Proposal of New Sports Video Expression using 8K Video by Simultaneous Analysis of Four Players

Takuya Sarugaku[1,*], Kanji Kitahama[2,†] and Mitsuho Yamada[1,‡]
[1]*Graduate School of Inf. and Telecom. Eng., Tokai University, Minato, Tokyo, Japan*
[2]*Liberal Arts Education Center, Tokai University, Minato, Tokyo, Japan*

Keywords: 8K, Sports, Wireless Eye Movement Measurement Device.

Abstract: With the start of 4K and 8K broadcasting from December 2018, ultra-high-definition video is becoming more familiar. In addition, international sporting events such as the Olympic Games are drawing more attention to sports. For this reason, the technology for sports video expression, such as free-viewpoint video, has been developed. In this paper, we propose the simultaneous measurement of four units using the wireless eye movement measurement device we developed and a new video expression method for sports that simultaneously displays the line of sight and movement of the athlete. In addition, experiments in dance, badminton singles and indiaca were conducted as a preliminary experiment. In the dance experiment, we evaluated the accuracy of the eye movement measurement device before and after the high-speed rotation of a dance expert. By analyzing eye movements and body motions, we successfully measured a technique called spotting, which is used by dancers to suppress dizziness. We found that the gaze movement of badminton and indiaca players leads the shuttle, instead of following it. In badminton doubles, four players were simultaneously measured and analyzed using 8K resolution. By simultaneously measuring the gaze of the four players, we were able to identify their tactics.

1 INTRODUCTION

The 4K and 8K broadcasts began in December 2018. With the widespread use of video cameras with 4K resolution, ultra-high-definition images are becoming more and more familiar (Ministry of Internal Affairs and Communications, n.d., Nojiri, 2007). In response to this, there is a need for video editing technology and video content management that utilizes ultra-high definition video resolution. In addition, international sporting events such as the Olympics have increased the attention to sports. For these reasons, various video expression technologies have been developed. Canon made headlines at the 2019 Rugby World Cup by providing free-viewpoint video (Canon Global, 2019). KDDI has succeeded in real-time delivery of free-viewpoint video at the stadium using a 5G-enabled tablet (KDDI,2018). Due to the influence of COVID-19, the opening of Nippon Professional Baseball (NPB) in 2020 has been delayed and the games have been played without spectators. A VR platform application that delivers a VR image of a baseball game is provided as a new way to watch a baseball game (Softbank, 2019). Spectators can use VR goggles to watch a realistic baseball game from the comfort of their own home. Thus, new contents for enjoying sports have been developed using various technologies.

In Japan, facilities such as the National Training Center have been established to train athletes who are active in international competitions (Japanese Olympic Committee[1], n.d.). Adjacent to the National Training Center is the Japan Institute of Sports Sciences (JISS) (Japanese Olympic Committee[2], n.d.). Sports science — which includes analyses of top athletes' performance — contributes to more efficient training of athletes, and many studies have been conducted at the JISS and elsewhere. Such research has also been active abroad, and in the U.S., Major League Baseball (MLB) has introduced a data analysis tool called Statcast to perform highly accurate analyses of players and ball

[*] https://www.u-tokai.ac.jp/english/academics/graduate/information_and_telecommunication_engineering.html
[†] https://www.u-tokai.ac.jp/staff/detail/MDgwMDcw/MjA2MTU4
[‡] http://eyemove.g1.xrea.com/yamadalab_ENG.htm

Sarugaku, T., Kitahama, K. and Yamada, M.
Proposal of New Sports Video Expression using 8K Video by Simultaneous Analysis of Four Players.
DOI: 10.5220/0010172200530063
In *Proceedings of the 8th International Conference on Sport Sciences Research and Technology Support (icSPORTS 2020)*, pages 53-63
ISBN: 978-989-758-481-7

movements (MLB[1], n.d.). Each MLB team has begun to use data obtained by Statcast, and an index called the “barrel”, which increases the probability of batters hitting home runs, has been implemented, resulting in increased numbers of home runs (MLB[2], n.d.). Thus, in the world of professional sports, various uses of science and technology have improved the performance of athletes in several different sports.

