Software Engineering for AR systems considering User Centered Design Approaches

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ABSTRACT

Technologies like augmented reality have the potential to support teams in their everyday working environment. In this paper, we present a user centered design approach for defining requirements based on a taxonomy for augmented reality systems. Therefore, we first go into detail of the taxonomy. Afterwards we present requirements engineering based on information about the context, user, and task of an AR system. According to this information, we will gather new requirements by inducing them into the taxonomy und describe how they can be used in a user centered design process. Finally, we will present a use case based on a water treatment simulation and map the previously derived requirements to the system. Additionally, we will describe two user studies to evaluate an ambient awareness tool, generated due to those requirements. Our work shows, that the gathered requirements can be used in an early stage of the user centered design as well as after the stage of usability testing to serve as comparative variables for further usability analysis. Additionally, in terms of the user centered design process, we developed a first prototype of the ambient awareness tool, which will be evaluated in future work.

KEYWORDS

Augmented Reality, Teamwork Processes, Taxonomy, Dispersed Team Members, User Centered Design, Ambient Awareness

1 Introduction

Augmented Reality (AR) technology can be utilized for various types of applications. For example, AR technology can be used for visualization of complex data as presented in [27] or to support the user with remote assistance to solve problems with a vehicle [12]. Many of those applications are designed for use by a single user only. New emerging AR hardware (for instance the Microsoft HoloLens [21]) and sensor technologies, such as depth sensors, cameras, gesture and voice recognition in combination with 3D rendering, can lead to a variety of new applications, especially for spatially dispersed working teams. The development process to create such multi-user systems may follow classic software engineering methods, such as shown in the brought research field of engineering of interactive systems [36]. Additionally, tools and methods used for engineering of interactive systems can be found, such as formal modeling approaches [37]. However, various factors must be considered: the environment, in which the users are located, the interaction techniques suitable for such a context, like gesture, voice or gaze control, and multi-user collaboration and cooperation. These factors might lead to a new type of requirements, which need to be addressed when designing AR-based multi-user systems. Especially the user and his needs have to be included in a very early stage of the development process to create user-optimized and intuitive AR systems [1].

To address the AR-specific aspects in the development of such systems, we present an extended user centered software design approach, which includes and is based on a taxonomy that focuses on the use of AR-technology in everyday teamwork scenarios. By means of a use case, we demonstrate the applicability of the developed approach. In this use case, an AR system is used for timely synchronization of spatially dispersed team members in a technical control room scenario [14]. This paper presents a first conceptual design of ongoing research work in terms of engineering methods for AR systems in everyday work context.

2 Taxonomy

From a psychological point of view and in line with the sociotechnical approach [for instance 6, 34], the development of technical systems in general and AR systems in particular, requires to consider technological and social aspects as mutually interacting factors [35]. Neglecting the specific task or work process for which the system is developed and/or the specific social context where the new technology is to be deployed, can lead to a mismatch between user demands and technological benefit of the system [28]. As the implementation of new technological systems in work environments aims at improving the team and/or task performance, one first step in the development process is to generate an understanding of the underlying team-work requirements and team-work skills [28] before determining the system capabilities.

