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VIKA – CONCEPT OF A DIGITAL PLATFORM FOR IMPLICIT KNOWLWEDGE AND VIRTUAL ASSISTANCE FOR ADDITIVE MANUFACTURED PARTS

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Abstract

The subject of this work is the conceptual elaboration of a virtual application that enables users in aircraft construction in the context of additive manufacturing to make important decisions for the component design process interactively and intuitively. The user can interact with a developed and integrated CMS-system and a virtual AI assistant.

Keywords: Additive manufacturing, construction consulting, multi-criteria decisions, decision support system, implicit knowledge representation, virtual AI

1. Introduction

1.1 Status quo – Knowledge representation in additive manufacturing

"Additive manufacturing is an emerging technology that encompasses numerous three-dimensional printing (3D printing) processes for joining materials layer-by-layer to produce parts from design data without tools" [1]. With this technology, complex shapes, multi-material and multifunctional components are manufactured in one operation, which represents a major advantage over conventional manufacturing processes [2]. In the last two decades, research has made significant progress in the development of innovative manufacturing processes such as selective laser sintering and laser melting [3]. The increasing use of AM (additive manufacturing) technologies in aerospace, automotive, biomedical and other industries has resulted in an increased demand for skilled professionals who need to master all aspects of product creation. To meet this need, users of the technology require advanced and in-depth expertise in the use of CAx (Computer aided) systems specifically tailored for the development of additive prototype and series parts and which focus on the design of 3D structures with an increasing number of metal, plastic and other materials [4].

AM is characterized by a novel approach to component design. The modeling of the geometry is no longer restricted to tool shapes and consequently lightweight construction potentials can be created through topology-optimized design strategies, without major follow-up costs. With AM, effective rationalizations are also possible in the assembly design, derived from functional integration.

As a result, the interest of the aviation industry in using additive manufactured components for flight operations continues is still growing. More experience-based special knowledge is required for an economically successful use of the technology. The numerous technical documentations and textbooks published in the meantime are too unspecific to serve as instructions for the construction. The expertise in AM has also grown dynamically.

By developing additive components, users are still faced with an inexhaustible and unmanageable representation of knowledge in digital media such as journal articles, e-books, tutorials, webinars and websites for design rules. In addition, the heterogeneous implicit knowledge levels of the users are widely distributed and the time-effective access to a consensus-based spectrum of valid data for the successful design of the components is severely restricted by the high dynamics of the flood of digital knowledge and by checking if the information is relevant and not outdated.

This circumstance, shown in figure 1, still presents users and other stakeholders in the aviation industry with different levels of knowledge and questions with the enormous challenge of selecting and validating the required knowledge in a time-efficient manner in order to make the right decisions for the entire development process (e.g. use cases, availability and robustness of design rules/ guidelines, material, machine selection, etc. ...).

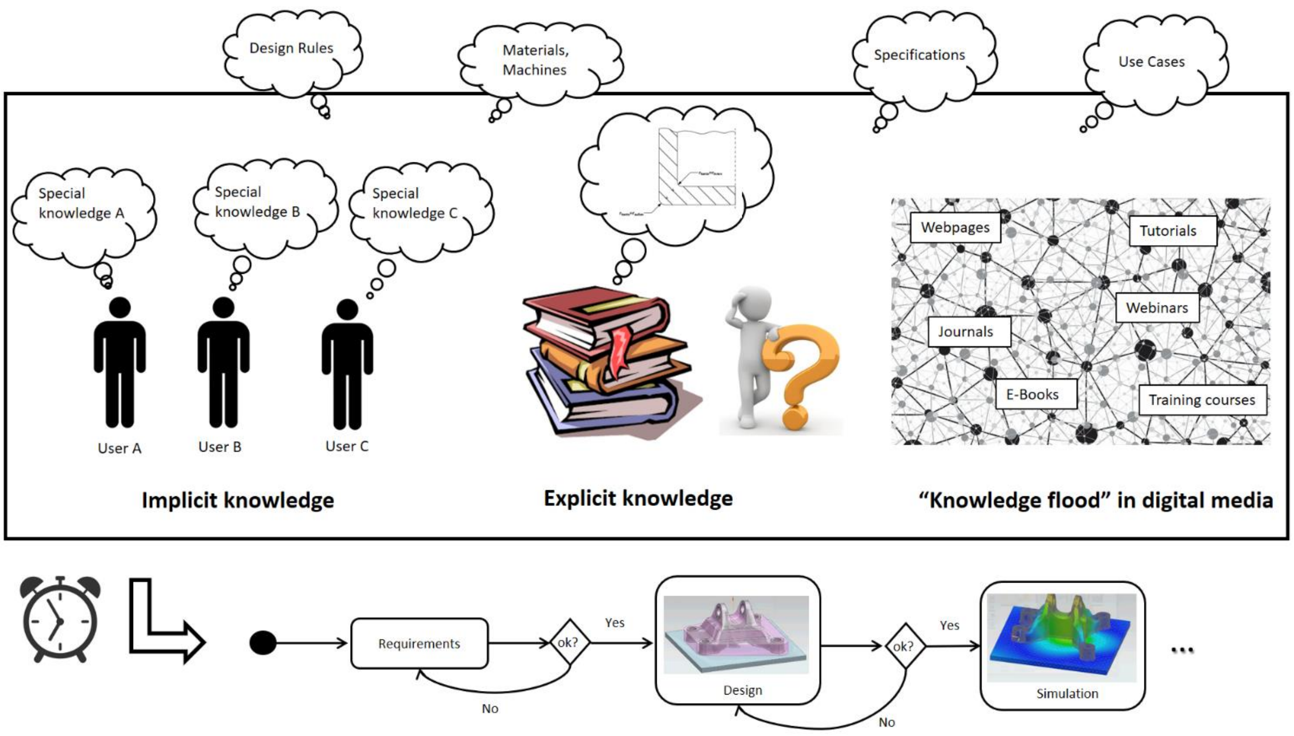

Figure 1 – "Status quo" - use of knowledge in additive manufacturing

Because of the problem described above, a noticeable downward trend already derived regarding to relevant results from scientific publications and industrial outcomes in the context of design decisions for AM aircraft components. This thesis is supported by market observations regarding training offers, intensive research and expert interviews conducted with representatives of the aviation industry. This effect is based on the model according to Partsch [5], in which it becomes apparent that every technology can go through different trend phases. In Figure 2 - marked by a circle - the AM aircraft components are currently located in the "stagnation" phase, after a steady growth in scientific and industrial activities in the last decade. This phase is often characterized by soundings, realignment and restructuring of business areas and activities in the aviation industry and the associated day-to-day business.

The currently intensified climate debate and the associated efforts of the aviation industry to operate with lower emissions or completely CO_2-neutral in the medium to long term have also led to the industry's priorities shifting away from the further development of AM towards revolutionary engine concepts. However, AM can and will also make a useful contribution by optimizing manufacturing processes and production costs as well as designing components to be more weight- and emission-efficient. It is now necessary to look for adequate solutions, which optimally meet the existing challenges for proactive knowledge transfer to bring about a trend reversal ("renaissance") for the technology of additive aircraft components in the future. Existing technologies and other trends from various social or technical areas have shown that a trend reversal can even lead to a so-called "boom". As an example, the use of multimedia devices can be mentioned, which are - after a significant leap in technology (user interface and compact design) - still in high market demand today. The technological leap in AM can succeed if the existing and future knowledge can be transferred from research to industry or on a B2B (Business-to-Business) basis in a systematic, easily accessible, time-efficient, valid and consensus-oriented manner.

