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ROAR - Role of Augmented Reality in Serious Games and Superhuman Sports

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ROAR - Role of Augmented Reality in Serious Games and Superhuman Sports

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ABSTRACT

In this paper we want to address the question of what role the use of AR plays in the fields of Serious Games and Superhuman Sports. This paper is the foundation of the ARES workshop on the IEEE VR 2022. We will reference the experiences gained from various projects over the last few years, which are discussed in the workshop. Furthermore, we want to shed light on needed research in the area of AR framework development and the involvement of tangible, augmented game objects to support future AR projects.

Index Terms: Augmented Reality, Superhuman Sports, Serious Games——

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1 ARES - AUGMENTED REALITY ENABLING SUPERHUMAN SPORTS AND SERIOUS GAMES

In recent years, the usage of Augmented Reality (AR) advanced into new frontiers through the widespread adoption of affordable mobile devices. AR enables 3D information or objects to be embedded in the user's field of vision through the use of displays. For example, in Superhuman Sports, AR provides the potential to be a driving factor by revolutionizing team sports or by introducing novel game mechanics. In the field of Serious Games, AR can bring 3D serious content into the physical world to enhance immersion and knowledge transfer. In both areas, the role of this vision-based technology is often overlooked and hence its full potential is limited. In this publication we introduce Superhuman Sports and Serious Games in combination with example projects, where AR is indispensable. We emphasize key roles (ROAR - Role Of Augmented Reality) this technology can have in such scenarios. Finally, remaining challenges which are discussed during the workshop, are be presented.

2 AUGMENTED REALITY FOR SERIOUS GAMES

Serious Games are defined as "using games in a non-gaming context" [1]. They combine the world of playing games for 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 a game concept. The role AR plays can vary depending on the project and the goal of the application. It can support gameplay on the one hand and knowledge transfer on the other. It is also possible that it supports both at the same time. Intended goals:

- Immersion →improved player experience [13]
- Interaction with the learning or gaming content
- Increased knowledge transfer

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We use AR to teach languages and knowledge about cultural heritage or historical facts. On top of that, concepts to utilize AR Serious Games with older adults and for therapy have been envisioned too. Particular for such use cases are tracking capabilities in 3D space, to ensure a connection to the surroundings of the person. Additional goals for such games can be described as:

- Precise markings of virtual objects in 3D space
- Involvement of the user's personal environment

2.1 DragonTale

Figure 1: AR Compositum (jukugo) - 日本, (Japan) [7]

DragonTale [7] is designed for teaching Japanese Kanji. Besides the story about a girl and a young dragon the players getting in touch with the meaning and the correct stroke order of Japanese Kanji. AR is used to augment an object symbolizing the meaning on top of the corresponding Kanji (marker). We also offer the possibility to combine the markers. The so-called AR composita (jukugo) combine two or more Kanji to build new words. Like it is shown in Figure 1, the application tracks the position of markers in relation to each other. If interrelated Kanjis (markers) are tracked, a line (green: right order, red: wrong order) is displayed. The meaning of the compositum is shown when the interrelated markers are placed side by side in the correct order.

ROAR: Meaning shown by corresponding virtual objects →supporting knowledge transfer

2.2 Oppidum

Our goal was to create a Serious-AR-Game about the tangible and intangible cultural heritage of the Celts. Common elements of boardgames were used in a new way to transfer declarative and procedural knowledge to the player.

The combination of Serious Games and AR is interesting, because it allows merging the advantages of both concepts. Developers seek to increase the learning effect of the Serious Games by augmenting the user's surroundings with virtual information and objects to interact with.

Oppidum [8] is a classic digital construction and management game, in which the player takes care of building a Celtic village. The second part consists of the use of AR. This technology makes it possible to include analog game elements such as a game board and cards, which serve as markers, in order to place the virtual buildings on them (see Figure 2). The third part is the serious content which consists in the fact that all buildings were

modeled after archaeological reconstructions. With the help of AR, the buildings can be inspected from the outside and inside. In addition, further information material is offered in the form of texts and images describing the daily life of Celtic villagers.

