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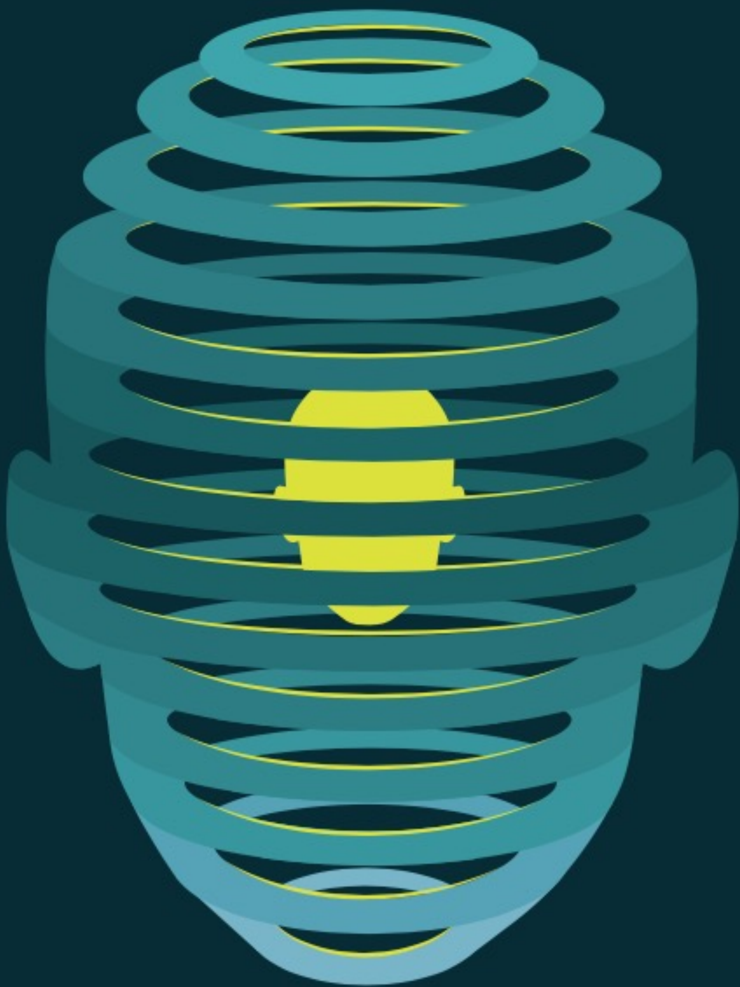
Virtual Reality International Conference 2021

CONVRGENCE



PROCEEDINGS

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FOREWORD

This document presents the proceedings of the VRIC - ConVRgence conference held on July 7-9, 2021. The conference was organized again this year in a particular context, that of the COVID-19 health crisis, and the usual dates were shifted from March to July to allow for a hybrid format both in-situ in Laval, and in the *Laval Virtual World*. We hope that next year will be back to normal, both in terms of organization and volume of submissions.

We would like to thank the authors who submitted their research works, as well as the reviewers for their contributions.

Finally, we would like to thank the two keynote speakers, Rachel Mc Donnell and Anthony Steed. The title of their presentation and a short biography are presented below.

Simon Richir, Arts et Métiers Institute of Technology, Scientific Director of Laval Virtual
Olivier Christmann, Arts et Métiers Institute of Technology, Co-chair
Geoffrey Gorisse, Arts et Métiers Institute of Technology, Co-chair

Title – Rachel Mc Donnell

Rachel McDonnell is an Associate Professor of Creative Technologies at Trinity College Dublin, and a principal investigator with ADAPT, Trinity's Centre for AI-driven Digital Content Technology. She combines research in cutting-edge computer graphics and investigating the perception of virtual characters to both deepen our understanding of how virtual humans are perceived, and directly provide new algorithms and guidelines for industry developers on where to focus their efforts. She has published over 100 papers in conferences and journals in her field, including many top-tier publications at venues such as SIGGRAPH, Eurographics, TOCHI, and IEEE TVCG, etc. She has served as Associate Editor journals such as ACM Transactions on Applied Perception and Computer Graphics Forum, and a regular member of many international program committees (including ACM SIGGRAPH and Eurographics). She was recently elected a Fellow of Trinity College Dublin.

Grand Challenges of Virtual Reality Technology – Anthony Steed

Anthony Steed is Head of the Virtual Environments and Computer Graphics group in the Department of Computer Science at University College London. He has over 25 years' experience in developing effective immersive experiences. While his early work focussed on the engineering of displays and software, more recently it has focussed on user engagement in collaborative and telepresent scenarios. He received the IEEE VGTC's 2016 Virtual Reality Technical Achievement Award. Recently he was a Visiting Researcher at Microsoft Research, Redmond and an Erskine Fellow at the Human Interface Technology Laboratory in Christchurch, New Zealand.

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LONG PAPER

Extending OpenSG for real-time synchronization of immersive environments in distributed collaboration

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Keywords: Open-Source Software – Distributed Systems – Synchronous Collaboration – Collaborative Virtual Environments

Abstract

Immersive technology enables the creation of virtual working environments for geographically distant team members to meet up and work simultaneously on highly interactive tasks. This paper presents our method for the real-time synchronization of distributed systems sharing a virtual 3D scene. Therefore, we extended the OpenSG scene-graph library, which is using the change list paradigm to synchronize virtual scenes within a rendering cluster. Our approach is to adapt this paradigm for the synchronization between remote systems to enable simultaneous cooperative work in a shared immersive environment. The implemented method has been validated on a use case in which two participants were remotely collaborating while inspecting a production line imported from CAD. Our result can be used by Virtual Reality developers to add state of the art collaboration features to their applications like scene synchronization, user avatars and simultaneous interaction with the virtual environment.

1. Introduction

Collaboration is an important process in our daily working life which helps multiple individuals or groups to achieve their common goals. During a face-to-face collaboration all participants have to be present at the same time and place to work with each other. However, in many cases it is not efficient or even possible to meet in person. The interest in immersive collaboration applications is significantly increasing since 2012 (de Belen et al., 2019; Ens et al., 2019; Ladwig & Geiger, 2018). In the days of globalization and social distancing remote collaboration applications have become very prominent.
In virtual engineering collaboration is often involved with highly interactive tasks which involve spatial information, for instance in training, support, maintenance and review scenarios with CAD data. On the one hand, highly interactive tasks require immersive working environments, but on the other hand, they are hard to implement. For immersive applications various frameworks exist which facilitate their creation. Nevertheless, frameworks to support the creation of immersive applications with a focus on remote collaboration barely exist, which is why we developed our approach.

A framework for immersive collaboration should provide support programs, tools, libraries and APIs to facilitate the development of Collaborative Virtual Environments (CVEs) while shielding the user from the standard low-level details, as for example 3D rendering. Nevertheless, most approaches in the immersive remote collaboration area simply provide a demonstrator as a proof of concept (de Belen et al., 2019). Because a demonstrator is an example application or a prototype, a more generalized approach for immersive collaboration is desirable to fit the needs of various application domains. Such a framework can be used to facilitate the development of collaborative applications or demonstrators.

CVEs provide multi-user sessions which allow multiple users to join the virtual environment in which they can interact with their work environment and with other users. In remote collaboration the CVE should also have the capability to connect the participants over the internet. Since each user has its own representation of the virtual environment, which is structured in a scene graph, all changes to the virtual objects have to be synchronized between the users to allow a consistent scene view. Without synchronization mechanisms the users would see different scene states, which hinders effective collaborative work. Because the participants can concurrently apply changes to the virtual scene which are synchronized between them, the CVE should also provide control mechanisms for a consistent scene outcome.

2. Related Work

In the following, frameworks for the development of CVE applications are presented. Since our focus lies on accessibility and extendibility, the selection was narrowed to noncommercial frameworks with unrestricted use and open-source access. Additionally, all solutions need to fulfill the requirement of clustering support for Cave Automatic Virtual Environments (CAVEs). The selected frameworks which are still maintained and developed consist of VirCA Net, COVISE and VRUI.

VirCA Net (Weidig et al. 2014) is an open-souce platform to enable a collaboration between humans and intelligent agents using immersive technologies. The access can be requested online. VirCA consists of a Virtual Reality (VR) engine, a web-interface which can be used to extend an existing virtual environment, and the Robot Technology Middleware which is responsible for the network extension and data transfer.

COVISE (Wierse, 1995) is a software environment which integrates simulations, postprocessing and visualization functionalities. The software environment is continuously expanded and is available on the open-source platform GitHub. COVISE is strongly focused on scientific visualization but also supports CAD formats for engineering. The development of the VR collaboration modes continues since 2008. The software environment supports several immersive technologies ranging from workbenches over powerwalls, curved screens up to full domes or CAVEs.

The VR engine VRUI (Menck et al. 2012) is another open-source VR framework which can be downloaded online. A collaborative platform was built upon VRUI which is a development kit for VR applications that supports various devices and can be adapted according to the user's needs. The platform supports different models of remote collaboration. For instance, in one collaboration model only one user has the right to interact with the virtual environment while in another model every user can move freely within the virtual environment. Unfortunately, the collaboration extension does not get updates since 2018.

Table 1: Overview of the related work including their features for immersive virtual collaboration requirements.

CVE Framework	VirCA Net	COVISE	VRUI	PolyVR
Scene Synchronization	✗	✓	✓	✓
Consistency Management	✗	✗	✗	✓
Decentralized Topology	✗	✓	✗	✓
Embodiment	✗	✗	✓	✓
Verbal Communication	✗	✓	✓	✗

Table 1 shows the comparison of the mentioned CVE frameworks at their current development state considering six characterising criteria for collaborative CVEs: scene synchronization, consistency management, network topology, embodiment and verbal communication.

The first criteria describes whether the framework implements a synchronization between the remote CVE for the scene graph objects or only of the user data. For collaborative work inside a CVE, participants should be able to interact with the shared scene objects. The framework should facilitate the creation, transformation and destruction of scene objects and synchronize the objects between all remote scenes (Reiners, 2002). The synchronization should ensure a consistent state of the shared scene to all participants and prevent divergent scene states of the CVE (Peciva, J., 2007).While the synchronization of scene graph objects is possible in

COVISE and VRUI, the VirCA Net framework does not synchronize the scene graphs. Nevertheless, since VirCA is focused on human-robot interaction, it does provide a synchronization between the real robots and their virtual twins.

The consistency management criteria describes how the framework manages concurrent user interactions and ensures a consistent state of the shared scene. In a shared CVE that allows the participants to interact with shared objects, concurrent object access can occur, for instance when two users want to grab the same object simultaneously. If not handled by the framework appropriately, this can cause inconsistent scene states and make the collaborative work ineffective (Peciva, J., 2007). There are different strategies to ensure scene consistency. One possibility is to simply disable concurrent interactions on objects, by giving the interaction privileges to only one participant, who is considered the master. VirCA Net, COVISE and VRUI only allow one user to simultaneously interact with the scene objects, but the privileges can be transferred to other users. Since concurrent manipulation is not supported yet, consistency control mechanisms do not have to be addressed.

A further criteria for differentiating CVEs is the underlying network topology supported by the framework (Steed & Fradinho Duarte de Oliveira, 2010). In the centralized server-client topology the remote systems of all participants are connected to a server which is responsible for data distribution and the validation of the CVE. The centralized topology is common for multi-user games; hence most game engines and VR frameworks implements it. In some applications, data confidentiality is of high priority, as for example in corporate use. In this case a framework implementing the decentralized peer-to-peer topology is desirable since confidential data has not to be uploaded to a server. The COVISE framework facilitates decentralized CVEs. VirCA Net and VRUI have a focus on the centralized server-client topology.

Embodiment can provide useful information for the virtual collaboration (Gutwin & Greenberg, 2002). An embodiment is a visible representation of the collaborators body within the virtual workspace. In CVEs 3D avatars are used to represent the body of the user. With avatars the collaborators can perceive each other including their positions, orientations and actions collaboration (Hindmarsh et al., 2000). An appropriate embodiment can compensate the loss of the physicality in remote collaborations and provide information about who is in the virtual environment, where they are and what they are doing. Additionally, it can enable consequential and gestural communication (Gutwin & Greenberg, 2002). In VirCA Net the position and gaze direction of the VR devices are visualized, but the users themselves are not represented within the CVE. The limited user representation hinders communication and interaction between users (Weidig et al. 2014). COVISE focuses on analyzing scientific datasets in an immersive environment but not on methods and tools for virtual face-to-face collaboration. Consequently, COVISE does not provide a representation of the remote users. Out of the compared frameworks, VRUI is the only framework which is already utilizing avatars.