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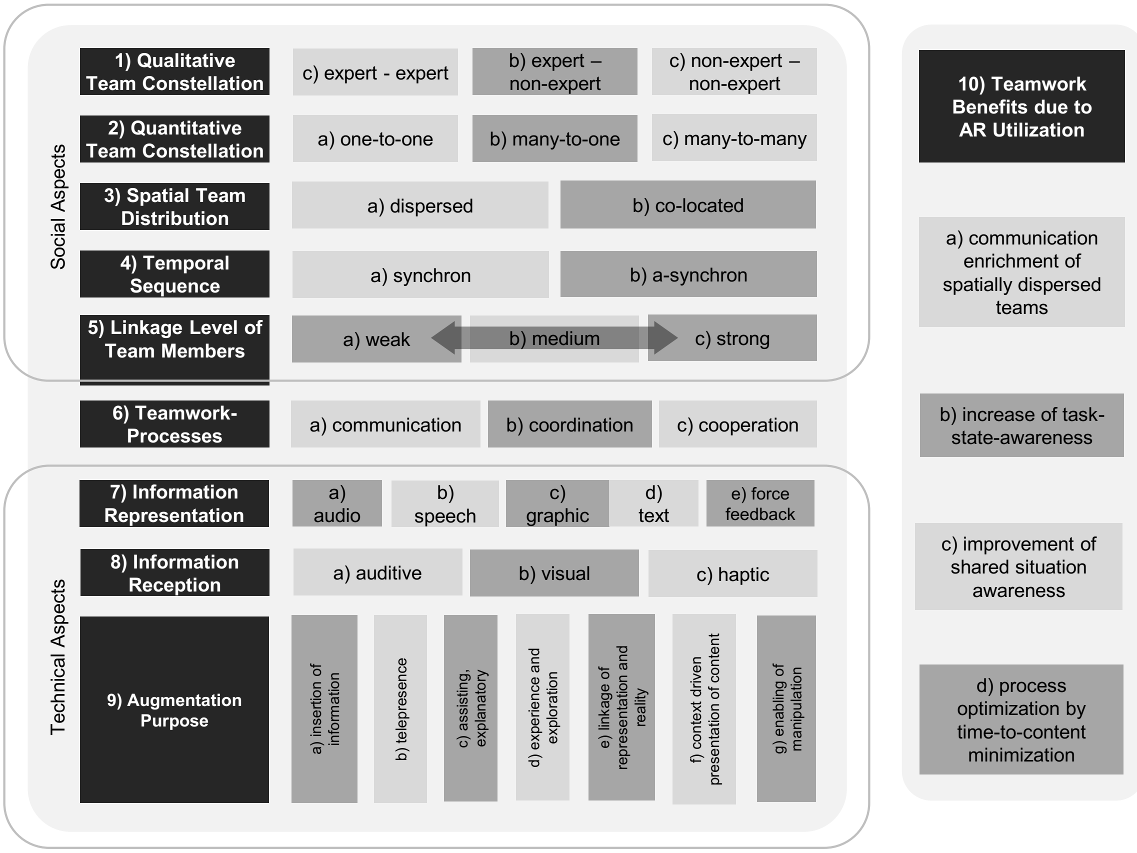

Figure 1: Taxonomy by Thomaschewski, Hermann & Kluge [33]

Therefore, designing new AR systems should be based on the analysis of the specific social context, encompassing individual determinants of the team-work processes and the team itself [14]. This enables the system's design to achieve both: the utilization of a technology that matches the team constellation and needs (i.e. team-technology fit) as well as the work-process- and task-related requirements (i.e. work-process- and task-technology-fit).

A theoretical approach that takes this into account is the psychologically based taxonomy presented by Thomaschewski, Herrmann & Kluge [33]. Building on the results of a thoroughly conducted literature research in the field of Computer Supported Cooperative Work (CSCW) and organizational psychology, the authors define four dimensions: *social aspects, technical aspects*, *teamwork-processes* (as interface of social and technical aspects), and *teamwork benefits due to AR utilization* (Figure 1).

The dimension *social aspects* serves for classifying the determinants of the specific social context in which the system is to be implemented. Thus, this part depicts the baseline in the development process, as it classifies determinants like team constellation, strength of linkage level between the team members or spatial team distribution. The dimension *teamwork-processes* represents the link between the social and technical aspects and can be used to classify specific teamwork processes which should be supported by an AR system.

In accordance with the model of an idealized teamwork process presented by Hagemann & Kluge [10], the *teamwork-processes* dimension differentiates between communication, coordination and cooperation. As already stated, to attain the best possible team- and task-technology-fit, it is crucial to initially define the determinants of the specific social context and the specific teamwork processes. Hence, the social system part of the taxonomy, comprising the social aspects of the team and the teamwork process, represents the baseline, on which the dimension *technical aspects* can be applied to infer appropriate technical features. This part of the taxonomy classifies how the AR-based information can be represented for the user (for instance force feedback or text), how the AR-based information can be received by the user (for instance haptic or visual), and the purpose of the augmentations to be implemented (for instance context driven presentation of content or insertion of information).

