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Stakeholder-oriented Elaboration of Artificial Intelligence use cases using the example of Special-Purpose engineering

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Abstract

Artificial Intelligence (AI) offers high potential for addressing various challenges in engineering. The supportive use of cognitive systems allows an efficient division of work, especially for knowledge workers. For example, error-prone, repetitive, and non-essential activities can be outsourced or supported by AI. However, the establishment of AI solutions often fails due to a purely technically oriented approach. Successful implementation requires a prior selection of potential and intended benefits, in which all stakeholders are involved systematically. Including stakeholders at an early stage prevents expensive mistakes. In this paper human-oriented methods are applied and adapted to further detail AI use cases and achieve a high benefit for multiple stakeholders. That is the reason why this method stands out from previous methods. Five steps for elaboration AI use cases are presented in this method: Stakeholder-Identification, Stakeholder-Analysis, Synthesis of the user problem, Testing and Benchmarking, and Detailed evaluation and prioritization. In Special-Purpose engineering, the focus is on individual products for the customer. Therefore, three AI use cases have emerged from the design department of a Special-Purpose engineering company. The content of detailed descriptions and initial demonstrators are discussed with the stakeholders along the method and the results are fed back into a reusable, comprehensive architecture framework including a Black-Box model. In addition, the technical side is detailed and its applicability in a company is examined. Subsequently, the use cases are further adapted and evaluated with the users. The result is an AI use case that can proceed to the next phase of implementation. The following paper illustrates this stakeholder-oriented procedure for evaluating and detailing AI use cases validated by three use cases - for example, “Reverse Engineering of functions”- in Special-Purpose engineering.

Keywords: Artificial Intelligence use cases, Stakeholder-oriented Elaboration; Human-oriented methods; User-driven development; Special-Purpose Engineering

1. Artificial Intelligence in engineering

Digitalization and sustainability are two key drivers of today's market economy. Increasing complexity and the rising software content of products and services call for new solutions. Securing the competitiveness of companies goes hand in hand with new technologies such as Artificial Intelligence (AI). Artificial Intelligence has the potential to automate recurring activities and support multiple stakeholders. Particularly in special machine construction, a high level of expertise is required due to the complexity and individuality of the machines. In this case, AI can help to process expert knowledge and keep it available within the company. This has been shown through the selection of use cases and numerous expert interviews. Therefore, the goal of the method and example is to make AI accessible to small and medium enterprises (SMEs) in Special-Purpose engineering with the help of new methods and approaches.

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Over the years, there has been a slight shift from technology push to market pull, an approach that focuses on producing the products the market demands [1]. Faster changing customer requirements [2] and the acceptance of new technologies [2] are two major reasons why a stronger orientation towards the user is necessary. In this case, the user directly uses the product or service, for example, the constructor who uses an AI application. In addition, there are numerous direct and indirect users and other important stakeholders. For the purposes of this paper, they are referred to as stakeholders. Often, the user is mainly involved in the early phases of a project [3]. However, it is also important to include the stakeholder in the concept phase and system design, which is shown in the following. This paper presents a stakeholder-oriented approach to enable enterprises to detail Artificial Intelligence use cases. The approach is validated and tested by exemplary use cases of a Special-Purpose engineering company, HARTING Applied Technologies. In addition, it focuses on improving stakeholder processes and creating value through use cases.

After analyzing the problem in chapter 2, chapter 3 explains the concept of the method. Subsequently, in chapter 4, the approach is carried out using an example of a Special-Purpose engineering company including the three use cases **Reverse Engineering of functions (1), Equal parts management of purchased parts (2)** and **Intelligent assembly analysis (3)**. The paper ends with a conclusion in chapter 5, which consists of a summary and an outlook.

2. Analysis of the problem

To avoid errors in the late phases of development, it is useful to specify the product or service in detail in earlier phases of development. This is also shown by the rule of ten, which states that error correction becomes exponentially more expensive over time in the life cycle [4]. Before detailing the solutions, the feasibility and practicability of the product should therefore be ensured first.