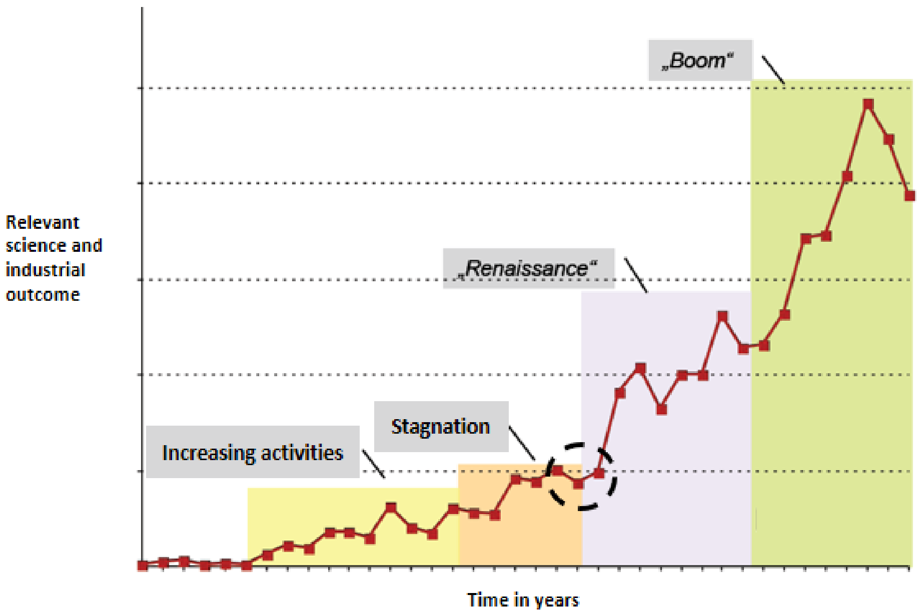

Figure 2 – Trend phases of a technology based on [5]

1.2 Purpose

The primary goal of the project is to research the extent to which an effective foundation for an interactive design and construction guide for additive manufactured components can be released as a preliminary concept. In the future, this should give designers quick and intuitive access to current and secure knowledge.

For this purpose, a concept of a virtual system was developed with the VIKA platform that authorized users can share knowledge proactively and selectively and exchange it with each other during the development process (Shown in figure 2). In the construction and development of parts for aviation and other domains it is common that the designer can get the most benefit from implicit knowledge which must be represented in a systematically way that it can be accessed easily and quick.

In the past, the way of the knowledge transfer in CAD (computer aided design) was often represented by reference constructions in which the designer extracted the important design rules, design solutions, iterative reviews of the mean time results and discussions with the stakeholders for inspiration for a way forward in the next design tasks. This conventional way of knowledge transfer can be improved by the digitalization with a level-based information platform and a virtual AI system, which can give recommendations and hints for the next design step to control restrictions and requirements of the construction. In addition, this research examines solutions of digital learning ways with e.g., interactive video tutorials and interactive book chapters to ensure a time efficient knowledge transfer. The investigations focus on the possibility to build up a virtual system, which can support the user with a digital tool set to support users in design and process decisions in the context of construction of 3D-printed aviation parts.

For the definition, maintenance and further development, a working group shall be founded, in which representatives of different organizational forms of the aviation industry can participate and who continuously contribute expert knowledge and findings based on consensus and check the knowledge base for topicality and accuracy.

The VIKA research project is therefore concerned with a scientific methodical approach to convert the above-mentioned problem into a conceptual solution by developing concrete proposals for the technical realization, implementing them as prototypes and evaluating them. The aim is to create a clear exploitation perspective for the further development of the virtual system, so that a relevant application for the aviation industry can derive from the concept study.

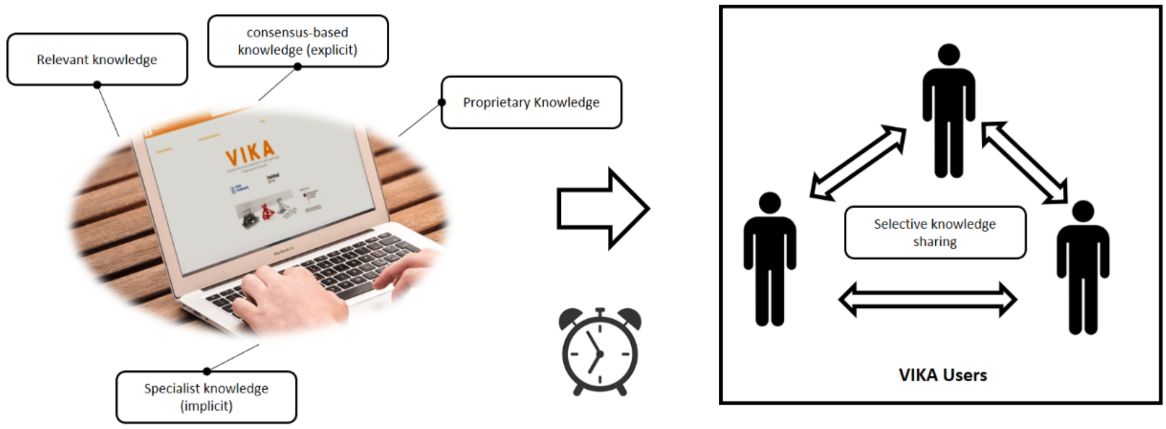

Figure 3 – Concept approach of a virtual application for knowledge transfer

2. Literature Review

In science and research, there is a broad and inexhaustible spectrum of technical papers, studies, methods and tools for the design decision-making process in the context of AM.

In a categorical framework, Qi et al. investigated the formalization of the AM process with the help of ontologies to model basic and general knowledge of design and process parameters, rules and guidelines and their mutual influence for integration in CAx platforms [6].

With a case study, Yao et al. investigated the approach of inexperienced designers to provide recommendations, construction features and design solutions with the help of machine learning in the form of hybrid algorithms of coded clusters that can be trained using existing use cases [7].

In the European Union’s Horizon 2020 program, the "Encompass" project developed an integral design, decision-making and support system for the entire process chain in the context of the laser-based powder bed process (LPBF). To demonstrate the efficiency of the system, use cases from the automotive, aviation and medical industries were used and evaluated under the aspects of "time to market", productivity of the process chain and effects on production costs [8].

Saue et al. proposed an XML-based portal in which the availability of information in design projects can be processed and stored in the form of semantic framesets. Using the proposed modeling, the definition of a product is demonstrated and information links between different partial results are stored in modules (processes, functions, effects and forms) [9].

