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ABSTRACT

In this paper we want to discuss the future potential of Serious Virtual Reality (VR) Simulations and VR Serious Games. This contribution is the foundation of the VENUS workshop presented on ISMAR 2022. We will provide insights into recent VR projects to lay a foundation for in-depth discussions with participants of the workshop. Furthermore, we want to shed light on needed research in the area of VR frameworks, further strengthening the subconscious transfer of knowledge through Serious Games and the involvement of tangible objects to increase immersion and presence.

Index Terms: VR—Serious VR—Serious Games—Simulation; Supermarket—Augmented Virtuality—Force Feedback; Augmented Senses—Older Adults—Controller—Human Computer Interaction

1 VENUS - VR ENABLING KNOWLEDGE GAIN FOR THE USER

With the introduction of affordable, high-quality and increasingly wireless Head-Mounted Displays (HMDs), Virtual Reality (VR) became a multimedia powerhouse driving futuristic visions like the metaverse. There is less time needed to think about tracking of controllers or performance restrictions, the basics of VR are provided more and more effortlessly. In combination with the widespread adoption, this opens up new possibilities for researchers working on different frontiers. In the area of Serious VR Simulations (e.g., Digital Twins), addon cameras allow for Mixed Reality (MR) concepts, fusing together reality with virtuality by e.g., integrating physical, tangible objects into the traditionally purely virtual world (Augmented Virtuality). The previously restrained VR Serious Games genre profits from high-quality serious content, which can be broadly experienced to enhance immersion and knowledge transfer.

We want to bring together experts from different computing and engineering disciplines to overcome the barriers of complex VR simulations and games. In both areas, the full potential of VR is still limited through the lack of framework support and tangible controller feedback for otherwise purely virtual objects. In this publication we present example projects, where VR is used in diverse serious applications like simulations. We describe key aspects how serious VR can be realized to enable knowledge gain (VENUS - VR Enabling Knowledge Gain for the User) in Serious Games. Finally, remaining challenges which are discussed during the workshop, are be presented.

2 VR AND CULTURAL HERITAGE

VR is already used several times in combination with tangible cultural heritage. The possibility to virtually travel to historical or cultural places independent of the user's location and time is one of the great advantages of VR. One example is the application *Nefertari: Journey to Eternity*[1] in which the user can virtually explore the scanned tomb of Nefertari, the wife of Ramesses the Great. This way, also access is given to parts of the tomb that are closed to tourists.

Figure 1: Visualization of the 3D scanned statues within the walkable area with the west pediment placed on the ground [15]

In a similar way, we have created a virtual walk through ancient Olympia [15]. While the reconstructed buildings were placed on the basis of archaeological maps, the focus was on the representation of the ancient statues in their current state of preservation (see Figure 1). This was possible because the Museum für Abgüsse Klassischer Bildwerke in Munich provided us with 3D scans of these statues.

VR also enables not only viewing but also interaction with exhibits. In this way, a completely new experience is created. In the *VRiedrich* project [1], we dealt with paintings by the German artist Casper David Friedrich. The 2D paintings "Wanderer above the Sea of Fog" and "The Stages of Life" were the basis for creating the 3D VR world. The users take on the role of the wanderer and view the scenery in the painting through their own eyes, so to speak (see Figure 2).

When the users turn around in the environment, they are no longer looking at the foggy mountain landscape but towards the beach and the sea. Paintings are static and often depict several actually successive states at the same time. This, of course, makes interpretation difficult. In "The Stages of Life", a person's life is depicted by means of ships. It starts as a small ship, which grows larger and larger until it turns full-size on the horizon and returns shrinking until it lies on the beach as a wreck. VR makes it possible to show these different states step by step through an animation and thus an easier interpretation for the viewer (see Figure 3).

