Skoltech
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Thesis Changes Log

Name of Candidate: Yaroslav Menshenin

PhD Program: Engineering Systems

Title of Thesis: Model-Based Framework for System Concept

Supervisor: Prof. Edward Crawley

Chair of PhD defense Jury: Prof. Anton Ivanov ***Email***: *a.ivanov2@skoltech.ru*

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The thesis document includes the following changes in answer to the external review process.

I would like to express my sincere appreciation to all Reviewers for their feedback and commentaries to my PhD Thesis. All of these commentaries are important and help me to better explain what has been done in my PhD Thesis, how it has been done, and what purpose it was done for.

Below I provide the Thesis Changes Log in details.

General change

- 22.07.2020 - a new paper has been accepted for publication in Peer-Reviewed Conference Proceedings (Scopus-indexed). Therefore, this paper has been added to the section "Publications" of the Thesis (page 6):
  Menshenin, Y., Brovar, Y., Crawley, E., and Fortin, C., 2020. Analysis of Systems Structural Relationships Through a DSM-Based Approach. In Proceedings of the 22nd International DSM Conference, Cambridge, MA, USA (Online conference)

The other changes are explained in the sections below.

Sincerely yours,
Yaroslav Menshenin

Prof. Dov Dori
1. The results can be applied in conceptual modeling frameworks and tools such as OPCloud, guiding systems engineers in the early, most fuzzy and least structured stages.

Response:
1. I agree with Prof. Dori and consider the integration of the proposed method with OPM/OPCloud capabilities as the direction of future work. OPCloud itself is used not only for the conceptual design stage, but also detailed design stage, as it is indicated in the paper published by Prof. Dori and his colleagues in 2019 (https://doi.org/10.1002/9781119513957.ch11). This is also a very promising direction of research work.

Prof. Claus Thorp Hansen
2.1 In order to obtain a proper balance between the primary purpose of research (to generate new knowledge) and the secondary purpose (practice/application), I ask the candidate to formulate relevant research questions and hypotheses. The research questions could be outlined in a section 1.5 Research questions and

hypotheses, and then they can be applied throughout the remaining chapters, e.g. in chapter 2 to focus the literature review, and in chapter 3 to make a sound and solid argumentation of why there are 5 propositions.
2.2 Section 2.6 Summary. Here the candidate states, "In summary, in the chapter we briefly reviewed ..." I agree with the candidate, that the literature review is brief. This is not a quality indicator for a thesis. I propose the candidate use explicitly formulated research questions to frame the literature review.
2.3 (In regards to Chapter 7) I ask the candidate to revise the conclusions taking required research questions and hypotheses into account.

Response:
2.1 Following the recommendation, the research questions and hypotheses were formulated more precisely and the specific section 1.5 has been added for this purpose. Please, see section 1.5 "Research questions and hypotheses" (page 43).
2.2 To support the discussion throughout the entire Thesis, corresponding changes were made at the beginning of section 2.1 "Concept in Literature" (page 47), as well as in sections 2.5 "Research Opportunities and Forms of Utility for Concept Framework Development" (page 62) and 2.6 "Summary" (page 63); at the beginning of section 3.1 "Introduction of System Concept Representation Framework" (page 64) and at the end of section 3.2 "Propositions and Entries of System Concept Representation Framework" (page 68) as well as in section 3.11 " Summary" (page 132);
2.3 One more paragraph has been added to section 7.1 "Thesis Summary" (pages 326 and 327) to address the research questions and hypotheses.

Prof. Claus Thorp Hansen
3.1 (In regards to Chapter 3) In Andreasen et al. (2015) we find a chapter on "Product Life Synthesis", so why is 'system life cycle' not included as a proposition?
3.2 When a concept is selected for further development, much design work remains to be carried through, viz. the system embodiment process. Thus, during concept selection it is important to consider not only the attributes of the concepts alternatives in relation to the five propositions and the 'system life cycle', but also the tractability of the system embodiment process. For introduction of the term 'tractability', see Asimow "Introduction to design" (1962). Why is 'tractability' not included as a proposition?
I ask the candidate to set up a thorough argumentation for the content of the system concept representation framework. I argue that the five propositions of the framework is not sufficient to describe a system concept.