ROAR: Immersive way to show and interact with archaeological reconstructions →support of knowledge transfer and gameplay.

Figure 2: Augmentation of archaeological reconstructions. Distance between the markers influences the gameplay (green line) [8]

Figure 3: Reducing the distance between camera and marker enables a view into the interior of the building [8]

2.3 Escape Rooms using AR

The concept of Escape Rooms is well known and can be used for pure entertainment but also in serious contexts. Variants of this game type are already existing using AR [9] and VR [6]. We are currently working on a serious AR-Escape Room, in which the players get to know the life of Galileo Galilei and his research step by step. Markers bring the scientific instruments, such as the newly invented telescope (see Figure 4), into the players' environment in a digital way. To structure the game, a coloured virtual lock is displayed on markers that are used later in the game. These can be unlocked by solving puzzles.

ROAR: Immersive way to show and interact with astronomical instruments →support of knowledge transfer and gameplay.

2.4 Jack the Ripper

On the Trail of Jack the Ripper [10] deals with the historical facts surrounding Jack the Ripper and the Whitechapel murders of 1888. AR is used to take players to the crime scenes (see Figure 5) in an immersive way and allow them to search for clues themselves. In the same

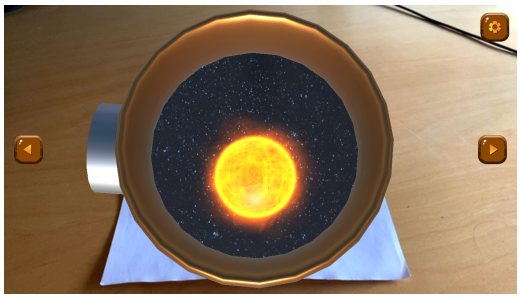


Figure 4: Escape Game "Galileo Galilei"; augmented telescope

way, original sources are presented or letters handwritten by Jack the Ripper are made readable through an augmented printed form.

ROAR: Inspection of crime scences and examination of virtual replica of clues and original documents

Figure 5: 3D reconstruction of the crime scene at Bucks Row augmented on a marker [10]

2.5 Serious AR Games for older Adults

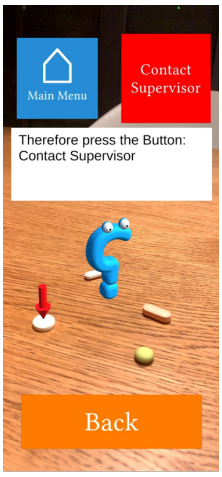


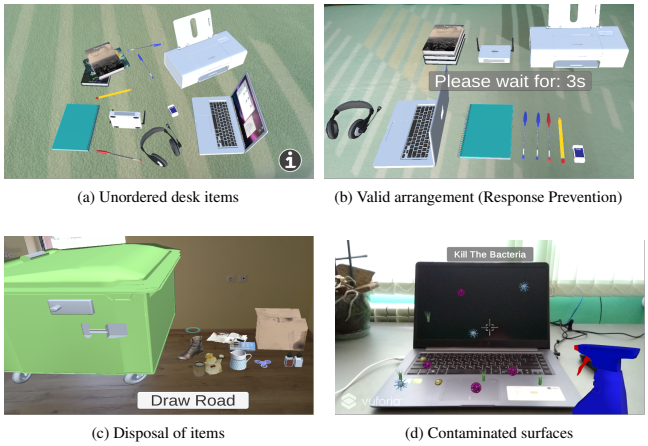
Figure 6: AR Serious Game for older adults

