A Conceptual Model for Data Collection and Analysis for AR-based Remote Collaboration Evaluation

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ABSTRACT

A significant effort has been devoted to the creation of the enabling technology and in the proposal of novel methods to support remote collaboration using Augmented Reality (AR), given the novelty of the field. As the field progresses to focus on the nuances of supporting collaboration and with the growing number of prototypes mediated by AR, the characterization and evaluation of the collaborative process becomes an essential, but difficult endeavor. Evaluation is particularly challenging in this multifaceted context involving many aspects that may influence the way collaboration occurs. Therefore, it is essential the existence of holistic evaluation strategies that monitor the use and performance of the proposed solutions regarding the team, its members, and the technology, allowing adequate characterization and report of collaborative processes. As a contribute, we propose a conceptual model for multi-user data collection and analysis that monitors several collaboration aspects: individual and team performance, behaviour and level of collaboration, as well as contextual data in scenarios of remote collaboration using AR-based solutions.

Index Terms: Collaboration—Augmented Reality—Evaluation—Conceptual Model;

1 INTRODUCTION

Collaboration implies that collaborators establish a joint effort to align and integrate their activities in a seamless manner. Among other fields, Computer-Supported Cooperative Work (CSCW) has focused on prototyping and designing solutions for knowledge sharing between distributed collaborators, resorting, for instance, to Augmented Reality (AR) [3]. Remote AR-based solutions aim to ensure collaborators can establish a shared understanding on the virtual space, analogous to their understanding of the physical space i.e., serve as a basis for situation mapping, allowing identification of issues, and making assumptions and beliefs visible [5]. By creating a common ground environment, it can enhance alertness, awareness, and understanding of the situation, allowing interactions between geographically dispersed collaborators [1, 5].

The lack of guidelines to guide the characterization of the collaborative process, and with the growing number of solutions mediated by AR, the evaluation of these services becomes an essential, but difficult endeavor, so that research can move forward and focus on the nuances of supporting collaboration [1, 3].

Scenarios of remote collaboration are multifaceted, which means many aspects may affect the way teams collaborate. Given the novelty of the field, even when evaluation is performed, it is frequently done using single-user methods [1–3], focusing only on one team member, on the technology being used or in quantifying task effectiveness, thus ignoring the collaborative process. Trying to apply conventional evaluation techniques to collaborative solutions without adapting them can lead to dubious results, falling short to retrieve the necessary amount of data for more comprehensive analysis. Hence, if the methods used are not properly applied, the results and findings reported may be misleading or of limited value, preventing observers from gaining access to the full picture [2–4].

Therefore, it is important to conduct thorough collaborative user studies to provide additional perspective. A better evaluation process demands improved data collection and data visualization tools [3, 4], which suggests that several measures may be needed to assess the collaborators at all times, and at specific situations, aiming at obtaining a more comprehensive understanding, while reducing a typically labor intensive activity.

In what follows, we propose a conceptual model for data collection and analysis to support evaluation of remote collaboration mediated by AR. The proposed model is aligned with the goal of providing an evaluation strategy that monitors data concerning the level of collaboration, behaviour and performance of each intervening party, individual and as a team, as well as contextual data, allowing researchers and developers to characterize and report the collaborative process.

2 CONCEPTUAL MODEL FOR DATA COLLECTION AND ANALYSIS

This section describes a conceptual model for multi-user data collection and analysis (Figure 1). It resulted from literature review and sections of brainstorming between experts in the areas of Collaboration, Human-Computer Interaction, Virtual and Augmented Reality and Multimodal Interaction. We propose the use of a distributed paradigm, allowing researchers and developers to monitor individual and team performance, behaviour and level of collaboration, as well as contextual data at different locations simultaneously.

2.1 Assessment of collaboration performance

Our proposal includes 4 modules: data gathering, analysis, inspection and report. An instance of the data collection and analysis can be deployed at each location, allowing to monitor the different collaborators simultaneously and thus evaluate at the same time the individual and the global collaborative effort.

The **data gathering module** must be interconnected with all instances, receiving from them synchronized information about the task, *individual and team profiles*, *collaborative context* including the environment itself, *pre-defined measures*, as well as *custom logging*, which can be collected through the AR-based tool being used or by *external devices* if they exist. In this context, *performance measures* may include: overall time and duration of specific events, e.g., when a task is started or completed; number and type of errors; number and type of interactions; frequency of using each feature, e.g., time spent and number of annotations created; Virtual content, including when it is created, when a position and orientation changes, accuracy, etc.; screenshots of the augmented content (for

