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Immersive Sport Live Viewing Using Dome Screens

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ABSTRACT

Many new imaging technologies have been tested and put to practical use when mega sport events are held. The Future Sport Viewing Project is an example of such use and was conducted using planetarium dome screens across Japan during a mega sport event held in Tokyo in the summer of 2021. The following report is an overview of the results of the demonstration experiment, and is based on data released by The Tokyo Organising Committee of the Olympic and Paralympic Games (the Organising Committee) and results of an online survey and interviews conducted at the screening sites.

1 Introduction

Since the world's first television broadcast and public viewing at the Berlin 1936 Olympics, new broadcasting technologies have been tested and put to practical use in mega sports events such as the Olympics. The Tokyo 1964 Olympics featured color and satellite broadcasting, the Los Angeles 1984 Olympics featured high-definition broadcasting, and the London 2012 Olympics featured 8K Super Hi-Vision and streaming broadcasting [1]. In addition, as a strategy for viewing sports with the highly realistic sensations of actually being at a specific sport venue, an image relay experiment was conducted at the 2002 FIFA World Cup. The experiment involved three demonstration sites with large screens, and used a 6K × 1K megavision system with high-definition images connected horizontally [2].

In recent years, 360-degree video, using head-mounted displays (HMDs) or smartphone-based VR goggles, has become readily available, and VR footage was shown at the Rio 2016 and the Pyeongchang 2018 Olympics. Articles based on these broadcasts have pointed out problems such as low image quality and poor camera positioning, and the fact that the subject passes through the field of view in an instant [3]. HMDs and other devices are not suitable for so-called public viewing where images are seen by many people together in a public venue, because they are imaging devices designed for personal use at home.

One of the authors Okyudo and colleagues suggested that dome images would be suitable for sport viewing, based on a live broadcast and feature analysis of a total solar eclipse projected on the planetarium dome screen. Then, they proposed a similar implementation in mega sport events such as the Olympics [4]. The Tokyo Organising Committee received this proposal and planned, promoted, and managed the Future Sport Viewing Project after conducting various preliminary experiments and coordinating with related parties. The authors made various proposals for this project, built a system to provide highly realistic sensations (an immersive live viewing system), and became involved in a demonstration experiment at a mega sport event held in Tokyo in the summer of 2021. In this study, we report the results of that demonstration experiment.

2 Experiment

The overall system structure is shown in Figure 1. Depending on the location, the system is divided into venues, dedicated lines, studios, distribution, general lines, and screening sites (planetariums). The key point of this project was to create a plan for the future by combining and utilizing the existing infrastructure and technology with as little operational cost as possible.

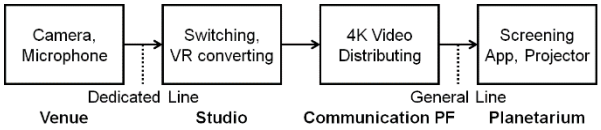

Fig. 1 Overall configuration of the distribution system

2.1 Camera system

In recent years, a wide variety of cameras capable of capturing 360-degree images have appeared on the market. These cameras contain different types of lenses ranging from two back-to-back fisheye lenses to a combination of multiple ultra-wide-angle lenses, and have resolutions ranging from 4K to more than 8K. However, when combining images from multiple cameras, there is a parallax for each camera. When the subject is far away or at a fixed distance from the subject, it is possible to combine images without stitching, but when the subject (player) is moving, as in sports, there is inevitably a gap where images are stitched. Considering that the screen is a hemispherical dome, we proposed using a consumer-grade, 4K resolution, mirrorless single-lens camera with a fisheye lens (Figure 2). The focal length of the lens was chosen so that the fisheye image would be inscribed in the vertical position of the 4K format to increase the resolution maximally.

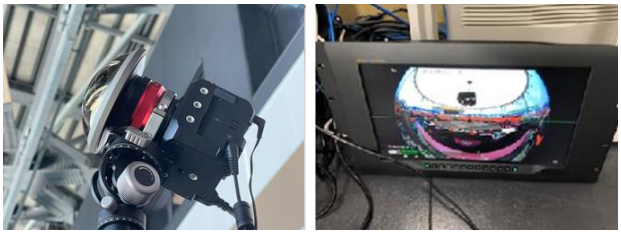

Fig. 2 Introduced SLR camera with fisheye lens and captured image

2.2 Distribution system

The proposed video format for distribution was 16:9 4K video, which is also used in TV broadcasting. Thus, a special system is not required. In addition, considering the distribution of images to planetariums throughout Japan, we proposed the use of a consumer-grade best-effort optical line instead of a dedicated line, to manage costs, ensure ease of operation, and maintain stability. Furthermore, we decided to use an existing Internet TV platform to distribute live and recorded images. Owing to this system, the personnel in charge of the showings at each planetarium could select the program menu on the set-top box with a remote controller, as if they were operating a television, thus minimizing operational problems.

