A Case Study on the Implementation of the 3C Collaboration Model in Virtual Environments

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***Abstract*—Throughout the years many studies have explored the potential of Virtual Reality (VR) technologies to support collaborative work. However few studies looked into CSCW (Computer Supported Cooperative Work) collaboration models that could help VR systems improve the support for collaborative tasks. This paper analyzes the applicability of the 3C collaboration model as a methodology to model and define collaborative tools in the development of a collaborative virtual reality application. A case study will be presented to illustrate the selection and evaluation of different tools that aim to support the actions of communication, cooperation and coordination between users that interact in a virtual environment. The main objective of this research is to show that the criteria defined by the 3C model can be mapped as a parameter for the classification of interactive tools used in the development of collaborative virtual environments.**

***Keywords*-Virtual Reality; Collaborative Systems; Virtual Training; Collaborative Virtual Environments;**

I. Introduction

Virtual Reality is an area that in recent years has been growing and expanding its applicability to various areas of action, such as medicine, industry, construction, education and military. One reason for this multidisciplinary relationship is the advantage of simulating and mapping, within a virtual scene, real situations and procedures that explores the needs of each scene.

Using a virtual environment, one can create applications for simulation and training capable of representing real-world scenes with reduced costs of time and resources. Furthermore, it increases the flexibility to make structural changes to objects and other aspects in the virtual scene in order to simulate more than one real situation.

Initially, the applications in virtual reality began to be experienced in a context focusing on its applicability, which is given by the high level of user immersion and interaction. Equipments such as *ImmersiveDesk* [1], HMD - *Head Mounted Display* and CAVE [2] were created for this purpose. However, extending the single-user use case to an environment where more than one user can participate in the same simulation was expected.

It is in this context that appeared the notion of *Collaborative Virtual Environment* (or CVE), which is defined by [3] as a "meeting point" in a shared space. One of the goals behind these applications is to allow analysis of features of collaboration between users within a virtual scene and also to evaluate what resources or tools should be given so that users can work together and perform a specific task.

The area of collaborative systems, among other topics, studies models and techniques used to classify and organize various features present in an environment where users work together. One such model is the 3C model (Communication, Cooperation and Coordination), originally proposed by Ellis et al.[4] and analyzed in works such as Fuks et al.[5] and [6]. The 3C model proposes that collaboration can be defined as a method where the internal procedures of communication, cooperation and coordination are combined, allowing users to work together to accomplish a certain goal.

The 3C model argues that the collaboration of individuals depends on three main features, here called 3Cs: communication, cooperation and coordination. This model states that in a collaborative environment individuals need to exchange information (communication) and to organize themselves (coordination) to work together in a shared space (cooperation). In Figure 1, we see the 3C model and how its main components are related.

The purpose of this study is to bring the concepts that the 3C model proposes and use them to model and organize the structure of a virtual reality application that supports a collaborative virtual environment. The case study, in which these concepts will be applied, is based on the creation of a virtual training environment for maintenance operations on an oil drilling platform located several miles at sea.

In the following sections the scene used in the case study will be presented and the components of the collaborative application for virtual training will be described. In section II the related work will be presented, and section III will describe the problems. The description of the virtual training application used as a case study is made in section IV. Conclusions are described in section V and future work are

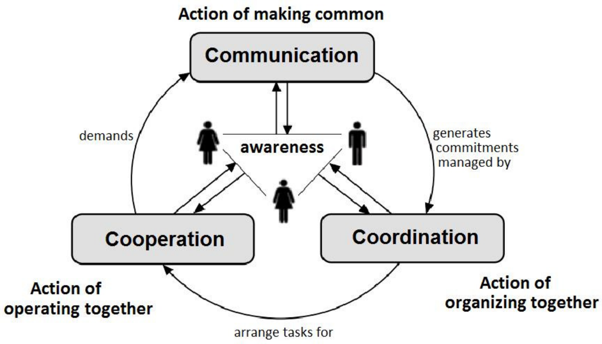

Figure 1. 3C Model [5]

presented in section VI.