There are various approaches to sports science, including the measurement of athletes’ eye movements, which has been demonstrated to be useful for analyzing the performance of top-ranked and other athletes.

Many sports science experiments using eye movements have been conducted (Hüttermann, 2018). Experiments have been conducted with the aim of elucidating the role of head, eye and arm movements during table tennis competitions (Rodrigues, 2002). However, the eye movement measurement device used in this experiment requires a wired connection between the device worn on the subject and an externally installed device. In addition, the study by Greg Wood et al. describes the eye movement and shooting strategy in soccer penalty kicks (Wood, 2010). The eye movement measurement device used in this study was linked to a PC via a 10m firewire cable from a recording device in a pouch wrapped around the waist, so it was not possible to measure in a completely free state. One study by Natsuhara et al. (Natsuhara,2015), measured the eye movements of athletes watching competition videos. As in these examples, few studies have measured eye movements in a state where athletes are free to compete.

We have developed a new technology for sports video expression using ultra-high definition images. In this paper, we describe four simultaneous measurements using our wireless eye movement measurement device and propose a method for editing 8K video content that displays the gaze and movement of an athlete simultaneously.

2 WIRELESS EYE MOVEMENT MEASUREMENT DEVICE

In order to solve the constraint, we have developed a wireless eye movement measurement device that adds wireless calibration, offset and measurement start/end to the eye movement measurement device.

Fig.1 shows the configuration of the eye movement measurement device, and a person wearing the device is shown in Fig.2. A video transmitter and external control system with a mouse were added to a TalkEye Lite system (Takei Science Instruments Co., Ltd., Niigata, Japan) which used corneal reflection method. The experimenter can control recording start, stop, offset of the line of sight, etc. with a Bluetooth mouse by watching a display transmitted wirelessly. Each device is shown in Fig.3. Two devices can be used at the same time. Experimental data is recorded in the TalkEye Lite. Therefore, the wireless delay does not directly affect the system. The device can be fixed to the head with a hook and loop fastener, so that eye movement sensors do not slip off during exercise. Fig.4 shows the operation screens displayed on the external display: (a) is the eye movement calibration screen, (b) is an offset button for correcting the displacement of gaze movement when the subject gazes at the center of the field of view before the experiment, and (c) is the experimental screen. Basic operation is possible wirelessly when the athlete carries the eye movement measuring equipment in a backpack. It is possible to measure the gaze movement of two athletes by radio simultaneously. The transmission distance of video in the room is 19.7m, and the distance at which the TalkEye Lite can be controlled is 43m. In addition, the weight of this device is 1.3kg. The size of the goggles with eye movement sensors and a field of view camera is 19 cm in length, 21 cm in width, and 9 cm in height.

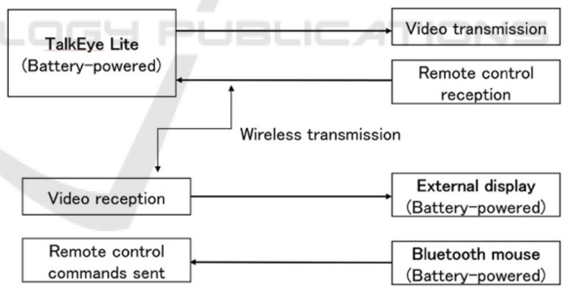

Figure 1: Configuration of the developed device.

Figure 2: A person wearing the device (the eye movement measuring device is in the backpack).