2.3 Projection system

Planetariums use special equipment to project point images of stars onto a hemispherical dome screen. However, recently, projectors have become capable of projecting images onto the entire dome screen so that images of constellation and astronomy simulation can be displayed. The resolution is improving year by year, and some facilities can now project 8K diameter dome images using multiple 4K and 8K projectors. At present, the systems are different from one facility to another, because they are developed by different manufacturers. However, if the image is a fisheye image (dome master format) with a 180-degree viewing angle inscribed in a square, it can be projected, although the maximum possible resolution varies from system to system.

Therefore, with the cooperation of the manufacturers of the planetarium systems installed in the facilities that participated in this demonstration experiment, we proposed the addition of a system that could cut out and project the dome master images inscribed between the top and bottom of the 16:9 4K images.

3 Practical experiment

3.1 Dates

There are two screening methods: live streaming and video-on-demand (VOD) screening as recorded images. Consequently, it was decided that the shooting dates would be from July 23 to August 8, 2021, and the screening dates would be from July 27 to August 8, 2021.

3.2 Contents format

The events that were selected for screening were the opening and closing ceremonies, volleyball, 3 × 3 basketball, badminton, and sport climbing. The selection criteria were as follows: sports with vertical movement, compactness, and an atmosphere similar to that of a normal venue where audience members move their head to follow athletes' movements, along with a viewpoint of entertainment as well as sports.

Three cameras were installed at each competition venue (four cameras for the opening and closing ceremonies only) to deliver highly realistic sensations, as if you were sitting in the spectator seats at the competition venue. For audio, microphones were installed with each camera and sound was mixed.

3.3 Camera location

Because this was an effort with limited budget and personnel, it was necessary to carefully select the events to be screened. Therefore, with the cooperation of amateur sport events, such as inter-high school competitions and university athletic clubs, we filmed various sports and proposed the events for the experiment. The filmed images were projected in a dome theater for experiments at Wakayama University for preliminary confirmation. An analysis of the gazing behavior of the audience at an inter-high school basketball game filmed from the spectators' seats revealed that subjects moved their heads from side to side to watch the game as if they were watching it in an actual venue. In a normal TV broadcast, a TV camera operator follows the game on a fixed, narrow screen; although the viewer's eyes move within the screen, viewers do not move their heads from side to side as they would if attending an actual game. For this reason, it was decided to place the camera on the spectator's seat rather than on the field, to reproduce the spectator's view of the game as much as possible.

Through negotiations with the sport organizations, it was decided to film the opening ceremony, volleyball, badminton, 3 × 3 basketball, and sport climbing from three or four camera positions in the spectator stands. In addition, for the sport climbing event, which involves climbing a high wall, we decided to install one camera in close proximity to the competition stage, because our prior test shooting revealed that filming up close would help convey the top of the wall.

3.4 Program

As for the events and disciplines to be filmed, a program schedule was formulated by combining consideration of the audience's perspectives (e.g., Japan's national athletes' participations and medal matches) and consideration of operational aspects.

3.5 Screening site

It was decided to leave the final screening schedule to each municipality and screening site. Consequently, a total

of 11 live screenings and more than 43 recorded VOD screenings were available. In advance, we prepared the means of communication and procedures in case of trouble, and all the scheduled programs were filmed, distributed, and screened without any major problems. As shown in Table 1, the planetarium facilities that participated in this event differed in terms of dome master diameter resolution, from 2K to 8K; dome diameter, from 9 m to 25.6 m; and dome screens, both horizontal and tilted.

Location		Capacity	Dome	
Planetarium	Prefecture	Seats	Diameter	Type
Katsushika City Museum	TOKYO	172	18m	Tilted
Fuchu City Museum	TOKYO	218	23m	Horizontal
Iida City Museum	NAGANO	90	12m	Horizontal
Fukui City Museum of Astronomy (Seiren Planet)	FUKUI	160	17m	Horizontal
Tsukuba Expo Center	IBARAGI	232	25.6m	Tilted
Fukuoka City Science Museum	FUKUOKA	220	25m	Horizontal
Ishigakijima Hoshinoumi Planetarium	OKINAWA	46	9m	Tilted
Miraikan (The National Museum of Emerging Science and Innovation)	TOKYO	112	15.24m	Tilted

Table 1 List of Screening Venues

3.6 Survey

At the screening sites, an online survey was conducted by Wakayama University to evaluate the realistic sensations of this demonstration experiment. At all the screening sites, leaflets introducing the program were distributed to the audience; they were asked to access the web page with their smartphones or other devices using the two-dimensional barcodes printed on the leaflets and answer the survey questions. In addition, the Iida City Museum conducted its own open-ended questionnaire surveys and exit interviews.

4 Results

Initially, 11 screening venues were scheduled to be open to the general public, but due to the spread of the new coronavirus infection, there was a nationwide movement to refrain from public viewing. Therefore, four venues were able to attract the general public, four venues were limited to events for venue-related parties, and three venues were canceled. Consequently, a total of 969 people (851 from the general public and 118 from related parties) participated in the demonstration experiment.