Another important point is the inclusion of the actual situation and checking the solution for relevance to the stakeholder. Developing close to stakeholders to react to changing requirements is an advantage. In this way, a solution is iteratively developed to provide the greatest benefit to the user and other stakeholders. Early integration therefore gives new ideas for development and requirements management [5]. The user-oriented integration also considers psychological aspects and ethical criteria of AI-based systems [6]. Motivation and confidence in technology can be increased [7].

Furthermore, users are motivated to understand and monitor AI systems. A user-oriented approach improves the user interface even for complex systems. [8] These advantages make it essential to integrate stakeholders in the concept and system development phase.

This sets this method apart from previous ones. Previous methods [9], [10], [11], [12] do not consider the human view to this extent. The focus of this paper is on the stakeholder-orientation with the direct user as a concrete stakeholder to support SMEs in their digitization efforts.

3. Concept for detailing AI use cases

Within this chapter, the concept of the method is described in five phases. A Phase/ Milestone Chart of the concept is shown in Figure 1. Starting from top to bottom the milestones are sequentially mentioned. With the auxiliary means of methods and tools, results need to be identified to pass each milestone. In the first phase, the stakeholders of the AI use cases are identified and represented in a stakeholder-map. For this purpose, methods for **Stakeholder-Identification** and the representation in a stakeholder-map with the help of guiding questions are used. This is followed by a **Stakeholder-Analysis** to include the relevant stakeholders in the process. Likewise, suitable methods for analysis of stakeholders are identified and adapted. Subsequently, the results of the analysis are included in scenario descriptions. To involve the users, an initial graphical demonstrator is planned as a result as well. The user problem is further detailed in **step 3**. Initial AI use cases and an overview of the use cases in the form of a potential map are the basis for the result of this phase. In addition, a systematic application description and a Black-Box Architecture is set up. The technical view is detailed in the **Testing and Benchmarking** and an implementation is further described. Furthermore, a validation environment will be considered. The results are preliminary technology recommendations. After testing and benchmarking, a **Detailed evaluation and prioritization** with key stakeholders can take place. In this last step all results are considered for an evaluation. Leading is an evaluation of the use cases by the stakeholder with a detailed evaluation system to meet their needs. The final outcome is an AI use case, that can be realized. The implementation of the chosen AI use case is based on the use cases previously evaluated in terms of benefits and effort [13]. The selection is based on the highest benefit of the user to find three use cases that can be further detailed and used in the following chapter 4.

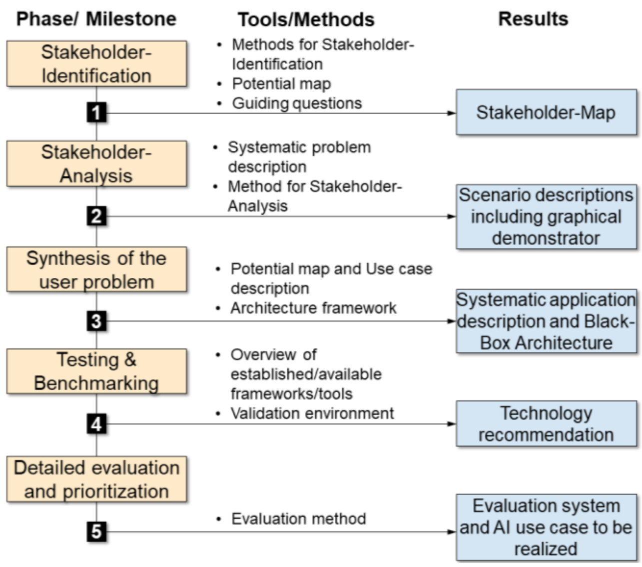

Fig. 1. Phase/ Milestone Chart of the concept

4. Application example of a Special-Purpose engineering company

Special-Purpose engineering is a special field of application. Each machine is designed and manufactured specifically for a customer. Therefore, the design department is a key area of Special-Purpose engineering. This area is selected in advance with the stakeholders. Several AI use cases are found in the construction. These are selected in a previous process [13].