The last criteria is verbal communication which describes the availability of speech transmission between the participants in the CVE. Verbal communication is already available in COVISE and VRUI. Furthermore, COVISE provides standard tools for audio- and videoconferencing. VirCA Net relies on Skype for verbal communication between the participants and thus does not provide integrated tools within the framework.

The presented frameworks for CVE development have different strengths and weaknesses. Consequently, since the interest in collaborative VR applications is rising (de Belen et al., 2019; Ens et al. 2019), it is necessary for future CVEs to provide a development framework which combines the strengths of all implementations and offers solutions for problems not approached yet. The following section describes our approach to provide such framework for CVEs upon the VR authoring system PolyVR (Haefner, 2019).

3. Collaboration Extension

In our approach the PolyVR (Haefner, 2019) authoring system for immersive environments was expanded by a collaboration module. PolyVR allows the user to dynamically create immersive and interactive virtual worlds. The created content is abstracted from the hardware setup, allowing a flexible deployment even on complex distributed visualization setups. The implemented collaboration module particularly extends the OpenSG scene graph library (Reiners, 2002), which can be used for the creation of real-time graphics applications and which is also used in PolyVR. As a result, a framework for the creation of distributed CVE is provided.

The OpenSG library is open source and provides efficient multi-threading for virtual environments. The clustering performance is very efficient, which is particularly important for CAVE systems (Haefner, 2019). Scene changes of every thread are collected locally in change lists and then synchronized between the threads. Similarly, the scene is synchronized within a distributed system, where different scene parts are rendered separately. OpenSG minimizes the amount of data needed for synchronization by only sending relatively small change messages instead of the actual geometry data. Therefore, OpenSG is very suitable for immersive real-time applications.

Remote CVE applications enable users from geographically remote locations to connect to a networked collaboration session where they can work together in a shared environment. As depicted in Figure 1a), each user has a replication of the virtual scene locally on their computers. In CVEs, the scenes of the users have to be consistent, otherwise the collaborators will not work in the same shared virtual environment but in different versions. During collaborative work users modify the virtual scene and generate scene changes. The scene changes on each local system result in deviations from the original scene state, which leads to inconsistent scene states within the collaboration system. To recover scene consistency local changes have to be distributed and applied to remote scenes which happens during the synchronization process. To enable simultaneous collaborative work, remote participants have to be updated about changes continuously. The implemented OpenSG extension enables a synchronization of the virtual scenes to ensure a consistent CVE.

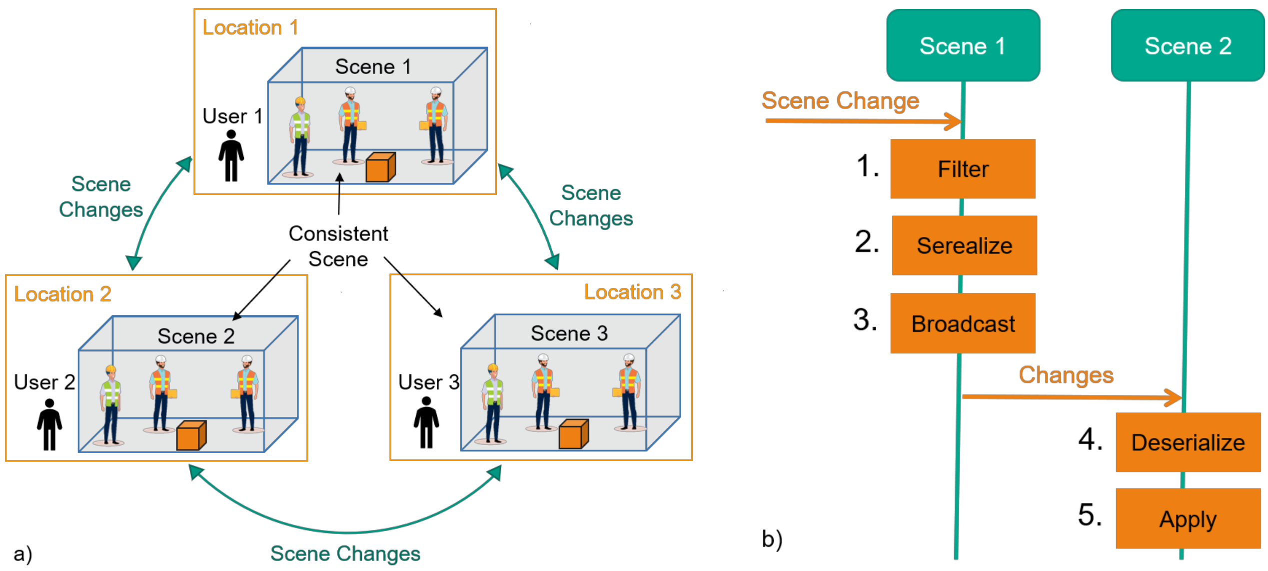

Figure 1: a) Overview of a decentralized synchronization system with three users in remote locations, b) The developed synchronization workflow between two remote scene graphs.

3.1. Change Lists

For the synchronization in remote CVEs the change list paradigm of OpenSG was adapted to extend the PolyVR authoring System by a collaboration module. Originally, change lists are used to synchronize distributed subparts of a scene which are each located on different nodes in a rendering cluster. In remote CVEs every participant potentially owns the whole scene graph and not just a subpart of it. Hence, the synchronization paradigm of OpenSG needed to be adapted for our purpose.

The synchronization workflow involves five main steps as Figure 1 b) shows. The local system generates a change list after the scene graph was manipulated by the user. Since not every local change has to be synchronized with remote scene graphs, the changes are filtered during step 1 of the synchronization process. Then the changes are serialized during the second step and shared with the remote systems via broadcast in the following step. On the remote end the changes are deserialized as soon as they are received which is done during step four. Eventually, the changes are applied to the remote scene graph during step five.

The following sub-sections further describe the remote collaboration cycle of obtaining, broadcasting and applying changes.

3.1.1.Generate the Change List

During virtual collaboration, the collaboration module of PolyVR observes all changes done to the local scene graph and collects them in change lists. Therefore, OpenSG change entries to the scene graph serve as an initial input. Since not all changes of the local scene are relevant for the remote scenes, for instance the local camera position, the collaboration system filters for certain changes of predefined scene objects before broadcasting them. User poses are tracked by VR devices and collected in separate changes to provide individual positions and views, otherwise every user would share the same position and view when synchronized. Our system can be extended by different filter approaches, for example the filtering can differ according to the user role in the collaboration.
As a result, the local change list is obtained – a list of change entries of the local system to be synchronized with the remote systems.

3.1.2.Broadcast of the Change List

After retrieving and filtering the change list, it needs to be broadcasted to the remote systems along with the user poses and consistency control information. Before broadcast, the change data must be serialized. During the serialization process relevant information is extracted from the change entries and stored in a new structure extended by additional synchronization meta-information. This is required for the proper reconstruction of the changes and for the identification of the corresponding objects on the remote side.
The identificators of the object, as well as its affected parameters, are stored as a bit vector mask which changes certain parameters when applied on the object. Since corresponding objects in the remote scenes have different ID's we implemented a method to map between local and remote ID's. For later deserialization it is also important to store the length of the serialized data which is stored in an additional variable. Finally, the ID's of the object's children within the generated struct are broadcasted for the reconstruction of object hierarchies on the remote side.
Since the device pose synchronization, objects' ownership status and mapping updates are not directly included in the change lists, the information needs to be broadcasted separately. For this, simple string messages containing identifiers, separators and values are sent to the remote systems. While device poses are broadcasted on every update of the user avatars, the mapping and ownership changes are occasionally triggered by functions. Mapping updates are only sent after an object was added and the ownership has changed after user interactions.

3.1.3. Apply changes from the Change List

After receiving change data from the remote systems, it must be preprocessed before it can be applied on the local scene. The mapping, device poses and ownership data is processed by corresponding handlers after which they can be directly applied on the scene. The change list data has first to be deserialized to reconstruct the change entries. The reconstruction proceeds change by change, wherefore the included information about the change list length is required. Additionally, the children ID's are deserialized to reconstruct the object hierarchy of the scene graph.

The retrieved changes can then be applied to the corresponding objects in the local scene graph. At this point the constantly updated mapping information is required which contains references of remote to local object ID's. Thereby, the local object, which the remote change refers to, is identified. If no related object exists it is created and added to the scene graph. In that case it is required to forward the new mapping information to the remote systems. After this initial registration future changes can directly be applied on the corresponding objects.

When the changes are applied OpenSG recognizes them and creates new change entries for its intern change list. The OpenSG change list is processed by our extension and since it keeps track on the synchronized objects, the currently received changes will be re-sent to the remotes. This behavior repeats on the remote systems which is causing infinite synchronization loops containing same changes. To prevent this behavior, the currently received changes are recorded and filtered out during the change list preprocessing.

3.2. Consistency Control

During synchronous collaboration users can simultaneously access and manipulate the same object. Unlike in real environments, in CVEs this will lead to concurrent synchronization updates and finally to inconsistent scene states. As a consequence, CVEs which allow concurrent user interaction need to implement consistency control mechanisms to prevent scene inconsistency.

Our collaboration module implements the ownership method to provide a simple consistency control. Initially, scene objects are owned by the user who creates them. Consequently, every user system knows which objects it owns. If a user wants to access not owned objects, an ownership request is broadcasted to the remote systems. On the other side, received ownership requests are processed on the local system. If the request addresses an owned object, the owner need to decide whether to transmit the ownership to the requesting system or not. Therefore, different behaviors can be implemented, especially behaviors based on team member roles. By default, the ownership is granted when the object is not used by the owner and rejected otherwise. Once a system receives the ownership it can access and manipulate the according object. The ownership is kept until it is requested by another user.

4. System Validation

With our work we intend to facilitate the creation of immersive collaboration applications for distributed participants. To validate our approach, we created a collaborative application in the industrial context using PolyVR. The created application, as depicted in Figure 2, enables a collaboration between two users, one using a desktop PC and the other working inside a CAVE. Since the scene is synchronized, a simultaneous work in the shared environment is practicable. The participants can see the avatars and movements of the remote user. The poses of the user inside the CAVE are tracked with the ART tracking system and forwarded to the remote users. On the remote side the tracked poses are applied to the corresponding avatars. On the desktop PC only direction of the mouse pointer and the camera pose are tracked and applied to the hand orientation and avatar pose.

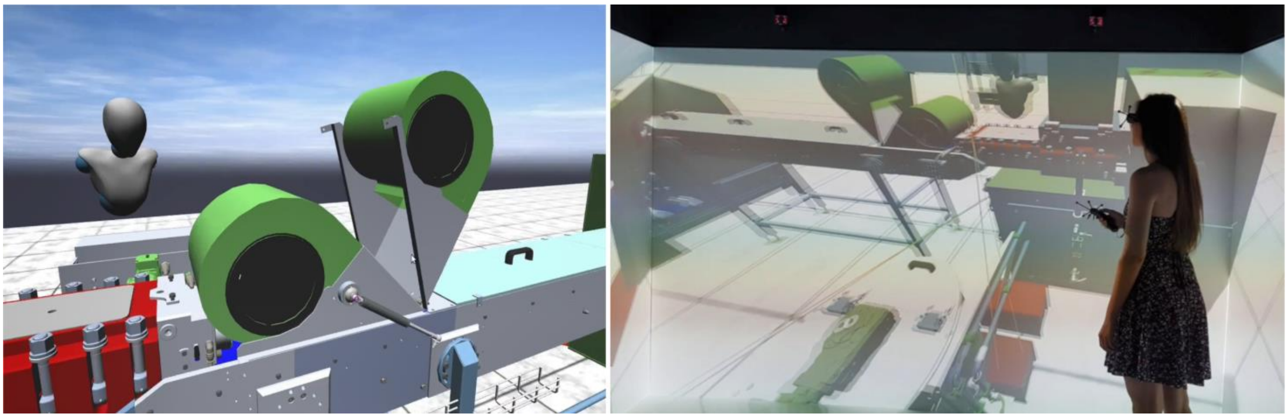

Figure 2: Collaboration inside a shared virtual environment enabled by the synchronization extension of OpenSG. The remote user is represented by an abstract avatar viewed from other user's perspective. Left: User's view from the desktop PC. Right: User's view inside a CAVE. For the collaboration environment a CAD model of a chewing gum production plant was imported into the scene.