Zheng et al. proposed an axiomatic design approach for the selection of AM processes, in which personalized evaluations introduced using the method of weighted preference diagrams. The fuzzy set theory adopted to convert qualitative performance evaluations of materials, parameters and states of machines into deterministic values such as costs and construction time. [10]

Huang et al. suggest one in a publication proposed a generic aggregation generator for multi-criteria design decisions for AM. An example of the AM machine, the material selection and an example of the optimal selection of the construction direction are presented. The demonstration results suggest that the method can effectively solve a multi-criteria decision-making problem in AM design. [11]

The article by Rafaelli et al. themed the complex information involved in the AM process. A framework is proposed to support and guide a designer through a structured and algorithmic process to assess the opportunity for AM adoption and arrive to an optimal design. A case study of an ultralight aircraft part is provided to demonstrate the proposed decision-making process [12].

To integrate the limitations caused by AM into an optimization process, the article by Wang et al. proposed a new generative design method with manufacturing validation so that the decision-making of the designer becomes more effective. This method uses a CSG (Solid Constructive Geometry) based technique to create and represent topology geometries with manufactural geometry and parametric control. The advantages are shown based on several demonstration examples and comparative case studies with existing methods [13].

The work of Bikas et al. presents a method to assist prospective adopters in AM assessment and process selection. The process includes four distinct steps for AM process suitability and alternative paths, which are evaluated and classified based on multiple user-defined criteria [14].

Wang et al. proposed in the context of suitable process selection a hybrid method from the so-called "design-by-shopping" approach in combination with a modified TOPSIS method, in which the user selects his preferences for process parameters in a virtual application in an interactive way to obtain a hierarchical order of solution approaches and suggestions using various formalization methods [15].

Eisman et al. propose a framework for the system design of virtual advisors in closed knowledge domains by creating a web-based user-client architecture with three user modules. These modules act with speech recognition, from which isolated information units are extracted and processed. A dialog manager executes actions based on grouped decision patterns and an ontology database. A communication generator transfers the algorithms into a natural speech output [16].

Regarding to design decisions in the context of AM, the scientific publications often focus on explorative and innovative methodological approaches to describe the decision process mathematically and algorithmically and to validate it by using a particular case study. A direct exploitation perspective for knowledge transfer between research and development and within the industry is often missing. It can be assumed that the work and the results mentioned above are comparable with the so-called rule based XPS (expert) system. Hartmann mentions that a rule-based XPS-System have corresponding components and forms of presentation and even have an advantage over human experts in the training field since the quality of knowledge transfer in the problem-solving process is very much dependent on the ability of the experts to make experience understandable and well explained. In the case of highly dynamic knowledge bases, however, constant maintenance and care is essential and, regarding to the provision of knowledge, an XPS system threatens to "become obsolete" in a timely outdated [17]. It is also important to check frequently for accuracy and completeness, which freezes up huge resources in companies. [18].
It is therefore not expedient to use such complex programmed systems or mathematically derived methods in a highly dynamic knowledge base represented by AM.

For sustainable use, the goal is to represent the knowledge in the domain of application-oriented design adequately and in a form so that the knowledge base can be edited dynamically and maintained with a low-threshold effort by authorized users.
In general, for the current state of research, it can be formalized that a consideration of all information which is relevant for the design of additively manufactured aircraft components as well as its interlinking

from the respective process parameters, construction or project specifications and derived design decisions in the form of a virtual advisory system with an adaptive information interface is still not available for the aviation industry. The integration, exchange and expansion of dynamic knowledge with the help of users acting with the system based on a neutral platform remain unaffected.

3. Approach and methodology

3.1 The change in AM design work and applied software solutions

To begin with, accessible software solutions and support systems which address with the virtual product development of additive components were examined and the state of research was developed in this context:

In AM, due to the tool-free production of the components, the goal is to keep the virtual process and supply chain continuous to reduce manufacturing and development costs. The transitions and boundaries of the domains: design, calculation and validation of the results flow into each other.

As a result, users in virtual product development challenged by building up or expanding their skills and specialist knowledge more on the cognitive and interdisciplinary level to conduct the design process in a more purposeful way.

In contrast to the computer-aided generation of geometries for conventional component development, which are based on the skills and abilities of the user to operate the CAD-System, the designer is about to evaluate the automatically generated topologies, taking manufacturability and verification of mechanical strength into consideration. Sometimes potentials for adaptive constructions must be explored to reduce the number of components or functions can be merged or substituted.
The processes in AM are still unstable, component properties only emerge during production and the reproducibility of the components based on materials, machines, geometries or entire processes that have already been certified, so it is necessary for the users to have knowledge about these important development parameters in a timely manner and made available on a case-by-case basis.

Many designers in context of AM work with proprietary references, specially developed method knowledge, and derived design rule catalogues, often communicated and transferred internally by a smaller group of users. In conclusion, the knowledge is allocated to local places and people and is available to a limited extent. For novices it is impossible or often difficult to get on existing expert knowledge and methods and to evaluate it in additive constructions for plausibility and validity. This fact leads to the thesis that the adaption of AM into new business models and related production and investments are still on hold for many companies in several industrial domains, because the implicit knowledge base for a successful construction and process production is often missing.

Due to the typical AM process properties, which are often accompanied by numerous and costly iterations, it is necessary to provide users specific knowledge about important development parameters of the entire virtual process chain in a timely and case-based way.

To support this change in basic assumptions in additive component design, specific software solutions have been created in recent years that enable a continuous and cross-disciplinary virtual process chain - however, an integrated knowledge base with expert and methodical knowledge is still not available. In such applications, possibilities were created to design and generate topologies intuitively automatically and to simulate the printing processes and to evaluate them quantitatively and qualitatively without a consideration of the user’s experience and knowledge in AM. Users are often confronted with the question "How?", whereby the answers to the questions "What" and "With what?" have already been resolved.

3.2 Scientific Questions

During the first explorations within the framework of a so called “black box” thinking about the virtual solution, scientific questions have been developed and will be answered with the help of this research work.

The research deals with the following questions in the scientific discourse:

1. Which procedures and scientific methods are suitable for the interdisciplinary development of VIKA?
2. How can be the considerable dynamic of the consulting environment (materials, machines, processes) and their parameters considered?
3. What are aviation-specific aspects of additive manufacturing advice and how can this knowledge be published and conveyed?
4. How can a virtual guidance system take the heterogeneous levels of knowledge and questions of users into account and give each user an individualized answer?
5. How can proprietary knowledge be mapped in a protected manner in the application and issued to authorized users and how can the owners of this knowledge be convinced to entrust it to the system (knowledge protection and role definition)?
6. With which toolset can the result of the concept studies be implemented into a software or virtual system solution?

3.3 Limitations and objectives

From the first preliminary investigations, it could be deduced that due to the inexhaustible number of existing software solutions, the development of a specifically coordinated CAx-interface or an API (Application Programming Interface) for a software solution involving the KBE method (knowledge-based engineering) for virtual design consulting cannot be considered.

The assumption mentioned above is supported by the thesis that the market for software applications is constantly evolving dynamically and that a designed system interface therefore severely limits the group of users through license provisions, familiarization with the respective software solution and acceptance. Elaborating various CAx interfaces exceed the scope of a research project. Furthermore, it is not possible to implement a universal CAx interface in terms of programming, since each solution works with its own algorithms, functions and system structures.

The aim is therefore to use the methods of the associated model-based way of thinking to develop a comprehensive digital solution for the representation of methodological knowledge in AM that advises users in addition to constructive work and adaptively and sequentially supports the decision-making process. Only this knowledge enables the user to learn heuristics to make the right assumptions and decisions in the design process.