Goal of VR: new perspectives and guidance

In cooperation with the archaeological department of the LMU in Munich we implemented a VR application focusing on the exploration on the wreck of a Roman merchant ship from the 5th century AD, which was found near Veliki Piruzi (Croatia). The virtual underwater environment and also the archaeological findings were

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[1] https://store.steampowered.com/app/861400/Nefertari_Journey_to_Eternity/

created based on photos and scans that were taken underwater by the archaeological team. Users can choose between different modes. It is possible to explore the scenery as they wish and activate an audio guide at marked locations. Furthermore, there is a gamified mode. Here, the users perform swimming movements with the VR controllers, moving underwater. The tour is marked by ancient coins, which have to be collected. In this way, the users reach the various points of interest, where the audio guide is activated and small quests have to be completed. [14]

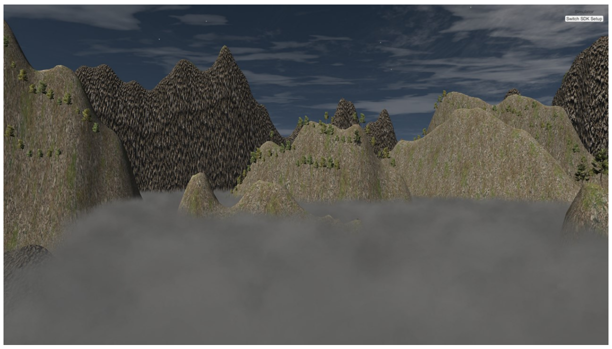

Figure 2: Cichor, Plecher 2018: C.D. Friedrich in VR - *"Wanderer above the Sea of Fog"* [1]

Figure 3: Cichor, Plecher 2018: C.D. Friedrich in VR - *"The Stages of Life"* [1]

Goal of VR: cultural experiences independent of location →Presence

2.1 Serious-VR-Games

VR Serious Games combine the world of playing games for immersive entertainment with the goal of learning in an almost subconsciously manner. Combining these two approaches requires meeting the demands of both. Learning content must be presented correctly and coherently, but on the other hand, it must be perfectly integrated into an enjoyable game concept.

The Serious Game HieroQuest [13] deals with the topic of Egyptian hieroglyphs. The players are in a kind of Escape Room, which is modeled on an Egyptian temple. In each room more hieroglyphs have to be unlocked to open the door to the next room. To achieve this, the transliteration (letters) must be assigned to the hieroglyphs on the door. In the VR version [9], this is done by a hand gesture. Figure 4 shows the mapping of the and the letter A.

Goal of VR: interactive learning

Figure 4: Mapping hieroglyph and transliteration to unlock the next room [9]

Ancient history and especially battles from that time are often themes in games. However, they are usually not historically accurate. The reasons for this are manifold. If you look at games that offer a multiplayer mode, troop strengths were adjusted and similar weapon types were integrated for reasons of equality. It was therefore our goal to create a Serious Game in VR [8, 16], which is on the one hand a fully functional strategy game and on the other hand a historically accurate Serious Game about the battles of the 2nd Punic War. Two battles (Battle of Cannae, Battle of Lake Trasimene) of the Romans against Carthage led by Hannibal can be replayed. If desired, animations can be started, which represent the historical course of the battle (see Figure 5.

Figure 5: Ancient Battles in VR [16]

Goal of VR: immersive gaming and learning environment →Immersion

3 SERIOUS VR SIMULATIONS

Serious VR Simulations range from traditional replicas of environments and evaluation scenarios to better understand the behavior of people [3], to skill training facilities for specific tasks [11], to deal with certain phobias [10, 12] or to operate complex remote technologies like robots. Over the last years, new user groups for simulated environments, such as users of remote teaching tools during the COVID-19 pandemic or elderly people who want to have an immersive traveling experience, have been emerging because of the progress and affordable nature of VR technology.

To achieve immersive simulations, virtual and tangible objects should be combined to maximize the effect of the system. Digital Twins contain this idea through a coupling of physical entities to virtual counterparts, which combines benefits of both the virtual and physical components [7]. This leads to natural and even subconscious interactions which mimic real-world behavior. The usage of tangible inputs in VR have been sparsely realized. Physical feedback in the form of a diverse framework is still overlooked and generic controller input is the norm. Limitations such as having additional cameras on the VR HMD and the lack of integration of custom tracking algorithms in existing platforms, e.g., game engines like Unity are hindering the potential of e.g., Digital Twins. In VENUS we want to spark the development of frameworks for game engines like Unity. To lower complexity, we present a solution for networking between devices and microcontrollers called Ubi-Interact [17]. Additionally, we present a Digital Twin in the form of a supermarket simulation, where the usage of a real smartphone to test health-related apps is proposed [4]. Another application targets older adults by providing insights into a playful simulation, that also needs to deliver benefits besides a simple setup to overcome the entry barriers of this target group. Furthermore, a versatile 3D printed controller setup, that can be reshaped based on requirements of the use case will be introduced. Serious VR Simulations are realized through the following aspects:

