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A knowledge capture framework for remote collaborative virtual environments

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Abstract. Due to globalization, the need for geographically separated teams to collaborate on engineering tasks and learn from each other has increased. As a result, being able to observe and hence understand the actions of others in collaborative sessions is very important because it enables the users to work towards a common task's goal. In this work, we propose and develop a novel collaborative knowledge framework that can be used to achieve a common task understanding during remote collaborative tasks. The collaborative knowledge framework provides playback and reuse facilities to enable the storage of knowledge elements (i.e. utterances, manipulations of shared representations, documents accessed during a collaborative session) as well as their recall in future engineering tasks. We validate the framework using an automotive use case.

Keywords. Remote collaboration; Knowledge framework; Virtual Reality; Gaming devices.

1. Introduction

In shared collaborative tasks that involve solving a problem, significant synthesis of knowledge can occur. Capturing the knowledge synthesized during these tasks present a challenge. This is partly due to the differences in level of expertise and exposure that each individual brings to the group as well as pre-existing tacit knowledge and pre-conceived ideas on how a particular task should be approached. As a result, being able to observe and hence understand the actions of others in the collaborative session is very important during collaborative sessions.

This is supported by [1] who mentioned the need for participants to effortlessly pick up what is going on in a collaborative environment, be it physical or virtual, and make sense of it. In such an environment, the participants should know how the tasks and activities taking place fit into a larger plan, the progress that has been achieved towards that plan as well as the participants involved in the task. This leads to the context of the task [2].

Furthermore, a collaborative environment as stated by [3] "should provide comparison perspectives, in which one can view and contrast alternative perspectives and adopt or adapt ideas from other people's perspectives. The idea of a comparison

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perspective is that it aggregates ideas from various individual and/or group perspectives and allows for easy comparison of them. This is an important source of bringing ideas together to foster convergence of thinking and sharing of insights or interpretations".

In addition, the function and features of workpieces in the collaborative environment should be capable of being understood towards deciding new actions as well as have the capability to be modified into future states [4][5]. As such, the environment should offer participants the capability to add, modify and manipulate workpieces [6][7].

Supporting the above needs in collaborative design tasks is currently a difficult conceptual challenge and is further compounded when teams are situated on different geographical sites [8]. Nevertheless, current technological developments make this challenge addressable. However, the question remains how to identify and store knowledge elements generated during this collaborative session as well as how to achieve common task understanding when working on the same workpiece. Towards addressing the former, [5] and also [9] discussed that group member activities, such as utterances, manipulations of shared representations are all elements that contribute to a group's construction of new knowledge. During this process, individual participants first use their existing knowledge to interpret and conceptualize the problem being worked on before attempting to solve it. Also, previous similar solved problems could be used as a jump start for the problem at hand. This requires access to past artefacts that were used in previous problems.

In this paper, we present a virtual environment that offers the possibility of achieving shared collaboration through the provision of: (i) ***Contextual elements***: the situation is modelled as a set of workpieces, (ii) ***Task and activity elements***: the ability for each participant to see their actions and effects on workpieces as well as what others are doing, (iii) ***Resources***: tools used towards the fulfilment of an interactions, (iv) ***Interactions***: with objects as well as with other participants and shared representations of an object.

In section 2.0, we propose a knowledge capture collaborative framework that enables us to achieve the above. An automotive use case is also presented. In section 3.0, we discuss the implementation of the knowledge capture collaborative framework as well as results. We conclude in section 4.0 with a brief discussion of our contributions, limitations and future work.

2.0 knowledge capture framework for remote collaborative teams

Using the framework of [10], we propose a knowledge capture collaborative framework as shown in Figure 1. This framework is made up (i) a personal component and (ii) a collaborative component. The green boxes reflect the elements that teams collaboratively contribute to, the blue box reflect the internal personal elements that only an individual can contribute while the red boxes represent the external elements that individual people involved in the collaboration contribute.

2.1 Personal component: During collaboration, the unique individual elements of the collaboration cannot be ignored. The personal elements (blue boxes in Figure 1) include cultural bias, pre-conceived ideas, pre-tacit understanding, personal belief and personal understanding [8]. This personal component should inform the creation of an environment in which an individual tests his understanding of a task, manipulate objects to test his hypothesize as well as get personal feedback. In this environment, traditional digital documents such as pdfs, images, and word documents could be

