# Immersive Previous Experience in VR for Sports Performance Enhancement

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## 1 OBJECTIVE

Scouting opponent players or teams before games on the basis of video has become generalized. In recent years, video-based-scouting opportunities have increased because of the popularization of video sharing services such as YouTube. Watching videos of opponent players or teams has two main advantages. One is that it enables the viewer to analyze tendencies the players or teams show in their play. This information can then be used to help devise strategies to use against the players or teams. The other is that it can provide pre-experience of a sort. In many sports, players having unique forms have significant advantages. In baseball, for example, left-hand sidearm pitchers are comparatively rare and so batters are likely to have problems confronting their deliveries. This paper focuses on video-based scouting as a tool for preparatory training.

In the context of ICT (information and communication technology), much research has been done on ways to provide immersive experience (Ochi et al., 2014). Three ways that have been developed merit particular attention. The first is the use of three-dimensional displays (or projectors). The second is a cave automatic virtual environment, better known by the acronym CAVE. It provides immersive experience by projecting videos to walls surrounding a user. The third is head mounted displays (HMDs). Recent developments in wide field-of-view HMDs with which head movements are tracked, such as Oculus, have made it relatively easy to provide immersive experience.

We believe that this kind of immersive high reality virtual experience enhances the effect of previous experience and can help users to significantly improve their own performance in practice. In this paper, we mainly focus on motions a player performs in hitting back an oncoming ball in sports such as baseball, and volleyball. We believe that these motions are particularly applicable in preparatory training.

## 2 RELATED WORK

In this section we review systems that have been developed and trials that have been conducted in the area of providing immersive experience in sports through the use of virtual reality (VR).

The Nissan PlayStation GT (Gran Turismo) Academy is a trial program for discovering and developing professional car racing drivers. It uses immersive VR experience for discovering drivers. Academy members are selected in a TV game titled “Gran Turismo”, and so far 16 members have become professional drivers through their participation in the program. However, it is still unknown whether the VR experience actually enhances performance in actual competitions.

Chua et al. (Chua et al., 2003) proposed an immersive VR system for motor learning. In this system, a trainee practices tai chi while wearing motion capture markers and a head mounted display (HMD). The HMD enables teacher and trainee motions to be observed. Although the system doesn’t aim at providing realistic previous experience, it provides an opportunity to examine the effects of immersive experience on motor learning.

## 3 POTENTIAL IMMERSIVE VR SYSTEM

To develop an immersive VR system, capturing or synthesizing omnidirectional videos of players and displaying them should be considered. This section shows possible methods of doing this and describes these advantages and disadvantages.

### 3.1 Capture Methods

**3D Camera:** The easiest way to capture a 3D video is to use a 3D camera, which has two lenses corresponding to the left and right eyes. Many commercial, easy-to-use 3D cameras are already

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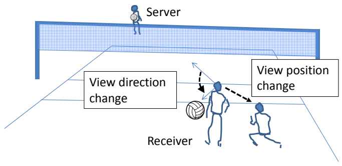


Figure 1: View direction and view position change.

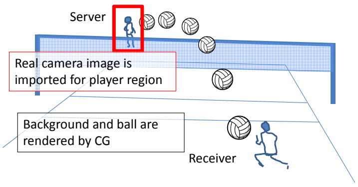


Figure 2: Combination of CG and video.

commercially available.

**Omnidirectional Camera:** Cameras that can capture omnidirectional views have also been released and are commercially available. They enable users to obtain arbitrary viewing angle directions from the camera's view point. The ease with which they capture images and provide immersive experience due to their wide field of view is a significant advantage. The advantage of having an omnidirectional video is particularly relevant in cases where the viewing angle changes markedly as one hit a ball back, as shown in the volleyball example in Fig. 1.

A number of research groups and companies have released omnidirectional stereo video synthesis systems (Zhu, 2001) that use sets of multiple cameras. There are also systems that use a single 3D camera, but there is one major difficulty with them: it is very difficult to change the view position. This is because these systems capture videos from the point where the camera is placed.

**Combination of 3D Modeling and CG:** To support changes in view positions and angles, one possible solution is using CG (computer graphics) as a basis for 3D modeling of a sports field. Because the shapes and sizes of sports fields are determined by regulations, 3D modeling them becomes relatively easy. In addition, recent developments in computer vision techniques have made it possible to ascertain ball trajectories in some sports. For example, the Hawk-Eye system shows ball trajectories in tennis and the "track man" system does the same for baseball.

An example for volleyball is shown in Fig. 2. In this example, to generate receiver's view, only the server is rendered by using captured video, and the rest of the scene, i.e., the background and playing field, is rendered by using CG.

## 3.2 Presentation Method

To provide immersive experience, we examine the following three representation methods, which are listed in Table 1.

