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An Ontology for Evaluation of Remote Collaboration using Augmented Reality

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Abstract. Research on remote collaboration mediated by Augmented Reality (AR) has been mostly devoted to creating and exploring the enabling technologies to establish a shared understanding among distributed collaborators. Yet, a more in-depth consideration of the nuances of collaboration should be considered in order to improve the methods to support, as well as to evaluate such processes. However, evaluation is a particularly challenging endeavor given the multitude of aspects that may influence remote collaboration scenarios that should be assessed to understand how collaboration occurs through this new medium. In this context, integrating characterization and evaluation methods for characterizing the collaborative process is of paramount importance. We propose a knowledge-based ontology describing relations among dimensions of collaboration and the main concepts of the evaluation process to guide researchers in designing and conducting their evaluations, thus providing a more comprehensive perspective on the collaborative process and the value of AR in this context.

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Introduction

Scenarios of remote collaboration imply that collaborators establish a joint effort to align and integrate their activities in a seamless manner. Usually, it requires context-related information to be exchanged among distributed team-members, providing support to communication, cooperation, assistance, training, learning as well as knowledge sharing (Lukosch et al., 2015; Kim et al., 2018; Ens et al., 2019).

In this vein, Augmented Reality (AR) appears as a valuable technology as it combines the advantages of virtual environments and seamless integration with the real-world objects. This allows multiple collaborators to overlay responsive computer-generated information on top of the real-world environment, in order to serve as basis for situation mapping, allowing identification of issues, analysis and discussion of complex problems and situations, as well as sharing assumptions and beliefs (Ens et al., 2019; Barroso et al., 2020; Madeira et al., 2020; Lee et al., 2020; Marques et al., 2021).

In the past three decades, most of the research efforts in AR remote collaboration have been focused on creating and exploring the enabling technology, as well as propose novel approaches to support its design and development. Solutions using AR can be used to empower distributed workers, which require know how and additional information from professionals unavailable on-site (Gurevich et al., 2015; Teo et al., 2019). Regardless of their localization, remote collaborators can provide guidance and real-time spatial information, highlighting specific areas of interest, or sharing information (Cidota et al., 2016; Hall et al., 2018; Ens et al., 2019; Zigart and Schlund, 2020) in the form of visual communication cues, e.g., pointers, annotations, hand gestures, among others (Gurevich et al., 2015; Ens et al., 2019).

These solutions can better support analysis, discussion and support of complex problems and situations, given its ability to enhance alertness, awareness, and understanding of the situation, allowing interactions between geographically dispersed collaborators (Neale et al., 2004; Ens et al., 2019; Belen et al., 2019).

As the field matures, the focus is being intensified on a wider range of human factors, particularly those that should be supported to embrace the ultimate goal, which is truly supporting collaboration. In this context, the evaluation of such scenarios becomes an essential aspect to ensure the quality and relevance of the growing number of prototypes, which are paramount to contribute to a more in-depth knowledge of how the collaborative effort occurs by assessing different aspects of collaboration itself.

This is a difficult endeavor, given that scenarios of remote collaboration are multifaceted, which means many aspects may affect the way teams collaborate (Belen et al., 2019; Ens et al., 2019; Marques et al., 2020; Merino et al., 2020). Without proper contextual information, the identification of key issues that need to be tackled to understand and improve collaboration becomes extremely difficult. In addition, current frameworks are not sufficient to characterize how collaboration occurs (Ens et al., 2019; Marques et al., 2020),

falling short to retrieve the necessary amount of data for a more comprehensive analysis, thus requiring an eclectic perspective. In this regard, trying to apply conventional evaluation techniques to scenarios of remote collaboration 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 researchers from gaining access to the whole picture. As a consequence, without the appropriate mechanisms, the research community does not accumulate enough experience and evidence to understand what works (and what does not), to which extent and how to use the analysis of the collaborative process to inform future improvements, thus allowing to build better AR-based solutions and improve collaboration among distributed team-members. Therefore, a better characterization of the collaborative process can lead to an additional perspective on the nuances of collaboration, and in turn, provide researchers with the possibility to easily extract results and conclusions and thus determine the success of the collaborative effort.

In this vein, the integration of proper characterization and evaluation methods regarding the collaborative process is of paramount importance. An example, is the use of ontologies, which may help surpass current evaluation challenges, by allowing researchers to tackle the lack of consideration for a common framework that encompasses remote collaboration, AR technologies and evaluation, which may serve as grounds for community practice and reporting, thus reaching the goal of improved assessment for the field. By considering these characteristics, ontologies may also contribute to make evident that many of the aspects that define an assessment of a collaborative effort supported by AR are not even addressed when considering how reporting is presented in current literature. For example, whether collaborators were able to use an AR solution to its full potential or how the available information was used to achieve their common-goals, which are important aspects for understanding the collaborative effort itself, which are rarely reported, making it difficult to judge the real meaning of the results presented and the proper assessment of all aspects associated to the collaborative process. To elaborate, if different dimensions of remote collaboration are considered, evaluation will certainly not be the same, thus requiring new measures, or the use of different tasks to motivate the use of AR technologies between distributed team-members.