The fourth-dimension *teamwork benefits due to AR utilization*, distinguishes properties, which can lead to improved team performance. The taxonomy proposes four different underlying processes, that can be enhanced by appropriate AR systems: communication of spatially dispersed teams [3, 7, 19], task-state-awareness [14, 16], shared situation awareness [9], and time-to-content-management [32]. Taken together, the taxonomy pursues the objective of describing specific teamwork situations to choose appropriate team- and task-specific augmentations based on a user- and task-centered design perspective.

3 Taxonomy-Induced User-Centered Design Process

According to the previously described taxonomy, a user centered design (UCD) process will be introduced below. Therefore, in a first step information about the context, user and task of the AR system is discussed, which follows general principals of the design of interactive systems [5, 26, 30] (Section 3.1). According to this, requirements will be extracted from the taxonomy by instantiating it with the related information (Section 3.2). These requirements will then be transferred into a user-centered design process focusing on the development of AR-based systems for teamwork (Section 3.3).

3.1 Requirements Engineering

To generate requirements for an AR system, the context needs to be considered, in which the user is using the application. Context in this sense can be defined by the physical environment in terms of different surrounding conditions like location or infrastructure and the human factors, including the social environment [30]. A work environment itself can have many characteristics which can lead to different requirements for AR systems: The user can work seated or non-seated in a building or in outside environments. Also, surrounding conditions like brightness or noise are relevant factors to be considered in the requirements analysis. Alike, the use of physical tools or the liberty of action in a physical environment either indoor or outdoor needs to be taken into account. Beside these factors, auxiliary properties based on organizational structure [24] can be identified. Work context and tasks often require users to work in collaboration with others. This team consist of various types of experts or non-experts, where each team member may be part of a different department. Thus, every member can have a distinct background knowledge of the application field as well as a specific role in the team. However, all team members share a common goal. Additionally, the social relationship between users must be considered, such as boss-employee relationships or task-related differences. When it comes to the factor of time, additionally characteristics in terms of synchronous and asynchronous scheduling should be considered for the generation of requirements (cf. the CSCW matrix [2]). Considering the user, an AR system depends on the characteristics of the human cognition and the human body. The latter address the extremities like arms and legs but also the properties of eyes, head or voice of the user. Additionally, physical disabilities need to be considered. For instance, if an application requires the interaction with 3D geometry based on hand movement, the system should consider disabled users and provide the appropriate functionality for an alternative interaction [22]. Additionally, the mental and cognitive characteristics, such as skills, knowledge, shared knowledge with other team members and capacity for teamwork must be considered when designing applications for AR. In general, various HCI approaches like personas or focus groups can be used to describe the user or user groups [8]. For example, a persona describes a fictive user including his work goals, professional background, as well as his motivation at work.

To instantiate the taxonomy and defining requirements, the user's task must be characterized. A task is typically goal driven, which can also include sub-goals. These goals can be reached by performing different system operations. Task related operations require either problem solving or routine cognitive skills from the user and are executed in sequence or in parallel [13]. Additionally, the computer system task, which addresses the system behavior towards the user, can be divided in a passive-system and active-system task. In passive-system tasks, a computer system waits on user input in contrast to active system tasks, where the user must react to system changes and notifications.

3.2 Gathering Requirements from the Taxonomy

Based on the presented characteristics of work context, user and task, we now induce this information into the taxonomy and extract requirements for an AR system to be used under these conditions. Thus, it needs to be considered that these factors can overlap and influence each other. For instance, if the context is given by a technical control room and the task is to manipulate various buttons, it depends on the user what kind of output the system is supposed to generate as feedback. If the user is blind, the system should generate speech output instead of showing visual information. Additionally, the input modalities need to address this specific user needs, too.

3.2.1 Qualitative Team Constellation. The first part of the social aspects in the taxonomy is addressing the qualitative team constellation. This can be specified by the context and the user of the system. Depending on the knowledge, the user can be an expert or a non-expert in the field of application. Hence, the team can consist of only experts. A non-expert team constellation is also strongly related to the users' knowledge. A non-expert to expert constellation can occur if users of different knowledge levels are involved. The latter may be the case in tele-maintenance where a remote expert is supporting a local technician through a complex maintenance task [22]. Thus, an AR system needs to take the knowledge level of every user into account, who uses the application, such that appropriate information and interactions can be provided.

