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Identification of requirements for the transfer of creativity techniques in virtual environments by using TRIZ-Box

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Abstract

Distributed teams are becoming a normality in nowadays product development. However certain activities pose additional challenges when carried out in a distributed setting. Activities involving creativity are some of them. To overcome these challenges support is needed that ensures the functioning of creativity techniques in distributed, i.e. virtual settings. To develop such support the challenges need to be identified exactly as well as the requirements for transferring Creativity Techniques (CTs) into virtual application. Therefore, a preliminary study in a LiveLab environment was carried out. The results are compared with the requirements found in the literature. The creativity technique TRIZ-Box which represents the 40 inventive principles in TRIZ as physical objects to assist the idea generation is the CT this contribution focuses on. With respect to the requirements, the TRIZ-Box is adapted for execution in Virtual Reality (VR). The resulting prototype is then validated by three teams of two experts for design method development that solve an example problem using the VR-TRIZ-Box. Conclusions on the first prototype of the VR-TRIZ-Box are drawn through the number of ideas generated with and without the CT and the observation of the participants during the process of applying the CT. Technical and procedural challenges are identified that require further development iterations, however, the VR-TRIZ-Box proves itself as a successful virtual pendant to the real TRIZ-Box and shows possible implementation in future metaverse applications.

Keywords: Creativity techniques in product development; Distributed teams; Design methodology, tools and technologies

1. Introduction

1.1. Metaverse – One enabler in product engineering

The possibility of having digital meetings not only in 2D but in 3D is starting to become a reality. With the former Facebooks Metaverse (Meta Horizon Workrooms) [1] and Nvidias Omniverse [2] first options are already present. But the Metaverse is not only a space for leisure time, it is starting to take hold in product engineering. Seven characteristics describe what the word metaverse refers to: open and interconnected systems of virtual and mixed worlds, space for social interaction, long-lasting but enabling integrating sessions that can be limited in time, open standards allowing for technology integration, possibilities to capture the real world condition of the user, possibility to change intensity and representation of participation of one's self, information, action and interaction in the real world and in metaverse mutually influence each other [3]. Given these characteristics, possible fields of action for product engineering in the metaverse include building validation environments, supporting cross-generational engineering of mechatronic systems, enabling co-design of

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product and production systems, teaching engineering competencies and adapting creativity methods in early ideation [4]. The latter will be the focus of this contribution. With the possibilities of working together in distributed settings come not only advantages but also difficulties. Especially activities that involve creativity are proven to be more difficult for distributed teams. Coming up with ideas while using the existing creativity techniques seems less stimulating in a virtual setting compared to being in the same room [5].

1.2. Creativity techniques for metaverse

Process steps that involve creativity are identified as critical activities in product development in a distributed setting [5]. Teams working together fully virtually experience barriers when it comes to creative problem-solving. Creativity itself describes the process of creating something that is considered to be new. The distinction is not made over the criteria of being useful, being new is what makes a process output creative [6,7]. Within the product development process ideas are generated in multiple phases and creativity is needed for each of these ideation processes [8]. Creativity techniques (CTs) support the creative processes. To enable appropriate support in the metaverse, CTs need to be suitable for the virtual setting [9]. Studies on transferring CTs into virtual use have been performed by [10] and are part of the theoretical basis of this study.

The adaption for virtual use of the CT TRIZ and more specifically the TRIZ-Box is described within this contribution. The TRIZ-Box was chosen since it combines the stimulation of the auditory and the tactile senses that need to be focused on when transferring CTs into virtual application, since especially haptic stimulation is not directly transferable into a virtual setting. The TRIZ-Box was developed, to make using TRIZ possible for beginners, since the effective use of TRIZ needs a lot of experience [11]. TRIZ is the theory of inventive problem-solving that has been created by Altschuller [12]. TRIZ consists of a variety of methods from which some use the approach of transferring a concrete problem to an abstract one. To the abstract problem, an abstract solution is to be found using the contradiction matrix and the 40 inventive principles. The abstract solution is then transferred back to reality to assist in finding the concrete solution [13]. At this point, the TRIZ-Box with physical objects representing the 40 inventive principles comes into play. The physical elements can help the user of the CT to transfer the abstract solution to the concrete solution of the problem [11]. The transfer of this creativity method is done by using VR. The physical elements of the TRIZ-Box are made available using VR and multiplayer to enable virtual use and support the critical product development activities involving creativity. The use of VR ensures the stimulation of the auditory sense when using the TRIZ-Box but leaves stimulation of the tactile sense out of consideration. Conclusions need to be drawn on the impact this has on the creative output and ability to collaborate in the virtual setting.

