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A Design Journey: Towards a Virtual Reality Simulation and Training Application

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Abstract. Through digital transformation and new technologies such as virtual reality (VR), employees can benefit from enormous advantages within the corporate context. In industrial computer-aided design (CAD), there are complex workflows that have a great influence on the maintenance processes. However, designers may not be fully aware of potential benefits of these influences. To sharpen this awareness, for such scenarios the demonstration of CAD objects in VR can be a solution. Virtual testing of a design is inexpensive and can be realized quickly. In addition, maintenance can already be trained virtual in detail on the VR image of the machines. This topic is taken up representatively and implemented in an information system (IS) based on VR and a design science research approach. The needs of the employees are strongly considered in this study and the developed software can be applied to a broad class of related problems. Finally, the demonstrator and the underlying processes will be evaluated to gain insights and knowledge about the design of a VR system.

Keywords: Digital Transformation, Virtual Reality, Design Science Research Methodology, Knowledge Transfer, Hybrid Value Chains

1 Introduction

In the course of digital transformation, the virtual and real worlds of work are increasingly merging (Friess, 2016). Products and services are equally subject to this process. The contribution, especially of highly specialized technical products, can be significantly increased by combining them with accompanying services (Vendrell-Herrero et al., 2017). Accordingly, it is necessary for products and services (such as construction and maintenance processes) to merge. To this end, the necessary competencies on the part of both producers and service providers must be identified and jointly expanded.

The value chain is the term used to describe various stages of production that can be described as an ordered sequence of activities. These activities create value, consume resources and are linked together in processes (Porter & Advantage, 1985). However, nowadays value chains are usually modified to hybrid value chains. This means that not only the product but also the services associated with the product are defined as hybrid value chains (Leimeister & Glauner, 2008).

This research aims to address the development process for an interactive VR demonstrator for the mediation of competencies over hybrid value chains (construction processes and workflows around maintenance) (Weigel, Hoffmann, et al., 2020). In addition to the conception of a digital environment for experience-based and subject-related competence development, the exchange of knowledge between maintenance personnel and other relevant employees (constructors, management, sales, information technology (IT), etc.) across departments and companies should be supported.

In the research process, both theoretical and practical elements in the VR demonstrator are illustrated in order to promote the transfer of knowledge along hybrid value chains. To better define this VR demonstrator, the relevant requirements and practices of the employees should first be determined empirically. Subsequently, the competence development is conceptualized in organizational terms (Weigel, Heger, et al., 2020). The aim is to provide employees with the best possible support in their competence development through the use of VR and to transfer this support into operational practice on a pilot basis.

This research is structured as follows: First, an overview of the related work on hybrid value chains, technology-supported perspective taking and VR will be given. Next, the research methodology based on the research framework of design science will be described (Peffers et al., 2007). Third, the results will be discussed and the limits of the research to date will be pointed out. Finally, a recommendation for future research will follow.

2 Related Work

In hybrid value chains, the alignment of corporate strategies is particularly important. Often, several organizations are represented in these hybrid value chains (Santos et al., 2015). They pursue different goals and strategies. However, good cooperation is characterized by the fact that these different organizations pursue similar goals. IT-Business Alignment considers the alignment of IT and business, (Reich & Benbasat, 1996). IT-Business Alignment will become increasingly important considering hybrid value chains between organizations (Ryan et al., 2013; Weigel, Hoffmann, et al., 2020).

One way to strengthen this IT-Business Alignment can be the technology-supported perspective taking (Weigel, Hoffmann, et al., 2020). The perspective taking originally comes from psychological research. It is an attempt to enable one person to take the perspective of another person (Boland Jr & Tenkasi, 1995). The literature often describe this empathy as a reflection of our own point of view. Customer and user orientation can be understood as a form of adopting a perspective that has a positive effect on the development of new products (Salomo et al., 2003). But also in the context of services, the ability to adopt the perspective of another client, has a positive effect on the ability to help (Axtell et al., 2007). Classically, perspective taking can be triggered by the explicit request to put oneself in the perspective of another person (Boland Jr & Tenkasi, 1995). However, digital technological developments in particular increasingly show that the adoption of the perspective can also be influenced by technical measures (Lee et al., 2018; Peng et al., 2017).

VR has enormous potential when it comes to teaching skills and processes. This has already been researched within the framework of VR research in the educational sector. (Wohlgenannt et al., 2019). Objects and even individual process steps can be displayed with a very high level of detail. In addition, a closed VR room enables a focused interactive experience (Martín-Gutiérrez et al., 2017). However, VR technologies can also be used to close a gap in the transfer of information (Jayaram et al., 1997). Nevertheless, research on the use of VR in the context of technology-supported perspective taking is limited (Weigel, Hoffmann, et al., 2020). There are only a few articles dealing with use cases in a business context. For example, it is argued that the combination of avatar manipulation and role-playing in the virtual world can also lead to the development of empathy (Jestice, 2016). This avatar manipulation was also considered in another experiment. Here, the conventional method of taking perspectives by means of mental simulation was combined with the immersive virtual environment. Different effects were observed depending on the group. For example, the negative effect of age discrimination was less pronounced if one was placed in the role of an older person in VR (Oh et al., 2016).