4.1. Consistency Control Validation

The implemented consistency control was tested during the collaboration of two users who tried to drag and move a synchronized object simultaneously. As a result, the owner could drag the object and was able to move it while the not-owner could not drag the object. After the operation both users were able to view the same scene state.

Without the ownership management mechanism, the interaction resulted in different scene states because their object poses were overwritten by the received remote poses. Consequently, the users were not seeing their own changes to the object but the changes of the remote user. Thus, the CVE resulted in an inconsistent state since it showed different object positions to each user.

The implemented ownership management worked well as a consistency control mechanism in the validated scenario. Although, more complex consistency control methods should be investigated in future work.

4.2. Synchronization Performance

In distributed real-time systems delay is an important parameter to consider. Delay occurs mainly from two sources, message transmission via network and the processing time of the application (Khalid et al. 2016). According to literature the ideal delay in real-time applications is less than 200 ms (Park et al. 1999; Saldana & Suznjevic 2015; Vaghi et al. 1999), while a delay of over 500 ms even hinders collaborative work (de Oliveira et al. 1999). To capture the delay of the synchronization in our collaboration module we created torus geometry primitives in a scene graph and measured the time required to synchronize the created objects to another scene graph. Later the determined synchronization delay could be broken down by single functions to determine bottlenecks and potentials for system improvement. The tests begun with a low number of objects which were increased by factor ten in each test. Additionally, the delay behavior was tested on different complexity levels of the objects by increasing the number of vertices for each object.

The overall delays for different geometry complexities are depicted in Figure 3 a). As expected, the delay increases with a higher complexity and an increasing number of objects. For low complexity geometries, with 100 vertices per instance, the delay is within the acceptable threshold. Only at very high numbers, around 750 created objects during an application update cycle, the recommended delay of 200 ms was exceeded by the synchronization. With our method it is possible to synchronize the creation of 750 objects with around 100 vertices without exceeding the recommended 200 ms. For objects with 1.000 vertices the simultaneously creation of about 250 geometries is possible within the recommended delay. Figure 3 a) furthermore shows that the geometrical complexity seems to have a greater impact on the delay than the number of objects, particularly considering the delay times for objects with over 10.000 vertices. Already a few instances of highly complex geometry exceed the delay recommendations.

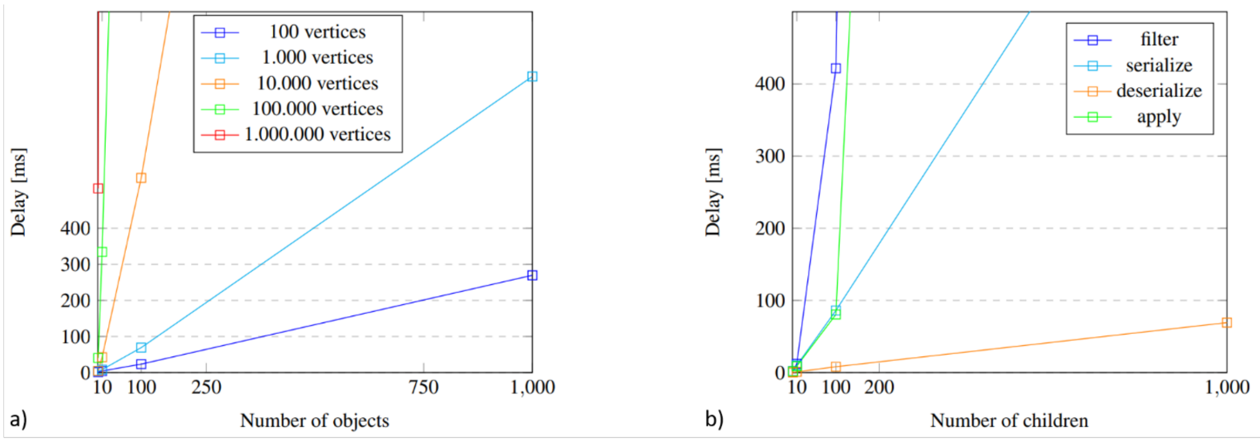

Figure 3: Performance of the implemented synchronization: a) application delay for an increasing number and complexity of created and synchronized objects b) delays of the main synchronization functions measured on ten primitives with 100 vertices and an increasing number of children.

In further tests the synchronization delay was measured for different complexities of the scene graph hierarchy. This is interesting to consider for the synchronization of complex 3D assets like CAD models, since they are organized in hierarchies of separate parts. Additionally, we split the delay by the involved synchronization functions as depicted in Figure 3 b). The main functions are filter, serialize, deserialize and apply. Low complexity geometry with 100 vertices was used during the tests. At the beginning ten primitives with each one child object were created which resulted in a total of 20 objects. The number of children per object recursively increased by factor ten in each test. Thereby, in the last test each initial object resulted in a recursive tree of 1.000 children. Figure 3 b) depicts the delay increase of each synchronization step. While the number of children merely affects the deserialization delay, it has a huge impact on the other three synchronization steps. Especially the filter and apply functions scale significantly bad with an increasing number of children. It is to be considered that values of all steps have to be summed up to retrieve the overall application delay. For the synchronization of simultaneously created object structures with about 100 children the filter, serialize and apply functions have to be optimized to lower the delay.
The performance tests were limited to the application delay in order to identify bottlenecks and opportunities for the improvement of our implementation. In final applications the network delay need to be considered additionally to determine the overall delay of the CVE.

5. Conclusion

Immersive collaboration applications for distributed participants require frameworks which shield the developers from the complexity of low-level APIs. In this paper we presented our method to expand the OpenSG scene graph library and thereby enable the real-time synchronization of remote scenes. Thus PolyVR, which builds on OpenSG can be used as a framework to develop immersive remote collaboration applications. Our framework was validated by building a CVE containing a production line where two users collaborated in real-time. During the collaboration the participants successfully tested the ownership concurrency control. In following work, more complex consistency control methods can be investigated. Furthermore, errors occurring with more than two users need to be fixed to provide a robust and scalable collaboration framework. Additional features are to be added to the collaboration module from other PolyVR modules, like the transmission of verbal speech and support of different HMD devices. Overall, future work should focus on the usability in order to improve accessibility and joy of use with the collaboration framework.

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SHORT PAPER

Leveraging Augmented Reality to Support Context-Aware Tasks in Alignment with Business Processes

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Keywords: Augmented Reality – Context-Awareness – Intelligent Business Processes – Smart Manufacturing

Abstract

The seamless inclusion of Augmented Reality (AR) with Business Process Management Systems (BPMSs) for Smart Factory and Industry 4.0 processes remains a challenge. Towards this end, this paper contributes an approach integrating context-aware AR into intelligent business processes to support and guide manufacturing personnel tasks and enable live task assignment optimization and support task execution quality. Our realization extends two BPMSs (Camunda and AristaFlow) and various AR devices. Various AR capabilities are demonstrated via a simulated industrial case study.

1. Introduction

As Industry 4.0 digitalization grows, both business and production processes and associated IT automation play a significant supporting role for increasingly complex scenarios. Furthermore, the integration of industrial augmented reality (IAR) to support human tasks in production processes has remained limited, as BPMS have hitherto not directly supported nor integrated AR. In prior work (Grambow, Oberhauser, & Reichert, 2010, 2011), we developed an approach for contextual process management tailored towards software engineering (SE) processes, while prior extended reality work includes (Oberhauser & Lecon, 2017), which focused on the potential of virtual reality for addressing certain SE-related challenges. This paper contributes an approach for integrating context-aware AR into intelligent business processes, enabling process-centric and context-aware AR support for manufacturing personnel tasks to support assignment optimization and execution quality. Our realization via two commercial BPMSs shows its feasibility.
The paper is structured as follows: Section 2 describes related work, and Section 3 describes our solution concept and realization. Section 4 provides an evaluation, followed by a conclusion and future work.

2. Related Work

In (Blattgerste et al., 2017), AR glasses provide mobile assistive instructions, but was largely restricted to one concrete problem or scenario rather than a generic business process. BPMN4SGA (Vogel & Thomas, 2019) integrates Smart Glasses as a BPMN extension, but primarily for documentation purposes rather than actionable AR content. In our approach, AR Actions are modeled and implemented via predefined AR templates containing attributes for nearly all BPMN elements, with the AR application interpreting the templates and sends feedback to the BPMN modeling application, avoiding implementing or syncing steps with the BPM engine. SenSoMod (Dörndorfer et al., 2018) adds context-awareness to conventional non-production applications like email, calendar, etc. (Gronau & Grum, 2017) combined the Knowledge Modeling and Description Language (KMDL) with AR and projected sensor data and process step association onto machines, but it lacks concrete tailored task guidance. BPMN4CPS (Graja et al., 2016) combines BPMN with cyber-physical systems, adding resources and context data to a business process for increased automation, but it does not integrate AR directly. HoloFlows (Seiger et al., 2019) is an AR process modeling approach for the Internet of Things (IoT), utilizing a simple state-machine and custom notation that lacks BPMN support and integration with mature BPMS - vital for industrial settings.

3. Solution and Realization

As shown in Figure 1a, our overall PARADIGMA solution addresses context-awareness and AR integration within business processes, including the user's positional data and objects of interest at that location, gathering AR-based content input from users, integrating AR-based user choices into the local process context, and providing AR-based guidance and prioritizes and optimizes task assignments based on context (detailed in Grambow et al., 2021a). Our logical architecture is shown in Figure 1b, the front end is the top layer which supports our AR app, while a BPMN app supports the modeling of AR processes with AR support (detailed in Grambow et al., 2021b). The AR app contains the 3D models, animations, videos and images that will be displayed in AR. The apps communicate with the PARADIGMA Backend via REST calls, primarily using JSON-based content. This Backend, in turn, can integrate with any BPMS via REST APIs, currently integrated with either Camunda or AristaFlow. While our solution considers many more facets, this paper primarily elucidates the AR relevant aspects.

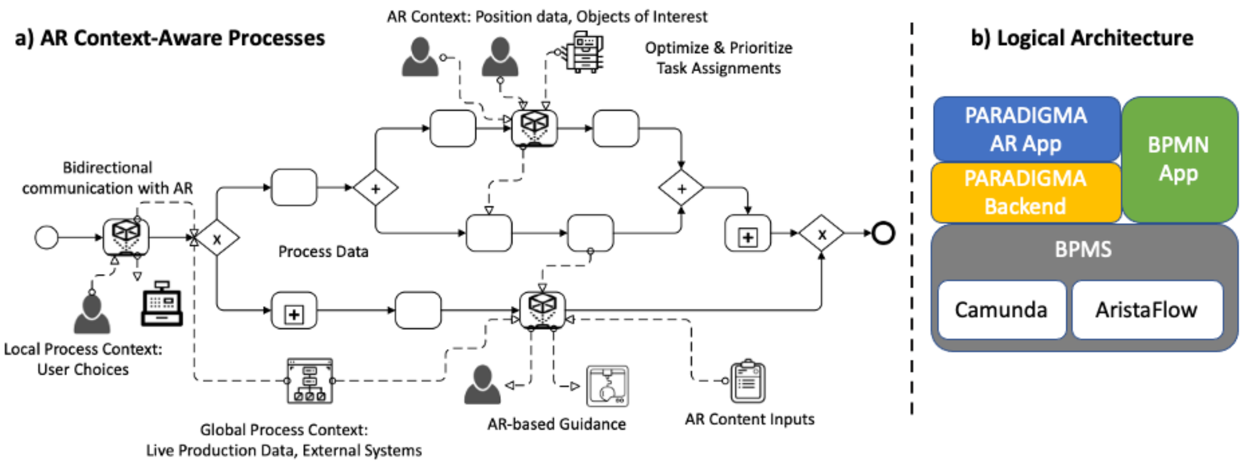

Figure 1: PARADIGMA Solution Approach: a) AR Context-Aware Processes and b) Logical Architecture.