The application should be user-friendly, updatable and expandable, so that consensus-based and relevant knowledge for the processing of additive constructions involving various software solutions can be mapped and retrieved. It seems important to make special proprietary knowledge protected and strategically available. In order to create an innovative and sustainable system, it is essential to deal scientifically with the entire knowledge management process.

With an extensive stakeholder need - analysis from the specialist discipline of systems engineering and a scenario technology, further conceivable user personality profiles generated by using the “Persona” method proposed by Cooper [19]. In the system development according to the "top down" principle, the possible user profiles with the identified needs and requirements for a virtual consulting solution transformed into generated use cases (excerpt shown in figure 4) with interaction scenarios in the system design.

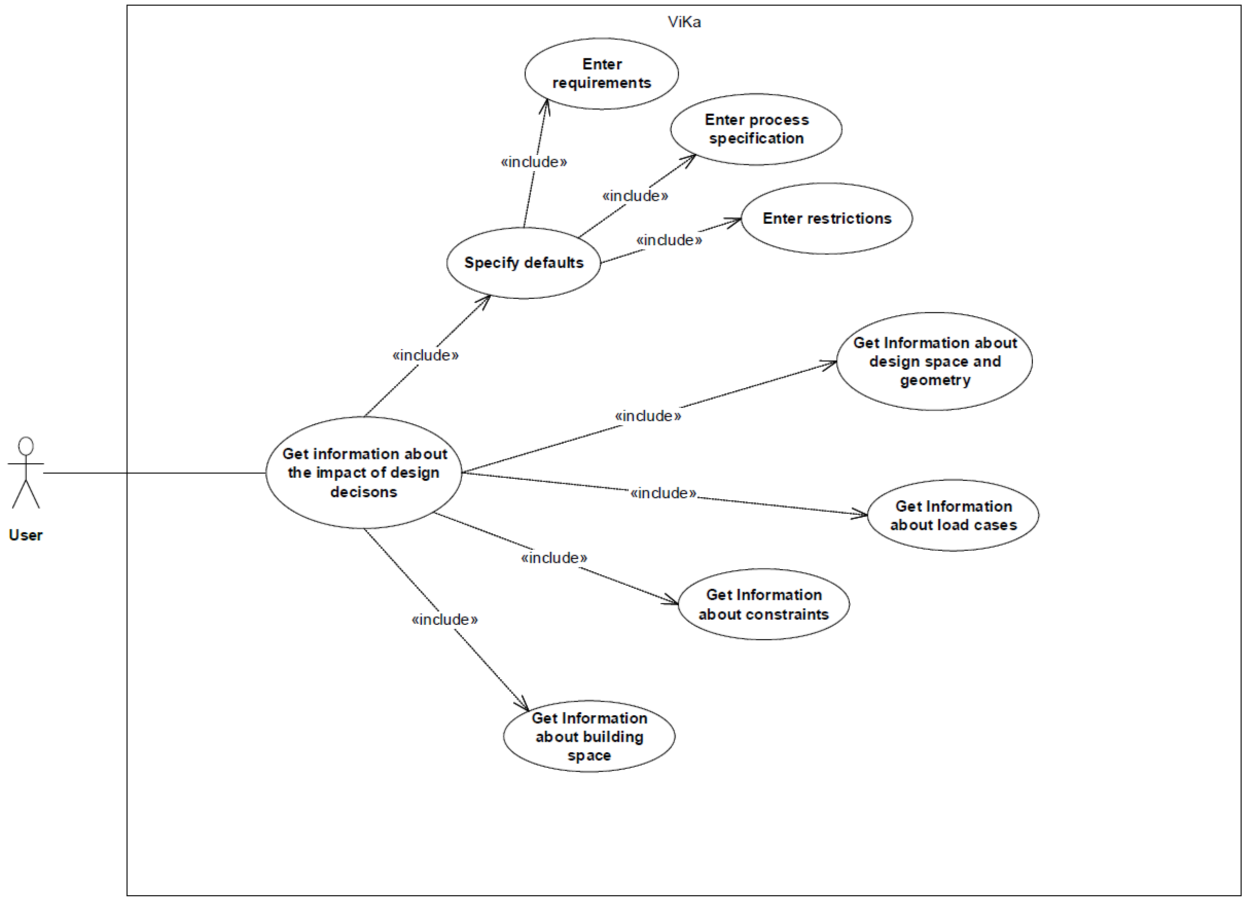

Figure 4 – Excerpt from use case analysis in according to persona method

The use cases provide important insights for the creation of an extensive list of functions (excerpt shown in figure 5). In a scientific discourse, the functions were evaluated, filtered and rated with the project partners to extract a lean function base. This serves as the starting point for the conceptual design structure of the virtual application.

The deliberately inverse path to the usual design strategy noted here: Requirements and associated system elements were developed from the derived function based on created use cases. This path had to be chosen because the research work is based on the first step on the system interaction of self-defined persona-user-cluster, which can be expanded or partially substituted by real user needs in the second step. The research covers a widely cluster of typical user characters (personas) and their different level of behavior in system interactions: Focused on different ages of users, different experiences in software systems and different experiences with AM a group of fourteen characters could be created to use this as a base for functional development.

Feature Listing by Persona Number feature additions are marked in red

Primary function		Subfunctions		Count
No.	Function	No.	Function	
5.	Provide suggestions for improvement in the design	5.1	**Make suggestions for improvement**	**3**
		5.2	Draw attention to mistakes	1
		5.3	Point out critical areas	-
		5.4	Suggest adaptation of existing parts	1
		5.5	Avoid thermal distortion	1
		5.6	Compensate for shrinkage, avoid wrapping	-
		5.7	Recognize optimization potential & uncertainties (topology/shape)	2
6.	Check construction (CAD-DATA)	6.1	Prepare geometry for manufacturing	
		6.2	**Check CAD data for completeness/errors**	**8**
		6.3	Support compliance with design guidelines (minimum wall thickness/layer thickness/spacing/overhangs)	2
7.	Support printing process	7.1	Display optimal orientation in the installation space	1
		7.2	Show/add support structure	-
		7.3	Show amount of support structure	-
		7.4	**Calculate material requirements/costs Estimate production times**	**5**
		7.5	Show necessary post-processing	-
8.	Recommend procedure	8.1	**Recommend AM process**	**3**
		8.2	Show suitability of AM processes	1
		8.3	Demonstrate advantages of AM processes	1
		8.4	Enable benchmarking	-
9.	Enable assistance	9.1	Show hints	2
		9.2	Answer FAQ	-
		9.3	**Enable contact (contact person, expert request)**	**5**
		9.4	Get level based answers	1

Figure 5 – Excerpt of a list of functions based on developed use case scenarios for the use of VIKA

4. Design-Structure / Development and findings

4.1 Functional view

To develop and answer the research questions presented above, it is necessary to proceed with the project in an orderly manner, including so-called "systems thinking".

With this method to develop the system design based on VDI 2206, a system modeling language is used to formalize requirements, system descriptions, use cases and structure definitions, and a final system design is derived [20].