In summary, hybrid value chains are a decisive factor in our today's economy. The better they function, the better the objectives of the various organizations are aligned. But not only the general objectives plays a role, but also the IT-Business Alignment. This IT-business orientation can be supported by technology-supported perspective taking, and VR can be a manifestation of this support.

3 Methodology

Design science research has become increasingly important in the research field of IS since the 1990s (March & Smith, 1995). But even today, the importance of design science research remains undiminished (Niehaves & Ortbach, 2016; Peffers et al., 2007). There are two areas of design science. One deals with the creation of a new IT artifact. The other one deals with the manipulation of an existing IT artifact. This current research shows that theoretical approaches to the influence and effects of e.g. IT artefacts only emerge after their development and use (Hevner et al., 2004).

This research follows the six phases of the design science research methodology for information systems research (Peffers et al., 2007). These are:

1. Identify problem and motivate

2. Define objectives of a solution

3. Design and development

4. Demonstration

5. Evaluation

6. Communication

First, an analysis of the existing processes was carried out to determine the exact procedures. An important part at this point was the understanding of the process knowledge. At the same time, the search for existing best practices was carried out. The technical possibilities for implementing a VR environment were explored. After an overview of the initial situation and the feasibility of the VR environment was available, the requirements for the demonstrator were determined.

Furthermore, a concept was developed how the VR environment should represent the researched approaches and the collected data. This step was followed by the actual development of the demonstrator. It was evaluated at regular intervals whether the demonstrator meets the requirements and the concept. This evaluation can be included in the further development. The steps of development and regular evaluation are currently repeated until the development goals are achieved. As a final step, the development of this prototype or a further application is discussed.

To date, phases one and two have been completed. Phases three and four are currently active, phases five and six will follow in the future.

3.1 Problem definition

In this research two organizations are considered, which are connected in a hybrid value chain. First, the producing organization and second an organization that offers accompanying services for the products. In order to define the problem situation precisely, interviews were conducted with six employees of the production organization and five employees of the service organization. The interviews provide good insights into the current situation. For example, maintenance work on a technical machine requires a head for heights and enormous skills. However, the person who maintains a machine is usually not the person who designs the machine. This means that there are knowledge gaps in the value chain between the services of assembly, maintenance, repair and product development. Therefore, important aspects for maintenance cannot be taken into account in the design.

It is obvious that this workflow offers the potential for improvements through digital transformation, more precisely through the VR demonstrator under consideration. On the one hand, competence development along the hybrid value chain has not been consistently pursued so far. On the other hand, there is no real evaluation of the service processes in relation to the actual construction of the product. There is uncertainty for all involved employees about the possibilities of the employees of the other organization.

3.2 Objective of Solution

The interviews from phase 1 were used to develop the objective of solution. This was pursued extensively, since previous research on VR environments has only marginally addressed the industrial context. Therefore the solution is planned in a cooperative, employee-centered approach. One example is a service employee who was accompanied on two days. During these two days, maintenance work on two different machines could be observed and scientifically documented. For this purpose the individual steps were recorded photographically. Due to the industrial environment and the applicable regulations, it was not possible to record the process on video. A maintenance manual was created from the documentation and photos, which was later discussed again with the service personnel to check for possible misunderstandings. The product development process was also documented in detail. A product development process was accompanied, from the integration of the standard parts to the static calculation of the designed product the steps could be traced.

The identified requirements can be specified as follows. This specification provides the basis for the next section, in which requirements can be generalized and implemented in the VR demonstrator.

RQ1: Requirement: Simulation environment

A simulation environment should be created to enable developers to evaluate their design in this process. This supports possible improvements to the machines.

RQ 2: Requirement: Training environment

A training environment must be created so that skills can be further developed and trained. This is mainly for the service organization to train service on new products. However, new employees from both organizations can also be trained accordingly.

The demonstrator therefore aims an interactive VR simulation for the visualization of maintenance work in order to make work processes and conditions tangible and to train interdisciplinary skills. This is intended to digitize and make the cross-organizational exchange of knowledge between maintenance personnel and designers comprehensible.

From the combination of these arguments the problem definition can be derived as follows. The two areas of construction and maintenance are not yet sufficiently coordinated. Consequently machines are developed, which are not optimally maintainable.

3.3 Design & Development

Access to the VR demonstrator is guaranteed by the consumer technology HTC Vive Pro Eye and the Unreal Engine. The goal is to provide a solution that can be used in numerous situations and different scenarios. Thus, an abstraction step of the constructures is performed before implementation. This will give us a more flexible approach that will be easy to use. Subsequently, with the help of the "Business Process Model and Notation" (BPMN) models are created, which will reproduce the recorded process steps in general and clearly for the software developer.

