Remote Asynchronous Collaboration in Maintenance scenarios using Augmented Reality and Annotations

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Abstract

This paper presents an Augmented Reality (AR) remote collaborative approach making use of different stabilized annotation features, part of an ongoing research with partners from the industry. It enables a remote expert to assist an on-site technician during asynchronous maintenance tasks. To foster the creation of a shared understanding, the on-site technician uses mobile AR, allowing the identification of issues, while the remote expert uses a computer to share annotations and provide spatial information about objects, events and areas of interest. The results of a pilot user study to evaluate asynchronous collaborative aspects while using the approach are also presented.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Collaborative interaction—Mixed / augmented reality;

1 Introduction

Augmented Reality (AR) annotations can be used to enhance remote collaboration in maintenance contexts where know-how and additional information from professionals unavailable on-site is required [1]. A number of studies have explored different annotation features [5]. Gauglitz et al. [2] explored how to stabilize annotations using AR tracking in handheld devices, i.e., annotations appear in the same position of the shared view, regardless of the viewpoint of the live video. Nevertheless, annotations could be anchored to an incorrect object, if the on-site user changed the viewpoint of the shared view when the remote user was drawing annotations [4]. To address this, Gauglitz et al. [2, 5] proposed a manual freeze method preventing annotations from being anchored to a wrong object. This way, a remote user could manually freeze the video received from the on-site user and draw on the still video frame returning to the video, when done. Most of these studies have focused on synchronous scenarios, meaning all users can act in real time. Irlitti et al. [3] highlighted the importance of also addressing remote asynchronous scenarios, in which collaborative actions take place at different times. This presents several research opportunities, namely: 1) study persistence of annotations in the environment and their consumption at a later time, 2) how multiple annotations are related and coexist and the 3) study of temporal sorting and clustering of information.

In this paper we adopt stabilized AR annotations to address asynchronous remote collaboration in maintenance scenarios. We create a prototype, which provides the possibility to: 1) presenting spatial annotations as additional layers of information, 2) providing temporal sorting and clustering of information, 3) sharing notifications and 4) reusing previous annotations for assistance or to create documentation. The prototype was evaluated with local and remote users based on usability and usefulness in asynchronous collaboration.

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2 Collaborative Augmented Reality Prototype

Based on our literature review and the analysis of industrial needs through a focus group with 8 domain experts, in the spirit of an iterative user-centered approach, we propose the following: since on-site technicians are constantly moving, it seems adequate to equip them with easy to carry handheld devices , while also enabling annotations as augmented content. Regarding the remote expert, we focus on the use of a laptop or desktop computer to facilitate the creation of enhanced content. A prototype was created, including a tailored set of features, based on the requirements defined with our partners from the industry sector (Figure 1 and Figure 2), namely: capturing the real-world environment context; supporting communication through audio, text, image(s) or video sharing; use of various annotation features to create enhanced images (e.g., drawings, notes, hand gestures, temporal sorting of information, among others); creation of step-by-step content to assist with a specific problem, instead of sharing different enhanced images and repeating the process; reuse of annotations if the same problem occurs in another equipment, or with another team member; visualization of annotations in standard 2D setting or as an augmentation of reality; integration of notifications to increase awareness between team members.

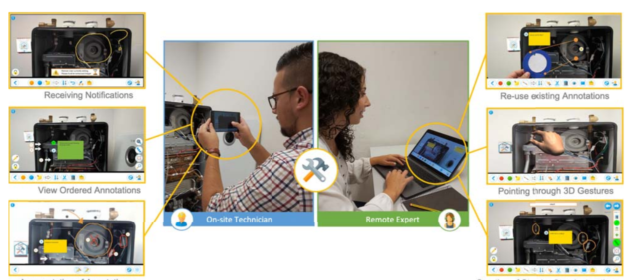

Figure 1: Example of features associated with the on-site technician (left) and the remote expert (right).

Figure 2 presents an overview of the proposed prototype for collaborative remote scenarios. When facing unfamiliar problems, on-site technicians can point a handheld device to the situation that requires assistance and manually capture (freeze) the context of the problem. Then, using annotation features, the technician can edit the captured picture, creating layers of additional information to illustrate difficulties, identify specific areas of interest or indicate questions. Next, the enhanced picture is sent to the remote expert as the basis to enable a shared understanding of the problem. When available, the expert can suggest instructions accordingly i.e., inform where to act, and what to do, using similar annotation features as before, plus some specific features to facilitate the creation of anno-

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tations. Afterwards, the on-site technician receives the annotations showing the suggestions and is enabled to follow the instructions in a hands-free setting/manner by placing/positioning a handheld device nearby. Alternatively, at any time the technician may pick up the device and perform an augmentation of the shared context, by re-aligning the spatial annotations with the real world.