For application the following three use cases are considered: **Reverse Engineering of functions (1)**, **Equal parts management of purchased parts (2)** and **Intelligent assembly analysis (3)**. The first use case describes the goal of proposing system elements based on data from the PDM system using functions and other inputs. The second use case aims at finding equal parts for better reusability based on a sketch or drawing to avoid duplications in the database. The intelligent assembly analysis, the third use case, is used for collision control of individual system elements to avoid loading of entire systems into the CAD system and to ensure error-free assembly. In the following, the method is explained by means of these three use cases in Special-Purpose engineering.

4.1. Stakeholder-Identification

After analyzing 100 design methods in [14], the authors chose a combination of design workshops to identify stakeholders in a stakeholder-map. In this context, the relevant stakeholders are identified by considering personas and scenarios, and distinguishing between external and internal stakeholders. Furthermore, interviews are conducted with other institutions, such as a trade union and a sociological institute. The goal is to identify additional stakeholders from various perspectives. In design workshops with multiple stakeholders of the Special-Purpose engineering company, it is possible to validate the outcome and enable the participation of stakeholders early in the design process. Hereby, a stakeholder-map, which is developed iteratively with stakeholder-identification and further steps, supports the visualization and communication. In a next step, the identified stakeholders are related to the AI use cases. Following [15], the focus is primarily on the relationships between the stakeholders and the planned AI application, as well as the relationships between the respective stakeholders, in order to create an understanding of the respective interests of the stakeholders and to integrate them in a targeted manner as part of the stakeholder analysis. The authors analyzed the different positions of the stakeholders within the use cases and defined relevant categories: The **User** (e.g. designer), **Secondary User** (Using the result e.g. production), **Indirect User** (Indirect User of the result e.g. Management), **AI-Developer**, further **Stakeholder** like Works Council and unauthorized User.

The categories are an important parameter in the concrete development of the application, since the users play an important role, for example, in the design of the user interface as well as the output to be delivered. Stakeholders representing the interests of the users must be involved in the development process, especially in an informative way. In addition to the defined classes, the authors recognized that the size of each stakeholder group can be relevant to the further involvement in the specific development process. For example, when selecting a method for gathering specific needs of individual stakeholders, one should consider whether the opinions of 10 or 100 people need to be gathered. The size of the stakeholder groups can be determined mainly for internal stakeholder groups by the number of employees. The classification and the size of the group are integrated into the representation as a stakeholder-map to support the visualization and communication. Fig. 2 shows a section of the stakeholder-map of the use case Reverse Engineering of functions. It is important that the method is carried out separately for each AI use case. For this reason, each use case has a separate stakeholder-map.

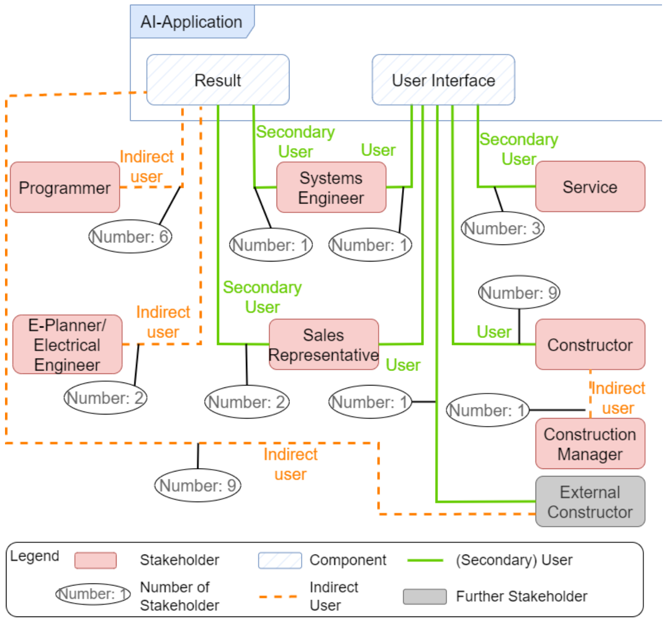

Fig. 2. Extract of the stakeholder-map for the AI use case "Reverse Engineering of functions" modeled in iQuavis

4.2. Stakeholder-Analysis

The goal of the Stakeholder-Analysis is to record the needs and specify the problem of the users of the AI use cases. In addition to the direct AI use case, the focus is on sociological and work organization effects.