2. Research profile

2.1 Research goal and questions

The subordinate goal of this contribution is the transfer of the TRIZ-Box into VR to find the relevant requirements when transferring creativity techniques into a virtual setting. To do so a preliminary study helped to understand basic requirements. Taking these requirements into consideration the TRIZ-Box was designed as a virtual TRIZ-Box (VR-TRIZ-Box). Three teams of experts were then asked to solve an example problem using the VR-TRIZ-Box and to evaluate the VR-TRIZ-Box. With the results, learnings for the transfer of other CTs for virtual application are to be drawn.

- What are the general requirements for transferring creativity techniques into virtual application? (RQ1)
- How can the TRIZ-Box be transferred into virtual reality? (RQ2)
- Can the first version of the VR-TRIZ-Box be applied to solve an example problem according to the TRIZ problem-solving process? (RQ3)
- What can be learned for distributed or metaverse application of creativity techniques? (RQ4)

2.2 Research approach

For answering RQ1 a literature review was performed followed by a preliminary study within the LiveLab ProVIL – Product development in a Virtual Idea Laboratory to define the general requirements for transferring creativity techniques into virtual use. To do so three CTs were explained to the student development teams and after the application, a questionnaire was used as the data collection method. The requirements found in the study were compared to the ones from the literature. With the requirements defined, the VR-TRIZ-Box was developed using Unreal Engine 5.2, answering RQ2. The first version of the VR-TRIZ-Box was then validated. After a pre-test, six experts for design method development were divided into groups of two to solve an example problem using the VR-TRIZ-Box (answering RQ 3). Each team of experts got an introduction to TRIZ in general, to ensure an equal state of knowledge. Furthermore, the use of the VR setup with HTC VIVE Pro 2 with a wireless adapter was explained before each team had to solve the same example problem. To ensure that only ideas generated through the method application are collected, the participants were asked right after the introduction to the example problem to give their initial ideas. The successful use of the VR-TRIZ-Box was evaluated over the number of ideas generated and further conclusions were drawn from the observation of the validation teams, giving the answer to RQ 4.

3. Preliminary study

The preliminary study was planned and carried out as part of the ProVIL master's course for engineering students at KIT. ProVIL – Product Development in a Virtual Idea Laboratory works as a Live-Lab research environment [14]. The goal was to identify general requirements for the application of CTs in virtual environments. The study subjects were presented with three CTs with proposed tools and materials to use for distributed work. Those three were 1) 6-3-5 Brainwriting, 2) the Six Thinking Hats, and 3) the stimulus method. At the end of the study, a questionnaire was used to examine the characteristics and important components of the used CT. The questionnaire items were derived from the technological requirements of virtual CTs [10] and requirements for virtual worlds [9]. The questionnaire consisted of four parts:

- 10-item-questionnaire with Likert-scale
  Examples from the questionnaire under the main question "How accurate are the following statements regarding the creativity techniques you used" are as follows. "The creativity technique/s was/were easy to apply" or "I did not need to communicate with my team members". The scale included the options *is applicable*, *tends to be applicable, tends not to be applicable*, *is not applicable*.
- Multiple Choice to specify the needed components in a virtual environment
  An example from the questionnaire is "Which of the following components are necessary for working in a virtual environment?" with the options to choose from *call*, *videocall*, *tools for drawing*, *documentation possibilities*, *shared space*, *instructions to the methodology* and the option to add further elements.
- Free text answers to identify preferences for in-person-work
  An example from the questionnaire is under the main question "Would you have rather performed the creativity technique in person" if yes is chosen, a field to specify why and give additional details.
- Free text field to add additional tools that had to be used

In total, 20 completed questionnaires were evaluated. The results showed the set requirements previously identified from the literature and showed no remarkable deviations or additional elements. Remarkably, it was shown that the representation of one's presence, e.g., via an avatar or picture, which was a hypothesis of the authors proven to be wrong.
For the development of the VR-TRIZ-Box, the known requirements from the literature were used and applied to the VR medium:

1) The VR-TRIZ-Box must make vocal communication possible for the user
2) The VR-TRIZ-Box must make being in a shared virtual space possible for the user
3) The VR-TRIZ-Box must make documentation possible for the user
4) The VR-TRIZ-Box must be intuitive and self-explanatory for the user
5) The VR-TRIZ-Box must make interacting with 3D objects possible for the user

4. Conception of VR-TRIZ-Box

The conception of the VR-TRIZ-Box was accomplished by the application of the DIN PAS 1032 to this VR-Prototype. DIN PAS 1032 is a standard by the German Institute of Standardization (Deutsches Institut für Normung) that specifies a process model for the planning, development, institutional and technological integration and evaluation of e-learning applications [15]. The main categories of this standard, that were followed step by step are as follows:

1. Identification of requirements
2. Framework conditions
3. Conception
4. Production
5. Introduction
6. Execution
7. Evaluation

The first and last steps for this process model were realized by the preliminary study and the validation study respectively. The VR-TRIZ-Box was developed in Epic Games' Unreal Engine 5.2 in addition to the VR Expansion Plugin [16].