The maintenance relevant process steps should be presented as detailed as necessary but as general as possible. Not every specific detail needs to be simulated and interactively designed in VR. This will allow the transfer to different machine types.

The simulation of machines designed in CAD will allow the developer a high degree of creativity. A pipeline is being developed for this purpose. This pipeline will convert CAD design files that are exported as STEP files to VR. The interaction with these transformed objects, however, is not possible. However, the designer can determine which CAD objects are replaced by interactive VR objects. This follows a previously defined naming scheme and enables the execution of simulated maintenance work on these VR objects.

3.4 Demonstration

The VR demonstrator is created as a hardware-software demonstrator. This development is done in an agile way to be able to flexibly take up the results of the parallel running evaluation. The VR demonstrator represents the technical solution comprehensively and focuses on the immersion of the user and the experience within the VR environment.

In the future, implementation strategies will be developed to anchor the VR demonstrators in the organizations. These implementation strategies determine how the processes are designed, how the target groups are integrated for productive use and how accompanying organizational measures (e.g. guidelines and workshops) are implemented. Based on these strategies, the VR demonstrator is implemented in the organizations in the form of a pilot project. The experience gained will be analysed and used to further develop the VR demonstators.

4 Future steps

4.1 Evaluation

The VR demonstrator will be continuously evaluated. In the future, this evaluation will take place with regard to the extent to which the respective status of the demonstrator can be used for competence development and for teaching in work processes along the hybrid value chain. In addition, it is examined whether the solution offers significant added value for networked working. A field evaluation with users will be planned. This will take place in the form of several field studies with the demonstrator. In the run-up to the demonstrator, individual aspects (e.g. VR simulation environments, learning/ supportability or applicability) will be evaluated in laboratory studies.

In the context of the quality assurance of the VR demonstrator, a formative evaluation is aimed at, which continuously checks technological (e.g. usability tests) and technical aspects (e.g. process step integration). Furthermore, the development will be discussed and reflected upon, e.g. in workshops with all project participants. The goal will be an iterative development with the results of the evaluation.

4.2 Communication

Project coordination is carried out continuously. At the beginning of each month there is a digital jour fixe using a web conference system with all persons and organizations involved in the project. The project organization is agile in order to incorporate possible feedback into the development of the demonstrator in a timely manner. The immediate communication via the web conference system ensures that the defined goals are achieved on time and according to plan. Problems can be detected early on due to the continuous exchange of information. A continuous exchange between the project partners helps to ensure the consolidation of the project results. All these measures are then additionally supported by regular physical project meetings. This exchange will form the basis for future communication about the project and its results.

5 Discussion

This research deals with the development of a VR demonstrator for the simulation of partly dangerous maintenance procedures. Inspired by developmental research method a problem-oriented research design was presented (Peffers et al., 2007). The requirements were then derived on the basis of the problems identified. On this basis, qualitative interviews were conducted with the organizations' practitioners. Afterwards, the resulting findings were evaluated by all participants in a workshop and learning scenarios were developed to solve the original problem of the lack of competence development along the hybrid value chain.

In the demonstration phase the VR demonstrator will be presented and explained to the employees of the organizations. Special attention is paid to the applicability, to the respective configuration and the simulation of the workflows. Subsequently, further feedback and evaluation phases are planned in the form of further workshops, qualitative interviews and experiments. According to the results obtained, the unique simulation properties of VR lead to an improvement in product quality as well as to an improvement in service quality. Especially, the pipeline management, which allows an immediate simulation of the CAD data, was highlighted as a key feature and an important contribution.

Another decisive factor is the hardware used. In the field of VR Head Mounted Displays the best possible immersion is a big discussion. The reduction of the CAD data with simultaneous possibility of interactive with components was solved by a hybrid approach.

As with any practice-oriented research study, there are some limitations: First, the empirical basis for the developed VR demonstrator is based only on the development and service scenario. In order to overcome this limitation, it is intended to transfer the VR demonstrator to further use cases. The research have verified the benefit of the VR demonstrator in a service scenario and development scenarios in two organizations. According to the interviews it is helpful to transfer at least the service scenario to other organizations. This way, the employees of other service organizations, who also maintain the machines of the organization, could be addressed. Second, the evaluation so far is limited, because on the one hand the project is not finished yet. On the other hand the participants of the evaluation could only test the VR demonstrator for a short period of time. Therefore this study intends to carry out a long-term evaluation in the future in order to gain a detailed insight into the effects of the demonstrator on the work of the employees.

Nevertheless, a demonstrator should be created that can be used in practice for the development of many products.

This paper has also introduced technology in an organizational context, which helps employees in the service sector to get to know their work processes better. This helps organizations keep pace with the competition by better training employees and saving resources. In the field of research, this study have made a scientific contribution to the design science research methodology for information systems research (Peffers et al., 2007)

Guidelines could be developed which could be extended to other use cases through extension, application and evaluation. The collected knowledge can further help to understand how VR can be integrated into the industrial context. It can be determined which concrete artifacts a VR needs to be better designed to support employees in their work processes.

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