After considering different methods and a direct exchange with a sociological institute, the group discussion [16] in the form of a face-to-face meeting is selected as the procedure for integrating the main stakeholder in the development process. Although the group discussion requires good time planning and active moderation, it promotes dynamics and enables a direct exchange between the stakeholders concerned. In preparation for the group discussion, the authors defined concrete guiding questions about the AI use cases to provide possible discussion directions. An example guiding question of the Reverse Engineering of functions use case is, "Which information about functions of former plants can be used in the future?". The result of the use case Reverse Engineering of functions in the group discussion is for example the desire for a feature to be able to evaluate a solution. These and other ideas are gathered as stakeholder needs for the Black-Box Architecture and must be taken into account in the future development.

In addition, a graphical demonstrator is presented during the group discussion to give stakeholders a first concrete idea of the application in the context of their daily work. With the software tool Balsamiq Wireframes [17], a first draft is created in form of a picture sequence. Figure 3 shows an image of the graphical demonstrator. **Functions** and other **requirements** can be entered to find components of the same function. The result (a **functional network**) shows the relationship between the function, the machine and the requirements.

Other outcomes of the group discussion are the need to clarify access rights and the requirement for external constructors to have access to the system. In addition, daily business must not be negatively influenced. Furthermore, one idea is to mark approved solutions to make them reusable [pin diagrams]. All results lead to scenario descriptions for the understanding of each use case.

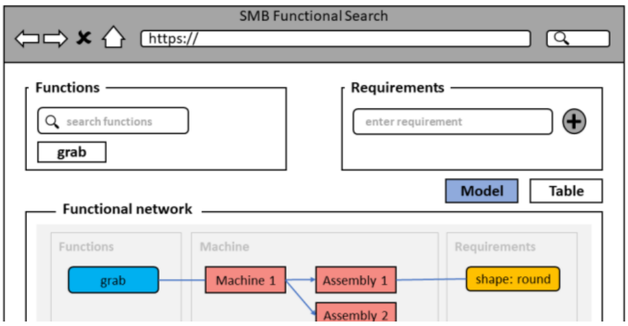

Fig. 3. Image of the graphical demonstrator of the AI use case "Reverse Engineering of functions"

4.3. Synthesis of the user problem

The next step is to detail the three selected use cases. For this purpose, all previous results from the stakeholder-identification and analysis are added. The information is used to specifically detail the description of benefit and effort analysis [13] and to incorporate changes in the stakeholder problem or scenario descriptions. The goal is to convey a more precise target picture to the users and to create a basis of understanding for the future implementation. A software architecture of the system context is consequently necessary. The software tool iQuavis [18] is used to model a Black-Box Architecture, which is later detailed to a White-Box Architecture and uses a notation similar to SysML. For the basic structure of the system architecture, an architecture framework [19] is used to create synergies for further usability in the context of a System of Systems (SoS). Furthermore, this increases transparency for the user of the framework [19]. For the Black-Box model, an environment model is first created. This can be seen in Figure 4. Around the use case Reverse Engineering of functions various elements for the mechatronic system have to be considered.

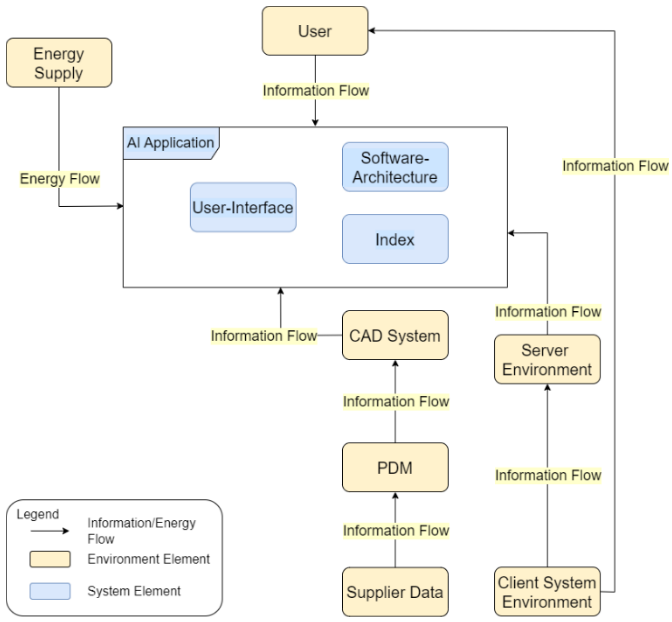

Fig. 4. Environment model of the AI use case "Reverse Engineering of functions" modeled in iQuavis