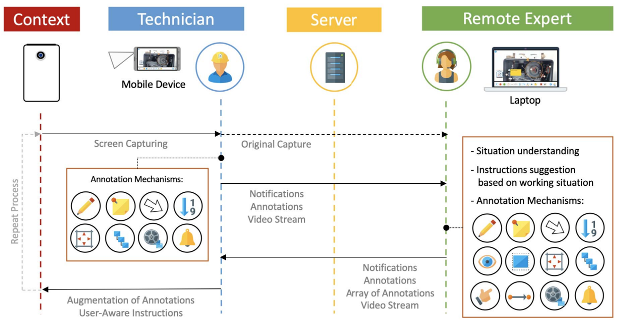

Figure 2: Prototype Overview. An on-site technician captures the real-world and annotates it. Then, shares the content and a remote expert provides instructions (using identical features). Finally, the technician views the augmented instructions and performs the intervention.

The prototype can be used on devices running Android, MAC OS, or Windows. It was developed using Unity 3D, based on C# scripts. To place the virtual content in the real-world environment, we used markers through the Vuforia library. Communication between the different collaborators is performed over Wi-Fi through specific calls to a PHP server.

3 Pilot Test and Results

A pilot study was conducted to evaluate usability and usefulness of the prototype in a real asynchronous remote setting and inform the next steps of our research towards its testing in an industrial context. As a case study, we focused on a scenario where an on-site technician had to perform a set of maintenance procedures over time requiring assistance from a remote expert. We defined asynchronously tasks based on feedback from our industry partners regarding their usual work and needs. e.g., **On-site participant:** capture the equipment and request which component must be replaced. Then, perform the instructions provided using the annotations as augmented content. These tasks focus on how multiple annotations coexist and their consumption at a later time. **Remote participant:** Instruct how to replace a component connected to several others, also advising on the use of specific tools from a large set of options. These tasks focus on temporal sorting and annotations relationships.

Task performance was collected: time needed to complete all procedures, logged in seconds by the device; number of errors; type and amount of annotations used, logged by the device and by an experimenter. Participants' opinion was also gathered through a post-task questionnaire, including: demographic information and questions concerning collaborative aspects, in order to assess usefulness and ease of use of each feature. Participants were instructed on the experimental setup, the tasks, and gave their informed consent, were introduced to the prototype and a time for adaptation was provided. Participants would act as an on-site technician or as a remote expert, while an experimenter was the counter part. While performing the tasks asynchronously, participants were observed by an experimenter who provided assistance, if necessary, and registered any relevant event. After finishing, participants answered the post-task questionnaire. We recruited 9 participants (3 female) from our University including researchers, Msc and PhD students having previous experience with AR systems and collaborative tools.

On average, each test lasted 70 minutes, including the aforementioned steps (tasks took 40 minutes to complete). Overall, participants were able to collaborate with their counter parts using the prototype. Participants found seeing AR-based annotations aligned with the real-world environment relevant and recognized it contributed to a better understanding of where to perform a given action. They consider drawing, notes, notifications and step-by-step as the most useful features, in that order. Drawing was considered versatile to address most needs in a collaborative scenario. The use of notes was considered useful to share messages, creating a richer context when combined with other types of annotations, particularly in asynchronous scenarios. Temporal sorting of annotations through the sorting feature was thought to become very useful when a significant number of annotations exists in a task with several procedures or in a large environment. Notifications were also considered relevant, in particular the inclusion of sound for alerting of information updates. All participants stated the step-by-step feature was interesting to deal with a larger set of simpler annotations (step-oriented approach) rather than a complex annotation with all the information at once. Finally, re-visiting annotations created for a specific problem, at a later time was considered interesting and could potentially minimize the need for remote assistance in some cases.

4 Final Remarks and Future Work

We explored asynchronous collaboration using AR-based stabilized annotations for remote scenarios. This work was motivated by ongoing user-centered design research with partners from the industry sector. We found that the proposed approach provides means for remote experts to collaborate with on-site professionals, regardless of their localization and time. The positive feedback by participants shows potential for merging the shared perceived realities of different professionals.This study is being expanded by planning a formal user study with domain experts to evaluate temporal sorting and consumption of annotations. We will also investigate how different notification methods can affect the collaboration process.

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