II. Related Work

A collaborative virtual environment's objective (CVE), according to Goebbels et al.[7], is to provide a common virtual space between distributed teams where they can meet each other as if in a "face to face" situation, coexisting and cooperating with each other as they share and manipulate data in real time.

The CVEs, as tools for collaborative work, became an area of intersection between the VR and CSCW communities. These communities encouraged the creation of these collaborative environments in key industry segments such as the oil industry.

The work described by Santos et al.[8] discusses some challenges and limitations of CVEs and specifies situations and scenes of the oil and gas industry, defining a workflow for creating a collaborative and interactive environment. However, the workflow used to create the collaborative environment does not follow the 3C model proposed by Ellis et al.[4].

The 3C model presented by Badiru[9], besides explaining in detail each of its aspects, presents use cases that use the model to manage processes within the oil and gas areas. However, the model is more comprehensive and can be used for other purposes like that of Bandinelli et al.[10], Borghoff & Schlichter[11], Lucena et al.[12], among others.

This article is based on papers presented by Santos et al.[13] and Fuks et al.[14], which describe virtual and collaborative environments in some way inspired by the 3C model and theme related to the oil industry. The following sections will make a similar combination of elements, but from a viewpoint of another interactive and immersive application.

III. Problems

The combination of collaborative systems with virtual reality environments is useful because it enables the cooperation of two or more people, paired with the use of unconventional devices and complex display systems, in order to increase the user's immersion and broaden the possibilities for collaboration in situations that are beyond the conventional desktop applications.

This study aims to apply the 3C collaboration model to the modeling and development of a collaborative virtual environment, using as scene an oil platform where users need to perform coordinated actions to complete certain tasks.

In this scene we proposed a system composed of two users talking to each other synchronously in a shared environment, in this case the platform.

The first user has an overhead view that allows you to see more general information of the environment, such as maps and the current position of the second user.

The second user, in turn, navigates through the scene in first person and can explore all of it, being able to request information from the first user to navigate more easily through the virtual environment.

In this system, both can cooperate with each other asking for information, such as an indication of the best way to go (*waypoints*).

In the proposed scene, the 3C model can be applied because users can synchronously exchange information ("communicate") at any time, "cooperating" in a shared environment, where they "coordinate" their actions to accomplish the proposed objective.

As an example of an actual situation in which this scene applies, a maintenance operation on an oil and gas platform can be considered, where the first user would be a technician who is not present on the platform, but has communication channels that provide general information such as the platform structure blueprints, the equipment status sensors, position of the workers, among others. With this information he can guide and assist a worker who is on the platform.

This worker, in this case, has a locator so the technician is able to observe his position on the platform map and the floor in which he is. In this context, the technician needs to perform a routine maintenance task with the worker, where the first challenge is to guide him through the platform to the piece of equipment that needs to be inspected.

A possible cooperation would be a situation in which the technician, who has an overview of the platform structure, indicates, through the use of visual elements, which is the best path or direction that the worker must follow to reach, in a short time, the part that needs to be analyzed. The capability for the technician to offer these resources comes from the overview of the platform that he has on his workstation.

These two characters of the scene must have a dedicated channel of communication (voice, text) so that they can coordinate their actions and help themselves at any time, as seen in Figure 2, which shows an overview of the proposed system.

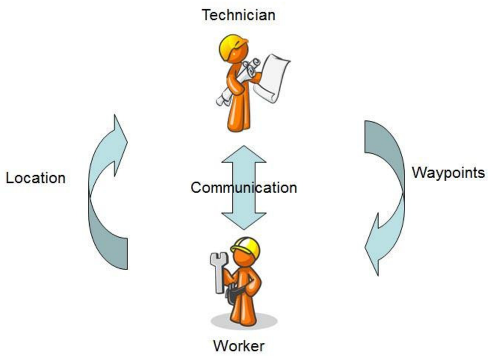

Figure 2. Overview of the application

Figure 3. Multi-touch table that was used

IV. Case Study

From the definition of the scene described in the previous section, we propose the development of a collaborative virtual reality application that represents the scene of maintenance operations performed on an oil and gas platform.