3.2.2 Quantitative Team Constellation. In contrast to the qualitative constellation, the quantitative constellation is additionally depending on the task, which the users must perform. If the task requires multiple operations with more than one user required, the team will have a many-to-many or a many-to-one constellation. Otherwise, a one-to-one constellation is present. In case of many-to-many or many-to-one situation, the system should support multi-user interactions to accomplish this aspect.

3.2.3 Spatial Team Distribution. In case of multi-user interaction, it has to be considered, that the spatial distribution of the AR system depends on the task and the context of use. Remote collaboration (for instance at several locations of a company) requires a dispersed team constellation, whereas working on the same physical object in the same room on a specific task, a co-located constellation needs to be supported by the system. AR systems designed for dispersed usage may have to support communication between the users in terms of voice or gestures, caused by spatial distribution.

3.2.4 Temporal Sequence. In the context of different locations spread worldwide, an asynchronous time schedule has to be considered. In this case, the system must provide information about the actions of every involved user in the past. Systems for co-located scenarios need to share their coordinate systems as well as should reduce latency to a minimum.

3.2.5 Linkage Level between Team Members. The next aspect of the taxonomy is the linkage level between team members. Here, a strong linkage level is accomplished if team members know each other and worked together previously. If that is not the case, the system has to provide suitable and enough information for the team members to enable successful cooperation or collaboration. The less the users know about each other and the workflow, the more information must be provided by the AR system.

3.2.6 Information Representation. The three technical aspects of the taxonomy start with the type of information representation in AR systems. This highly depends on the context, user and task. If the user is working in an industrial plant in a loud surrounding, speech output might not be the best choice to present information. Graphical representations, like texts or images, can be linked to the various operations and stages in an active system task as presented in [15].

3.2.7 Information Reception. In contrast, speech output would apply to the auditory reception while haptic feedback is perceived, for instance, through physical objects. In this case, the user can interact with vibrotactile stimuli originating from force feedback hardware. This part of the taxonomy is linked to the type of information representation. Therefore, the system needs to consider the human perception when deciding which output should be presented.

3.2.8 Augmentation Purpose. Depending on context and task, the provided augmentation can have different functionalities. For instance, if the user is wearing an HMD in a museum, the information needed can be augmented over objects. This would concern the functionalities “Insertion of Information”, “Assisting, Explanatory” and “Linkage of representation and reality”. According to the taxonomy, different requirements can be derived for these types of augmentation: The system should provide an appropriate level of qualitative and quantitative information. For instance, in case of telepresence, it should consider a suitable representation of other users. For assistance, the information representation should not interrupt the user from interacting with his environment. Also, for linking information with the physical environment, the AR system must provide technologies for an accurate tracking of the environment and a good visualization of the provided augmentation. Furthermore, the system has to offer suitable interaction techniques to manipulate the environment and the artificial objects.

3.2.9 Teamwork Processes. To link the social and the technical part of the taxonomy, teamwork processes can be characterized by the considered context and task. A cooperative teamwork process is given, if two or more team members are working towards similar goals that are positive interdependent [4]. Thus, the system has to support the users by providing functionalities, so that each user can reach its personal goal. Coordination instead requires the system to support the team members by balancing task related activities and resources [29]. Communication processes envelope the exchange of information as well as the sharing of perspectives and are not restricted to verbal communication. In the context of teamwork processes, communication can be regarded as both, a stand-alone process as well as a requirement for coordination and cooperation. Therefore, the AR system needs to support suitable possibilities of communication between all team members.

3.2.10 Teamwork Benefits due to AR Utilization. In addition to the presented requirements, the taxonomy defines four categories of usefulness for teamwork under consideration of AR technologies. Depending on the defined requirements that are based on the context, user and task, different categories will be relevant for a specific system design. For instance, let us assume that several users work spatially dispersed as a team in a synchronous work environment on an expert-to-expert basis and with a weak linkage level between team members. Thus, an AR system with graphical, textual and audio information representation, which offers explanatory functionalities including insertion of information, may lead to enhanced communication between dispersed working team members.