The framework of this research presents a self-contained concept study of a virtual consulting application. Interfaces to other systems and other software applications were excluded from further consideration.

The functional consideration of the system provided opportunities to specify the system behavior and its functional processes. Scientific considerations were used to extract the user-system interactions and functional/logical structures for the VIKA platform from a defined persona cluster.

Based on the VDI 2206, a comprehensive list of requirements for the development of an initial concept idea were developed from revised functions. For a coherent system design, the consulting process examined by using the design thinking approach and ten options were identified. The subsequent scientific discussion and comparison of the ideas were evaluated with the help of a morphological box and under the aspects of "feasibility", "degree of fulfillment of the planned system functions", "innovative potential", "user acceptance" and "exploitation perspective".

A dialogical textual assistant was rated as very innovative. A virtual solution in the form of an agent/avatar/bot based on artificial intelligence and machine learning could provide users with significant support in their daily design work without a specific CAx system interface. This concept was presented to a selected auditorium from the aviation industry and embedded in a scientific discourse. It was consensus that a web-based platform with administratively distributed user roles would offer itself as a purposeful solution to convey the implicit knowledge of design methodology and approaches in AM in the form of interactive tutorials and to prepare user guides as well as instruction documents. In such a platform, a consulting module in the form of an AI-agent could be integrated in a meaningful way. To promote user networking and to provide a dynamically expandable and editable knowledge database, the integration of a content management system is a necessary basement. The usefulness and effectiveness of such a knowledge structure derived from the analogy of digital platforms that have been established for many years. With this concept, knowledge can be exchanged proactively and selectively, whereby the user can freely choose between purely explorative searches and dialogical advice.

For this purpose, a complex digital solution was developed and worked out as a prototype over a period of 1.5 years. Open-source solutions and license-independent tools used to generate a platform structure that results from the requirements mentioned above.

4.2 Structural view

On the base of the preliminary investigations and modeled interaction sequences with the system, the following system components emerge for further prototyping implementation:

- A dialogical design advice module
- A module for exploratory searches of terms and ontologies
- A wiki module
- A module for administrative user account and project management
- A user networking module (forums, messages, discussion board)
- A support interface (FAQ, contact)
- A CMS-database (backend) for adaptive knowledge representation

After the first concept proposals for the system design and its structure sketched in interactive presentation modules, a first basic framework for the individual system components and their networking have been released. A solution was proposed to implement the CMS (content management) system in the tiered information level structure of a web frontend application developed with WordPress (see Figure 6). The CMS system, in which all users administrated via the backend, manages the editable knowledge management and the IP (intellectual property). Various implementation options for the CMS were previously identified and evaluated according to their suitability for the project.

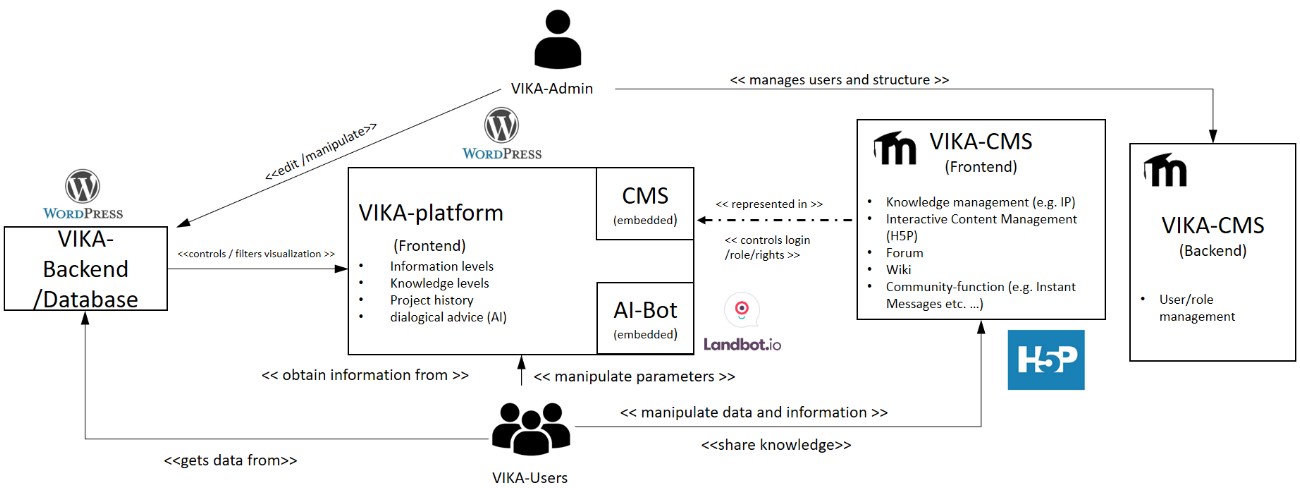

Figure 6 – VIKA System Structure

In digital teaching, schools, colleges and universities it has been used a specially developed learning system (Moodle) for knowledge transfer for several years. The digital learning tools and especially methods grown in the past two years and because of the high demand of new and useful functions the learning platform expand their offer of toolsets to improve the way of learning and knowledge transfer.

Such an open-source system has the advantage that it can be adapted and configured from scratch via a user-friendly UI (user interface) to the desired requirements for the planned use in the context of the knowledge domain. In addition, numerous sub-modules such as a forum, a WIKI and other community functions (e.g. instant messaging) are available from scratch. CMS systems often characterized by a lateral structure, so that ordered and graded information levels can be implemented by embedding them in a logical framework in the VIKA platform. In such a system, all authorized users with assigned roles and rights can manipulate the knowledge modules via the frontend in a low-threshold and time-efficient manner. Depending on the authorization release, the dynamic knowledge base can be edited and updated in the context of AM.