**3D Display:** In this decade, many 3D movies and their DVDs have been released. This has made it possible for people to get 3D display devices without difficulty. The most popular devices of this sort are 3D TV sets and 3D projectors. Systems using these devices are the easiest way for users to enjoy immersive experience; all that is needed is a pair of 3D glasses.

**CAVE:** The aforementioned cave automatic virtual environment (CAVE) is known as a representative method for providing immersive virtual reality experience. This environment usually comprises a small room whose walls are rear-projected screens. When users go into the CAVE, they feel as if they are standing on the place created by projected images. Since the projected images change depending on the usersf viewpoint, in the common CAVE system it is necessary to capture users' view position and rotation. Thus, CAVE is an extensive and expensive solution.

**HMD:** Recent years have seen head mounted displays (HMDs) become increasingly popular. These displays intuitively control view positions and angles by tracking head position and rotation. The Oculus Rift DK2 supports head tracking by means of a supplemental tracking camera that has a tracking range from 0.4 to 2.5 meters for horizontal angles within 74 degrees and vertical angles within 54 degrees.

A well known easier solution is Google cardboard, which uses a smartphone and a gyrometer to detect view angles. Although it does not support view position changes, it still provides a nice intuitive immersive experience.

# 4 IMPLEMENTATION

We implemented two combinations from among the potential solutions described above. The first one is capturing 3D video by using a 3D camera and displaying the video on a 3D display (3D camera + 3D display). The second one is synthesizing a whole 3D model of a sports field and showing view dependent images from the model on a HMD (3D CG + HMD). Detailed analysis is needed for these combinations, but in this paper we only describe intuitive findings

Table 1: Possible representation method for immersive experience; (*) when omnidirectional stereo camera is used, binocular disparity images can be obtained.

| | | View change | | |
|---|---|---|---|---|
| | Binocular disparity | Translation | Rotation | Correctness |
| 3D camera | ✓ | × | × | ✓ |
| Omnidirectional Camera | * | × | × | ✓ |
| 3D Modeling & CG | ✓ | ✓ | ✓ | × |

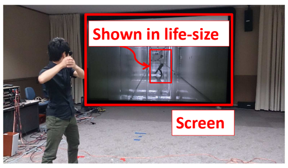


Figure 3: 3D camera + 3D display.

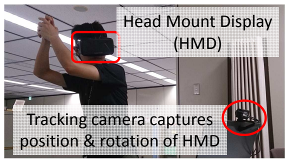


Figure 4: User wearing HMD for immersive experience.

we found from implementing them. For implementation purposes, we used the situation in which a user hits back a pitched baseball.

### 4.1 3D Camera + 3D Display

Figure 3 shows an example image of this implementation. The pitcher, who is displayed life-size on a 3D screen, pitches the ball to the batter, who is wearing 3D glasses. We believe that having to wear 3D glasses only should not be unduly annoying to users.

The most important advantage of this setting is ease of preparation. This is suitable for situations in which a user doesn't move much, such as catching a ball coming toward his face.

However, situations in which the viewing angle changes significantly when a ball is hit back, such as in the volleyball example in Fig.1, or when hitting a ball thrown by a pitcher, are difficult to reproduce virtually. If the 3D camera focuses on a server or a pitcher, the video at hand will be difficult to reproduce. However, if the 3D camera is located so that it will correctly reproduce the players' hands, the appearance of initial motions (service and pitching) becomes invisible. This setting makes it difficult to achieve accuracy in the area around the pitcher and the area near home plate from the batter's view simultaneously.

### 4.2 CG Model and HMD

Figure 4 shows an example of practice in a VR environment comprising a 3D CG and an Oculus HMD. The baseball stadium was modeled based on baseball rules, and the trajectory of the ball was manually obtained. Both were rendered by CG. In addition, the area around the pitcher was overlaid from video.

Because this setting involves a model of a whole baseball field, arbitrary view positions and orientation can be generated. Therefore, the areas around the pitcher area and home plate from the batter's view can be accurately reproduced simultaneously. In the trials we conducted, the users got a very high sense of reality that they were standing in the batter's box, and many of them actually lurched back from the ball when they sensed it was heading toward their face.

There are two points we should consider. One is that the users' motions are restricted. This is because the HMD, which is connected to a PC with an HDMI cable, is relatively large and heavier than 3D glasses.

The other is that the position of the pitcher is restricted. Generally speaking, it is difficult to render a player, who is a non-rigid object, by CG. Therefore, we used an actual video to overlay the area around the pitcher. This is a suitable approach because the pitcher stands well away from the batter and the distance between them does not vary.

## 5 CONCLUSION

In our study we focused on providing pre-experience for enhancing sports performance. This paper reviewed potential solutions for capturing, rendering, and displaying 3D video, from which we implemented two systems. The implementations were quite limited in scope, but they gave us the strong feeling that the use of omnidirectional video is an important means for providing pre-experience. In future work we will analyze the current implementations and others through objective evaluations for perception of 3D space, and through subjective evaluations for effects on performance improvement.

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