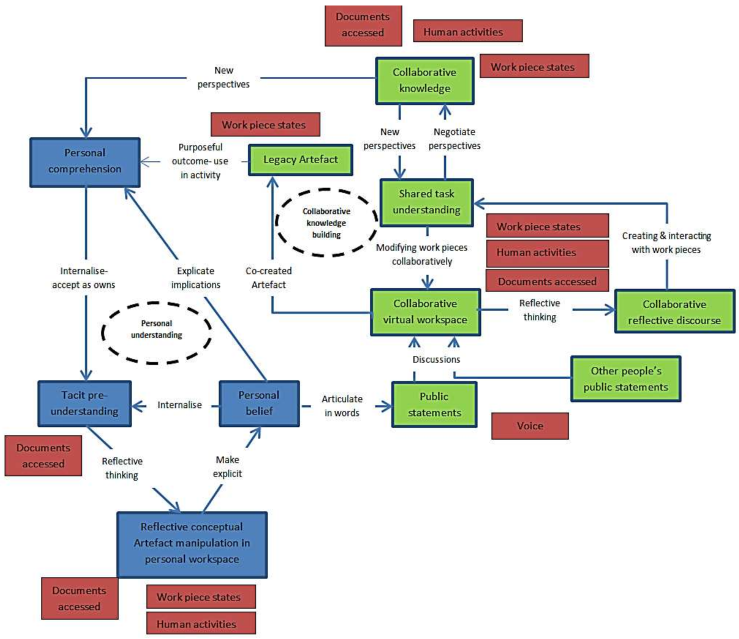


Figure 1. Collaborative Knowledge framework

accessed as well as captured recordings from previous collaborative sessions to aid understanding.

The personal component could either be an existing physical environment or a constructed virtual environment. In a physical environment, the user can physical touch, move, manipulate and assemble objects. In a constructed immersive virtual environment, users will be able to zoom into objects; fly around the scene to see intricate details of objects being manipulated as well as potentially playback previously captured and stored collaborative sessions. The flexibility of flying around a scene is a unique feature that is not possible with current 2D based video recordings.

In our work, human actions on objects in both the physical and virtual environments were captured through the use of a Microsoft Kinect. This makes it possible to capture and digitized human actions for replication in a virtual collaborative environment. The virtual collaborative environment was developed using a game engine called Unity3D.

2.2 Collaborative component: Collaborative environments in which design tasks take place are often physical ones [8]. Nevertheless, latest technology trends also enable collaborative tasks to take place in digital and online environments as such in the construction of a video [6].

In this work, we attempt to bridge physical and virtual environments together. By digitizing human actions and physical environments, we were able to replicate an individual's physical personal space and hence extend it into a virtual collaborative environment in which with other people, work pieces could be collaboratively worked on and knowledge exchanged. This environment was created in Unity3D and actions of all the collaborative participants on the work pieces were captured at their respective personal sites through the use of the Microsoft Kinect and expressed via personalized virtual Avatars. The personal environments of individuals were connected through the use of ubiquitous network connection.

Through public statements and individual actions on virtual work pieces, personal beliefs of participants are made known to all in the collaborative environment. Public statements and actions on work pieces can be used to negotiate perspectives as well as personal understanding. They also aid collaborative reflective discourse. In order to support the collaborative session, traditional documents as well as past recorded collaborative sessions could be accessed in order to aid understanding and negotiate individual perspective [10]. Consequently, public statements (voice), documents accessed, work piece states, human actions (encoded as skeletal data) as well as gestures are important pieces of information that lead to collaborative knowledge. In our work, data streams that conveyed these pieces of information were identified, captured as well as time stamped for storage, future playback and reuse. These pieces of information contribute to a legacy artifact in which every one's knowledge is embedded in one form or the other in the final product. Consequently, the name of the final product was used as a tag in order to recall the knowledge captured in the collaborative session for reuse in the future.

Using concepts from the collaborative knowledge framework in Figure 1 and an automotive use case, a remote collaboration platform to enable geographically separated teams collaborate on an engineering task was developed. In the automotive use case, an engineer was required to remove a wheel from a physical vehicle while a remote engineer collaborates with the physical engineer via a virtual environment. The Microsoft Kinect was used to enable the capturing of identified data for the collaborative knowledge framework. This included voice, human gestures, work piece states, and documents accessed.

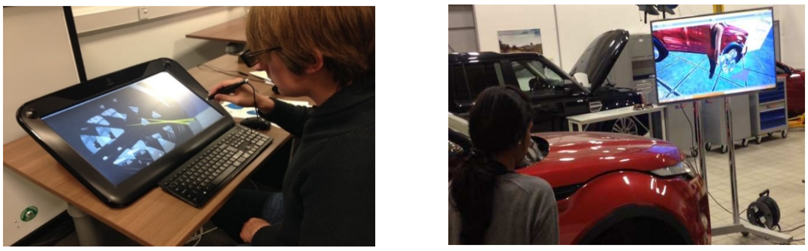
In order to capture the collaborative knowledge for future playback, a database was designed in Microsoft Access. During a capture session, the model names of the various car models, the components of the model as well as the ones interacted with by the human are stored in the Models and Components tables of the database. Also, the JointTypes in an avatar as well as the avatar transforms during a collaborative session are recorded for future playback. Similarly, components interacted with as well as their transforms are stored as well. Also recorded are the start positions for components and avatars. The recording is saved using tags with the TagsMapping table relating a tagsID to a specific recordingID.