Older adults are prone to deal with many diseases and hence have to take a variation of medication over the day. Because of the age-related decline, situational factors such as mild dementia in high age and the similarities of pills, taking medication can be a challenge and mistakes in dose or taking the wrong pill at the wrong time is common. Available smart devices in combination with machine learning and AR offer a solution. A neural network

is trained to identify the correct pill and with the help of AR the 3D location is precisely marked in three dimensions on the screen (see Figure 6). In the situation of having similar pills, hence there is a lack of high confidence for the neural network output, it is possible to transfer the video stream to the phone of the caregiver. This person can mark the correct pill with the arrow in 3D space by hand. Older adults often can't comprehend the issues associated with wrongly taken medication and on top of that there is the need to introduce them to smart devices. The app is designed to work as a Serious Game, where together with the caregiver the older adult gets introduced to the setup. This should ensure the acceptance of the smart device and app, which are then integrated into the daily life. Furthermore, it is possible to interact with the companion in a playful way and collect reward points to raise motivation [2]. In this scenario the focus is lifted off the medication topic to let them feel comfortable with the app.

ROAR: AR is essential to convey the serious content for each individual case →Precise markings of virtual objects in 3D space

2.6 Serious AR Games Disorder Therapy



(a) Unordered desk items (b) Valid arrangement (Response Prevention)

(c) Disposal of items (d) Contaminated surfaces

Figure 7: Disorder therapy app

Obsessive thoughts and compulsive behaviors affect people with Obsessive-Compulsive Disorder (OCD). Many patients remain untreated due to a lack of well-trained therapists or are ashamed to seek help. Therefore, a self-help solution in combination with spreading awareness and educating for both healthy people and patients is seen as beneficial. The Serious Game presented here utilizes AR to visualize and explain OCD symptoms in an educational setting. Furthermore, the exercises performed in the app are related to OCD therapy. In comparison to existing solutions, e.g., a PC game or a VR app, an AR approach incorporates the real surroundings of the patient. This connection to the own living room enhances the training effect. Visualized in Figure 7a, ordering rituals are addressed by forcing a person to accept an unordered situation of the items on their desk before repositioning them later (see Figure 7b). In Figure 7c a person needs to dispose of items by carrying them to a wastebin. In Figure 7d the player needs to accept a contaminated surface for a certain amount of time before being allowed to cleanse it. Here machine learning is used to identify the object and precisely place germs on its surfaces. This game concept has been evaluated by healthy people and OCD patients.

ROAR: AR helps through the augmentation of the personal space to trigger symptoms and hence improve the training outcome →Involvement of the user's personal environment

3 Augmented Reality in Superhuman Sports

In *Superhuman Sports* the focus is on surpassing the limitations of the human body in a competitive sports experience by incorporating technology [5]. Sports-related platforms such as Microsoft Kinect or Nintendo Wii are restricting the experience to arranged environmental settings and are not targeting arena-style sports. Mobile device-based AR sports can be played spontaneously, anywhere and anytime based on portable solutions. In general, team sports can be defined as:

Sports activity by the user in a predefined playing field with a given set of game rules, allowing competition through e.g. fitness, game mechanics or coordination.

To achieve truly dynamic experiences in AR sports, a fusion of virtual and tangible objects is inevitable, e.g., catching or throwing a ball which can be felt in the player's hand. Immersion and flow are drastically enhanced through mid-air interactions with augmented game objects which provide physical feedback. Furthermore, this allows the player to develop skills with which to successfully outcompete the opponent. But usage of tangible game objects in AR games have been sparsely accomplished. While there are single-player concepts, such as *LevioPole* [11] working with haptic feedback, multiplayer games are generally harder to realize. AR delivers the virtual component, but with traditional AR frameworks, e.g. ARCore or ARKit, the tangible aspect can't be mediated. On the other hand, custom tracking algorithms can't be freely integrated in existing platforms, e.g., game engines like Unity. For that reason, the development of demanding game concepts repeatedly forces the developers to strive for custom solutions. In ARES we want to spark the development of frameworks for existing platforms, e.g., Unity. As a starting point, we present a solution for networking between AR capable devices and microcontrollers called Ubi-Interact [12]. Furthermore, for AR Superhuman Sports we introduce a framework concept to overcome known challenges such as changing device setups, integration of custom tracking algorithms and modeling of complex game states [3].