The elements **User**, **PDM** and **CAD System** or **Server Environment** are important environment elements connected to the **AI Application**. Furthermore, a use case diagram and activity diagram are created to show the use cases of the AI solution and the individual activities of the main use case. Another diagram, the activity diagram is shown in Figure 5.

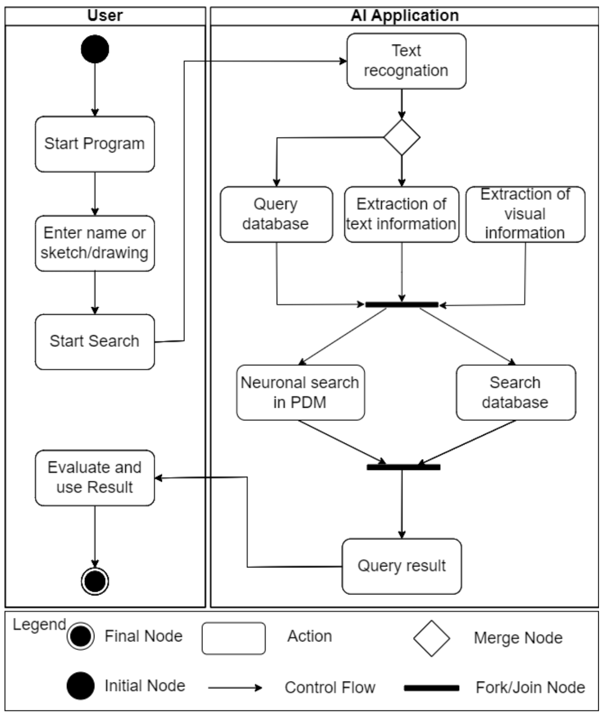

Fig. 5. Activity diagram of the use case "Operate AI application" of the AI use case "Reverse Engineering of functions" modeled in iQuavis

The diagram is a simplified version that can be shown to the user. In a first approach the user is interviewed using the simplified diagram for validation purposes, which is described in more detail in the outlook. The survey leads to new ideas and increases the knowledge base.

4.4. Testing & Benchmarking

The step testing and benchmarking ensures that the three use cases can be implemented. The goal is to carry out the first practical tests. Based on the system description and previous results, the implementation effort is estimated in more detail. A comparison of possible tools and frameworks for the implementation of the application is made to differentiate from other solutions [20], [21] or to use standards.

An initial analysis of the existing data situation in the company shows that for Reverse Engineering of functions the data can be extracted and used for initial tests. In this case Standard Tessellation Language (STL) files are derived from the existing PDM system with further information. Using the example of a cylinder, sometimes there is a fixed naming scheme. Previously, there was also no uniform naming structure, which is why only new cylinders are stored in assigned folders. A data-centric approach is chosen to ensure technical feasibility. The focus of ensuring technical implementation is not initially on the algorithm. First, the data quantity and quality are identified. For example, the PDM is examined and the purchased parts are considered. In addition, the information that is available for the parts (e.g. information about the last modification or the creation date) is relevant. These and similar challenges are already apparent at this stage and must be taken into account before the implementation decision is made.