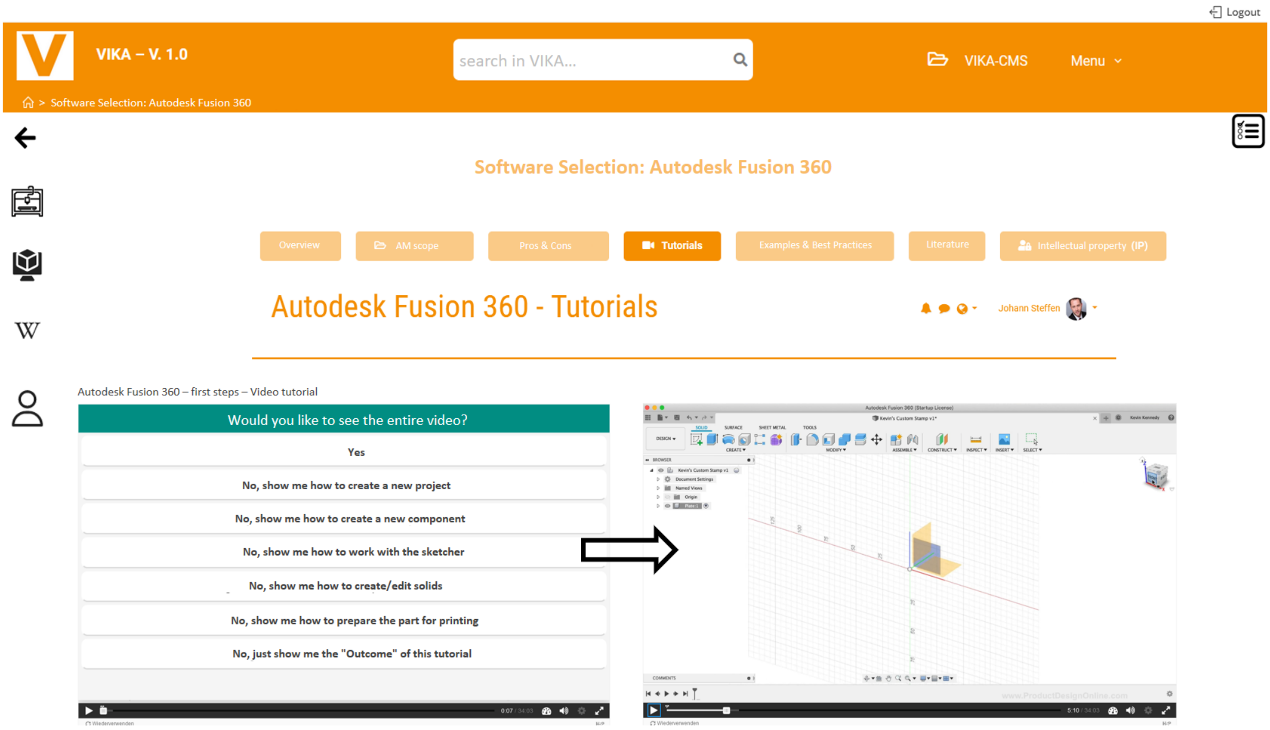

Figure 7 – Interactive embedded CMS medial content in the VIKA platform

In addition, it was investigated which effective methods and techniques can be used to integrate media and interactive knowledge representation modules into the platform in a time effective way. This concept achieves the possibility that new knowledge building blocks in the form of so-called “H5P” modules can be generated intuitively and user-friendly via the CMS system as a universal interface within Moodle. These self-sufficient modules can be downloaded from the CMS or manipulated directly in the frontend. It was examined with which building blocks the knowledge from the domain of AM can be presented to the user to create a sustainable transfer of knowledge for design instructions, best practice examples, design rules, AM Scope or operating instructions for AM software solutions. The AM knowledge transfer is achieved in diverse ways: The user has the option of capturing the AM scope via interactive book modules or interactive video tutorials (see figure 7). Studies from university courses have shown that the acquisition of knowledge - based on interaction with the user - is significantly increased compared to conventional methods such as books, presentations or manuscripts.

A gap in research was identified in holistic process consulting to the effect of presenting the user with the semantic relationships and interactions of the process components and parameters using an interactive and virtual application with tiered information levels. In such an application, the generation of so-called view levels (see figure 8) organized via aggregation and "details on demand" in the "intra-level change" according to Gundelsweiler, could be proposed to the user in the front end of the application [21]. For this, a multi-level base structure of the system building blocks and their networking have been developed. These structures have been worked out in detail according to the top-down principle mentioned and checked for plausibility.

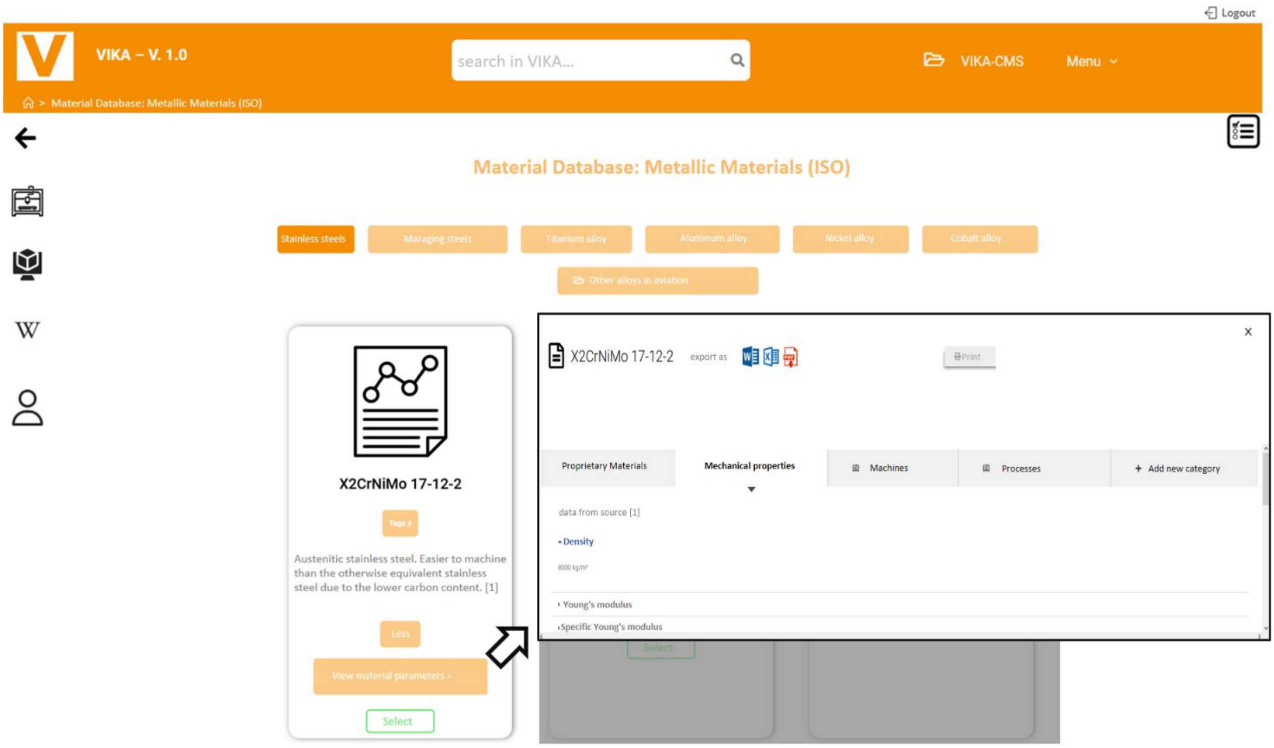

Figure 8 – “Details on demand” for deposited Materials in context of process consulting

Textual dialogic advisory sequences were implemented in the subchapter of the design requirements. It is useful to model potentials for the user in the section of determining requirements for the design within the virtual process chain via an AI agent module that a virtual system provides recommendations, information and possible derived design decisions. The API was realized via an external platform (Landbot.io) connection link and HTML-code. The virtual agent is based on a level 1 script and can be edited or expanded manually by the admin or authorized users. Such level 1 agents are state of research and technology. The scale explained the level of complexity according to machine learning and AI whereby level 5 represents a fully empathic machine learning AI agent.

In addition to textual data, media references (videos, images and voice records) were implemented in the agent sequences via a user-friendly interface with frontend access to manipulate the information structure. The concept until now shows a decision path without saving the entries made by the user. It can be mentioned that many aspects of the process consultation consist of connecting topics (e.g., machine parameter, material parameter and their belonging AM Process). These connections lead to redundancies within the consultation subchapters. Later, the sequences categorized in different domain sub-chapters of the virtual process chain shall be filtered in their representational content according to user input. In this way, the redundancy of several aspects transferred into a lean and logical question board.