Response:
These commentaries are important, as they are dealing with the fundamental essence of system concept representation framework. I answer the questions in sections 3.1 and 3.2, yet here would like to mention that the proposed framework is representative in nature, its core utility and purpose is to support the design process.
3.1 In regards to "Product Life Synthesis": some elements of 'system life cycle' are present in the system concept representation framework. In particular, Andreasen et al. make a special emphasis on the importance of context and clear definition of 'actors'. We base the (I) stakeholders and (V) concept of operations propositions on this understanding. Moreover, Andreasen et al. have raised a very important fundamental question on the relationship between product and lifecycle. They indicate that "...we need product life insight; ideally early in the design activity but in practice this comes gradually". In lights of this, the purpose of the framework presented in my Thesis is to support the design process with this early stage in such a way that the knowledge is reused in later stages as well.
3.2 'Tractability' as it is developed in Asimow's work would better fit the idea of criteria based on which we select the design alternative. So, I absolutely agree on the importance of traceability as a criterion for concept selection. The purpose of 'propositions' was to identify the areas of knowledge and practice that are necessary to know upstream and downstream from the concept itself - in order to have system concept representation.

Prof. Claus Thorp Hansen
4. (In regards to Chapter 3) For the solution-neutral process, the framework defines one attribute. It is not clear to me why only one attribute is sufficient. According to Andreasen et al. (2015) any activity/process can be measured by the 'universal virtues': cost, quality, time, efficiency, flexibility, risk and environmental effects. Thus, I would expect more than one SNP attribute is required? Furthermore, on page 76 it is stated, "The solution-neutral process "transporting" has an attribute "safely", since regardless the chosen concept, transporting should be performed in a safe manner." With respect to solution-neutral this is non-sense to me. Firstly, why "safe"? Any universal virtue, e.g. time and environmental effects, are equally important. Secondly, it is only because the candidate thinks about air- or space transportation he sees "safe" transportation as an important issue. If he was thinking about bicycles as means of transportation "safe"

would not be an important issue, but “energy consumption” might be. Thus, I argue Solution-neutral process attributes do not exist. It is no until the systems architect begins to think about possible solutions the attributes pops up: Air- or space transportation has to be “safe”, whereas bike transportation has to be “energy effective”.
I do not expect the candidate to make any changes in the thesis regarding the comment on solution-neutral process attributes, but I would like to discuss it at the defence.

Response:
4. Thank you for this important commentary! The attribute definition is representative, rather than complete. In other words, we do not claim that ‘safely’ is the only one attribute: we demonstrate that we can encode it, and if necessary – the number of them. In light of this, this is in full line with Andreasen's approach of ‘universal virtues’, since potentially each one of them (cost, quality, time, efficiency, flexibility, risk and environmental effects) could be represented by the framework.

Prof. Claus Thorp Hansen
5. Section 3.5.3 Applying the Methodology to the Running Example of Aircraft Concept demonstrates an application of the framework to the “tube and wing aircraft” and the “blended wing body aircraft”. In order to understand figures 3.13 and 3.14 illustrations of the two concepts are necessary**.** I ask the candidate to insert illustrations (sketches, drawings or photos) of the two aircraft concepts.

Response:
5. This change has been made to make the concepts of “tube and wing aircraft” and the “blended wing body aircraft” clear for the reader. It is implemented in section 3.5.3 “Applying the Methodology to the Running Example of Aircraft Concept” (page 86) and corresponding changes are made throughout the Chapter 3 (Figures’ numbers, etc.)

