Holographic Sports Training

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Figure 1: Holograms for sports training. From left to right: golf, tennis, yoga, martial arts, and juggling.

ABSTRACT

Sport practicing through video can be challenging because of missing spatial information. Hence, we present a holographic sports library of short sports exercises used to practice sports. The sports holograms were captured in a volumetric recording studio. Users can watch the holograms on augmented reality (AR) devices like mobile phones and headsets. The user can take advantage of the spatial information and watch the holograms from multiple angles. Moreover, the user can imitate the hologram's motion, an innovative method to teach sports.

CCS CONCEPTS

• **Computing methodologies** → **Volumetric models**; • **Software and its engineering** → **Interactive games**.

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1 INTRODUCTION

In our aging population, physical activity such as sports is crucial to maintain mental and physical health [4, 5]. An essential factor for well-being at higher ages is regular physical activity. We introduce holographic sports to motivate people of all ages to practice sports. Holographic sports can help lower the entry barrier for beginners and improve professionals' skills. Our sports exercise library can teach people with different levels of skills without the need for expensive instructors. Especially for beginners, holographic sports lowers the barrier of entry.

A recent trend pushed by the Covid-19 pandemic shows that many people like to practice sports at home [8]. It saves them time to go to a gym or other sports facilities. Moreover, women prefer to practice in private sometimes. Holographic sports can be enjoyed

from home. Compared to video coaching like Peloton services [19], holographic sports uses augmented reality (AR) and volumetric models to give the user an even richer experience.

Sports holograms are volumetric recordings of one or many people practicing a sport. First, the viewer watches the volumetric model that includes spatial information to understand the exercise deeply. Then, the viewer imitates the hologram to practice the exercise from their preferred viewing angle. A second person, for example, a coach, can watch the hologram and athlete side-by-side, compare, and comment on the execution of the exercise. The objective of holographic sports is to animate people to practice sports. Moreover, sports holograms act as instructors so athletes can watch and practice sports exercises to improve their skill set.

2 BACKGROUND

Gaming console companies noticed the desire for more interactive and physically challenging sports games. Therefore, gaming consoles, like the Nintendo Wii Sports [1, 3] and Microsoft Xbox Kinect [6, 7], brought sports into the living rooms of sports enthusiasts. They allowed the gamer to use their whole body to play. Moreover, the games made the player imitate the motions needed in real sports. Although the gaming consoles teach some concepts of the underlying sports [14], the degree of realism is not high. People who are good at practicing certain sports are not necessarily successful at the sports console equivalent game. The primary purpose of these products is entertainment rather than realism.

In contrast, sports analysis technology is centered around sports and aims to assist athletes and coaches. The technology utilizes computer vision [9, 16, 17], video overlays, annotation [2], and other tools to deeply analyze all detailed aspects of the sport [13]. The technology also assists referees with their decisions. The referee can watch replays of a play to make better-informed decisions. Moreover, computer vision technology can provide additional information. At the 2022 FIFA World Cup, computer vision algorithms animated offside situations by 3D modeling the scene on the field. The offside animation allowed referees to make highly accurate offside decisions. Furthermore, viewers could easily see close situations from a perfect angle onto the scene.

From a technological standpoint, Microsoft Xbox Kinect uses human pose tracking [20], and Nintendo Wii uses a position and motion-tracked controller to detect the players' actions. Both technologies have limitations: demanding that the player holds a controller in their hands, space requirements, a sensor setup, occlusions, and tracking inaccuracy.

Our sports holograms are platform-independent. We propose to use mobile phones and augmented reality headsets to view the volumetric captures. Mobile phones with AR capabilities are widely used and have the lowest entry barrier. AR headsets, such as the Microsoft Hololens, are not widely available but provide the best experience. The athlete can wear the headset to practice the exercises hand-free.