The goal of an ontology is to define a common vocabulary, i.e., set of terms for researchers who need to describe the facts of a given field. It captures the intrinsic conceptual structure of a field and usually covers classes that describe concepts of interest. In addition, ontologies may also help systematization of existing works, allowing to share knowledge about reasoning strategies or problem-solving methods with researchers from the community, who have similar needs for knowledge representation in such field, thereby eliminating the need for replicating the knowledge-analysis process (Chandrasekaran et al., 1999; Noy and McGuinness, 2001).

In this paper, we present an ontology to support a semantic knowledge base, which can be used to understand relations among different dimensions of remote collaboration and the main concepts of the evaluation process. The goal is to provide a common ground to help guide researchers comprehend the scope of evaluations tackling scenarios of remote collaboration using AR, e.g., how they were designed, their results and interpretations. Thus, generating an additional perspective on the nuances of collaboration in scenarios where distributed team-members collaborate through AR to achieve a common goal.

Ontology for Evaluation of AR Remote Collaboration

This section describes an initial effort towards the creation of an ontology for conducting evaluations in scenarios of remote collaboration mediated by AR. Literature shows that a wide range of approaches can be adopted for developing an ontology, since its design is considered a creative process and every individual effort may result in different ontologies. The applications of the ontology and the designer's understanding of the domain will undoubtedly affect the ontology design choices (Chandrasekaran et al., 1999; Noy and McGuinness, 2001).

To this effect, we performed sessions of brainstorming (Jacko, 2012; Jerald, 2015) with 6 experts, including researchers and faculty members with several years of experience in multidisciplinary areas, such as Human-Computer Interaction (HCI), Virtual and Augmented Reality (VR/AR), multimodal interaction, as well as remote collaboration, who co-authored multiple publications, and participated in international projects on these subjects, over the years. In this vein, we conducted several face-to-face and remote meetings to obtain ideas and discuss the creation of the ontology, sometimes with different combinations of experts, according to their availability over several months. Likewise, two experts were randomly selected to be absent from these meetings, in order to provide richer feedback later during an independent critical analysis of the ontology, i.e., understand possible ambiguity of some concepts, attributes and relations. This process resulted in the refinement of the ontology over several iterations.

The strategy chosen to define and populate the ontology (Figure 1) was to consider the main dimensions of collaboration (e.g., team, time, task, communication, interaction, among others) (Marques et al., 2021) as the core classes and associate them with other concepts (following an existing ontology for groupware evaluation (Araujo et al., 2003, 2004)) that exist in common evaluation processes, like scope, design, setup, data, instruments, and others, as depicted in Figure 1. The proposed ontology aims to support a semantic knowledge base to understand the scope of evaluations addressing remote collaboration mediated by AR, e.g., how they were designed, their results and interpretations. More specifically, for registry how contextualized information can be used during the evaluation of the nuances of collaboration in scenarios where distributed team-members need to collaborate through AR to achieve a common goal.