Prof. Claus Thorp Hansen
6. Section 2.4.2 Concurrent Engineering Centers in the World is problematic for two reasons. Firstly, the content is not really a part of a literature review. Secondly, I find the argument “This makes us confidents that concurrent engineering is ...” rather weak. It is not clear to me why “dozens of engineering concurrent engineering centers appeared” in a world of almost 200 countries and 7 billions people is an indication of effectivity.

Response:
6. The new paragraph that connects the discussion of concurrent engineering and the research question has been added at the end of section 2.4.1 “Overview of Concurrent Engineering Approach” (pages 58-60). Also the phrase has been revised in section 2.4.2 “Concurrent Engineering Centers in the World” (pages 60-61)

Prof. Claus Thorp Hansen:
7. In table 3.7 both the generic form attribute and the specific form attribute is set to “Cost” without an argument or explanation. It seems to me to be an arbitrary choice of attribute. What kind of cost: production cost or operation cost? Setting the generic form attribute to “Fuel consumption” could be equally relevant and sensible. I ask the candidate to include an argument or explanation regarding the generic and specific form attribute.

Response:
7. Thank you for this important commentary, because the discussion of attributes might require additional explanation. It is important to mention that the chosen attributes are important ones, yet we do not aim at claiming that they are exhaustive. The other attributes can also be important and can be added as the blocks, so this is the designer's or design team's choice. The choice of attributes depend on the specific problem we are planning to solve, and depend on the context.
In case of the example of table 3.7 this cost is more related to the production cost. The note about this has been added to the paragraph after the Figure 3.9 (page 88).

Prof. Claus Thorp Hansen
8.1 On page 86 it is stated, “... highlights four key conceptual decisions. First, the operand .... Next the process...” [My underlining] Four conceptual decisions requires ‘First’, ‘Second’, ‘Third’, and ‘Fourth’; and not only ‘First’ and ‘Next’. I ask the candidate to describe all four key conceptual decisions.
8.2 On page 117 we find figure 3.32 (a) with strange attribute values.
- SNO value attribute is “Taste”, but “Temperature” is missing. Explanation: A good cup of coffee requires the coffee drink having right taste and right temperature!
- SNP attribute is “Safely”. This is strange: Which user is concerned about “safety” when brewing their daily cup of coffee? A more relevant SNP attribute could be “Time”, as the author write on page 128, “... an Espresso Machine is the option which will provide you a coffee faster.” [My underlining] ‘Faster’ relates to time, not to safety.

I ask the candidate to reconsider the attribute values in the example and explain his choice.
8.3 Figure 5.5, page 195. It is not clear to me why Specific Form Attribute is “Cost”. It seems to me to be an arbitrary choice of attribute. What kind of cost: production cost or operation cost? Setting the generic form attribute to “Fuel consumption” could be equally relevant and sensible.
8.4 On page 205 the author states, “Thus, the model-based concept framework can be effectively used to capture the conceptual difference between alternative concepts.” [My underlining] I cannot find any measurement (numbers) of effectivity. I ask the candidate to explain how effectivity has been measured and include results, or if it has not been measured please delete the word “effectively”.

Response:
8.1 The change has been implemented in section 3.5.3 “Applying the Methodology to the Running Example of Aircraft Concept” (page 89)
8.2 Thank you for this important commentary! The answer on it is in line with answers on the commentaries №6 and №7.3. I agree that “Temperature” is also a very important value attribute. However, it is left for the designer’s choice, and this choice would depend on concrete stakeholders' needs (proposition I) and context (proposition V).
8.3 This has a common ground with my answer on the commentary №6. The chosen attributes are important ones, yet we do not aim at claiming that they are exhaustive. The other attributes can also be important and can be added as the blocks, so this is the designer's or design team's choice. The choice of attributes depend on the specific problem we are planning to solve, and depend on the context.
In case of the example of Figure 5.5 this cost is more related to the production cost. The note about this has been added to the paragraph after the Figure 5.5 (page 198).
8.4 The change has been implemented in section 5.5.7 “Outcomes of the First Level Decomposition of Alternative Concepts” (page 204)

Prof. Ola Isaksson
9. The research gap (p 40) seem more to an objective rather than a gap. It would be interesting to learn about what deficiencies in current theories (reviewed) that the proposed framework can do better?