For BPMN compatibility, our BPMN elements are not directly distinguishable from normal BPMN elements without AR Actions. During modeling the distinction is made by viewing the Variables Tab for a BPMN element in the corresponding BPMN modeling application. As shown in Figure 2, a modular system of AR components supports various AR content-specific types, some of which we highlight below.

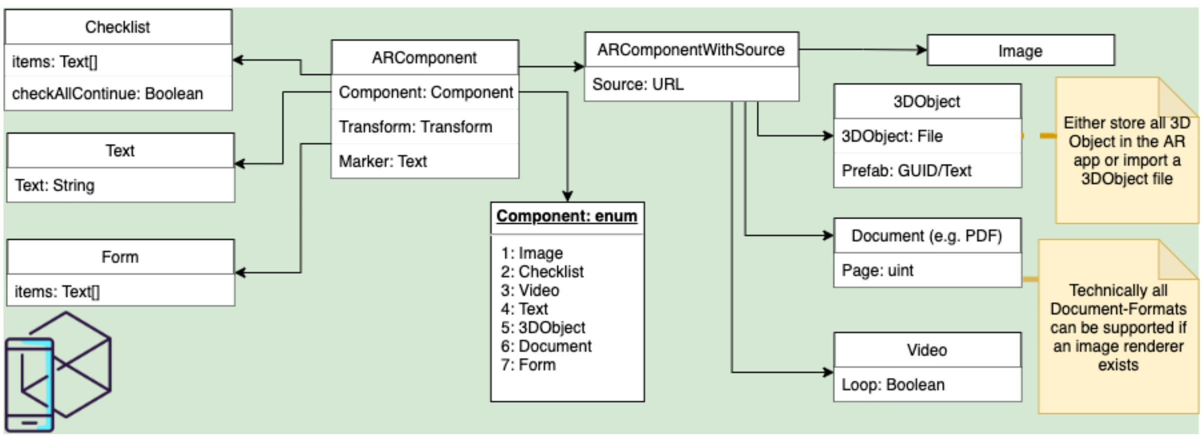

Figure 2: Overview of the currently implemented AR Modules.

The AR Video / Image module supports video (with an alpha channel) or image (with an alpha channel) placement in the AR world. The AR Checklist module supports task quality via checklists in AR. The 3D Overlay module renders and positions 3D virtual objects in space.
The AR app was realized with Unity 2020.3.8f1 with AR Foundation, ARCore XR Plugin, ARKit XR Plugin, and Magic Leap XR Plugin. It integrates REST call interaction containing JSON content with the PARADIGMA backend (and implicitly BPMS) and handles the placement of objects in the virtual AR space.

4. Evaluation

Due to current restrictive COVID-19 industrial access, we simulated various industrial scenarios in an analogous academic setting. Due to space constraints, only our machine modification scenario is described here. The BPMN model for our case study is shown in Figure 3. For this scenario, an additional part (PCI card) is added to a PC, analogous to adding or replacing a machine part in an industrial scenario. We tested our system with a tablet (fixated by a hands-free tool) since not all workers will have access to AR goggles, and a Magic Leap 1 as shown in Figure 3a and using its pointing device in Figure 3c. As Figure 3h shows, checklists are spatially anchored (static) to ease reading, pointing, and checking; settings (top left) and a task list (top right) are accessible; the active task (green) is shown with a white checkbox to its left to permit ending the task (even if some items remain unchecked).

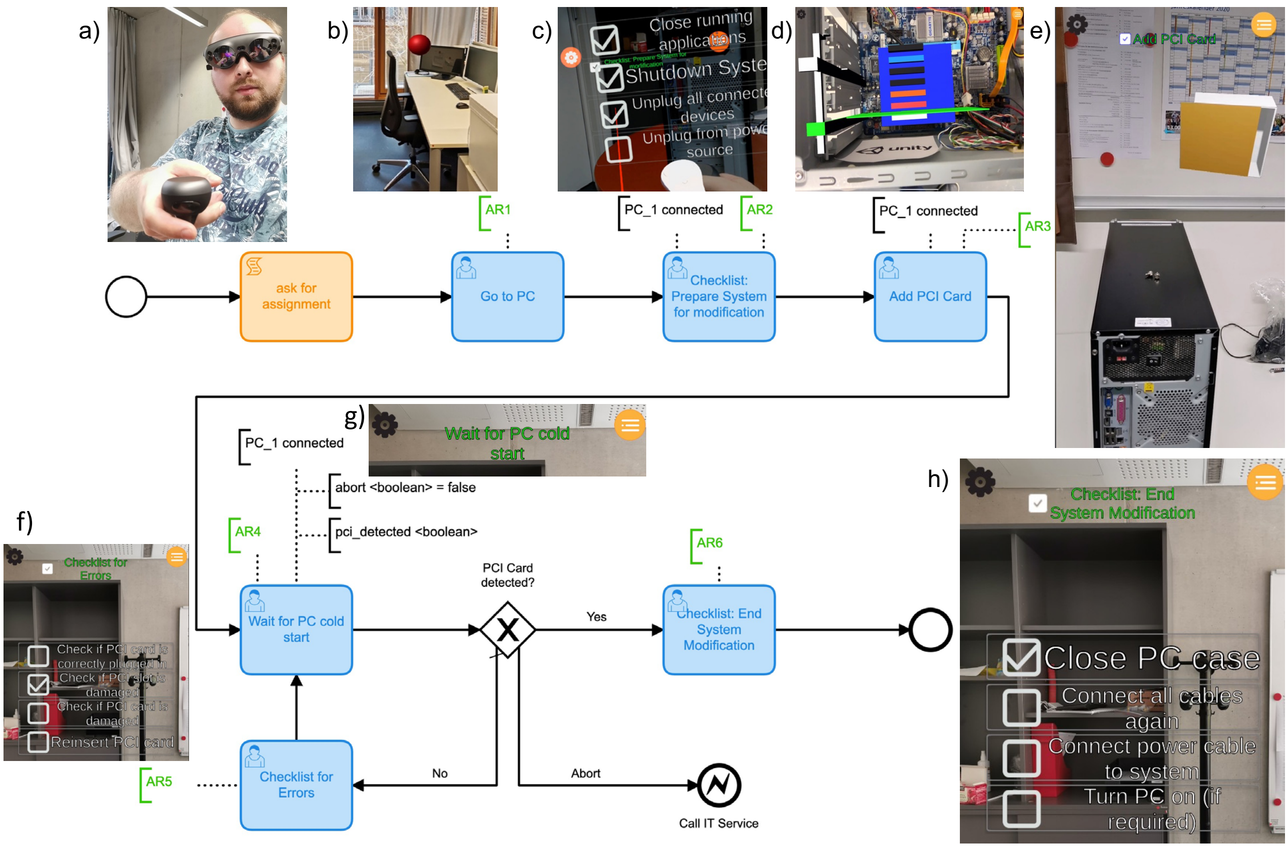

Figure 3: BPMN Model in Camunda Modeler annotated with AR tasks in green; a) Magic Leap b) AR navigation support c) AR Checklist for task preparation d) AR overlay e) AR video guidance f) AR error checklist g) AR PARADIGMA backend automatic machine sensor detection h) AR process completion checklist

The scenario process (Figure 3 Camunda BPMN with AR annotations in green) consists of the following:

1. "ask for assignment" activity: the PARADIGMA-Backend determines the optimal worker for an assignment via our backend IAC (Intelligent Assignment Component) and assigns it to that worker.
2. User is notified of an assignment in the AR App: The upper right “Task Button” displays a red dot.
3. "Go to PC" [AR1 task]: red spheres (anchors) are used to guide the User to the destination (Figure 3b).
4. [AR2] Displays a checklist (Figure 3c) for system hardware modification preparation (Figure 3d).

5. [AR3] An AR-Video-Overlay is shown on how to open up a PC case (Figure 3e). Once the marker inside the PC is scanned, the video stops and a 3D PCI Card and mainboard overlay is shown (Figure 3d). The user ends the AR task by selecting the checkmark next to the active task.
6. [AR4] The user waits (Figure 3g) for PARADIGMA context sensors to detect PC and PCI card.
7. [AR5] If undetected or a timeout occurs, an Error Checklist is shown (Figure 3f) and [AR4] is repeated.
8. [AR6] PCI Card was “detected” so the completion checklist (Figure 3h) is shown. Once all items or task is checked, the activity and process are ended and PARADIGMA provides the next assignment.

5. Conclusion

Towards improving IAR and Smart Factory and Industry 4.0 process integration, we contributed a context-aware approach for IAR modeling and integration that aligns business processes with worker situations and global and local industrial context. It contextually integrates process-based guidance and support for manufacturing personnel tasks, live task assignment optimization, and improved task execution quality. Our realization via integration with two BPMSs and various AR devices showed its feasibility. Our evaluation case study demonstrated primary IAR capabilities. Future work includes automatically determining the expertise of an AR user (e.g., based on errors and/or performance and guidance usage) and auto-adjusting the guidance appropriately; integrating additional hand-tracking and gesture detection mechanisms; improving AR marker recognition; supporting manual process task jumps to previously completed activities; supporting task preview mode; addressing AR darkness/light condition sensitivity for object positioning; and a comprehensive empirical study in an industrial setting.

6. Acknowledgments

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POSTERS

Early driver-in-the-loop with virtual reality driving simulator in ADAS development methodology

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Keywords: ADAS development methodology– Virtual reality – Driving simulator validation – Bias reality/virtual – Early driver-in-the-loop

Abstract

Today, ADAS developments usually include drivers in the final validation tests, their results can lead to modifications of the design phase. Therefore, we want to propose a new ADAS development methodology integrating driver-in-the-loop tests as early as possible during the model-in-the-loop or software-in-the-loop phases. Early integration implies that the tests must be able to be set up quickly and allow diversified scenarios. The tests will take place in a virtual environment, and thus, before any use, it will be necessary to study the biases between the reality and the simulation of human behavior to validate the simulator and take these biases into account during the tests.

Presentation

Advanced driver-assistance systems (ADAS) are on-board safety or comfort systems present in our vehicles since the 1980s (Shaout et al., 2011). Some ADAS have become mandatory, for some categories of vehicles, within the European Union like the Emergency brake assist (EBA) or the Lane Departure Warning System (LDWS) (RÈGLEMENT (CE) No 661/2009 DU PARLEMENT EUROPÉEN ET DU CONSEIL, 2009).

The development of ADAS uses usually the X-in-the-loop (Moten et al., 2018) principle well-known in the software embedded system. It means that they first test the ADAS functionality with a complete numeric model including the environment (model-in-the-loop), then the embedded software (software-in-the-loop), the electronic control unit prototype (hardware-in-the-loop) and finally the behavior of humans in relation to the ADAS (human-in-the-loop or driver-in-the-loop). These different modeling phases describe the V-cycle development method (Garousi et al., 2018) including a battery of tests verifying requirements at each modelling level. The major drawback of this method is that the human is included last. If a problem occurs in the driver-in-the-loop, they are sometimes forced to go back to the model itself and repeat the process, which includes the need for additional resources.

Furthermore, an ideal driver-in-the-loop test has to be checked on a real prototype. But the ADAS critical tests cannot be conducted in real life without endangering the subject. That is why the industry and research have turned to driving simulators and more particularly to virtual reality (Bouchner, 2016). The virtual reality driving simulator try to recreate the real environment in a control and safe place using a virtual environment which simulate the different senses and interactions. The simulator can allow testing with different weather conditions, constraints, all quickly and without restriction.

Historically, the first virtual reality driving simulators use a camera on scaled-down models that retransmitted the up-scaled image to a driver on a screen. With the development of computers, the environment begins to be simulated digitally from the 1960s with a projection on simple screens. From the 1990s, some simulators begin to use virtual reality headset (Kemeny, 2014). Subsequently, CAVEs (Cave Automatic Virtual Environment) (Havig et al., 2011) begin to be used and developed in the 2000s. Since 2010, virtual reality headset starts to be democratized in simulators with technological advance. Despite the innovations, there are still differences of behavior between real test and virtual reality test. For example, there are the problem of sensations to get closer to reality, trying to recreate vibrations, noises, movements, or visuals. Another example, the feeling of danger is also an obstacle: a person aware of being in a simulator will not have the same behavior in front of a virtual pedestrian as in front of a real pedestrian.