To model this application we identified two modules: the technician and the worker. Within these modules will be represented the view and the tools that each character possess to carry out their work within the maintenance operation.

We also identified interaction techniques and technologies where the two modules were better represented in order to present all the necessary content, as well as enabling communication between them.

In the next subsections we will present the modules that make up the virtual training system and the ways of communication between them. Moreover, within the description of each module, the correlations between the proposed collaboration tools and the 3C model will be made.

A. Technician Module

In the technician application the key elements to be incorporated were identified: information of the levels of the map and the position of the second user, the worker. We thought of means of aiding the second user's navigation, using his current position to assist in choosing a route to his final destination.

The adopted approach was the addition of virtual arrows (*waypoints*) on the map to indicate the path to the second user. The technician can create as many arrows he feels necessary, organizing his actions (coordination, in the 3C model) with the second user to help him fulfill certain tasks. The arrow on the map set is inserted and displayed in real time within the virtual scene where the worker is navigating, which creates a channel for real time cooperation between users. The arrow is an artificial clue that allows the user to find the path for a particular purpose, an activity called *wayfinding*. Bowman et al.[15] defines *wayfinding* as the cognitive process of defining a path through an environment, using and acquiring spatial knowledge, aided by natural and artificial clues.

For the technician application we listed possibilities for information provision in the application interface so that the user could interact with the application in a simple and intuitive fashion. To enable the provision of these elements several interaction platforms were analyzed, such as mobile devices, multi-touch tables, virtual reality devices, and computers equipped with conventional mouse and keyboard.

A first approach suggested the use of mobile devices for the technician application which would control the module via the telephone and would receive map information on the screen. But we realized that with this approach it would not be possible to organize all the necessary information on the device, given its limitation in screen size and computing capacity. So it was thought the use of a multitouch table [16], which provides a similar form of interaction through touch, besides having the advantage of a larger screen compared to a tablet.

The multitouch table used was developed by the authors (Figure 3) based on the diffuse lighting model[17], using a projector to create the 50 inch touch surface. The table was used together with another projector to provide the view of the user who is on the platform (Figure 4). The software chosen for treating the touches, using computer vision techniques, is called Community Core Vision[18], which was paired with the TUIO protocol[19] for communication between both applications.

Determined the type of interaction to be used, the technician interface was then drafted. The map, main component of the interface, had a prominent role. This leading role is justified by the representation of the unique environment of the platform on which both users work (cooperation), causing both to perform coordinated actions in this common space.

Because a platform has different levels, it was necessary to include buttons that enable the change in level of the map. A map consists of an overhead view of the platform level so

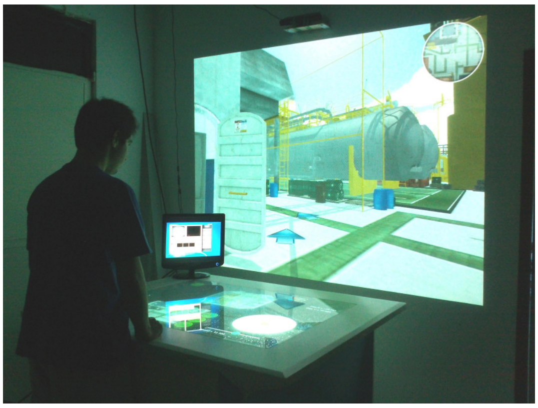

Figure 4. Technician application

Figure 6. Worker application

as to have a high level of detail. Therefore, we proposed a way to display, by means of a selection tool, a specific area of the map displayed in a different part of the screen of the application.

This selection tool also assists in the placing of the arrows that the worker uses in pursuit of his goal. The arrows have been included in the interface through an icon, which when touched creates a new arrow handle, in Figure 5 it is represented by the items ”7” and ”8”. It is possible to perform rotation and scaling operations, as well as placing them in the desired portion of the map. Next a detailed description will be made of the interaction elements created in the application of multi-touch table.

