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A Toolkit to Evaluate and Characterize the Collaborative Process in Scenarios of Remote Collaboration Supported by AR

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Abstract

Remote collaboration using Augmented Reality (AR) has enormous potential to support collaborators that need to achieve a common goal. However, there is a lack of tools for evaluating these multi-faceted contexts, involving many aspects that may influence the way collaboration occurs. Therefore, it is essential to develop solutions to monitor AR-supported collaboration in a more structured manner, allowing adequate portrayal and report of such efforts. As a contribute, we describe *CAPTURE*, a toolkit to instrument AR-based tools via visual editors, enabling rapid data collection and filtering during distributed evaluations. We illustrate the use of the toolkit through a case study on remote maintenance and report the results obtained, which can elicit a more complete characterization of the collaborative process moving forward.

Index Terms: Remote Collaboration—Augmented Reality—Evaluation Toolkit—Characterization Collaborative Process;

1 Introduction

Remote collaboration requires that collaborators establish a joint effort towards aligning and integrating their activities in a seamless manner. In this vein, Augmented Reality (AR) has been explored to ensure collaborators can build a shared understanding, i.e., serve as a basis for situation mapping, allowing identification of issues, making assumptions and beliefs visible, thus leading to improved alertness, awareness, and understanding of the situation [2].

Thus far, most research efforts have been devoted to design and explore the enabling technology. However, for the field to advance into more in-depth studies regarding the nuances of supporting collaboration through these technologies, it is paramount to improve how evaluation is conducted [2, 5, 6]. Dey et al. suggests the existence of *"opportunities for increased user studies in collaboration"* and the need for *"a wider range of evaluation methods"* [1]. In addition, Ratcliffe et al. reports that *"remote settings introduce additional uncontrolled variables that need to be considered by researchers, such as potential unknown distractions, (...) participants and their motivation, and issues with remote environmental spaces"* [7]. In this context, current frameworks are not adequate to collect and store data remotely, as well as describe how collaboration mediated by AR happens [1, 2, 5, 7]. Therefore, conduct thorough collaborative evaluations is paramount to retrieve the necessary amount of data for more comprehensive analysis. Hence, provide a better perspective on the different factors of collaboration supported by AR.

In what follows, the *CAPTURE* toolkit is presented, allowing to instrument AR-based tools for filter and rapid data collection in distributed scenarios, leading to a more complete characterization of the collaborative process. Then, the results of a distributed user study are discussed, aimed at assessing the feasibility of using the toolkit on a scenario of remote maintenance supported by AR.

2 Toolkit for Distributed Evaluations using AR

This section describes *CAPTURE*, a toolkit for distributed multi-user data collection and analysis in distributed scenarios (Figure 1), following prior work [3–5]. The toolkit can be integrated into AR-based tools via visual editors, i.e., with minimal need for programming skills, allowing to collect information on selected dimensions of collaboration. For example, it is possible to drag and drop pre-defined prefabs and scripts into Unity 3D projects, which can be edited according to the evaluation scope. In detail, the toolkit enables data gathering regarding *individual and team profile*: demographic data, knowledge of other collaborators, participants background, emotional state, experience with AR technologies and remote tools; *collaborative context*: details on the task and environment, like the number of completion stages, resources available or the amount of persons, movement and noise in the space; *list of events*: task duration, augmented content shared and received, relevant occurrences; *interaction with the collaborative tool*: duration of the collaborative process and specific events, e.g., when creation of augmented content is started or completed, number and type of interactions;

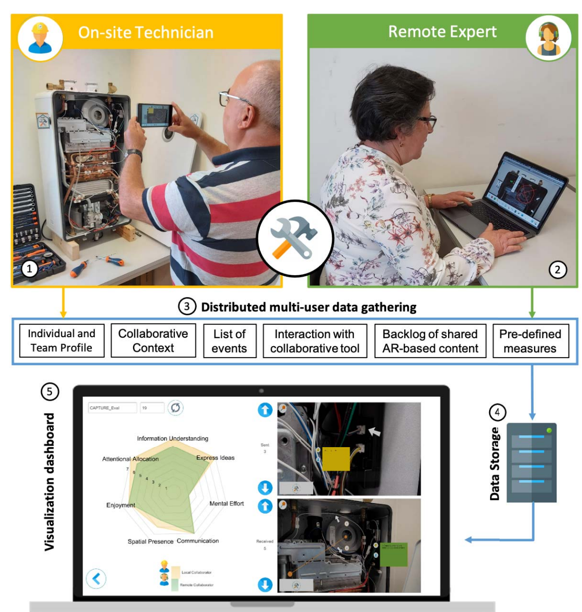

Figure 1: Scenario of remote collaboration using an AR-based tool instrumented with the *CAPTURE* toolkit: 1- On-site technician requiring assistance; 2- Expert using AR to provide remote guidance; 3- Distributed multi-user data gathering; 4- Evaluation data storage; 5- Visualization dashboard for analysis of the collaborative process.