As bias may exist between reality and simulation, they have to be defined on virtual reality driving simulator before it can be used for tests or research. The study of these bias will allow to characterize parameters and thus to know the differences of behavior between reality and simulation. The paper of Godley (Godley et al., 2002) proposes a validation on the driving speed of the drivers based an absolute validation and a relative validation. The absolute validation means that there are no differences between data of a real-world experiment and data of the same experiment in the virtual reality simulator. The relative validation means there is a constant bias between the real-world data and data of the simulator. Since the bias is constant between subjects, it becomes possible to study the simulator data considering the bias existing with reality.

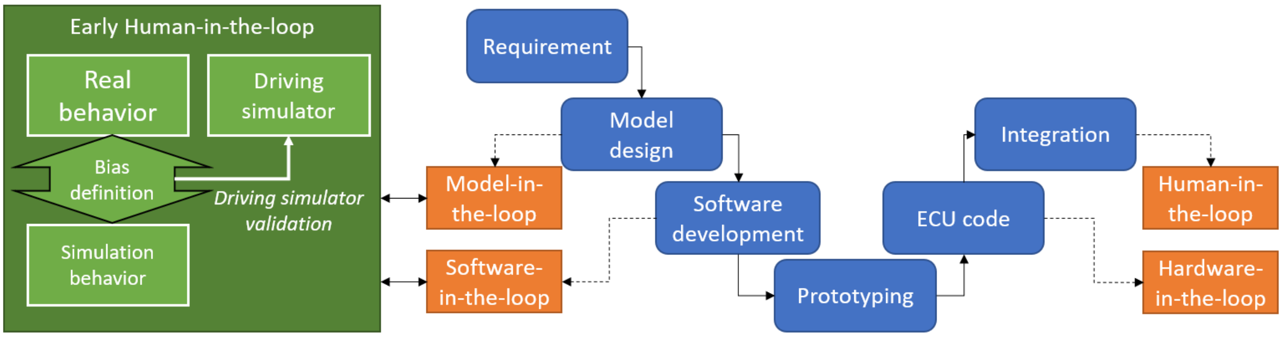

Figure 1 :Stages of proof of concept

In conclusion, the Figure 1 shows our new ADAS design methodology which include early driver-in-the-loop tests in the development cycle (green box), during the model-in-the-loop or software-in-the-loop phases, using virtual reality driving simulator. Since the tests take place early in the development process, the test environment (software/hardware) must be lightweight to involve different test drivers, so the use of a low-cost driving simulator is appropriate. The bias of this simulator will be defined comparing simulator data to database of real-world driving experiment in literature (Si et al., 2018). Then, the absolute and relative validation (Godley et al., 2002) of the driving simulator will be done. Finally, a demonstrator will be developed to test this new methodology on an ADAS development.

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Polyphonic XR/WebXR Museums: an effective but unused methodology

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Keywords: Virtual Museum – Cybermuseum – Interpretive Museology – Polyphony –.Educational – Constructive Realism

Abstract

This article is part of the elaboration of cybermuseological concepts about polyphonic methodologies. Polyphonic museology is projected from real museums to cybermuseums. It expresses a metaphor of a multiple point of view exhibition mode which has stemmed in new museology. It is specifically realizable in cybermuseums using XR/WebXR interactive, non-linear, gamified narratives possibilities, able to give an embodied experience of alterity. However, this paper shows that, although digital art explores collaborative trends and co-creation, XR/WebXR digital museums develop themselves along a more conservative path.

1. Introduction

This article develops a reflection about a specific kind of virtual museum following polyphonic museological principles. It wants to show a new way of making museums, forecasted by ICOM executive board as being a museums' main caracteristic, called polyphony, which introduces the possibility to assemble and share multiple points of views inside exhibition procedures can get many advantages from WebXR technologies. It could be possible to deploy museographical means that are quite unrealizable in tangible museums.

2. From Polyphonic Museums to Polyphonic Digital Museums:

Polyphony is a musical concept, referring to a "the simultaneous combination of two or more tones or melodic lines"[1]. It is associated with counterpoint, a coded part of composition dealing with combining different melodic and rhythmic lines, as opposed to harmony. As a museological metaphor, we use this name to point to collaborative methods going along subaltern anthropology principles. Coming from world cultures museums, the ICOM has turned polyphony into general museum's labelising practice in 2019: "Museums are democratising, inclusive and polyphonic spaces for critical dialogue about the pasts and the futures" [2] .

As Steven Engelsman explains, ethnographic museums have gone through a big crisis since the 90s'. "They address issues of cultural identity and diversity and are driven by social responsibility issues. [3]" These museums have learned to work with the population's tangible work they showcase or to give their material heritage back. Knowledge is gathered and shared by the communities themselves, as one can see with Frankfurt Historical Museum 2018 case study, "The Polyphonic Museum" by Jan Gerchow, Angela Jannelli and Aikaterini Dori[4]. Immigrants stories are collected, through audio or audiovisual recordings. Their stories are making the city immigration history since 1945. A similar approach is held with the German capital residents in a web app, Digital CityLab[5], which draws contemporary history directly from its inhabitants. One can retrieve 2D audio and video documents from an interactive map of the city. Another popular attempt, during the lockdown crisis, has been launched by Bradford's National Science and Media Museum (UK), with #SonicFriday, an "online project that collects people's memories related to sound, music and sound technologies"[6]. Studying technological impact on people's sensibilities, has drawn public participation in producing repositories of thematized memories.

Polyphonic method is a participative one, including every participant in the procedure of creating a part of a museum exhibition including one' point of view amongst many other. It does not aim at consensus, on the contrary, it wants to present the patchwork which composes real life and let viewers, visitors make their own experience from these heterogenous sources. "This misinformation and the communication-block" which pretend to show a consensus must let the way to "establishing a sense of polyphony instead of global consensus", hold "Whale Chong, An Audiovisual Whaling Polyphony from the Bergen Museum, Norway" curator, Nina Svane-Mikkelsen[7].

3. VR & WebXR museums' lack of polyphonic methods

3.1 XR/WebXR museums realistic paradigm

If polyphonic methods exist in tangible museums, and are using digital means, they hardly exist within XR and WebXR museums. WebXR platforms exist for collaborative art galleries and museums. "The Invisible Museum"[8] provides the possibility for curators and gallerists to create collaboratively interactive and immersive exhibitions environments. However, the choice of content does not integrate a participative perspective. End-users are not meant to be collaborators. One can note that galleries and museums aesthetics are similar. They refer to a paradigmatic 19th century institutional museum. Museologically, it belongs to traditional hierarchical professionals/ public relationship. In Google Arts and Culture[9], Google technologies are shared with museums' professionals. This collaboration does not include the public either, as it is the case in polyphonic museums.

The same property can characterise a platform like "Occupy White Walls"[10], by Yarden Yaroshevski, who created a VR space with customizable galleries architectures and contents, with plenty of decorative additives and art collections reproductions which have fallen in public domain. The creator and developer collaborates with all the potentially interested public. This platform could look as if it were made from a polyphonic museological method. However, it sounds more like a randomly twitting tree, as each gallery maker fulfils her own projects.

3.2 High interest of XR/WebXR technologies for polyphonic museology

We think that polyphonic methods can successfully build experiences with XR and WebXR. These kinds of technologies mix immersion, interactivity, connectivity. VR brings about a possibility to enter an artificial world as if it were a real one. It can provide multi-voices using interactivity and non-linear narrative possibilities. It can reveal complex points of views and give a sense of presence and reality to them that 2D digital means can hardly achieve. Visitors could see their sense of empathy enhanced by emotions and construct their representation of reality by projecting themselves in plural multisensorial and kinesthetic virtual realities. WebXR museums adds the opportunity of real time collaboration, a participative dimension which follows a polyphonic methodology.

3.1 Lack of Polyphonic XR/WebXR museums

Collaborative digital art works are being made on the Web, like WADS, a co-creation in Mozilla Hub[11]. However one can wonder why the museum figure in XR museum makers occults this renewed polyphonic way shown in RL world culture museums. Maybe ethnologic museums have not invested virtual worlds despite their qualities for polyphony. And XR/WebXR historic museums tend towards realistic reconstitutions rather than patchworks of mentally and socially constructed realities.

4. Conclusion

Making a XR/WebXR polyphonic museums can bring about a multi-sensorial kinesthetic experience, open empathy to non-linear threads of heterogeneous storytelling. Using polyphony enhances drastically the sense of real experience as it makes people meet visitors and visitors meet the real people and participate to their cultural life. It is remarkable that such tools have not yet been used in XR/WebXR world culture and historic museums which aim towards a kind of cinerealism. They seem to follow an ideal conservative museum figure which real life museums and their websites have largely overpassed, setting themselves towards adventurous museological principles.

5. Endnotes

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Virtual reality sex-work: phantom touch and “tricks.”

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Keywords: virtual reality – phantom touch – avatar mediated interactions – user experience – sex-work

Abstract

This poster explores a Japanese virtual reality (VR) sex-work service — X-Oasis — user experience (UX) design for avatar-mediated sexual encounters. Quantitative data was collected, participant observation and interviews were conducted. The results reveal that the UX allows sex workers to perform their activities in VR. Moreover, it relies on sex workers’ capacity to experience phantom touch and “tricks” to awaken guests’ body parts as the latter cannot move their bodies in the X-Oasis virtual environments. By engaging directly with the engineers and co-founder of X-Oasis, this poster paper could spark discussions among industry professionals and enhance our comprehension of VR intimacy.

1. Introduction

Avatar-mediated sexual interactions in virtual environments (Wardle, 2018) have been researched in the context of Second Life (Koski, 2010). “Good” virtual coitus occurs when role play compensates for the lack of physical touch and individuals interact using their voice (Lynch, 2010). Virtual intimacy can provide emotional fulfillment, support, and satisfy communication needs (Freeman et al., 2016). This poster presents X-Oasis, a Japanese virtual reality (VR) sex-work service launched in July 2020. The sexual interactions are mediated via anime-like-looking avatars. Guests (customers) can choose among twelve virtual environments and thirty-seven scenarios inspired by Japanese pornographic material. They can also select their gender and genitalia. The guests can access the service via desktop or using a smartphone and VR goggles. Unlike the guests, the casts (sex workers) can move their bodies in virtual environments using motion tracking. X-Oasis developed a unique user experience (UX) design system and “tricks” inducing touch-like sensations. By interviewing X-Oasis, we hope to provide inside knowledge on UX from industry professionals.

2. Methodology and data

We conducted participant observation during six 40 min sessions at X-Oasis using iPhone X and Hamswan VR goggles. The protocol was as following: our avatar body appeared in the virtual space, the cast greeted us, scenarios were played out (lasting 10-15min each), feelings were discussed. Furthermore, two quantitative surveys were conducted amongst five casts in the Summer of 2020 and March 2021. X-Oasis engineer and co-founder were interviewed to elicit methods for stimulating arousal.

The quantitative data is as follows: age distribution of X-Oasis workers is 23-26 years old (60%), 27-30 years old (20%), 31-34 years old (20%). The average number of customers per week is 10,3. The casts spend an average of 5,8h per week in X-Oasis. 60% of the cast change their gender identity based on the avatar, and 60% consistently identify differently from their physical gender identity.

3. Discussions

According to X-Oasis co-founder, “sitting and playing sex animations while chatting and watching avatars has a strong ‘acting’ feel to it” in Second Life. Their competitor Virtual Live Chat from DMM only provides chatting services with 2D anime characters moved using computer-programmed animations. Building upon this, X-Oasis founders wanted to create an environment where sex workers could have a virtual body and experience intercourse by “sharing the same space.” They developed a unique UX that relies on the casts’ capacity to experience phantom touch. “The level of VR immersion of the cast equals the level of virtual immersion of the guest, so we develop mostly for casts to increase guests’ UX,” the engineer says. He enumerates the elements taken into consideration when designing the UX. 1) the cast can use their licensed avatar, 2) they are given liberty regarding fashion, 3) the guest is represented by an avatar, giving the sensation of talking “to someone who is there,” 4) penis and nipples can dynamically erect, 5) breasts can move when touched, 6) implementation of a customizable and sexually sensitive face dynamic system with custom tongue movements, 7) no risk of privacy violation. Regarding the latter, X-Oasis co-founder remarks that “the sense of safety covered and protected as a commercial service lets the casts immerse in front of guests.” The UX was built in Unity 2019.4. The service uses Unity SteamVR plugins to receive inputs from the cast’s VR equipment. The avatars were created in VRoid. The real-time movements are rendered using FinalIK. X-Oasis uses its own AWS broadcast server implemented with webRTC or a third-party webRTC server.