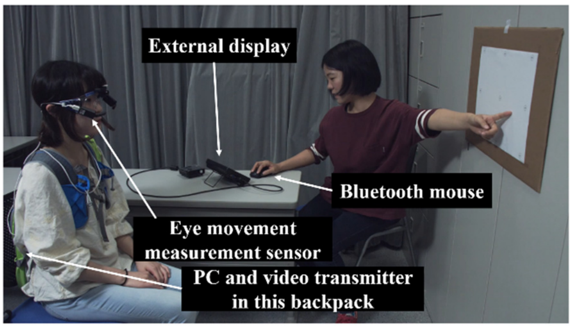

Figure 3: The devices comprising a wireless eye movement measurement device.

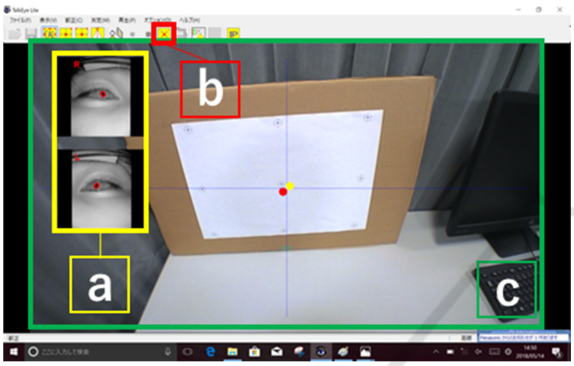

Figure 4: The operation screen to be displayed on the external display.

3 DEVICE ACCURACY EXPERIMENT

In this section, we describe the dance experiments that were carried out using this device. These experiments were conducted with one dance expert as the subject. All test subjects in this study were properly informed about the experimental procedures and measurement protocols, and have provided their written consent to their involvement. Ethical approval for the study was granted by the Tokai University Ethics Committee on "Research on People."

The experiment was conducted in the 4K studio on the Takanawa campus of Tokai University. Figs. 5 and 6 show the positions of the dancer and four cameras during the experiment. The dancer wore a wireless eye movement measurement device, and a five-point calibration was performed using the fixation points shown in Fig. 7. We had the dancer perform two high-speed turns and compared eye movement accuracy before and after the turns. Five-point calibration was applied, as shown in Fig.7. Standard deviation of the gazing points when gazing at the calibration points before and after two high-speed turns are shown in Fig.8. Accuracy before turning was x: -0.82±0.64 degrees, y: -0.72±0.69 degrees, and that after turning was x: 0.92±0.87 degrees, y: -1.71±1.75 degrees. Considering that the of the fovea, which has the highest resolution on the retina, is about 1 degree, it was confirmed that eye movement accuracy barely changes at all with high-speed turns.

Eye movements were measured during rotation and video cameras were used to capture body motions. Figs. 9 and 10 show the rotation angles and rotation velocities, respectively, of the head, body, and right eye during 11 trials. The vertical axis represents the rotation angle (Fig. 9) and the rotation velocity (Fig. 10), and the horizontal axis represents time, expressed as the number of frames. Eye movements were not measured between Frames 12 and 16 because the subject was blinking. Fig.9 shows that the dancer rotates only the body at first, and when the body rotation angle exceeds 50 to 90 degrees, the head is then also rapidly rotated. The head overtakes the angle of rotation of the body by the time the body makes a half turn, and the dancer blinks at that time. This indicates that the dancer is rotating his head at high speed. At this time, the velocity of the head rotation angle reached a high speed of over 1900 deg/sec. Focusing on eye movement, the eye rotation angle gradually rotates counter-clockwise from 0 deg. However, after the dancer blinks, it gradually returns to the front from the position to which it had rotated greatly to the right. It is thought that this series of movements comes about because the dancer is trying to gaze at a point in front of him. In fact, when asked after the experiment, the dancer stated that he was conscious of looking straight ahead. In general, when a person sitting in a swivel chair rotates, the vestibulo-ocular reflex (VOR) is activated and dizziness may occur. However, dancers keep their eyes on a specific point during rotation to stabilize their posture without dizziness. (Dehesdin, 2014, Kheradmand, 2016, Letzter, 2018) This behavior is called spotting. The above-mentioned experimental results are considered to support them. In exercises that involve rotation, such as figure skating and various types of dance, training in spotting is provided. However, to the best of our knowledge, there have been no reports on the measurement of eye movements during rotation, and we believe that this will provide an effective means of skills analysis in the performance of sports that involve rotation.