The implementation of requirement are explained in more detail in the following.
Shared virtual space. The shared virtual space, requirement 2, is implemented by the possibility of a multiplayer session hosting in local networks as pictured in Figure 1.

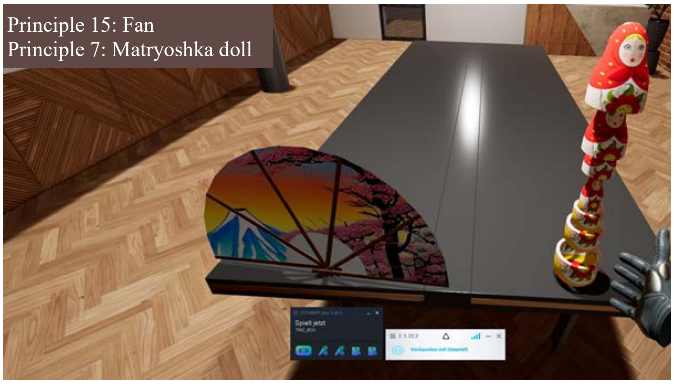

Figure 1. First person perspective in VR-TRIZ-Box in multiplayer

40 TRIZ-Box artifacts. For each general TRIZ inventive principle, a representative artifact was chosen based on either the real TRIZ-Box at IPEK at KIT [11] or from the examples by TRIZ Group [17]. These artifacts are grabbable 3D objects that may implement a function that can be triggered while holding (e.g. opening and closing a fan as shown in Figure 2), ensuring that the requirement concerning the ability to interact with 3D objects (requirement 5) is met. The selection of artifacts was based on the perceived feasibility and suitability for VR.

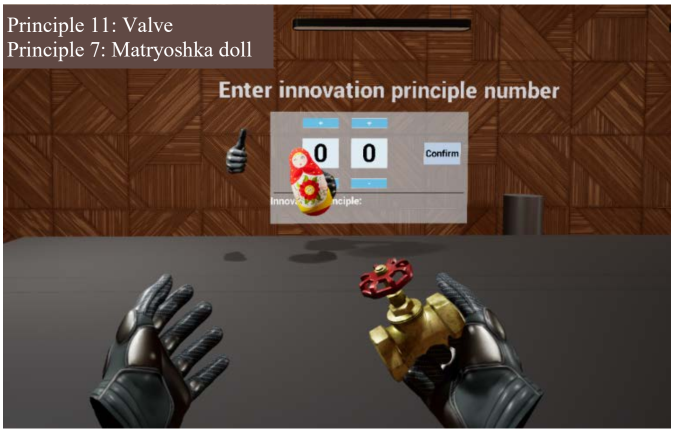

Figure 2. Examples of virtual TRIZ-Box artifacts

Vocal communication is ensured since the participants are in the same room together. This aspect is excluded from the validation since it has not yet been implemented for an actual distributed setting. **Documentation** is possible over screen recording but since the voice cannot be optimally recorded, since participants are moving through the room and speaking without using the microphone, this requirement is also not included for validation and needs to be part of a second version of the VR-TRIZ-box. Components such as voice chat or documentation tools have not been implemented yet. Instead, the VR-TRIZ-Box has been used in a shared environment with a dual computer setup so that users can communicate directly. To document possible solutions and results, a moderator accompanies the users outside of VR.

5. Validation study

The validation study was conducted at IPEK – Institute of Product Engineering at KIT - Karlsruhe Institute of Technology with experts for design method development as study subjects. The subjects were split into three groups consisting of two participants. For each run, the participants were presented with the technical problem to be solved. Afterward, the participants were instructed to generate ideas for the given problem without any specific methodical assistance or CT. After finishing the first idea generation phase, a function analysis was presented as part of the TRIZ approach to solving the problem. Multiple possible technical contradictions were formed by identifying the technical parameters and the corresponding inventive principles were then looked up in the TRIZ Matrix 2003 [18]. The subjects were transported to VR where they joined in a shared virtual environment with the VR-TRIZ-Box. They were reminded of the identified inventive principles which they could explore freely via the corresponding artifacts. While in VR, the second idea generation phase started. Table 1 compares the quantity of each phase's generated ideas.