At the screening venues open to the general public, the management provided advance notice, introduced from MCs, and explained the game (rules) before the screenings. Accordingly, the level of understanding of the images may have differed among the screening venues. In addition, it is believed that differences occurred due to the efforts made to gather audiences, such as providing novelties as incentives for attendance. Furthermore, the screening content greatly affected the venue's ability to gather audiences. For example, many cancelations occurred on the day before or on the day of the badminton match because the leading players were eliminated early in the qualifying round. We believe that various factors must be considered when interpreting the results of the online survey.

5 Conclusions

Because it was not possible to watch and compare each screening site simultaneously, some of the authors' impressions of the programs they were able to watch are presented in the following.

In the live performance of the badminton women's final match at the Iida City Museum, images of the surrounding area, which are not in the field of view of the TV broadcast, were projected, and the respective work scenes of the TV camera operators and various staff working around the area came into view. While watching the game in this type of visual space, we felt as if we were watching the game at the venue. When this experiment was first conceived, we believe that the audience at the planetarium would be able to share in the spectators' excitement of the competition venue. However, because the event was held without spectators due to the COVID-19 pandemic, it was difficult to create the expected emotional sharing. In addition, because there were no spectators, we believe that people paid more attention to things like the peripheral activities of the staff, than they normally would in a crowded sport venue.

This was also evident in the open-ended questionnaire survey conducted at the Iida City Museum. From the data collected from 107 participants, we heard various firsthand opinions. In general, 80%-90% of the opinions were positive, and we were able to confirm that they wanted to continue to enjoy this type of immersive live project in the future. These results suggest that this demonstration experiment has the potential to become an attractive program for future mega sport projects.

As for the realistic sensations for each sport, in the case of badminton, the shuttle flies off the screen during a game in a normal TV broadcast, thereby losing continuity. However, in the dome image, as the trajectory of a high lob or serve can be followed, realistic sensations of watching the game at the venue can be experienced. In addition, in terms of audio, the sounds of the game, such as the shuttle and the players stomping on the ground, were faithfully reproduced. We could also hear the sound of announcements and background music at the venue, which are usually suppressed in TV broadcasts.

Table 2 shows a piece of descriptive results of the online survey.

Location		Level of Reality		
Planetarium	Prefecture	Place #	Mean	Sample
Katsushika City Museum	TOKYO	7th	3.57	14
Fuchu City Museum	TOKYO	5th	4.20	15
Iida City Museum	NAGANO	2nd	4.42	36
Fukui City Museum of Astronomy (Seiren Planet)	FUKUI	3rd	4.31	16
Tsukuba Expo Center	IBARAGI	4th	4.30	20
Fukuoka City Science Museum	FUKUOKA	8th	2.40	10
Ishigakijima Hoshinoumi Planetarium	OKINAWA	6th	3.95	21
Miraikan (The National Museum of Emerging Science and Innovation)	TOKYO	1st	4.47	19

Table 2 Survey Results

This data set was selected from a part of the online survey results (151 useable samples). A level of perceived realistic sensations was measured with a 5-point scale from the most ″realistic″ video (5) to the least ″realistic″ video (1). In other words, a smaller averaged mean indicated a more ″realistic″ video.

Comparing the averaged means for each planetarium, the National Museum of Emerging Science and Innovation (Miraikan) received the highest mean, followed by the Iida City Museum. Although further analysis is required, Miraikan renovated its facilities in 2020 and is able to project bright and vivid images on a dome screen by using two ultra-bright RGB laser 4K projectors. In addition, the Iida City Museum installed temporary projectors and a 5.1-channel surround sound system for this project; thus, it is believed that both video and audio were presented in the best environment. Based on these facts, the components of the video and audio systems appear to have a great impact on realistic sensations.

Okyudo et al. performed the experiment that prompted the Future Sport Viewing Project—the live relay of 4K resolution dome images to a planetarium—during the total solar eclipse that occurred on Amami Oshima Island in 2009. The camera and projection system were custom-designed for that experiment, and the connection was made using the most advanced technology of the time, including a high-speed research network [5]. In this demonstration experiment, a commercial best-effort line was used with a consumer camera. The images were delivered to each site and projected onto planetarium systems with completely different specifications, making it clear that this was a sufficiently practical approach. At present, planetarium facilities with a dome master diameter resolution of 8K (equivalent to 16K in broadcast format) are becoming available, and self-luminous domes with LED panels that offer superior contrast and brightness will be replacing projector-type projection systems. In the future, we hope to conduct similar experiments using LED domes with images that exceed 8K.

Lastly, in conducting this demonstration experiment, we received the assistance from many people involved in the broadcasting, federations, people concerned with this mega sport event, companies, organizations related to each system, as well as people from local governments and planetariums throughout Japan who gathered participants. We would like to express our appreciation to all of them.

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