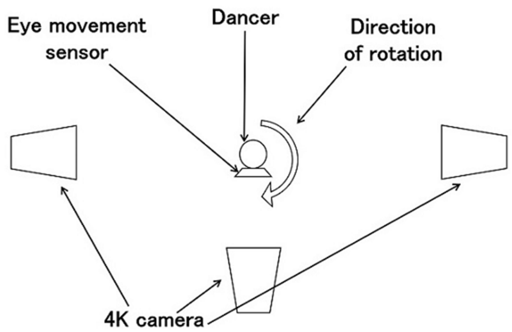

Figure 5: Arrangement of the equipment and players from top.

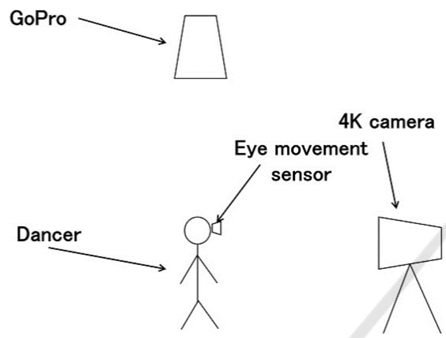

Figure 6: Arrangement of the equipment and players from side.

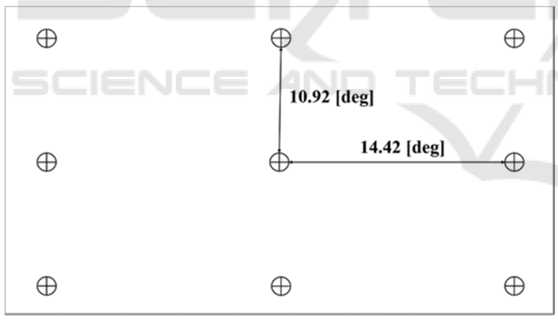

Figure 7: Fixation points for five points calibration.

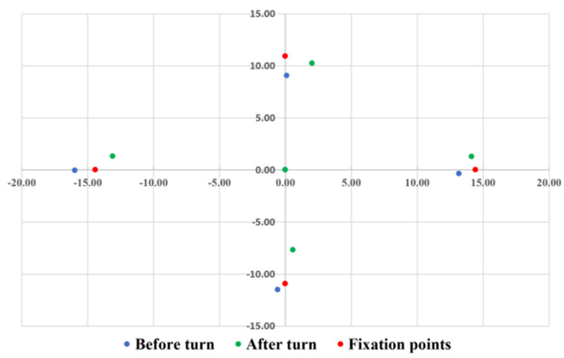

Figure 8: Standard deviation of eye movements during gazing at each fixation point.

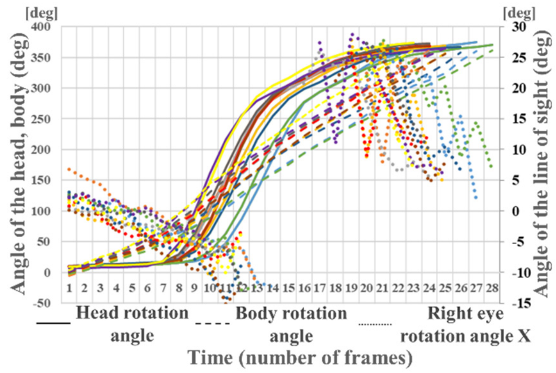

Figure 9: Angle of gaze, head, body (11 trials).