1) Description of the technician interface: The interface (Figure 5) was developed for a user, the technician, to have easy and quick access to any necessary functions to assist the navigation of another user (the worker) through the platform environment. For this to be done we created the following:

1. 2D View of the Environment Map: Placed so that the technician may guide himself through the environment and view the workers.

2. Map View with Zoom: Created to provide a detailed view of the environment map without impairing other elements of the interface. This allows to place arrows with greater accuracy in the virtual scene.

3. 2D Navigator: This tool allows the technician to navigate in a virtual scene that represents the platform's structure. This way the technician can provide more precise information to the worker.

4. Zoom Navigator: This green colored rectangular area defines and allows the technician to move the zoom area.

5. Navigator Speed Control: Controls the navigation speed defined in item ”3”.

6. Users: In this area are represented the position, orientation and current floor, in the 3D environment, of a given worker. For example, in Figure 5 a small blue cololred arrow represents the position of a worker on the third floor of the platform. The worker's current floor is given by the color defined in item ”11”.

7. Arrow (*waypoint*): Controlled by the technician to assist other users in reaching their goals. For an arrow to be placed in the environment it must first be placed on the zoom area and scaled/rotated as desired. Once that is done the technician must press a confirmation button (”8”) to finally finish the process.

8. Confirmation Button (OK): Created to avoid a waypoint being accidentally placed in the environment.

9. Floor Buttons: Provide the technician's floor control, allowing him to change between floors in the 3D environment.

10. Reset: In case the technician reaches an invalid position, he may choose to reset some parameters of the environment, such as navigator position, navigation speed and current floor.

11. Floors: View of the technician's current floor and the floor in which a given user is currently on.

B. Worker Module

The worker module (Figure 6) was developed to simulate the real scene of an oil platform through which the worker will navigate. In this application we used a simple first-person view interaction method.

In this module the user may navigate freely around the scene, being able to access all of the platform's floors. On the interface of this module the arrows will also be drawn according to data received from the technician application, also the tasks that need to be performed will be presented.

With this interface the worker has a first-person view and may receive assistance from the other user (technician), as well as having a mini-map to help him locate himself in the environment. The worker can move around the scene