3.3 Using Taxonomy Requirements in User Centered Design Processes for AR-based Systems in everyday Work

The term “User Centered Design” was first introduced in the 1980s by Norman and Draper [23]. In common software development processes, which are using UCD approaches, the user can be involved in different stages of the iterative design cycle [26]: at the beginning, in an early stage before any code is written, in the mid-

Technique	Purpose	Stage of the Design Cycle
Background Interviews and questionnaires	Collecting data related to the needs and expectations of users; evaluation of design alternatives, prototypes and the final artifact	At the beginning of the design project
Taxonomy based Requirements Engineering	**Induce collected information into the taxonomy and gather requirements**	**At the beginning of the design project**
Sequence of work interviews and questionnaires	Collecting data related to the sequence of work to be performed with the artifact	Early in the design cycle
Focus groups	Include a wide range of stakeholders to discuss issues and requirements	Early in the design cycle
On-site observation	Collecting information concerning the environment in which the artifact will be used	Early in the design cycle
Role Playing, walkthroughs, and simulations	Evaluation of alternative designs and gaining additional information about user needs and expectations; prototype evaluation	Early and mid-point in the design cycle
Usability testing	Collecting quantities data related to measurable usability criteria	Final stage of the design cycle
Interviews and questionnaires	Collecting qualitative data related to user satisfaction with the artifact	Final stage of the design cycle

informs & supports

validate against

Figure 2: Involving users in the extended design process [25]

point of development, for example, to evaluate a prototype, and in the final stage of the design cycle. In each stage, different techniques can be used to gather information about the users and their needs. At the beginning of the UCD process, different background interviews and questionnaires can be conducted to collect user specific data and to evaluate design alternatives and prototypes [1]. In this stage, different requirements extracted from the taxonomy (as discussed above) can be used to support the evaluation process. Figure 2 (first introduced in [25]) presents, at which point in time the taxonomy based requirements engineering approach can be included in the UCD process. Additionally, this approach can support or inform other parts of the UCD and is being validated again in the stage of usability testing.

The information about the qualitative and quantitative team constellations should be considered in the first design attempts, due to the differing knowledge and shared knowledge levels of the users. Additionally, the interaction techniques for multiple user setups need to be considered in close relation to the representation of information to fit the information reception of the users.

In an early point of software design, mostly in the stage of requirements analysis, different HCI techniques like focus groups, sequence of work interviews, card sorting, task scenarios and sorting, as well as essential use cases or ethnographical observation of the user are used to gather more information [1, 20]. Focus groups, card and task sorting or essential use cases are used to reveal potential issues and requirements. Sequence of work interviews and questionnaires will help to collect data regarding the sequence of work to be performed with the AR system. With ethnographical observations, information about the environment in which the AR system will be used can be gathered. At this point, requirements concerning spatial distribution, temporal sequence and linkage level of team members should be considered to characterize the environment in more detail to eventually extract relevant requirements for the system design.

Within the final stage, evaluation processes like usability tests or additional questionnaires are popular ways to retrieve important quantities and qualitative data about the user satisfaction and system usability [26]. At this point, the dimension *Teamwork Benefits due to AR Utilization* of the taxonomy should be considered. The classes of this dimension can be regarded as dependent variables and thus serve as benchmarks or comparative values for further quantitative usability analyses. In addition to this type of data collection approach, the users can be actively integrated into the development process in a so called *participatory software design approach* [1]. Thus, they can be seen as co-designers who co-determine the design process. For instance, end-users can be equipped with a selection of icons and graphical interaction elements (buttons, checkboxes, progress bars, etc.) to create their own UI prototypes according to their imagination. This is done by prototyping techniques like for instance paper based mockups [17] or card sorting [31]. Additionally, by the use of think aloud techniques, experts may be able to create additional software requirements.

4 Use Case: AR for Timely Synchronization of Spatially Dispersed Team Members

In the following use case, we will first describe the scenario based on previous investigations by [14, 15, 38] (Section 4.1). In the next step, we will gather requirements for the AR scenario (Section 4.2). These software requirements will be used as a part of the UCD process described in Section 3 to develop a prototype of the ambient awareness tool (AAT) (Section 4.3). To validate those requirements, we plan to conduct two empirical user studies (Section 4.4).

