*. Both in the problem and in the solution domain alternatives are described, compared, and decided upon. This is done in multidisciplinary teams –the times of sequential mechanical, electrical, software design etc. are passé–.

In this paper we treat the vital role of communication. As we will see, communication is essential to create knowledge and consequently reduce complexity. The paper combines findings from literature with those from practice. We will see that there is a conflict between the need and practice in industry and the main stream of research in systems architecting support.

The paper will deal with system architecture and architecting (Section 2). Next, complexity is regarded from an engineering viewpoint (Section 3). Then knowledge and knowledge creation (Section 4), and communication (Section 5) will be treated. It turns out knowledge is created in a social process among individuals. Then, we will address issues that are identified from the daily practice of system architects in several manners (Section 6). Section 7 summarizes the current trend in systems engineering research. Based on the material treated, we will list the main ingredients for successful complex systems architecting in Section 8; these also serve as a basis for the recommendations for further research in the last section.

2. Architecture and Architecting

Any system has an architecture, consciously created, or evolved during many design cycles and updates. IEEE 1471 [1] elaborates on the definition of an architecture as shown in Figure 1, where a clear distinction is made between the

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doi:10.1016/j.procir.2014.03.188

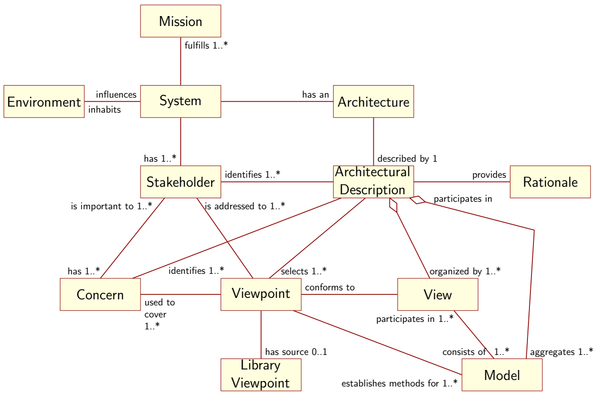

Fig. 1. The function and context of a system architecture, according to IEEE1471[2][1].

`architecture` and `architectural description`. The term architectural description is further elaborated as "a collection of products to document an architecture". Note the plural for products. In the accompanying documentation and explanation on the IEEE1471 website [1] an important remark is made: "Lesson: One view isn't enough, the single hierarchy of components doesn't describe the real world." This is also shown by the "aggregates" relation of 1. . . * between `architectural description` and `model`. For instance [2] and [3] illustrate this further.

This shows the architecture of a system is represented in different ways. The products contained in the architectural description are the explicit representations of the architecture that is implemented or being designed in the system, and the relations of the system with the user(s) and context that are part of the `Environment` in Figure 1, and as elaborated in ISO/IEC/IEEE 42010 which superseded the IEEE1471 standard. As these models of the architectural description may be in different places in documents, diagrams, or even parts and names of the system it can be a challenge to really *know* the architecture. Even more so, one model can express different meanings to different persons (see Section 6.2).

3. Notes about Complexity

The body of knowledge on complexity is large [4–9] to name a few. While size and number of components do play a role, they are not the only determinants of complexity [9,10]. The publication on complexity factors [11] gives a broad overview. This overview also shows that defining complexity is hard, and is sometimes even omitted. For the perspective of this paper we will look at the classification of complexity by Suh [8]. Here complexity is narrowly defined as "the measure of uncertainty in satisfying the FRs[3] within their design range". It is further divided into two major categories [8]:

- *time-independent complexity* divided into two subtypes:
  - *time-independent* real *complexity*: the problem to be solved, or the system to be designed is difficult by nature. An example is the physics involved in a magnetic resonance imaging (MRI) system.
  - *time-independent* imaginary *complexity*: "is defined as uncertainty that is not real uncertainty, but arises because of the designer's lack of knowledge and understanding of a specific design itself."
- *time-dependent complexity*, here "future events affect the system in unpredictable ways". This can be wear in system components, unforeseen system usage, catastrophic events, etc.

Comparing to the findings in [11], time-independent real complexity largely equals objective complexity. Imaginary complexity compares largely to subjective complexity. For the remainder of this paper, we will use the terms real and imaginary complexity as defined by Suh [8].

As we deal in this paper with system architecting, we limit ourselves to the two forms of time-independent complexity. This, however, does not mean that a system designer or system architect should not consider as many as possible improbable events in his design; the time-dependent complexity. This has been illustrated dramatically by the developments in the Japanese Fukushima nuclear power plants. Systems Thinking is a good approach to deal with this type of complexity and provides means to avoid problems [13–15]

From the description of the two subtypes of time-independent complexity, we can conclude that the way to handle complexity is by increasing knowledge. The types and sources of knowledge differ for the two subtypes of time-independent complexity.

In the case of time-independent *real* complexity the technology is difficult by nature. To handle this type of complexity, new knowledge has to be created. In many cases the source of knowledge to handle this type of complexity is fundamental or applied research.

Digesting the definition of imaginary complexity, we can conclude that in this case the difficulty arises from not knowing *enough* about the problem or about the solution; not necessarily because the problem in itself is difficult. This complexity is, one could say, inversely related to the knowledge available to the designers and architects. The remedy here is investigation, knowledge sharing and making the implicit (tacit) knowledge explicit.

The above confirms (and formalises) the observations from architects and researchers, including the author, that multidisciplinarity complicates design and architecting. Causes are found in diverse formalisms, different opinions (including opinions of what is difficult), and different approaches (see for instance [16–19]).

Therefore, we will look at both knowledge creation and communication briefly in the next two sections.

4. Knowledge Creation

Nonaka and Takeuchi [20] treat the way organizations create knowledge. They have investigated in particular Japanese organizations. With influences from other cultures, they come to a way of working for organizations in what Peter Drucker

[2]The standard has been superseded by ISO/IEC/IEEE 42010. Yet for illustration we use IEEE 1471, as it shows Architecture and Architecture Description in one scheme.

[3]Functional Requirement, according to Suh's Axiomatic Design theory [12].