The guest cannot move, and their viewpoint is positioned in the avatar’s head. However, the cast can move the guest’s body, and a mirror can be placed in front of them. Due to the static nature of guests’ avatars, the cast has to master the phantom touch, transmitting the feeling of immersion. They are trained “tricks” to induce sensations of touch and awaken avatar-mediated arousal. The X-Oasis founders share with us three of them. First, the cast sucks their finger for a second, then slowly lets the guest conduct the same action by bringing the finger into their mouth — “a ritual that awakes guest’s tongue,” the engineer clarifies. Then, the cast proceeds to kiss, stimulating “feeling the tongue,” he adds. Second, casts explain that to mimic the sound of kissing, penetration, and licking, providing “realistic” real-time audio feedback, the cast “licks fingers and kisses between the thumb and index finger of their hand.” Third, during the sessions, it has been noticed that the cast comes remarkably close to the guest’s head. The engineer explains that provoking phantom touch is simpler with body parts closer to the head. He adds that the guest’s “eyes can focus on VR 3D, making their body feel that it is there in reality.”

As a final remark, the casts mention that, unlike in a game, there is a sense of “mental connection and spiritual openness” when they conduct their activities at X-Oasis. They further note that for “good” intercourse, “immersive experience” and “high-end VR equipment” are paramount. Adding trackers on hips and legs enables higher quality full-body tracking and leads to “better sex,” as they claim.

4. Conclusion

Akin to Second Life, X-Oasis allows its cast members and guests to experience different gender identities and various erotic encounters different from their daily lives (Lynch, 2010). This poster engaged with industry professionals to understand the thought process behind designing the UX and what “tricks” are deployed to awaking body parts in avatar-mediated sex work. The UX allows sex workers to conduct their activities from home in VR. The UX was built to stimulate the casts’ phantom touch, leading to immersive experiences for static guests. According to gathered testimonies, casts’ capacity to experience phantom touch and deploy “tricks” compensates for the absence of haptic feedback. This poster could spark discussions among industry professionals designing VR sex-work services, enhance our comprehension of VR intimacy using phantom touch, and provide an insight into the inner mechanisms of VR coitus.

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A new option in pain prevention with Bliss©, a Digital Therapeutic solution leveraging Virtual Reality: results of a French open-label multicenter phase III study (REVEH Trial)

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Keywords: Virtual reality – Bone marrow biopsy – Digital Therapeutics (Dtx)

1. Purpose

The prevention of care-induced pain is a central concern for all healthcare teams in hematology units. Use of MEOPA (Oxygen + Nitrous Oxide) is today a standard of care. "Bliss©" is a new Digital Therapeutic / Virtual Reality solution for pain distraction, with four imaginary interactive environments in three dimensions (image and sound) augmented by binaural sound. Immersion in virtual reality (VR) has already documented its analgesic effects in several phase II trials in cancer but comparison with standard treatments in larger randomized study is needed.

2. Methods

We conducted an open-label multicenter randomized phase III trial (ClinicalTrials.gov identifier: NCT03483194) in 5 sites in France. Patients were randomly assigned in a 1:1 ratio to receive pain prevention. We assessed the safety and efficacy of Bliss© in prevention of pain and anxiety before performing and during a bone marrow biopsy. Efficacy was assessed by pain intensity with visual analogic scale immediately after the biopsy. The primary end point was patient-assessed pain intensity after the bone marrow procedure.

3. Results

A total of 126 patients were enrolled with previously untreated malignant hemopathy between September 6, 2018, and May 18, 2020. They were randomly assigned in a 1:1 ratio to receive pain prevention with MEOPA (n=63) or Bliss© (n=63) before and during their bone marrow biopsy. All patients received a local anesthesia with lidocaïne before the biopsy. Median age of the study population was 65.5 years old (range 18 to 87) and 54.2% were men. The average pain intensity was 3.5 (standard deviation 2.6) for the MEOPA group and 3.0 (SD 2.4) for the VR group (p=0.26) without any significant difference according to age, gender or hemopathy. Immersion in VR was well tolerated in 100% of patients included in the VR group. Physicians were very satisfied by the relaxation procedure in 64.9% of cases (52.5% in the MEOPA group and 77.6% in the VR group, p=0.01) and recommended re-use of the technique in 54.2% in the MEOPA group and 79,1% in the VR group (p=0.02).

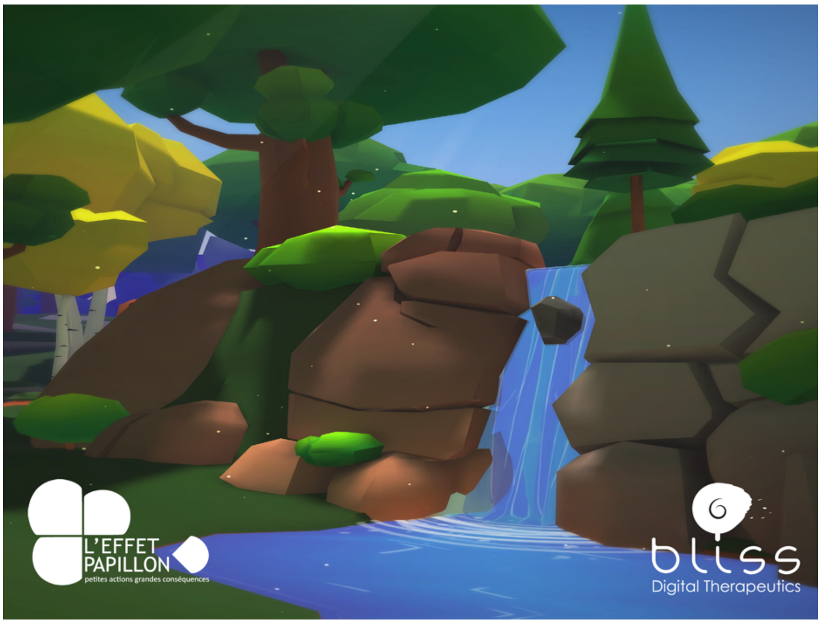

Figure 1: Example of forest environment

4. Conclusion

The intensity of pain did not significantly differ in both arms. Bliss©-based relaxation method was well tolerated, and the satisfaction of patients and physicians was very high in VR group. This study validates the use of immersion in VR with Bliss© as new digital therapeutics and support the integration of the software in the panel of supportive care.

5. Acknowledgments

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Navigation Volumes in UMI3D-Based CVE

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Keywords: UMI3D – Navigation – Collaborative Virtual Environment – Embodiment

Abstract

UMI3D is a data exchange protocol [1] allowing the creation of collaborative virtual environments, accessible via device-specifics applications called UMI3D browsers. An extension for user tracking and embodiments integration has been recently presented [3]. However, navigation has not been properly described in UMI3D yet. This poster introduces a navigation volume concept for UMI3D to describe navigable spaces and optimize network flow.

1. Objectives

Navigation. We consider navigation as the action of the user to pass from a position to another, the path taken by the user being considered as a straight line. We argue that every navigation method (teleportation, walking, flying, orbiting, …) can be described this way (for instance, the walk would be discretized into smalls individual steps). The user will here be considered as a single point, but the model remains valid for a volumetric approach. In this paper we will focus on describing where users can stand and which path they are allowed to take between two available positions. As an example, we can picture two rooms where the user can stand, but in order to go from a room to the other, he has to go through the door and not through the wall. We will not discuss here the navigation method used by the user.

Networking Optimization. As previously described, the UMI3D protocol ensures the real time synchronization of a virtual environment located on a server and its copy on multiple browsers. Added to that the volume of exchanged tracking data (needed for avatars animation) exponentially increases with the number of connected users. This phenomenon risks to unconditionally lead to the bandwidth saturation of regular network installations. Therefore, a strategy based on the sparing of the transferred data seems to be a significant progress, for distant or non-visible objects (including avatars). However, it remains essential to ensure fluid animations and the fidelity of user movements regardless of the quality of data.

2. Constraints

First, the navigation system must not introduce any motion sickness into the user experience, especially for VR users. When a user tries to go out of bounds, the misbehaviour must be notified to the user and/or corrected instantaneously. Also, the nature of the correction should be adequate to the user's hardware: we might stop the avatar's motion on a desktop application if the user hits a wall, but we cannot use this approach on a VR headset without causing motion sickness to the user (a black-screen approach would be more suited). Therefore, those decisions must be made by the UMI3D browser itself and not by the environment.

3. Data Model

We first considered to use IndoorGML by OGC [2] as a base for our data model as a way to describe volumes, but it seems to be more suited for real-life environment description than virtual ones and therefore would not be the best choice for UMI3D. However, our model is heavily inspired by the IndoorGML approach, and an automatic parsing of IndoorGML data into UMI3D should be possible.
We introduced the notion of Volume Cell, which is an object containing a volume descriptor and a list of neighbours. A volume descriptor is an object describing a 3D volume and could either be a primitive (cube,

sphere, capsule, …), an external mesh data (.obj, .gltf, .fbx, …) or a mesh build with our UMI3D mesh designing tool (still under development). A neighbour is an object containing a reference to another volume cell and a list of adjacencies between the first cell and the referenced neighbour cell. Each adjacency is a volume descriptor describing the transition between the two cells. For example, we can picture the same two rooms than before, each room would be described by a primitive (a cube) and would be the neighbour of the other. The adjacency between the rooms would be a cube around the door. We could add another door between the rooms and add another adjacency item into the neighbourhood data. This data model allows browsers to build a connectivity graph of volumes and run path finding algorithm to guide the user's navigation if needed. Each Volume Cell can be divided into sub volumes to ensure different levels of details (LOD). For instance, the 5th floor of a building can be first described as a simple cube while the user is outside of the building, and then be subdivided into multiple rooms as it gets closer. Depending on its performance limitations, a UMI3D browser may ask the environment for different LOD of the volumes. Finally, events will be sent from the browser to the environment when a user enter or exit a volume cell for the environment to run some specific behaviours if needed. Although the environment might already be able to compute this information using the tracking data, this computation would cost more time as more users connect to the environment.

4. Usages

Volume Cells are firstly designed to restrict users' navigation to allowed spaces, generate collision when necessary, and if no navmesh [4] has been provided to generate one on browsers using walking or teleportation-based navigation. In addition, we are working on a structure for collaboration rooms. Its specificity relies on a data relays system, within which each request to send data will be evaluated according to several custom rules based on whether objects are in the same volume or not.
The solution we have chosen to maximize the use of the tracking data consists in the integration of Kalman filters into the browsers. These filters allow to set up a prediction system from the data received periodically. A real-time interpolation is then locally applied to the result of these predictions, making it possible to obtain continuous estimates of the evolution of the data concerned. In the end, we consider that the use of Kalman filters can be generalized to each numeric data that can be filtered and will contribute to the network optimization of the UMI3D protocol.

5. Conclusion and Discussion

With the introduction of Volumes in UMI3D, we are now able to describe the navigable areas inside UMI3D environments and we operate a network decongestion by applying spatial rules on avatars and moving objects data exchange. The model presented here is still under development and may evolve in the future months. We do not yet specify which navigation method the user should use in the environment, which would require to use a generic classification of navigation methods, this will be another research work.

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Development of a Japanese tea ceremony VR that enables tea serving and communication with telepresence for remote users

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Keywords: VR – Robot – Machine Learning – Telepresence – Culture

Abstract
Due to the epidemic of the new coronavirus, the tea ceremony, a traditional Japanese culture, has been facing the problem of not being able to conduct in person. The purpose of this research is to develop a new Japanese tea ceremony VR that can provide tea to users in remote locations and allow users to communicate with each other while maintaining telepresence. To achieve this goal, we used VR Chat, machine learning, and the robot arm. The robot arm makes tea in synchronization with the tea-serving movement of the host in the VR space. As a result, the user feels as if they are experiencing a tea ceremony in the same space as the remote host and can drink the tea prepared by the robot as if the host prepared it.
This achievement is significant because it enables a new tea ceremony experience in the Corona disaster and contributes to the spread of traditional tea ceremony culture.