4.1 Scenario

The following scenario describes a simulated team-work-framed production setting which is based on previous investigations of the Wastewater Treatment Simulation (WaTrSim / AWASim) [15] and the gaze guiding tool (GGT) [38]. The general task in WaTrSim is to start-up the simulation in a very efficient way in order to maximize the amount of purified water and gas and to minimize the amount of wastewater. The start-up is defined as a Standard Operation Procedure (SOP; [15]) which comprises 13 fixed steps, like for instance changing flow rates by manipulating valves of the plant or waiting until specific fill level of tanks have been reached. In order to accomplish the start-up as successful as possible, the operator/ user must consider the right sequence of the SOP as well as the timing of her actions during the SOP. The execution of the tasks in the correct sequence thereby is supported by the GGT [14, 38]. The GGT basically is an AR-based superimposition using the HoloLens [21], that cues the part of the simulated plant that is to be manipulated, so that the user's gaze is guided to the right place of action.

In the present use case, we assume that two team members are spatially dispersed without any possibility to communicate orally. Both team members execute the start-up SOP concurrently as an individual task (IT) and additionally as a team task (TT). More precisely, each team member completes all 13 steps individually (IT) and a subset of steps in parallel interdependently, so that each team member undertakes certain steps of the TT. Thus, in the TT the start-up SOP is executed once cooperatively as team. To achieve a good timing, the operators must orchestrate their IT-steps in accordance with their TT-steps (and vice versa). To do so, a prototype of the AAT according to the gathered requirements will be implemented and evaluated (for evaluation see Section 4.4) in future work.

4.2 Gathering Requirements Using the Taxonomy

The requirements gathered in Section 3.2 can now be mapped onto the use case of WaTrSim. The first requirement according to the qualitative team constellation defines that the system should take the level of knowledge of every user into account. The user of WaTrSim, with a non-expert to non-expert constellation, haven't used the simulation before and do not know the exact information about every step in the SOP. According to that, the system must provide information about each step at a specific point in

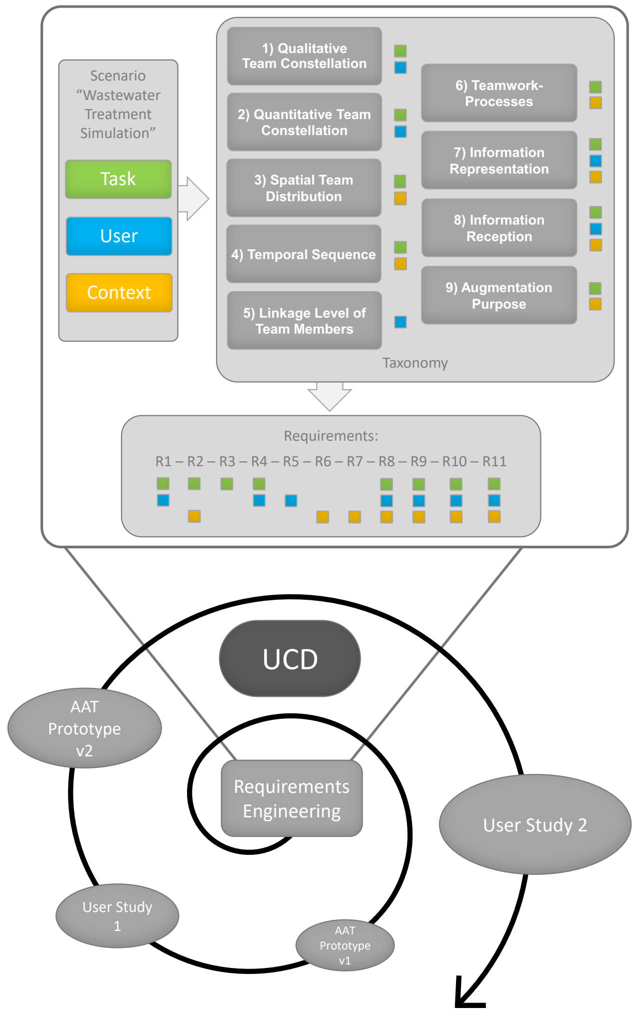

Figure 3: Requirements Engineering in UCD Process

time for efficient task execution (Figure 3; R1). The quantitative team constellation requirement states that the AR system should provide multi-user interactions. Accordingly, to the one-to-one team constellation, the system has to support the transmission of task or AAT related messages between the users (R2). The spatial dispersion of the team members leads to the requirement of communication between the users. In this case, the communication is limited on information provided by the progress of the team members in TT (R3). Additionally, the tasks of the simulation will be executed synchronously. This also requires, that the TT is synchronized for each user (R4). The linkage level between the users is weak. They do not know each other and never worked together before. Thus, the AR system must provide enough information, such that every user knows exactly what to do at every moment (see R1).