4.5. Detailed Evaluation and prioritization

Based on a first prioritization of use cases published in [13], the authors extend the evaluation to include additional categories. The focus is on unintended consequences of the AI application. An evaluation is again carried out with the trade union and a sociological institute so that the users can be interviewed with the evaluation scheme. This results in precise questions to the stakeholders for a concrete specification of the most relevant use cases. The questions are summarized in a score card with three categories considering the effort: *Research Effort, Data Engineering, AI/ML & Software Engineering*. In addition, the two positive categories *Performance, Innovation potential* are included as well as the user-oriented category called *User support for users*, *direct and indirect users*. For instance, the question of how frequent and elaborate the interaction with the users' is, should be answered by the users. As a questionnaire, this scheme is sent to seven direct users after building a common understanding of the AI use cases. The results can be seen in Figure 6. The percentage of responses is plotted above the use cases. In general, the composition of the workshop participants has to be considered for the selection of the use case. In this instance, the results reflected the discussion of the workshop participants. The result with the highest score is the AI use case Reverse Engineering of functions. The fact that the AI use cases are graphically close to each other may be due to the pre-selection and illustrates their usefulness. However, the possibility of technical implementation must also be taken into account, which is why the Equal part management of purchased parts is implemented as the first basic use case. Afterwards, it is possible to implement the aforementioned use case based on it. During the evaluation, a detailed one-pager consisting of scenario descriptions, stakeholder-map, Black-Box model and the detailed evaluation information is finalized to provide an overview of the results of this method.

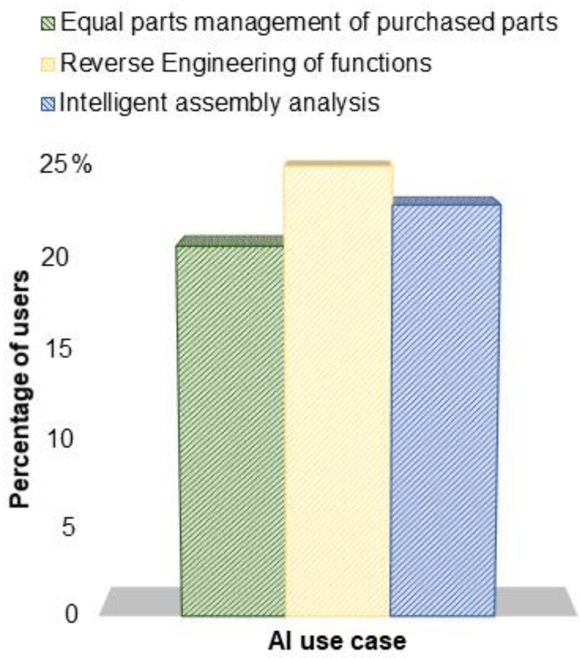

Fig. 6. Outcome of the evaluation of the AI use cases [Percentage of users above the AI use cases]

5. Conclusion

In summary, the method details and evaluates the AI use cases. All relevant stakeholders are identified and integrated in a stakeholder-map. Within the analysis of use cases a graphical demonstrator and scenario descriptions are created. This shows that the accompanying collection of stakeholder needs and reservations is useful to ensure a successful implementation of an AI application. It increases the benefits for the stakeholders and their acceptance. At the same time, the technology recommendations and detailed feasibility analysis help to check the feasibility of implementation and prevent failure from a technical perspective. After an evaluation by the users, a use case has been selected for the next detailing phase. Thus, it is evident that the selection of AI use cases requires interdisciplinary methods. The method and the example also contribute with different use cases and an innovative approach to enable AI for small and medium-sized enterprises in Special-Purpose engineering and to generate added value for the employees.

At the beginning it is mentioned that sustainability is also important for today's economy. In addition to the stakeholder-oriented approach, important social needs such as sustainability must also be considered when describing and analyzing AI use cases. Furthermore, a transfer or integration of the approach to other areas, such as manufacturing with Product-production co-design, is conceivable. Hereby, one limitation of this approach is that only a small group of stakeholders was used in the group discussion. For a larger group of stakeholders, the method of Stakeholder-Analysis should be reconsidered. In addition, the authors focus on the user as a particularly important stakeholder. A stronger consideration of other stakeholders can also be considered.

Further research integrates the method into a holistic system architecture. By considering a System of Systems, multiple stakeholders are taken into account, which results in more challenging applications. The question to be answered is, whether a validation of the AI use cases in the context of a SoS is possible with the help of the system architecture or whether a user-friendly architecture modeling is necessary and which stakeholders can be addressed.