Table 1. Comparison of quantity of generated solutions between different phases

Group	Generated solutions in first phase	Generated solutions in second phase
1	7	16
2	11	24
3	7	21

As the technical problem to be solved an example problem was chosen to ensure comparability between the groups and to make solving the problem within a time frame of two hours possible. The following example was chosen, which can be formulated into a contradiction as required by TRIZ and also by product developers not very familiar with TRIZ.

> *"A lamp is to be fitted with a lampshade. Without the lampshade, the light is too bright and disturbs the guests. However, guests will also bump into the lampshade if it is attached."*

Some of the solutions generated within the first phase by Group 1 are "using a less powerful light source" or "adapting the shape to be smaller but longer". Solutions generated by the same group but within the second phase, meaning when supported with the CT are "Integrate light into the wall to avoid glare" or "gradual construction of lampshade: many hollow spaces and flat or pieced in the direction of view so that the person is not dazzled and a design element is generated". The ideas generated in the second phase seem more elaborated. Since that might only be due to the participants knowing the problem already within the second phase, only the number of ideas generated has been taken into consideration within the evaluation. An additional limitation to a quantitative analysis of the results is that evaluating the quality of the solutions generated is difficult on an objective level. A follow-up study could focus on including the qualitative evaluation of the creativity of the solutions generated or a cost-benefit evaluation of the solutions.

After the usage of the VR-TRIZ-Box the subjects were asked what would change if they had the artifacts physically in their hands. Table 2 depicts which answers were given and how often.

Table 2. Listing of answers for the validation study

Times stated	Answer
3	Haptic feedback enriches the experience for some artifacts
2	Some artifacts are better represented in VR
2	Real objects result in a better technical understanding
2	Worse perceptions for materials in VR
2	Technical understanding (controls) can be a challenge

The validation shows that the usage of the VR-TRIZ-Box does influence the idea generation process positively. The specific feedback shows the relevance of haptic stimulation; however, it also shows the potential of the virtual representation of the inventive principles in a simulated 3D space. Multiple possible, technical improvements have been identified, such as the implementation of an advanced grabbing system, for interaction over distances. Following the result of the validation study two new general requirements have been raised concerning virtualized CTs:

Ideality. The requirement of ideality focuses on the best possible implementation of needed artifacts, materials or interactions that are part of the original CT.

Usability. The usability of a system is a well-known aspect of the development and evaluation of information systems. Without given usability, the said system will not be used, even if it fulfills its goal. For this purpose, the System Usability Score is a proposed methodology as part of the evaluation [19].

Concerning the process of the validation the use of an example problem was necessary but the validation with an actual development problem a team faces is an important next step.

6. Conclusion and Outlook

This contribution provides insight into the possibilities and challenges of transferring CTs into virtual application. Although the results of the preliminary study did not raise newly found requirements for CTs, they were coherent with the underlying literature. Additionally, two new requirements were raised from the results of the validation study (RQ1). The application of the chosen DIN standard led to the virtualization of the TRIZ-Box within the VR medium (RQ2). The validation showed that the developed VR-TRIZ-Box contributes to the ideation of possible solutions in the context of TRIZ. The current state of the VR-TRIZ-Box, however, only supports setups in a local network and therefore only simulates its application in distributed teams. Future iterations should include the implementation of documentation tools and the transfer to online networks (RQ3).

Follow-up research questions should concern the improvement of the VR-TRIZ-Box prototype to include complete documentation and a possibility for vocal communication that is suitable for an actual distributed application. Moreover, the effect of other variables, like the design of the virtual environment on the user should be examined. Furthermore, the VR-TRIZ-Box shows how 3D representation can successfully convey CTs in a virtual environment. Therefore, it may be important to evaluate whether VR is the optimal medium or whether virtual CTs can be implemented in existing virtual environments, e.g. virtually augmented desktops using XR headsets like the upcoming Apple Vision Pro or Microsoft's HoloLens (RQ4).

The validation study shows, that the transfer of the TRIZ-Box into virtual application was successful but that the possibility for stimulation of the tactile sense is still needed. Additionally, the technique of TRIZ-Box itself needs adaptation to ensure the same quality as a site-bound application. Special attention for the adaptation should be given to the transmission of technical understanding. Furthermore, the positive effects that lead to the participants sensing a better representation in VR need to be studied to e.g. set the focus on what is leading to this perception.

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