The information representation for WaTrSim is based on graphical and textual augmentation. This leads to the requirements that the text must be readable (R5), the graphical information need to be located at a predefined position on IT as well as TT (R6), and the brightness needs to be set to a high or low level, depending on the lightning conditions in the room and the display brightness of the HoloLens (R7). The information reception with WaTrSim will only be visual. According to that, users with color blindness have to be considered when designing the system (R8). The last aspect of the taxonomy, the augmentation purpose, can be defined by insertion of information, assisting and explanatory, linkage of representation and reality and context driven presentation of content. This leads to the following requirements. The AR system must provide a suitable level of qualitative and quantitative information (R9), as well as scheduled information representation (R10). Additionally, the objects presented by the HMD need to be tracked accurately to the real-world objects in terms of the projector's outputs (R11).

4.3 Tool Development according to Requirements

As a part of the UCD process, the gathered requirements can now be used to help developing a first prototype of the AAT to validate the superimposed elements (Figure 3). According to the requirements, the user must know, what kind of action he has to perform in the next step. Thus, we assume that the tool should show three elements as 2D graphics beside the task (Figure 4: Left Panel). Those elements can also be differed by color blind test user caused by their shapes (R8). The highest symbol represents the next object, which the user has to interact with in the opposite task (R1, R2, R3). We assume, that three symbols are enough and not overstrain the user's attention. Messages between the team members are represented by animations and progress bars (R3, R4, R8, R9, R10) (according to Figure 4: Left Panel). For instance, when a user is finished with a subtask in the TT, the other user gets informed by an animated symbol. WaTrSim includes the following controllable elements: heater, tanks and valves. Thus, the tool provides one representation for each element. With support of the readable GG (R5), we assume to prevent an information overflow for the user. As described in Section 4.4.1, we will evaluate the usability of the AAT, including the position of the elements. Therefore, the elements are accurately tracked by the system and projected at the right place in the room (R6, R11) (Figure 4: Left Panel). Also, according to the brightness of the beamers, the brightness of the AAT elements is set to a sufficient level (R7).

4.4 Empirical Validation through User Studies

To initiate the next level of development in the UCD, empirical validation of the AAT is necessary (Figure 3). Therefore, two user studies are planned. The first study investigates the usability and the user experience (UX) of the AAT, thus aiming at developing a most appropriate AR interface. The second study then focuses on gathering general insights in the effects of the AAT on the temporal coordination of spatially dispersed teams. All experiments are planned to be conducted with the above described WaTrSim and the Microsoft HoloLens as AR headset.

4.4.1 Study 1: Evaluating Usability and User Experience. Study 1 is designed as a two-part expert evaluation, comprising a laboratory study (part 1) and a follow-up online survey (part 2). In this