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backlog of shared AR-based content: captures of the augmented instructions being shared; *pre-defined measures*: characteristics like spatial presence, communication, enjoyment, mental effort, information understanding, attention allocation and ability to express ideas. During this process, all data gathered is stored in a central server to be used for post-evaluation analysis by the researchers through a visualization dashboard. It enables data preview regarding the collaborative process of a particular team or comparison between a set of teams or different AR-based tools.

The toolkit was developed using Unity 3D, based on C# scripts. Communication between each instance was performed over Wi-Fi through specific calls to a central server created using PHP scripts.

3 User Study

A user study was conducted to assess the feasibility of using the proposed toolkit during distributed evaluations. We focused on a case study where an on-site technician using a handheld device had to perform a maintenance procedure while being assisted from a remote expert using a computer on how to replace a component connected to several others. Hence, the proposed toolkit was integrated into an existing AR-based tool using stabilized annotations to create a common ground, following prior work [Omitted for review].

Participants were instructed on the setup, the task, and gave their informed consent. Then, they were introduced to the AR-based tool and a time for adaptation was provided. Participants would act as on-site technicians, while a researcher was the remote counter part. At the end, an interview was conducted to understand participants opinion towards the collaborative process supported by AR. All measures were followed to ensure a COVID-19 safe environment.

4 Results and Discussion

We recruited 26 participants (9 female - 34.7%), whose ages ranged from 20 to 63 years old (M = 33.1, SD = 11.7). With respect to *individual and team profile*, 14 participants had prior experience with AR and 24 with collaborative tools. The emotional state at the end of the study varied among joy (61.6%), surprise (15.4%) and excitement (23.0%). With the exception of 1 team, all collaborators had knowledge of each other prior to the study.

As for the *collaborative context*, sessions lasted 28 min on average (SD = 3.03). The task was a defined-problem with 3 completion stages, forcing communication in a continuous way while acting alternately (reciprocal interdependence), taking 12 min on average to complete in an indoor environment with controlled illumination conditions and reduced noise. The on-site participant needed to use different hand tools to perform the procedures with low physical movement. Concerning *the collaborative tool*, it provided a similar level of user actuation for both team-members, having identical features to view, create, share and interact with augmented content.

On average, each participant captured 4 screenshots of the task context and each team shared 6 augmented images. With respect to frequency of using each feature, creation of personalized drawings, use of existing shapes (e.g., arrows, notes) and sorting of annotations was preferred in this order. Seeing AR annotations aligned with the task context was considered relevant to establish a shared understanding and obtain a better perception of where to perform a given action, allowing all participants to fulfil the task with success. Regarding *pre-defined measures*, participants rated the collaborative process (Likert-type scale: 1- Low; 7- High) as following: express ideas (M= 6), attentional allocation (M= 7), information understanding (M= 7), mental effort (M= 2), enjoyment (M= 6), communication (M= 6), spatial presence (M= 5). It is noticeable that CAPTURE allowed comparing different teams; e.g. teams knowing each other rated higher the dimensions: express ideas, information understanding, spatial presence, communication and enjoyment (Figure 2 - left). Contrarily, the level of mental effort was lower, suggesting the collaborative effort was smoother and easier to conduct for these individuals, when compared to the values reported by a team that didn't knew each other prior (Figure 2 - right).

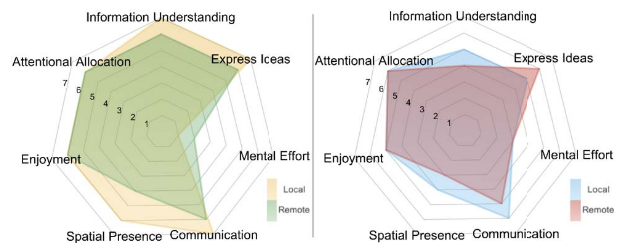

Figure 2: Collaborative process of two teams (*left - knew each other; right - don't knew each other*) during a scenario of remote maintenance using AR, based on the data gathered using the *CAPTURE* toolkit. Data displayed using a Likert-type scale: 1- Low; 7- High.

5 Concluding Remarks and Future Work

Remote collaboration using AR creates challenges to the contextualization of the actions of each collaborator and the problems/barriers they may face. This work presented *CAPTURE*, a toolkit to elicit more complete characterizations of the collaborative process through instrumentation of AR-based tools for remote scenarios. Researchers may assess a wide range of information when analyzing data and establishing conclusions. The possibility to conduct comparative analysis of distributed teams supported by AR may benefit researchers in better understanding the collaborative phenomenon. Later, we intend to study how the toolkit may be used by the community, to comprehend how it may fit their needs, leading to newer data gathering and analysis features for more comprehensive evaluations.

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