3 OUR APPROACH

We present holograms for sports engagement. Viewers of our content utilize holographic recordings to learn and engage in sports activities. The sports holograms were recorded in a volumetric studio. Athletes performed exercises for five different sports, golf, tennis, yoga, martial arts, and juggling, shown in Figure 1. The rendered volumetric models include the athlete with their sports equipment. The user can watch the holograms on different devices, including AR headsets and mobile phones. The AR technology provides the best experience within the Artificial Reality Continuum [10] because the user can see their environment, including their own body, when exercising. When observed through the device, the volumetric models appear "in the air" and are thus called holograms. The user then embeds the sports hologram into the real environment at their desired location. Due to the volumetric model, the hologram can be watched from different angles. Moreover, the user can practice sports drills by imitating the hologram.

3.1 Holographic recording

We recorded the holograms in a volumetric studio which consists of cameras, projectors, and lights surrounding the athlete. The stage is three meters in diameter. The studio uses structured light technology [15] to gather depth information. Infrared patterns are projected onto the athletes captured by stereo monochrome sensors. The four infrared projectors are oriented at a 90-degree angle from each other, all pointing at the actor. In addition to the depth map, the texture is captured by RGB cameras. The studio uses 32 cameras to capture all angles necessary to render a full volumetric model.

All recorded sports drills are between 5 and 30 seconds long. Due to limitations of the structured light technology, transparent, shiny, and small objects were not captured by the system. Thus, the holograms have some artifacts or are missing information, such as tennis racket strings. The issues can be addressed by animating 3D models on the recorded holograms. Due to the small stage size of volumetric studios, only parts of the whole sports scene can be captured. In most sports, the athlete and their equipment can be captured in the studio. If necessary, bigger scenes, such as soccer fields and tennis courts, can be added in a post-processing step.

3.2 Sports interactivity

We load the rendered holograms into the Unity Engine to support multiple platforms. The interactive user experience depends on the device used for presentation, as shown in Figure 2. When using widely available AR mobile phone capabilities, the hologram can be placed in the real environment and looked at from different angles. Not the user itself, but a third person can use the device and compare holographic content against real-life performance side-by-side or on top of each other.

When using an AR headset such as the Microsoft Hololens, the experience becomes more interactive because the user can watch and execute the sports exercises simultaneously. This allows for multiple possibilities for interaction. The user can position the hologram next to them so they can watch while practicing. In addition, the user can mimic the hologram on top of it and learn that way.

3.3 Limitations

The most significant limitation of sports holograms is related to the presentation technology, which only works stable indoors. The device must scan and track its position in 3D space to display