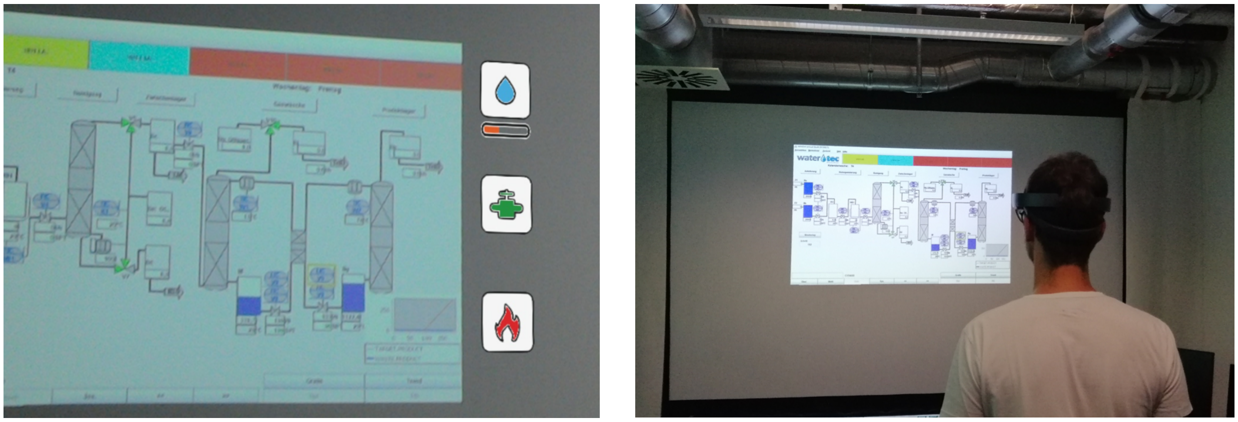

Figure 4: Ambient Awareness 2D Graphics (Left Panel) and Participants View on WaTrSim (Right Panel)

case, experts are defined as students from the engineering department who already participated in another WaTrSim experiment and thus are already trained in operating the simulation. To evaluate the usability of the ambient awareness interface, we show our participants different object properties via Microsoft HoloLens while they are looking at an on-wall projection of WaTrSim. The participant’s task thereby is to choose the respective property most appropriate in their opinion. In total, we defined nine object properties and predefined the presentation order as follows: *level of abstraction*, *object size*, *object distance*, *object position*, *object-simulation distance*, *progress bar position*, *critical process state indication*, *object background*, and *object dimensionality* (2D vs. 2.5D). That means, if the participant chooses abstraction level one, then the condition *object size* is displayed with abstraction level one objects. Assuming the participant chooses object size medium, the next condition *object distance* is displayed with abstraction level one objects with medium distance between the objects and so on. This interdependent choice paradigm results in an individually assembled AR-interface for every participant. By means of descriptive parameters and a cluster analysis, we then define a small set of possible interface configurations with the data gathered in part one of the first study. Thereafter, part two of the first study serves for evaluating the UX. For this purpose, we ask the participants who participated in part one of the study to evaluate the UX of the previously generated interface configurations by means of the AttrakDiff [11], the scales attractiveness, dependability, stimulation, and novelty of the User Experience Questionnaire (UEQ,[18]), and an adaptation of the General Ambient Awareness Questionnaire developed by Weyers, Frank, Bischof & Kluge [38]. The questionnaires and the interfaces will be provided via an online survey. The interface configuration with the highest over-all UX score will be implemented in the second study to examine the effectiveness of ambient awareness artifacts on the temporal coordination of spatially dispersed team members.

4.4.2 Study 2: Evaluating the Effects of the Ambient Awareness Tool on the temporal Coordination of Spatially dispersed Teams. The second user study aims at investigating if the application of the previously developed AAT can support temporal coordination of spatially dispersed team members in general (compared to no support by an AAT), and if there are differences in the amount of enhancement between 2D vs. 2.5D and static vs. dynamic process state superimpositions. The general set-up of the experiment is based on the scenario described in 4.1: for each run, we invite two participants who form a team. In order to emulate spatial dispersion, the team members are located in separate rooms without the opportunity of oral communication. Their task is to execute the 13-step start-up SOP described above concurrently as IT and as TT. For a distinct representation of IT and TT in each room, two WaTrSim process screens are projected on separate walls at a 90-degree angle. Thus, the team members cannot gather task state information about both tasks at the same time. Therefore, we assist each team member with AR-displaying information of the process state of the task (AAT), which currently cannot be seen.

For the evaluation, we will use a two-factorial experimental design with four experimental groups: 2D / 2.5D superimpositions (Factor 1) and static/ dynamic superimpositions (Factor 2), and an additional control group (no superimpositions). The between-group effects will be calculated by ANOVA.

5 Discussion and Future Work

We have presented a UCD approach, based on a taxonomy for AR systems. Induced with user, context and task related information, we accomplished gathering first requirements for this UCD process out of the taxonomy. Additionally, we defined, in which stage of an UCD process those requirements can be used. We can conclude that the new requirements can be used in early stages of the process and after the stage of usability testing to serve as comparative variables for further usability analysis. We also successfully mapped those gathered requirements to a use case of WaTrSim and according to that, developed a first prototype of the AAT.

In the future, we will focus our research on developing the AAT for the second study. Additionally, we will develop more generalized UCD approaches specifically focusing on AR application development, which includes a sophisticated requirement engineering process. The latter may include basic requirements specific for AR, which are gathered from common software engineering processes.

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