- Tangible Authenticity (visual) & (Force Feedback)
- Immersion
- Presence
- Adaptability

3.1 Physical Smartphone in a VR Supermarket

Figure 6: VR supermarket: (left side) shows the authentic virtual environment with realistic German products and store layout; (right side) Augmented Virtuality setup used with mobile health apps on the physical smartphone

In this project presence, usability and interactions are enhanced through a familiar environment combined with the integration of the personal physical smartphone in an authentic VR supermarket simulation [4]. This results in a standardized evaluation platform for mobile health apps. Despite advances in VR technology, HMDs and controllers alike, in previous VR simulations there is a limited integration of tangible, tracked objects because of software/hardware challenges. For the mentioned VR supermarket use case, solutions are demonstrated by focusing on a recognizable replica of a discounter and utilizing Augmented Virtuality (AV) to include a physical smartphone in the virtual simulation (Digital Twin). In upcoming studies, the goal is to understand the changing shopping behavior influenced by health-targeting nutrition apps on mobile devices. To achieve reliable tracking of the smartphone screen, we propose a hybrid approach, which combines fiducial marker tracking with information acquired through a WiFi connection between the VR system and smartphone. The user is able to manipulate the simulation from within the smartphone app through this versatile, highly usability-centered controller. Furthermore, the AV concept is utilized to build scenarios for Mixed Reality use cases such as highlighting products by simulating AR, which were previously impossible to test in a standardized setting.

Goal of VR: VR provides a standardized and recognizable evaluation environment resulting in →Presence, Tangible Authenticity (visual), Adaptability

3.2 VR Travel App for older Adults

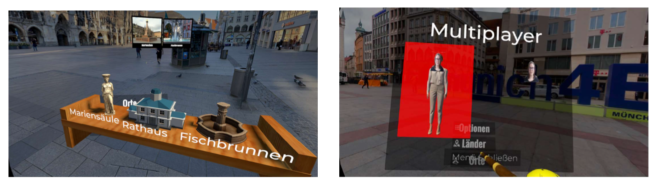

Figure 7: (Left side) VR travel App based on interactions with 3D objects, which need to be touched by the walking stick to travel to other places; (right side) Multiplayer setup with 3D avatars based on images taken of the person

Recently with the advances in HMDs, VR has been envisioned in use with the older generation. A lack of clear approaches to enhance the user experience and the inclusion of safety concerns are missing in existing research. We address these challenges in a travel application. Up to five older adults can travel together as a group (multiplayer) to various cities and countries by experiencing 360° images or videos (see Figure 7, right side). Traveling to other places is done through a virtual walking stick augmenting the standard VR HMD controller which is used to point on places, hence giving a natural interaction to which the target group can easily be accustomed to (see Figure7, left side). Natural interactions in combination with known objects can overcome fear towards modern technology [5,6].

Figure 8: (Left side) Augmented Virtuality in use to prevent disorientation and panic reactions and the selection method based on a walking stick; (right side) System to generate warm or cold airflow with changing directions and through the use of essential oil bottles different types of odours are created

To prevent disorientation and panic reactions from occurring through the perception of virtual objects, a camera is used to track a marker on the table (see Figure 8, left side) with the goal to include the arms of the person as an anchor in the real world (Augmented Virtuality). To further improve realism, other senses can be triggered. A specialized system has been built, which allows through the combination of electronics such as small engines and 3D printing to create warm/cold airflow in combination with odours realized through essential oil bottles (see Figure 8, right side). In combination with the visual input this could be a powerful approach to reactivate old memories in dementia patients. In the future it will be the goal to allow older adults to drink while being immersed

Key criteria	Type	Description
Immersion	SG/SS	Hooked through an interactive environment
Presence	SG/SS	Full absorption independently perceived of space and time
Knowledge Transfer	SG	Spatial visualization of the learning content
Tangible Authenticity (visual)	SS	Haptic interactions with visual integration
Tangible Authenticity (Force Feedback)	SS	Multi-dimensional haptic feedback
Adaptability	SS	Unlimited possibilities to model realistic environments
Augmented Senses	SS	Precisely targeting a specific spectrum of human senses

Table 1: Summary - Serious Virtual Reality (SG = Serious Game, SS = Serious Simulation)

in the virtual world through further extending the Augmented Virtuality concept. Thereby a drinking cub is tracked through the attached camera and included in the virtual world. Merging reality with virtuality can help to boost acceptance of the target group.