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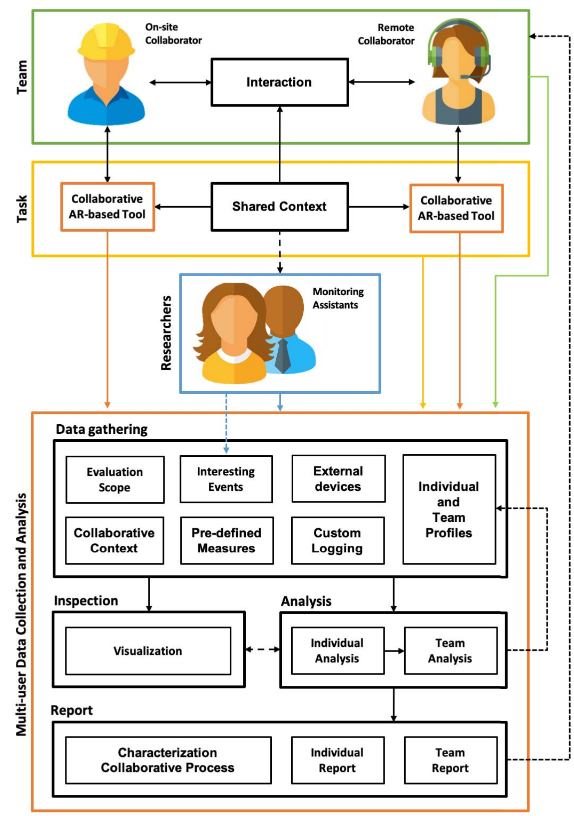

Figure 1: Conceptual model for multi-user data collection and analysis in scenarios of remote collaboration using Augmented Reality.

post-study analysis), among others. Likewise, *behaviour measures* may comprise: communication, e.g., conversation, overlap or feedback; physical movement around the environment; number and type of hand gestures; physiological variables and emotions; eye gaze; video and audio recording (for post-study analysis), and similar. Regarding *collaboration measures*, these may address the level of effectiveness; perception; interest; engagement; awareness; togetherness; social interest; enjoyment/satisfaction; mental stress, or others also relevant. Moreover, researchers overseeing the collaborative effort may use the method to register *interesting events* they detect, including the type (e.g., guide, request, express, propose, etc.) and frequency of communication (e.g., never, sometimes, often, continuously), which can be later reviewed in post-task analysis. Then, the data aggregation can be conducted, with respect to each individual and to the team, as well as the collaborative process.

The **analysis module** will be responsible for assessing specified measures, as well as create individual and team profiles. In this context, we suggest creating a visualization for post-task exploration and revision. By doing so, the module should allow visual analysis of the data as to provide insight on how collaboration occurred. With minor effort, researchers and developers may have access to a greater amount of data regarding the collaboration process, having a better grasp over the measures being collected, allowing understanding the impact of AR in a specific context of collaboration.

Moreover, an **inspection module** can use interactive tools to reconstruct the collaborative process using the collected data, allowing researchers to understand specific events in time through flexible data visualizations. The goal is to gain insight into what data exists and how it is related, which can also provide clues about relevant aspects to integrate the analysis module. For example, a default timeline can be provided together with interaction charts, video and physiological data of the team members, as well as a top-down view of their physical movement in the environment, as well as screenshots of the AR content in the specific positions they were used, thus providing means to replay sessions as they unfolded over time. In addition, a toolbox must exist, allowing selecting and filtering individual data, combinations of different measures and sets of interesting events marked by the researchers, from which they can build customized visualizations, as needed.

At the end of the analysis, two kinds of reports may be generated through the **report module**: individual and team assessment reports. These will describe the characterization of the collaborative nuances that occurred, including all interaction measures considered during the data gathering, as well as tables, graphics, and images reproducing the visualization features of the analysis and inspection modules. The outcomes can lead to improvements in individual behaviour and team collaboration in specific procedures and tasks over time.

2.2 Final remarks

The proposed model, besides providing key findings, makes available to researchers and developers a comprehensive description of relations between individuals, their interconnection as a team and how the solution affected the accomplishment of the tasks and the collaborative process. In this line, the characterization outcomes can help identify limitations regarding the collaborative tools, providing opportunities for future work in a technical level.

3 Conclusions and Future Work

A better evaluation strategy is required by the field of remote collaboration using AR, given the challenge involved in evaluate many aspects that may influence the way collaboration occurs.

We proposed a conceptual model for multi-user data collection and analysis in scenarios of remote collaboration mediated by AR. With the proposed model, it will be possible to monitor each intervening party involved in the collaborative effort at all times, and at specific situations, thus obtaining a richer set of data, leading to a more comprehensive understanding of the collaboration process.

Work on the first instantiation of the model has already started and will be applied to scenarios of remote assistance in an industry context in the near future. Later, we intend to conduct formal user studies to demonstrate how our method may lead to a richer and comprehensive characterization of the collaborative process.

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