Based on modeled interaction sequences with the modeling language SYS-ML, advisory paths for previously categorized sub-chapters (e.g., Geometry/Product Shape) of the requirements determination were designed (see figure 9). For this purpose, questions from the perspective of the user to the system have been developed and associated recommendations from the literature and science were stored via references in the dialogical advice. The virtual system asks the user questions based on a step-by-step principle by a decision-making path for the further tasks in the design or component creation process. The user can interrupt the consultation at any time if a necessary information is missing and must be obtained from the project environment. The recommendations and notes intended to guide the user through the design process in an orderly manner and to provide outcome for user thoughts when making a design or a process decision. It should be noted that the virtual platform can support the user in the decision-making process and cannot make decisions for the user independently so far.

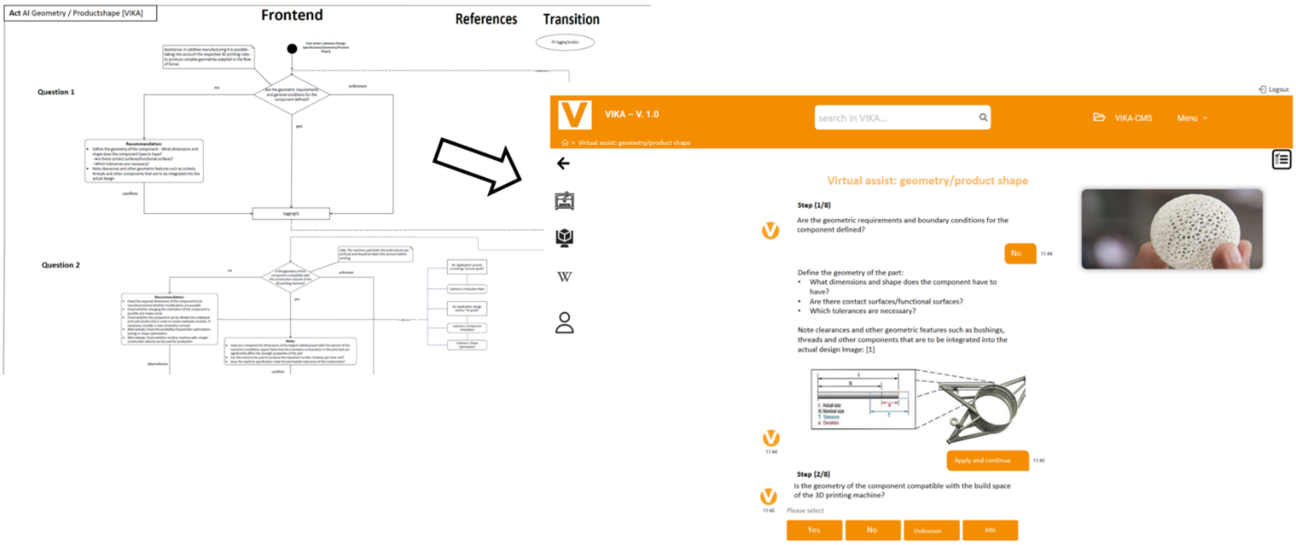

Figure 9 – Modelled AI Agent-Script vial SYS ML and embedded consultation in VIKA

4.3 Analysis view

After reaching a defined level of maturity, the concept study was released for a detailed review. The concept mentioned above is hosted on a local host machine and cannot be accessed online so far. Therefor it was investigated a way how to analyze and review the systems structure, the system functions and the designed way for knowledge transfer:

In the past year, the research results generated presented successively to stakeholders from aviation industry, design offices, software developers and other university and research institutions in a bilateral and virtual form, realized by detailed digital presentation of the platform, the system structure and the implemented functions due to the pandemic situation.

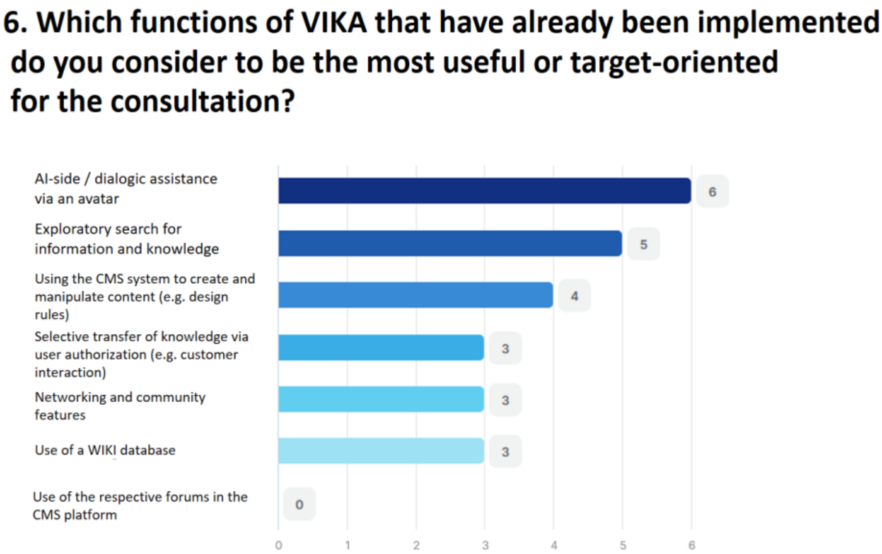

Figure 10 – Concept review – Functions

To extract the results of the assessment systematically, a comprehensive questionnaire, which have been sent to the project stakeholders in the form of an online survey, was drafted beforehand. The survey with twenty designed specific questions should provide information on how the research questions from Section 3 have already been answered. Ten meaningful surveys were conducted: The questionnaire focused on improvements or contradictions the stakeholders have been asked before. It could be extracted that the VIKA platform shall focus on learnings strategies / learning engine (compare “Command Map” in Autodesk Fusion 360 plugin). The platform shall contain different skill-level user profiles (e.g., beginner, experts etc.). These profiles shall filter the representation base of knowledge content and information in context of AM. This will support the thesis of one interviewed stakeholder mentioned that the platform consists actual of too many features and functions which can be better organized by such profiles. The automatic approximation of the 3D-construction or the part check for validity according to AM restrictions were mentioned as desired functions which are still missing in the concept. One impulse discusses the implementation of a so-called “NLI” (Natural language interface) which allows the user to talk with the system. The surveyed consider the use of editable interactive content to be important and this with the implemented solution of using H5P-learning modules offered by the CMS system. With the shown concept the stakeholders agreed that the platform contain the potential to support design decision in context of AM constructions and related processes.

As a result, it could be mentioned that most of the stakeholders were able to confirm the successful implementation of the design consultant and a great interest to use a mature version of the VIKA platform for everyday work in the context of AM.

The virtual advice agent and the explorative search for information were identified as sensibly implemented core functions of the platform (see figure 10). In addition, the feedback from the respondents was used to further edit or expand the virtual solution in the individual information levels and functionalities. It was confirmed by the stakeholders that protected knowledge is accessible and can be transferred to the virtual application (see figure 11). This aspect related to the fact that users agree for the time intensive workload to implement such implicit knowledge into the platform by considering the restrictions and limitations of knowledge share and transfer given by the companies.