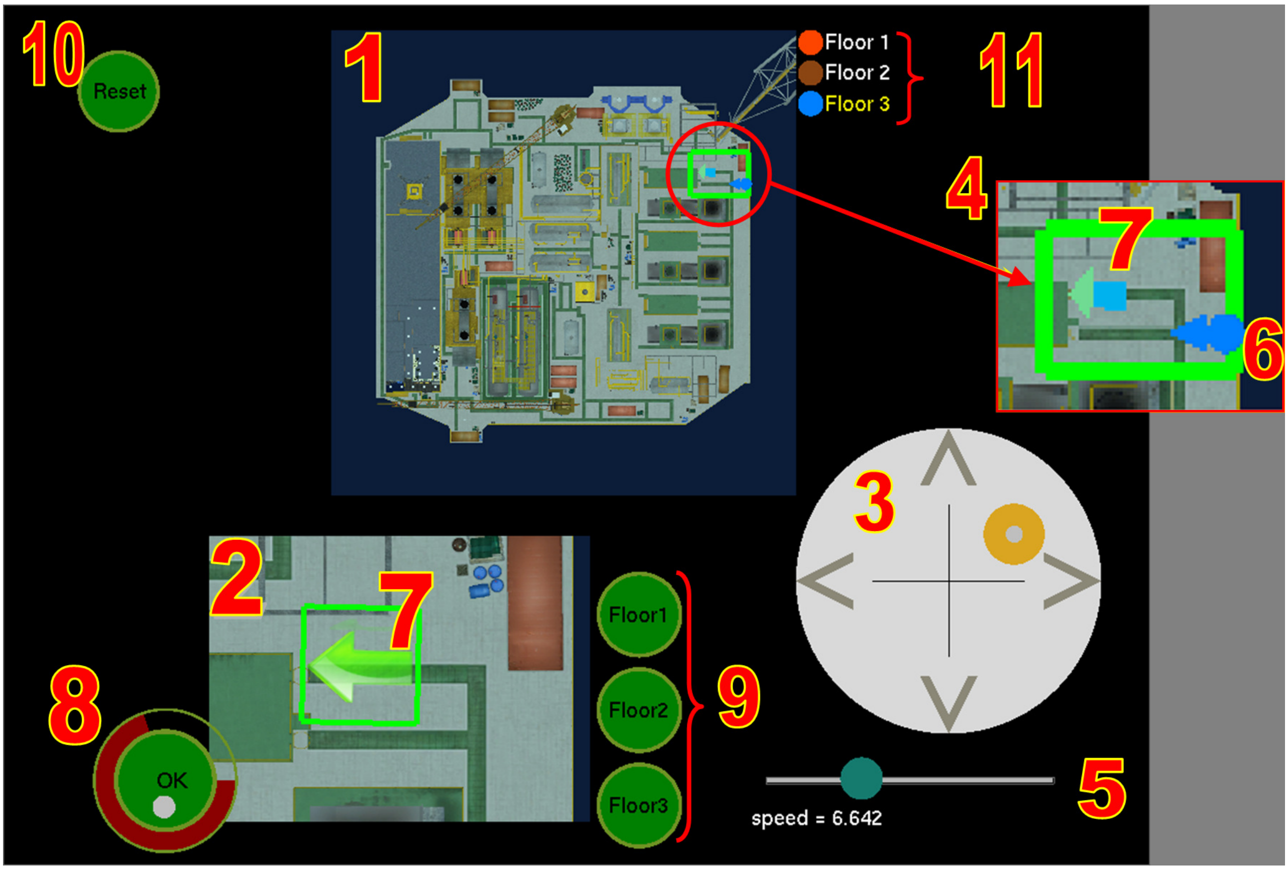

Figure 5. Technician application interface implemented for the multi-touch table.

Figure 7. Joystick button mapping

using a wireless joystick, which buttons are mapped to allow movement and interaction.

1) Description of the worker interface: The movement and interaction mapping of the joystick for the worker application (Figure 7) is described next.

1. Analog 1: This analog stick allows the user to move around the scene.
2. Analog 2: This analog stick allows the user to interact and manipulate objects that are in the scene.
3. No functions for this button.
4. Crouch: By pressing this button the user will crouch. This is used to inspect elements that are closer to the floor.
5. No functions for this button.
6. Jump: This button allows the user to jump.
7. No functions for this button.
8. Activate Interaction: Confirms the current selection and allows the user to begin interacting with the selected object.
9. Run: Increases the user's movement speed.

C. Applying the 3C model to the communication between modules

In this section we describe how the 3C model was used to design the developed tools in each module to allow the collaborative work between the users: technician and worker.

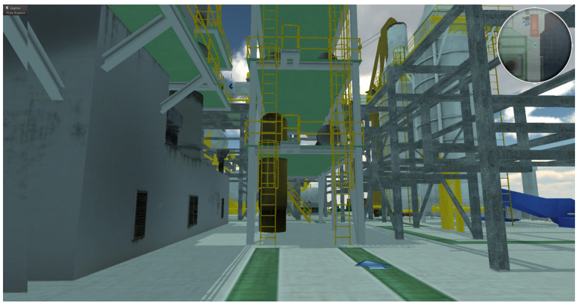

Figure 8. Virtual scene from the worker's view

In the case of communication between the modules we thought of a quick way to send and receive messages. As the speed of sending and receiving is an important point in the application we decided to use technologies that do not impair *frame-rate* of any of the applications, ie, without sacrificing performance. For this we used asynchronous UDP sockets in both applications.

To provide communication between users we chose voice communication (item 4, Figure 9), because it is less intrusive for virtual reality applications and does not pollute the interface of both users with textual elements.