1. Introduction

Due to the outbreak of the new coronavirus, the tea ceremony, a traditional Japanese culture, could no longer be conducted in person. This is because tea ceremonies are generally held in an enclosed space, where multiple people drink tea from a single cup passed around, increasing the risk of viral infection. If this situation continues, the decline of the tea ceremony population, which has been considered a problem in the past, may become more serious (Agency for Cultural Affairs, 2015).
We consider VR as an effective means of realizing the tea ceremony experience in the Corona disaster. This is because VR allows users to participate in the experience from any location, with minimal risk of infection. In the past, various methods have been attempted to make the Japanese tea ceremony VR.
However, most of the existing tea ceremony VRs are designed to be experienced by a single person, or the experience is completed in the VR space (e.g., Hatakeyama & Komiyama, 2020; Takashi, 2020).
Initially, the tea ceremony is a culture in which multiple people gather to drink tea prepared by the host and have conversations with other participants. Therefore, we believe that in order to convey the appeal of tea ceremony culture, it is necessary to be able to communicate and drink tea, even in VR.
This paper proposes a new tea ceremony VR that can serve tea while achieving both communication and telepresence by combining VR Chat, robot arm, and machine learning. We will confirm the feasibility of the proposal through demonstration experiments. The realization of this proposal will enable a new tea ceremony experience in the Corona-related confusion and contribute to the spread of traditional tea ceremony culture.

2. Methods

2.1 Real-time tea delivery using machine learning and robotic arms

In this project, we will use machine learning to estimate the host's movements by image classification. Based on the results of the inference, the robot arm performs the action of making tea.

2.1.1 Preparation

1 Set up HMD, PC, and camera in the experience space of the host (Figure 1 (a)).

2 Set up HMD, PC, robot arms, and tea utensils in the experience space of the guest (Figure 1(b)).

3 The host wears an HMD, and the guest wears an HMD and earmuffs to enter the tearoom in the VR Chat (Figure 1(c)).

(a) Host space (b) Guest space (c)Tea room in VR Chat

Figure 1: Experience space.

2.1.2 System flow (host side)

① Start the machine learning program and tea-serving movements of the host.

② At the same time, the camera starts up and records the host’s movements at 30 frames per second.

③ The host uses 3D models of tea utensils placed in the tearoom in the VR space to perform the movements of the tea ceremony.

④ In the meantime, divide the video into frame-by-frame images, and perform image classification by machine learning for each image (Figure 2).

⑤ The machine learning model can infer in real-time which of the three actions the host is performing: “Spooning green powdered tea from the container (natsume) and transferring it to the tea bowl,” “Pouring hot water into the tea bowl,” “Making up tea.”

⑥ Count the inference results for each classification and use the action with the highest count as the final inference result.

⑦ Check the inference result against the checklist.

A) If the inference results do not match the contents of the checklist, return to ②.

B) If the inference results match the contents of the checklist, update the list and proceed to ⑧.

⑧ Write the inference result to a text file in the cloud. At this time, if the inference result is "Making up tea," write a stop instruction of the robot arm to the text file.

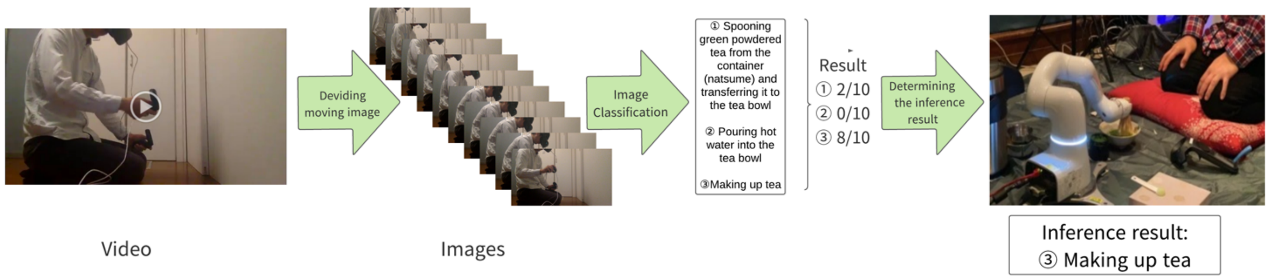

Figure 2: The process of image recognition.

2.1.3 System flow (guest side)

① Based on the inference results of the machine learning model, RPA operates the robot arm's operation software on the customer's PC and instructs the robot arm to perform the corresponding action.

② The robot arm uses the tea utensils to perform the tea-making operation.

③ Refer to the text file to check the stop instruction of the robot arm is written on it.

A) If there is no instruction, return to ② in the system flow (host side)

B) If the instruction is given, the robot arm will stop moving and proceed to ④.

④ The guest user takes off the HMD and drinks the completed tea.

2.2 Verification

At the IVRC (Interverse Virtual Reality Challenge) showcase on November 4, 2020, eight men and women (7 men and one woman) in their 20s to 40s participated in the experience as the guest from Akihabara, Tokyo. A man in his 20s who had experience in tea ceremonies participated remotely as the host from Chiba Prefecture. We set the duration of the experience at five minutes per person, during which time the participants were free to speak freely.

After the experience was over, we asked the participants to share their impressions of the experience.

3. Results and Limitation

- Seven out of eight people could have a conversation with the host until the end of the experience.
- After the experience, we were able to provide tea to 6 out of 8 people.
- The equipment required for the experience, such as robot arm, is expensive.
- Currently, it is not possible to drink tea in VR space.

4. Conclusion

This paper has proposed a Japanese tea ceremony VR that can serve tea while balancing communication between remote users and the telepresence of the experiencer by combining technologies such as VR, robot arm, and machine learning. The movements of the robot are synchronized with the movements of the host in the VR space and depending on who plays the role of the host, and the tea is made each time differently.

This gives the impression to the experiencer that a human made the tea, even if a robot made it, and can feel as if they are experiencing a tea ceremony in the same space as the remote host.

This method will be helpful in the Japanese tea ceremony industry as a new option for experiencing tea ceremony in Corona (COVID-19) related confusion.

However, there are still some technical and price issues. It is expected that the method proposed in this paper will be improved by lowering the cost of robot arms and improving machine learning technology.

In the future, we plan to use this method to promote the spread of Japanese tea ceremony culture, both domestically and internationally.

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Pseudo Real-Time Live Event: Virtualization for Nonverbal Live Entertainment and Sharing

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Keywords: Nonverbal interaction – Pseudo real-time – Live entertainment – VibeShare

Abstract

We have developed a pseudo real-time live system that allows users to share nonverbal interactions with past or future audiences. To test this system, we added nonverbal "Entities" such as sound and visual effects to an online video. We experimented with three conditions: (1) the Entities were added to only the first half of the video, (2) the Entities were added to only the second half, and (3) no Entities were added. The results showed that more participants were attracted to the experiment under the first condition than the others, and participants spontaneously interacted with the added Entities. This suggests that pseudo real-time interaction enhances the user experience for online video audiences.

1. Introduction

This paper aims to contribute to computer-human interaction in the post-Covid-19 era. Video conference tools and broadcast services solve distance and physical restrictions in online classrooms, international conferences, and live performances. However, the interaction between the performers and the audiences is limited to sending emoticons and questions and answers via text comments. These limited interactions, further limited by time zone differences, lack some nonverbal elements experienced at live events: the presence, applause, cheers, and vibes from audiences. To address the loss of nonverbal engagement, we developed VibeShare (GREE VR Studio Laboratory, 2021), which converts nonverbal input into multimodal feedback. VibeShare enables nonverbal, real-time live interaction between the performers and audiences (SHIRAI et al., 2019).

This paper proposes a pseudo real-time live system (Figure 1), which enables asynchronous nonverbal communication and reports how it affects the user experience of watching online video content.

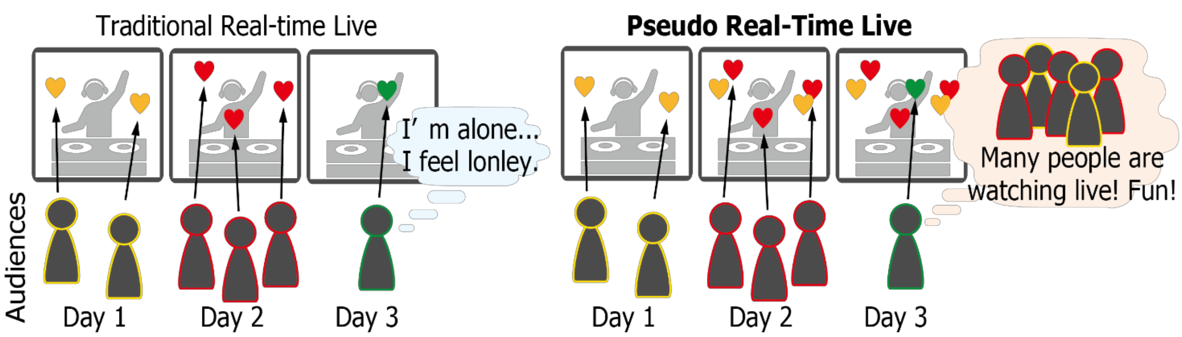

Figure 1: Concept of "pseudo real-time live." The audiences watching a traditional real-time live event can only see the reactions of those present. The audiences watching pseudo real-time live can enjoy the reactions of past participants and feel like they are participating with them, even if they are the sole participant at that particular time.

2. Evaluation

To examine the effect of our concept on user experience, we prepared the video shown in Figure 2 and experimented with three conditions: (1) the recorded sound effects and emoticons (hereinafter called Entities) were added to only the first half of the video (the condition called *FH*), (2) the Entities were added to only the second half (*SH*), and (3) no Entities were added (*NO*). An experimental web page (https://vibeshare-ex2101.herokuapp.com/), including the video and Entities, was developed in JavaScript. The URL was shared as an experiment with anonymous participants via mailing lists and Twitter without explaining the aim. The participants were able to drop out of the experiment if they felt bored. We defined "completions" as instances of participants watching the video to the end.

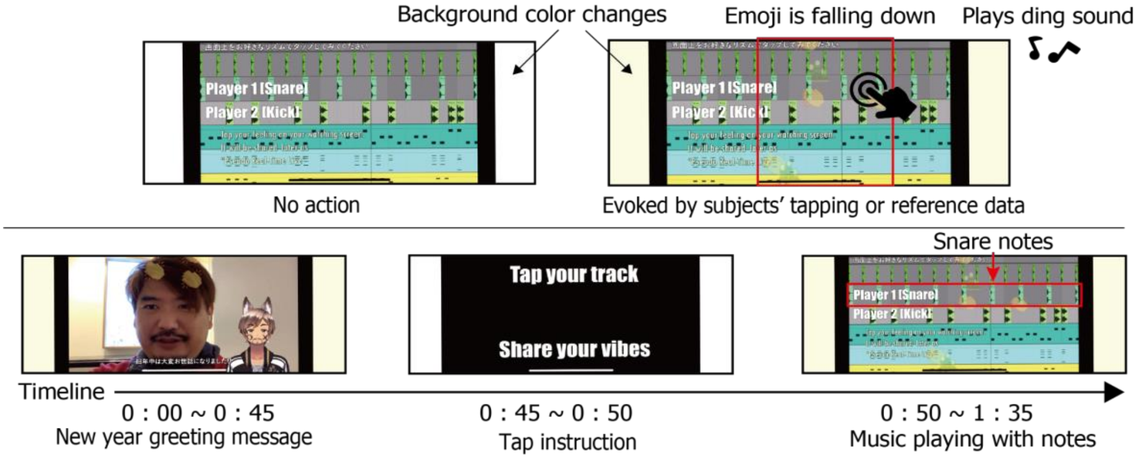

Figure 2. Depiction of the video and Entities. The top part shows the Entity that occurs when a player touches the screen or the recorded Entities play. The bottom part shows the sequence of the video. *FH* had Entities at appropriate times, such as at the end of the greeting message and on beat with the music. *SH* had Entities appearing in the timings of the snare notes.