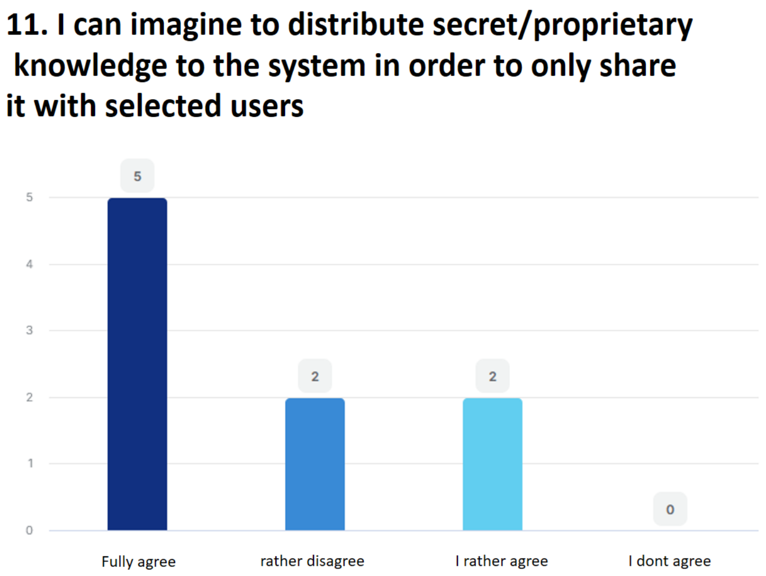

Figure 11 – Concept review- intellectual property (IP)

5. Perspective and future work

The survey presented in chapter four contained questions which functions should be implemented or developed in VIKA for the future work. From the survey it can be deduced that future research efforts should focus on AI-side and dialogical advice and different user level profiles. The integration of dialogical consultations via created scripts (Level 1-2) is currently provided. In the long term, it would be conceivable to replace the scripts with a level 4-5 AI agent, which could interact with the user in a self-learning and empathetic manner. For the first, it can be investigated how to find an internal solution based on programming HTML code to implement the level 1 agent without any external resources in terms of online availability of the Landbot.io agent.

A second aspect of expanding the AI-activities of the dialogical advice is to implement the agent in other subchapters and to use the agent to navigate through the entire platform so that beginner have an easily access to the user interface. For the moment users can access from the menu bar an interactive handbook/manual which guides someone through all subchapters with explanations and future concept ideas.

It needs to be discussed whether dialogical advice could be purely textual or even via voice output or a meaningful combination of both. Expert interviews from the industry and science confirm the thesis that working methods in construction in the context of AM have evolved from silent work to interactive and communicative teamwork.

AM is an enclosure domain with a high dynamic but limited knowledge base. Kabel mentioned about textual or voice agents that such virtual solutions like chatbots or voice assists based on scripts or later machine learning/AI can be adapted ideal on such a limited and dynamic knowledge base because all questions the user formalized can be defined. It differs fully from an open knowledge base domain like well-known voice assists must deal with. In such an open domain, the systems respond base must be very extensive otherwise, the frustration potential of the user can increase fast which leads to a dismissive attitude. The same thesis can be formalized for an immature system, which reach the market too early. [22]

The platform treats the graded and filtered information representation as an example (see Figure 12), so that the user can select specific parameters or values via pull-down menus via defined input masks in the sub-chapters to display derived result representations. The selected method can support the end user in providing targeted information in a timely manner and it is used in large databases in massively shorten searches. The basis for such an implementation is the extensive programming of a large database, in which all input and output parameters are coded and connected in such a way that the system can compare them and extract them. This method can also be effectively expanded later using machine learning, so that the knowledge base can be edited and expanded by authorized users in a low-threshold way.

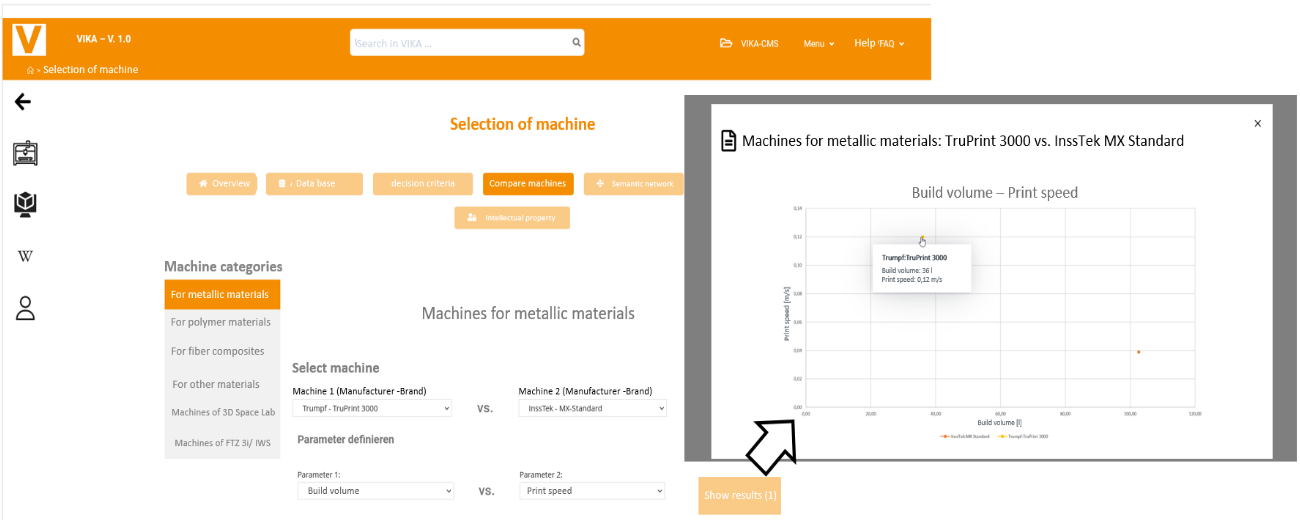

Figure 12 – Concept – dynamic filtering of information representation

The stakeholders of the project evaluated the VIKA-platform concept study as a successful exploitation perspective in the context of teaching and training, a dynamic knowledge database and a virtual support system.

To create a meaningful exploitation perspective, the content and knowledge structures developed are transferred to a digital learning platform in cooperation with a company in context of FDM Part Production, so that the knowledge already generated can be offered to a larger group of users in the form of training courses. For the moment, there is a great need for specially developed digital training models on the market, which differ from classic online training formats with a live lecture.

For this purpose, a first learning path is currently being created using a design example and the Fused Deposition Modeling (FDM) process, which is being enriched with media content and didactically useful methods to explore whether a successful transfer of knowledge for beginners and/or advanced users in AM succeed. From a systematic and strategic point of view, the training model developed in such a way that a working group can be founded subsequently to implement implicit expert knowledge from various knowledge sources in a beta version of the VIKA platform. The tasks of the consortium should include advancing the platform with capacitive resources, building and maintaining a dynamic database that enables users to provide and/or exchange selected knowledge promptly via filtered view levels.

Future research efforts could be implemented cooperatively with the domain of computer science to transfer existing expert knowledge and expertise on virtual bots /AI to higher levels in the context of AM. A coalition of experts with in-depth prior knowledge in the field of AI and AM can realize such a future perspective of this project.

6. Copyright Statement

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