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References

[1] Dixon J. The Market Pull Versus Technology Push Continuum Of Engineering Education. In: 2001 Annual Conference Proceedings, ASEE Conferences; 2001. p. 6.1027.1-6.1027.15.

[2] Dumitrescu R, Albers A, Gausemeier J, Riedel O, Stark R. Engineering in Deutschland – Status quo in Wirtschaft und Wissenschaft. Ein Beitrag zum Advanced Systems Engineering; 2021. p. 65-91.

[3] Mule S, Hehenberger P. An empirical study on the usage of agile methods in the mechatronics industry. In: 2020 21st International Conference on Research and Education in Mechatronics (REM). IEEE; 2020. p. 1.

[4] INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities. 4th ed. New York: John Wiley & Sons; 2015.

[5] Humpert L, Röhm B, Anacker H, Dumitrescu R et al.. Method for direct end customer integration into the agile product development; 2022. p. 215.

[6] Schlicht L, Melzer M, Rösler U, Voß S. et al.. An Integrative and Transdisciplinary Approach for a Human-Centered Design of AI-Based Work Systems. In: American Society of Mechanical Engineers Digital Collection; 2022.

[7] Smuha N. Ethics Guidelines For Trustworthy Ai - High-Level Expert Group on Artificial Intelligence. Brussels: European Commission; 2019.

[8] Pfeiffer T, Hellmers, J, Schön, EM, Thomaschewski J. Empowering User Interfaces for Industrie 4.0 104; 2016. p. 1.

[9] Hofmann P, Jöhnk J, Protschky D, Urbach N. Developing Purposeful AI Use Cases - A Structured Method and Its Application in Project Management; 2020.

[10] Brunnbauer M, Piller G, Rothlauf F. idea-AI: Developing a Method for the Systematic Identification of AI Use Cases; 2021.

[11] Chui M, Manyika J, Miremadi M et al. Notes-from-the-AI-frontier-Insights-from-hundreds-of-use-cases-Discussion-paper; 2018.

[12] Sarker IH. AI-Based Modeling: Techniques, Applications and Research Issues Towards Automation, Intelligent and Smart Systems. SN Comput Sci 3; 2022. p. 158.

[13] Kharatyan A, Humpert L, Anacker H, Wäschle M, Albers A, Horstmeyer S, Dumitrescu R. Künstliche Intelligenz im Engineering: Menschorientierte Analyse von Potenzialen am Beispiel vom Sondermaschinenbau // Künstliche Intelligenz im Engineering. Zeitschrift für wirtschaftlichen Fabrikbetrieb 2022; p. 117:6:427-431.

[14] Martin B. Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions. Beverly: Rockport Publishers; 2012.

[15] Melbinger W. Stakeholder-Management für IT-Projekte. In: Handbuch IT-Projektmanagement. München: Carl Hansen Verlag GmbH & Co. KG; 2014. p. 609.

[16] Vogl S. Gruppendiskussion. In: Handbuch Methoden der empirischen Sozialforschung. Wiesbaden: Springer Fachmedien; 2014. p. 581.

[17] Balsamiq Wireframes - Industry Standard Low-Fidelity Wireframing Software. https://balsamiq.com/wireframes/. Accessed 19 September 2022.

[18] Two Pillars. iQUAVIS 4.0 – Two Pillars. https://www.two-pillars.de/iquavis-4-0/. Accessed 19 September 2022.

[19] Mandel C, Martin A, Albers A. Addressing Factors for User Acceptance of Model-Based Systems Engineering; 2022.

[20] Bernijazov R, Dicks A, Dumitrescu R, Foullois M, Hanselle JM, Hüllermeier E, Karakaya G, Ködding P, Lohweg V, Malatyali M, Meyer auf der Heide F, Panzner M, Soltenborn C. A-Meta-Review-on-Artificial-Intelligence-in-Product-Creation, Proceedings of the 30th International Joint Conference on Artificial Intelligence (IJCAI-21), 2021.

[21] Deteringdesign. KI in Computer Aided Design | Integration von KI in Computer Aided Design (CAx) » KI-Marktplatz. https://ki-marktplatz.com/claas/. Accessed 10 October 2022.