Goal of VR: triggering memories and enhancing virtual experiences through interaction →Presence, Augmented Senses

3.3 Multi-dimensional Force Feedback Controller

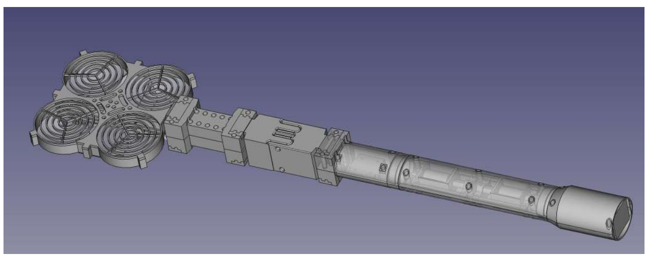

Figure 9: CAD model of the prototype: at the front four engines provide active feedback through airflow; in the middle there is a joint which contains pins to connect the front part with the rest of the electronics; the handle contains two solenoids for impact feedback, as well as the microcontroller with other electronics and the battery

Developing custom controllers for VR which simulate unique forces such air resistance [19] or changing shapes [18] have been accelerated through further innovation in HMD technology. Nevertheless, there is limited success in simulating realistic and diverse feedback outside of expensive cave setups. Furthermore, most developed controllers are highly specialized, with few supporting different functionality or provide multidimensional feedback. Our goal is to build a sports controller which can be used for multiple ball games, where the force of the impact can be felt as a shock and the controller is being pulled backwards at the area of impact (see Figure 9). Additionally, flexible feedback options are included, in one situation the controller can function as a tennis bat and by swapping the front part with the engine setup, other options are feasible such as e.g., a golf bat. Traditional HMD controllers contain electric vibration engines. They don't offer realistic impact behavior when hitting objects such as a ball and can't replicate the forces being placed on the controller. Through electric engines we can provide airflow in the direction of the force. By utilizing multiple solenoids it is possible to simulate an impact with its direction and spontaneous nature. In a pure virtual world it is even possible to generate super powers by enhancing the virtual response of an action.

Goal of VR: VR provides a customizable environment for sports →Tangible Authenticity (Force Feedback), Immersion

4 Summary VENUS

In Table 1 identified key criteria for Serious VR are summarized. Immersion and Presence are core concepts of VR. Thereby Immersion is reached through catching the user in an reactive environment which answers on the will of the user. Presence is achieved by pushing Immersion through a loss of connection to time and space, absorbing the mind of the specific user [2]. We separated Tangible Authenticity in a visual and Force Feedback category to further divide these rich experiences. Through visual representation an included physical object becomes a functioning part of the virtual world. While on the other hand, some sports controllers may offer a different visual appearance, but are solely targeting a realistic haptic feeling through multi-dimensional haptic feedback.

There are still various unsolved and related challenges for Serious VR Simulations and VR Serious Games. Major challenges include, but are not limited to:

- **Tangible Objects and alternative Controller Designs:** Traditionally, the included HMD controllers and trackers are mostly used to interact with virtual objects. This limits the possibilities to have rich, multi-dimensional feedback and to enhance physical presence through tangible non-controller-shaped items. Tracking physical objects and including them into the virtual world (Augmented Virtuality) is a challenge with the need for a tracking pipeline. Addon cameras in combination with state-of-the-art algorithms can overcome those limitations. In this workshop we want to explore the realization of such rich and tangible experiences.

- **VR Multiplayer Framework:** Reliably connecting users and supporting versatility in terms of platforms (including microcontrollers for smart items), is still an open issue. In a game engine such as Unity, there is up until this day a limitation in supporting self-made tracking algorithms, e.g., Machine Learning-based ones. On the other hand, game engines provide the important capability to efficiently render virtual content and provide the central game logic. We want to propose building blocks to solve such limitations and bring together mobile and microcontroller platforms into a framework.

- **VR Serious Games:** Based on an immersive learning environment knowledge gain can be realized. Thereby the virtual world can adapt to the learning content. For example, let the user travel virtually to distant places or offer the possibility of virtual time travel to specific points in time or events in history. The potential to enhance immersion and presence through e.g., added realism can achieve noticeable effects for specific target groups and scenarios. In VENUS we want to explore new possibilities to enrich Serious Games in VR.

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