Another reason for the use of voice as a communication channel is the fact that the user running the training can not be equipped with traditional means of interaction with the system (eg mouse and keyboard). The use of specific devices for navigation such as Wii, joysticks and kinect preclude the use of text input.

In this scene voice communication allows both users to communicate, and consequently, coordinate to perform tasks together.

Coordination is achieved by defining the map (item 1, Figure 9) in both applications: the multitouch table (Figure 5) and the worker interface (Figure 6); and the aid of virtual arrows (item 2, Figure 9), used for both users to guide themselves through the virtual scene to achieve their goal.

The interfaces of the two modules provide a common virtual space where two users interact with each other (cooperation) (item 5, Figure 9), supported by other communication channels and coordination mechanisms previously defined.

Finally, as described in previous sections, the applications and tools defined in each module allow the collaborative process to flow supported by the concepts defined in the 3C model. The relationship between the developed tools and the model are illustrated in Figure 9.

V. Conclusion

In VR applications, which require some type of collaborative work among its users, it is necessary to adopt an appropriate methodology for modeling the basic features of

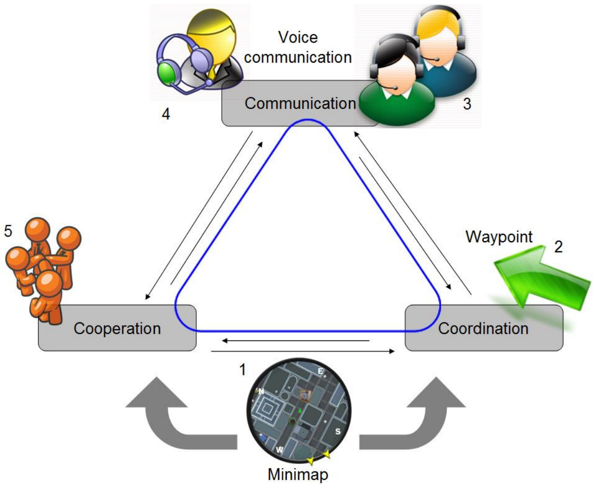

Figure 9. Relationship between the application tools and the 3C model

the area of collaborative systems within the modeling and construction of these virtual environments.

This was shown, in a specific use case, the application of the 3C model to design the collaboration tools present within a collaborative virtual reality application that meets the interaction requirements proposed within the case study environment.

The test application based on case study showed that it is possible to model and choose the adequate collaboration tools based on concepts from the 3C model. The tools chosen to support communication, coordination and cooperation between users provide a fluid interaction between the participants.

The evaluation of these tools enhance them with another application criteria, which is defined by the best match between the characteristics of the tool and its applicability within the model of the 3C's.

Finally, this work is only the beginning of a real evaluation of the use of the 3C model, proposed in the area of collaborative systems, and its applicability in the modeling and implementation of collaborative virtual reality systems.

VI. Future Work

As future work the following improvements will be focused: making the multi-touch interface more intuitive and allow new gestures, define classes of users (doctors, engineers, sailors, etc.) within the application and improve each category (Communication, Cooperation and Coordination) of the 3C model, simulate real training situations and creating a support system for emergencies.

For the multi-touch interface, papers are being studied such as Wigdor et al.[20] and Bachl et al.[21] that describe theories, techniques, challenges and other aspects found in the creation of a multi-touch system. Another line of study is the creation of an interface concept similar to those used in games that use the Kinect as a controller. The interfaces found are intuitive, minimalist and respond to simple gestures. The gestures are based in Villamor et al.[22].

The creation of classes within the application allows coordination to be done in a directed manner. For example, in a real simulation, a valve operator injured his hand while trying to close a valve, and therefore needs medical help. Instead of sending the help request to all users, this request is sent only to the medical class that may cooperate more quickly and efficiently.

In the 3C model we study the possibility of creating an audio-visual channel where users can communicate and exchange information. Creating a file system to store information, actions and notes shared by users allowing the technician to, through the experiences reported by the workers, take a decision or perform an action more accurately. Enhancing the concept of perception within the virtual environment based on works such as those of Pinheiro et al[23].

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