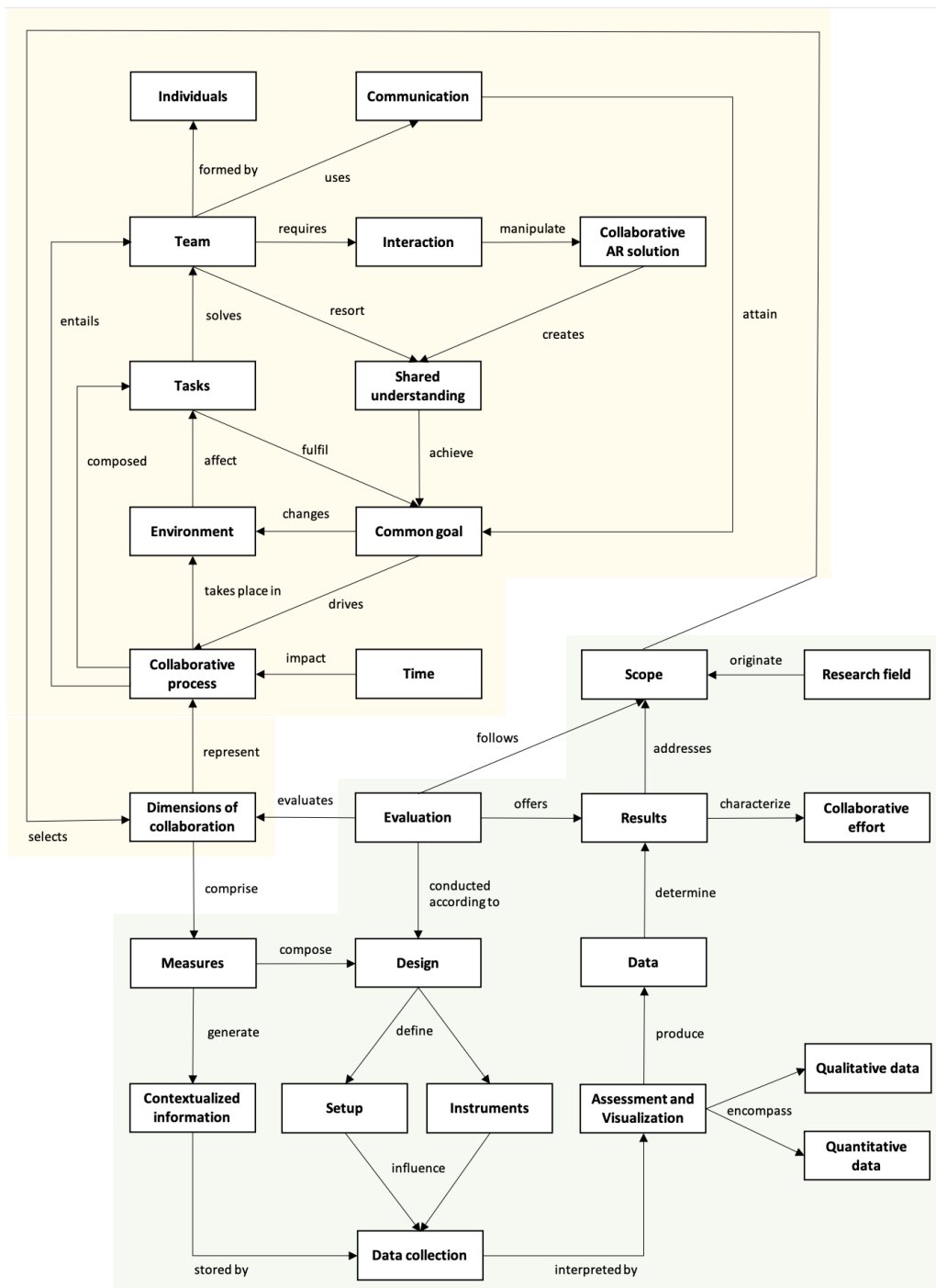


Figure 1. Ontology for contextualized evaluation in scenarios of remote collaboration mediated by Augmented Reality, which can be used to understand and guide the scope of the evaluations, how they were designed, their results and interpretations. In yellow: classes, properties and relations among dimensions of collaboration. In green: the main concepts of the evaluation process

The classes, concepts and attributes in the ontology serve as a guideline for the evaluation design. Evaluation is needed in order to address a specific scope generated within a research field. In scenarios of remote collaboration, the collaborative process entails tasks that need to be fulfilled, time representing the synchronicity of the tasks, environments in which these tasks occur, and a team formed by distributed individuals. The team members must interact with each other through a collaborative AR solution, which serves as basis for situation mapping and creation of a shared understanding. By communicating, the team members can analyze and discuss possible solutions to attain a common goal.

The first step for designing an evaluation in scenarios of remote collaboration, is to properly identify which dimensions of collaboration are going to be evaluated, depending on the research scope. Each evaluation dimension comprises pre-defined measures that can be chosen to compose the evaluation design as dependent/independent or secondary variables. The evaluation can be designed in terms of the setup that will be used by the team, as well as the instruments that can be used to gather data based on the selected dimensions. The results of an evaluation comprise contextualized data (qualitative and quantitative) as the outcome of the collaboration process, which can be used to characterize the collaborative effort and in turn understand if the collaboration was effective or not.

Final Remarks and Future Work

Augmented Reality (AR) is considered as a powerful solution for analysis, discussion and support of complex problems and situations in scenarios of remote collaboration. As the field matures, evaluation becomes essential to ensure the quality and relevance of the growing number of prototypes by assessing the different aspects of collaboration itself.

However, planning, designing, performing, and replicating an evaluation are demanding activities in remote scenarios mediated by AR. Given the difficulty to evaluate such scenarios, it is important to propose enhanced evaluation strategies to conduct thorough collaborative studies and provide an additional perspective on the different dimensions of collaboration supported by AR.

As a contribute, we presented an ontology to guide researchers in designing and conducting their evaluations, aiming to generate an additional perspective on the nuances of collaboration in remote scenarios and the value of AR. The proposed ontology facilitates these activities by establishing relations among the main dimensions of collaboration and concepts of the evaluation process, in order to guide researchers define variables associated to the collaborative process, select which instruments should be applied, as well as collecting measures and obtaining results that are pertinent for interpretation in light of the scope of the evaluation. By following this systematic structure, researchers may be able to analyse and compare a variety of evaluation approaches and results, as well as make considerations and draw conclusions about the use of AR-based solutions for remote scenarios.

The proposed ontology is not intended as a closed work, but should, instead, be taken as the grounds that might enable the community to elaborate, expand, and refine it. Although some of the proposed classes, concepts and attributes might still not reflect the full scope of some categories, we consider that they create a clear enough organization to make itself evident where to insert new characteristics.

The next step is to use this ontology to create a methodological framework, aiming to support the process of conducting evaluations in a more structured manner, and thus eliciting a more complete characterization of the collaboration process in remote scenarios mediated by AR moving forward.

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