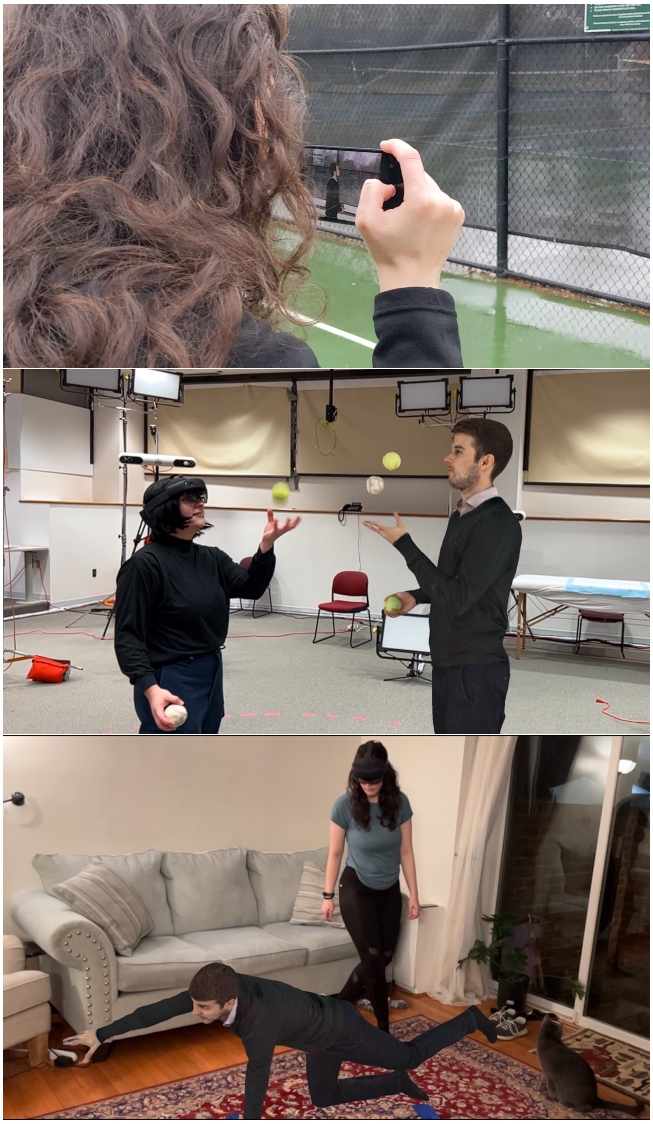

Figure 2: Top: Watching a tennis serve on the court using a mobile phone during practice. Center: Juggling practice face-to-face with the hologram using a head-mounted augmented reality (AR) headset. Bottom: Yoga exercises on top of the hologram using an AR headset.

holograms. Most of the devices rely on depth maps that interfere with sunlight and only work reliably indoors.

Another limitation is that the holograms cannot be altered after they are rendered. Thus, the user does not have to option to change the behavior of the hologram. All holograms need to be rendered beforehand. The user can then select one and move, rotate, and scale.

3.4 User Study

We tested our system on 11 users (6 female, 5 male) with an average age of 30.3 years. Participants expressed positive sentiments, enjoying the system's interactive and encouraging nature, particularly for learning yoga and juggling. Users found the system applicable to real-world training processes. However, some criticized the limited number of sports. Accessibility was appreciated, but concerns were raised about potential job displacement for trainers. Participants highlighted the absence of the social aspect in AR training compared to in-person sessions. Opinions varied if this is to be seen as a positive or negative characteristic. Benefits identified included readily available training information, the ability to follow virtual trainers repeatedly, and the convenience of learning anytime and anywhere. Improvement suggestions included

- simplified technologies for older or less tech-versed individuals,
- diversifying the range of sports and videos, particularly in yoga, and
- addressing the challenge of using the phone while following instructions if no headset is used.

According to the participants, the advantages of learning sports in AR encompass early exposure for children from low-income families, time savings, accessibility for those with limited mobility, and a comfortable learning environment for individuals with social anxiety.

3.5 Future Work

In the future, we plan to conduct a user study to evaluate users' performance after they complete holographic training sessions. We want to learn which sport benefits the most from the technology. We are also interested in how users interact with the holograms. Moreover, we plan on extending the library to record more sports and exercises.

The holograms can be evaluated across devices. The study should include more devices, such as the Magic Leap headset, traditional 2D displays, and virtual reality (VR) headsets. For the VR experience, a suitable virtual environment needs to be modeled.

Holographic scanning and recording using mobile phones can be added such that users can record their own sports holograms, similar to what Wen *et al.* [18] propose. This would allow them to side-by-side compare their hologram with the instructor's hologram. Calculating a matching score between the hologram and the user's body would be possible. This score can be used to track the performance of the user.

Moreover, we will combine offline and online teaching for medical procedures [11, 12]. A holographic medical procedure library, similar to the sports library presented in this paper, will be recorded and combined with the real-time collaboration system introduced in [12].

4 CONCLUSION

We presented holographic sports to motivate people to practice and improve their sports skills. We recorded volumetric models of exercises for five different sports and exercises: golf, tennis, yoga, martial arts, and juggling. The recorded exercises can be consumed on two different platforms, mobile phones and AR headsets. The

user watches the exercise to visualize the correct execution. Since the hologram can be placed statically in a real environment, the user can imitate the exercise on top of the hologram. The proposed method presents an innovative way of learning sports.

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