Intended goals for the usage of AR in Superhuman Sports:

- Tangible augmented game objects
- Wireless arena-style team sports

3.1 Catching the Drone

Figure 8: Illustration of the game concept (drawn by Kao-Hua Liu)

In this game concept, two teams are competing against each other by trying to catch a smart drone ball [3]. The drone can detect the players via a camera and sensors positioned around

the cage and then strategically evade them. When the drone is caught, based on a set of rules, superhuman throwing patterns can be triggered, e.g., throwing around an enemy player or increasing the speed and distance of a throw. Furthermore, with the help of AR HMDs and LEDs positioned on the cage, the drone is augmented, which adds an additional layer of immersion 8. This game is a continuation of previous research with the goal to integrate tangible augmented game objects in Superhuman Sports [4].

ROAR: Natural ball interactions with superhuman moves →Tangible augmented game objects & Wireless arena-style team sports

3.2 Force Feedback Controller

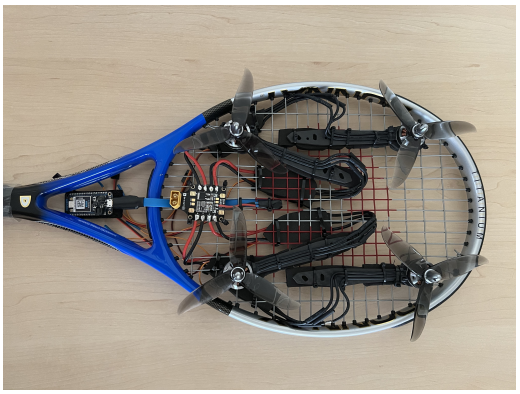


Figure 9: Testbed for force feedback system: four brushless electric motors and their respective ESCs with anti vibration foam

The research field of simulating all types of realistic interactions with virtual objects is broad, e.g., the resistance of water [11] or drag and weight shift [14]. Often these specialized controllers target one specific sense, hence there is a lack of multidimensional solutions such as for a tennis ball hitting a bat, where the force of the impact can be felt as a shock in the palm of the hand and the mesh is being pulled backwards at the area of impact. Especially for Superhuman Sports, where the goal is to augment and extend the capabilities of the body, having rich multidimensional feedback is fundamental to create the sense of realism behind virtual object interactions. For an AR sports use case, a force feedback tennis bat has been developed. It relies on a combination of directed airflow provided through four brushless electric motors to push the bat backwards at the area of impact and on vibration motors, which can send out a distinct impact pattern. In an AR use case, a realistic training environment based on the surroundings of the player can be created. Because of the virtual aspect, it is possible to manipulate the ball and opponent, so a full-sized tennis court isn't necessary. Additionally, the controller has a connector with which it will be possible to exchange the head (the upper portion, including the engine setup) with different designs to vary the force feedback use case. The handle is kept and houses the battery, vibration motors and electronics inside. This allows the effective development of one platform with diverse scenarios in mind.

ROAR: Combination of a natural training environment with realistic ball feedback →Tangible augmented game objects

4 Summary ARES

Remaining challenges discussed in the workshop ARES:

- **AR Multiplayer Framework:** Reliably connecting mobile devices and supporting versatility in terms of augmentation platforms, is still an open issue. In a game engines, 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 an AR framework.

- **Tangible and Augmented Game Objects:** Traditionally, purely virtual game objects are used in AR games, because they can be easily manipulated in 3D space and hence require no tracking pipeline. On the other hand, they don't offer rich haptic feedback. To achieve realistic interactions, a combination of tangible and augmented game objects such as sports equipment or Serious Game objects are required.

Role	Type	Description of the virtual content
Immersion	SG	Interaction with virtual 3D objects
Knowledge Transfer	SG	Spatial visualization of the learning content
Context 3D Space	SG/SHS	Dynamic and precise location
Natural Environment	SG/SHS	Personal connection and freedom of movement
Perception	SHS	Tangible and augmented game object

Table 1: Summary - Role of AR in Serious Games (SG) and Superhuman Sports (SHS)

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