Response:
9. This phrase has been reformulated and corresponding change has been implemented in section 1.3 “Background and Literature Review” (page 39)

Prof. Ola Isaksson
10. Why the OPM was selected in favor of SYS ML? What could – potentially, be better represented if SYS ML would have been selected?

Response:
10. Thank you for this important commentary. Although I don't think any change in the text of the Thesis is required, I'd like to provide some rationale for this. We believe that OPM has a smaller number of constructs (systems entities – object, process, and state) and their relationships; and that this ontology is powerful for conceptual design stage. However, SysML is also important, as it is widely recognized in industry. Therefore, SysML could be used at the detailed stage of the design process. At the same time, it still needs to be explored further, as the current version of OPCloud is aimed at not only conceptual design phase, but also the detailed design phase.

Prof. Ola Isaksson
11. The validation sections are set up to be objective, yet have been carried out by the author(s). How much does personal knowledge and framework tacit knowledge influence interpretation and mapping?

Response:
11. In order to limit the potential bias, we have developed and presented a Table 4.2 (page 140), which specifies the criteria based on which the information from patents/patterns was or wasn’t included into the framework for specific samples under examination. Yet, it is true that current study has been performed by means of human reasoning. In future studies could substitute human reasoning by machine learning, for example. We recognize this as a direction of future work in our paper (https://doi.org/10.1002/sys.21547)

Prof. Ola Isaksson
12. A remark and criticism is that the utility and implementation of the system is likely to reveal a number of issues that is not yet discovered. It would have been most valuable with system engineering architects and practitioners feedback on the framework.

Response:
12. Thank you for this important comment! I recognized this need and have mentioned it in the text of the Thesis. A paragraph has been added to the section 7.3 “Limitations and Future Work” (page 335). This paragraph recognizes the importance of the practitioners’ involvement as a direction of future work.

Prof. Anton Ivanov 13. Recommendation to change the example of Figure 2.6
Response: 13. Following the recommendation of Prof. Ivanov the example has been changed to the Spaceship, corresponding process, operand, and states were identified (see pages 55 and 56).
Prof. Anton Ivanov 14. The comment in regards to triangle in Figure 3.2 and its meaning
Response: 14. It is explained in-text that triangle denotes the "attribute". It is explained in the text related to Figure 3.2 (see page 72).
Prof. Anton Ivanov 15. The comment in regards to maintenance for aircraft concept: a very important part of aircraft CONOPS is maintenance. This is one of the most expensive parts of the aircraft
Response: 15. I agree with this important comment and have included this important accompanying system into the representation in Figure 3.25 and in text related to this Figure (see page 112).
Prof. Ighor Uzhinsky 16. The proposed approach's value is limited by descriptive character of the methodologies and tools applied. Final selection of the concept is done, usually, not on the basis of its architectural features or its structural representation but on the basis of quantitative assessments of resulting characteristics of a system to be designed. Transition from qualitative description of the analyzed concept to its even high-level quantitative qualification is in the primary interest for any practically applicable conceptual design tool-kit. An example is the incorporated within Dassault 3DEXPERIENCE platform products of NoMagic. Another issue with practical implementation of the proposed tool-kit is its dependency on intensive and extensive efforts of the user required for obtaining of the resulting conceptual representation. The proposed in several sections of the work introduction of the Machine Learning and Artificial Intelligence tools for automated use of the proposed methodology may help in the future but it seems that there is a long way ahead for practical applications.
Response: 16. In my PhD Thesis I have presented the way to quantitatively assess the level of conceptual similarity among competing design alternatives. This is true that it was done on a "high-level quantitative qualification", following the term mentioned in Prof. Uzhinsky's commentary. I also agree with the need to further explore the Machine Learning and Artificial Intelligence tools for automated use of the proposed methodology - I see this as an opportunity for practical implementation.