3.0 Results

We now present results of the implemented collaborative knowledge framework for the construction of personal spaces, virtual to virtual and physical to virtual collaboration spaces as well as knowledge recording for reuse in a vehicle maintenance use case.

3.1 Construction of personal spaces: In implementing a virtual environment for the personal space component of Figure 2(b), the Microsoft Kinect was placed in a room such that it enabled the digitization of the work space and the accurate replication of a physical personal space into a virtual environment using techniques discussed [11]. As a result, the accurate placement of the user and her actions in relation to a physical vehicle was achieved.

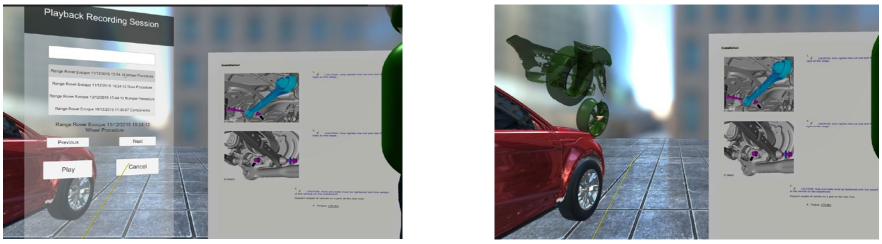
3.2 Construction of collaboration spaces for physical to virtual sessions: A test scenario in which one participant was interacting with a work piece in a virtual environment (zspace) while the second participant was interacting with physical objects was set up as shown in Figure 2(a). The googles wore by the user in Figure 2(a) enabled him to see and manipulate the wheel in 3D. These actions are captured and transmitted to the physical world site where the user in Figure 2(b) can observe the actions as instructions to follow in carrying out the task on the physical vehicle. The actions of the user in the physical environment is captured by the Microsoft Kinect and relayed to the virtual environment for the trainer to give feedback on.



(a) A participant acting as trainer and using a zSpace google to view the virtual collaborative environment.

(b) A participant viewing the actions of the trainer on a display in the physical world.

Figure 2. Setup for physical to virtual collaboration session



(a) Showing how the wheel removal playback was chosen via a GUI as well as the pdf for the procedure.

(b) Showing how previously recorded workpieces were superimposed onto current virtual workpieces.

Figure 3. Showing playback of recorded knowledge

3.3 Recording for playback and reuse: Due to the high data requirements and the complexity resulting from the database design, not all data from the human body joints were recorded. It was decided to record data associated with only the hand and how it interacts with the workpieces. The workpiece states at various time steps were recorded resulting in the possibility to replay the sequence of steps associated with the creation of the legacy artifact. Figure 3 shows the playback of the sequence of steps for various actions that were previously captured and recorded. As will be seen in Figure 3(b), the actions of the playback were such that they were superimposed onto the virtual vehicle and did not affect it. This capability enables the user to see the playback superimposed onto the workpiece that he/she is currently working on thereby enabling the reuse of previous knowledge.

4.0 Discussion and conclusions

In recent years, due to the global spread of manufacturing enterprises, various stages of product development and upgrades are taking place in geographically separated sites.

This calls for a platform to enable real-time collaboration between teams. Till now, most research have not considered how the knowledge exchanged during the construction of a legacy artifact can be identified, captured and stored for future reuse.

In this work, we propose a collaborative knowledge framework that could be used to inform the construction of collaborative virtual environments for product development and identify elements that can be stored and reused in future engineering tasks. We used this framework and low cost gaming devices to develop a platform that provided real-time collaboration with another physically separated site. The platform enabled knowledge elements to be captured, digitized and transmitted across an ubiquitous network for replication in a participating collaboration immersive virtual environment. The task specific knowledge elements included human actions, gestures, and workspace states.

The task specific knowledge elements enabled the platform to provide common task understanding as well as task situation awareness between two geographically separated sites collaborating on an engineering task. The functionality of the platform was validated using a vehicle maintenance use case on a physical world vehicle. Through the use of a knowledge playback facility, it was possible to superimpose previously captured actions and work piece states onto current work pieces towards the provision of instructions on current tasks. This enabled the reuse of previous knowledge. Although the playback function was tested in a virtual environment, in future work, this will be tested in a physical environment. This will be achieved in future work through (i) the accurate mapping of physical work pieces with the physical position of users and (ii) an augmented reality device such as Oculus rift or a tablet.

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