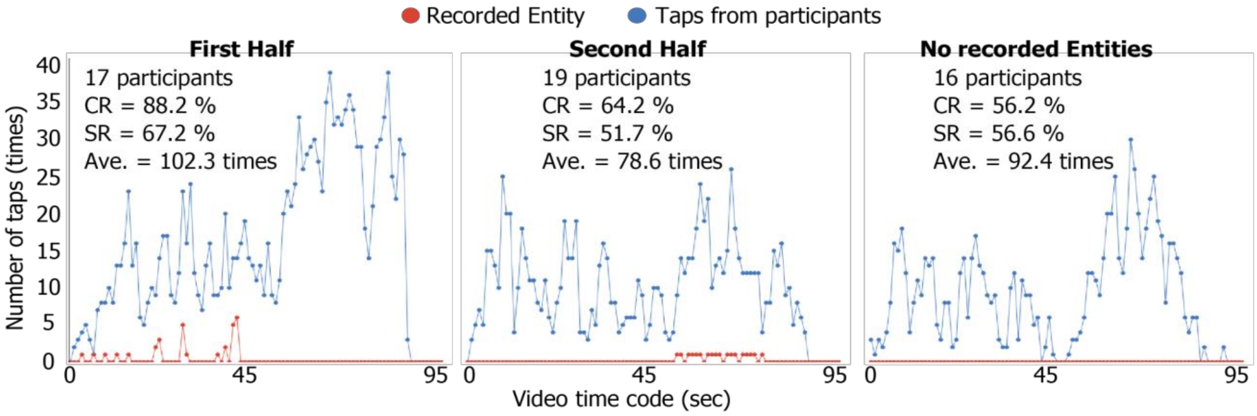

Figure 3. The number of taps associated with the video time code. The red series shows the number of recorded Entities. The blue series shows the total number of taps from all participants. "CR" stands for completion rate, the percentage of participants who watched the video to the end. "SR" stands for the second-half tap rate. "Ave." stands for the average number of taps per participant.

3. Discussion and Conclusion

In Figure 3, the highest completion rate (CR) of *FH* suggests that the Entities that appeared in the first half probably attracted the participants and prevented them from dropping out. The second-half tap rate (SR) was also highest in *FH*, even though there were no recorded Entities in the second half. This indicates that the recorded Entities helped familiarize participants with the proposed experience and encouraged them to feel free to tap and enjoy making the Entities. These results suggest that the proposed experience, which expresses the past presence of others by Entities, even if asynchronously, positively attracts the users. We expect the pseudo real-time live system can redesign the interaction between online audiences.

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PANELS

Virtual Architecture in the Digital Realm

Pierre-François Gerard[1], Andrea Ion Cojocaru[2], Kim Baumann Larsen[3], Alex Coulombe[4], Eoin[5]

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Panel description

The core of this discussion is about the architectural space in a digital world. The concept of space is tied to conventions and codes that allow a group of individuals to inhabit the same shared physical or virtual place. It is therefore a polysemic idea. A multiplicity of space exists at the same time. Each field of research, each art, each culture determines its own space. Moreover, the perception of space is a function of the human body. Space is the result of the representation that an individual or a group of individuals has created. There is an apparent analogy between nascent VR technology and the childlike novelty of trying out a new VR experience, as if discovering a new world. Theories of cognitive development in children, gradually acquiring information about their surroundings, can be used as a base to this discussion. However, with the exponential growth of the XR industry, it is time to get more specific about what works and what does not when building virtual worlds.

For that a series of specific topics will be discussed by the panelists:

- What is virtual architecture?
- Unique affordances of virtual spaces
- The benefits and pitfalls of skeuomorphism driving UX in VR
- What are the tools of the trade?
- Inspiration from world building, film, and art.
- The feeling of awe.

Pierre-Francois Gerard Is the founder of a virtual architecture studio based in London and Brussels, Metaxu.studio. He is an architect, 3D visualiser with 15 years of experience working with many architecture practices. He also completed a PhD in Computing from Goldsmiths, University of London. The main output was a framework to evaluate the effectiveness of spatial design on people performance in VR.

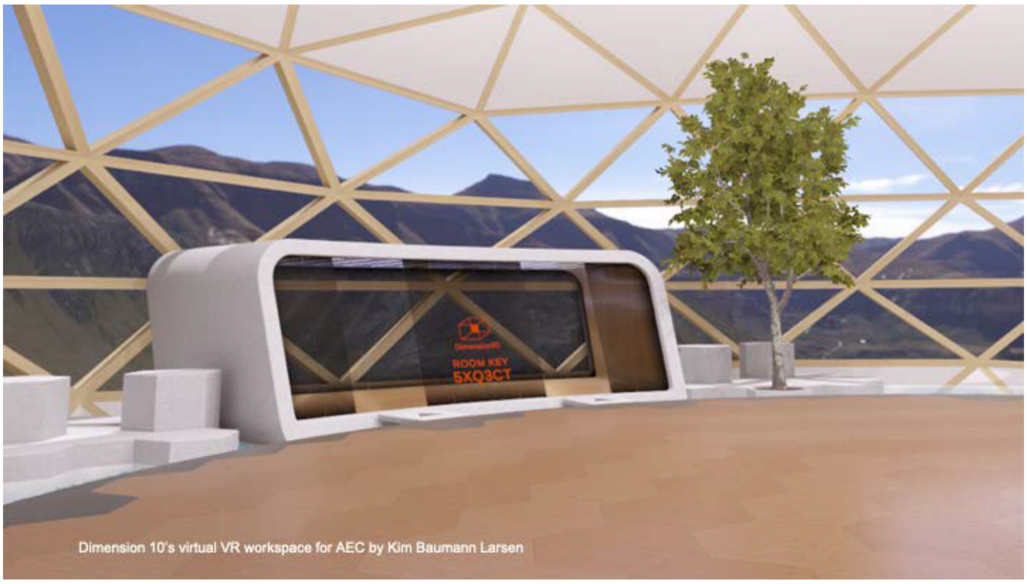
Andrea Ion Cojocaru is a licensed architect, software developer and the CEO and co-founder of NUMENA, an award-winning interdisciplinary company that designs and develops both physical and virtual spaces. NUMENA has worked with clients such as BMW and B. Braun to develop experimental virtual experiences and is currently working on a virtual reality tool for spatial design.

Kim Bauman Larsen is CEO and founder of Dimension Design, a virtual architecture studio and VR production company and the director of Art Lab at Kulturtanken - Arts for Young Audiences Norway. He started his career in VR in Houston 25 years ago. For the past ten years, he has designed, produced and published narrative real-time, AR, and VR experiences. The design of social spaces for VR is his passion.

Alex Coulombe runs an XR studio in NYC, Agile Lens, and he has been building immersive experiences for over a decade now across AEC, real estate, as well as theatre and live events. He has been excited about virtual architecture going back to when he was designing theaters with Fisher Dachs Associates and realized they could use the first Oculus Rift Development Kit to make people feel like they were watching performances in their projects even when they were still at the concept
stage.

The virtual art gallery is a collaboration with Curaty, a young startup that works as a fine art platform that curates, rents and sells artworks by the world's most inspiring artists. The main idea is to place the art pieces into a space that brings back to life the atmosphere of the art gallery where many people are able to have different conversations at the same time or even discuss directly with the artists.

This image is taken in the lobby of a virtual hospital and it is part of an interactive VR application NUMENA developed for B. Braun, a medical device company. Inside the application, users can freely navigate an entire surgical wing and play the role of various medical staff. The architecture reflects the spatial logic of a physical ward where location and spatial relationships affect the protection measures that need to be implemented.



In designing this virtual workspace for the AEC industry for Dimension 10 Baumann Larsen seeked to implement the concept of prospect and refuge creating more intimate meeting rooms on the outskirts of the larger open space which is used to view and work with large CAD models at one to one scale.

A digital model of the Brockman Hall for Opera. Theaters are an architectural typology with very clear accepted rituals and behaviors for a virtual audience to abide by. This is an argument to infuse spaces with cues from real-life to help people understand how to use the metaverse / virtual spaces.

Training experts in Virtual and Augmented Reality

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The importance of privacy and ethics in emotion recognition and emotion elicitation in Virtual Reality scenarios

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Keywords: emotion recognition – emotion elicitation - virtual reality – ethics – privacy

1. Panel description and proposed speakers

Affective Computing is the study and development of systems that can automatically recognize, simulate and elicit emotions to users (Picard, 2000). It has been applied in several areas such as education, security, healthcare and entertainment (Daily et al., 2017; Gross & Levenson, 1995). In most of the studies, emotion recognition and elicitation has been carried out with non-immersive environments (Aharonson & Amir, 2006; Faita et al., 2016). Virtual Reality (VR) is defined as an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment (Aukstakalnis et al., 1992). It provides simulated experiences increasing the feeling of immersion or presence experienced by the user (Okechukwu & Udoka, 2011). In past years, even recent, affective interactions using VR have been analyzed in studies which demonstrate that virtual environments can be used to recognize or elicit emotions in the user such as relaxation, stress or anxiety (Marín-Morales et al., 2020; Riva et al., 2007). In addition, some works show that emotional content increases the sense of immersion in a virtual environment (Gorini et al., 2011; Marín-Morales et al., 2018). However, regardless of the various studies conducted, the success of emotion recognition in virtual reality scenarios will depend on how safe can be made and how the privacy of users can be protected and respected (Cowie, 2014). In addition, users must be able to trust the virtual reality scenario knowing that their emotional states can be recognized and elicited.
The purpose of this panel is to address several points regarding ethics and privacy issues, risks, challenges and opportunities about the impact that emotion recognition and elicitation can achieve in virtual reality scenarios. The questions we will try to answer are, for example:

- What are the biggest opportunities and risks of recognizing and eliciting emotions in Virtual Reality scenarios?
- Are there emotional states (recognition and elicitation) in Virtual Reality applications that we should completely avoid?
- What are the risks of not protecting or not anonymizing the emotional data from users in Virtual Reality scenarios?
- Are there different ethical implications of affective computing systems between real life scenarios and VR scenarios? If so, which ones?

For this panel, three researchers will give their point of view and discuss about several questions related to all these points. The proposed speakers represent a wide spectrum of expertise and experience in research in the field, from Research Institute to SME:

Dr Cathérine Pelachaud (catherine.pelachaud@upmc.fr): is CNRS Research Director at ISIR, Sorbonne University. Her research interests focus on affective computing and socio-emotional agents. She is associate editor of several journals including IEEE Trans on Affective Computing, ACM Transactions on Interactive Intelligent Systems, and International Journal of Human-Computer Studies. For many years, she and her collaborators have worked to develop the Greta conversational agent platform. She received the ACM - SIGAI

Autonomous Agents Research Award in 2015. Her article by Siggraph'94 received the Influential Paper Award from IFAAMAS (International Foundation for Autonomous Agents and Multiagent Systems) in 2017.

Dr Julien Castet (julien.castet@immersion.fr): is the director of Immersion research activities. His main areas of expertise are interaction, mixed reality and computer music. He is an active expert with the ANR and with the European Commission for expertise and project evaluation. He conducted research on 3D interaction and haptics at the Grenoble Institute of Technology where he obtained his PhD at the University of Grenoble. He has been the driving force behind several projects funded by Europe since 2005 (Enactive interfaces, INDIGO, Esponder, TASS, VASCO, MAGELLAN, TACTILITY, EVOLVED5G etc.). He has been the author of more than 30 articles published in international journals and conference proceedings in his field of research (Siggraph, CHI, TEI, IEEE VR ...).

Dr Samory Houzangbe (samory.houzangbe@ensam.eu): after completing a Master's degree in Virtual and Augmented Reality, he pursued a PhD at Arts et Métiers, under the supervision of Dr. Olivier Christmann and Pr. Simon Richir studying the impact on user experience in immersive virtual environments using smart wearables for biofeedback. After successfully defending his PhD he started a postdoctoral project between Arts et Métiers and ESTIA using physiological recording and non-verbal behavior. He is now studying the creativity process in virtual reality during ideation tasks.

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360° view of Do It Together

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Adaptive Interaction in XR

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