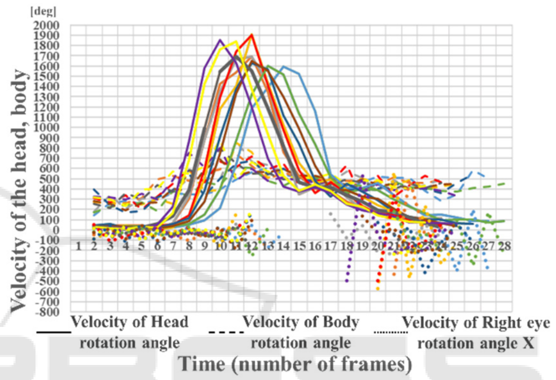

Figure 10: Velocity of gaze, head, and body rotation angle (11 trials).

4 PRELIMINARY EXPERIMENT

We conducted a preliminary experiment on the line of sight during singles badminton competition. Subjects are students of the Tokai University Takanawa Campus Badminton Club. They have been playing badminton since junior high school or high school. The experiment was conducted at the gymnasium on the Takanawa campus. This time, we asked them to rally on the half-court, acquired their eye movements during the competition, and shot the competition with two high-definition cameras. Fig. 11 is a photograph during the competition. Fig. 12 shows the positions of the players and two cameras during the competition.

Figure 11: A photo during a badminton preliminary experiment.

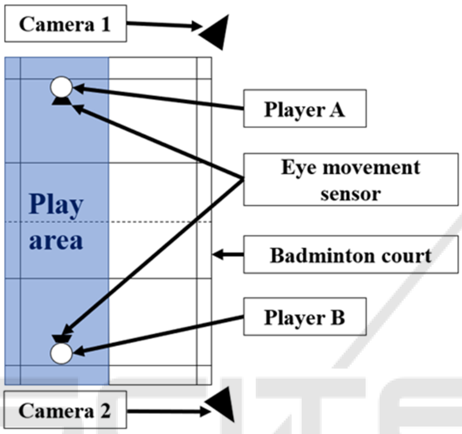

Figure 12: Arrangement of the equipment and players(singles).

5 RESULT OF PRELIMINARY EXPERIMENT

After the experiment, the images of two player's visual field camera attached to the goggles of the eye movement sensor and the image of two high-definition cameras were combined at 4K resolution. An example of the edited video frames is shown in Fig.13. In this scene, the line of sight is displayed in blue while both players are watching the shuttle. The upper left shows the line of sight of Player A, the lower left shows the movement during his play, the upper right shows the line of sight of Player B, and the lower right shows the movement during his play. As can be seen from Fig.13, the image is divided into four sections each image maintaining the resolution of 2K because it is edited in 4K. That is, by using the 4K resolution, the line of sight and movement of each subject can be analyzed in time series while maintaining the high resolution.

Fig.14 is a time series analysis of the line of sight and movement of Player B. This scene is where Player B hit the Player A shuttle high. It took 1.97 seconds for this scene. First, the line of sight of Player B on the right side of Fig.14 will be described. Player B is gazing at a shuttle ① through ④ that were launched higher by himself. 1.13 seconds after the hit shuttle ; the shuttle reached the highest point, Player B's line of sight precedes the shuttle (⑤) and moves to the opponent player (⑥). Player B looked at Player A for 0.7 seconds. After Player B hit the shuttle to Player A, it is probable that Player B quickly moved his gaze direction to Player A to predict the next shot.

Next, we analyze the movement of the player B's body. Compared to the posture when Player B hit the shuttle in(①), he started lowering his posture in (④), and when he gazed at the opponent in (⑥), he dropped his waist to prepare for the shot of the opponent. This posture which dropped waist is called a power position and is a basic posture to prepare for an attack by the opponent. It is said that a player can move quickly from the stationary posture in any directions by keeping the power position. By analyzing the player's line of sight and movement at the same time as in this example, it was possible not only to measure eye movement when following the shuttle but also to observe the line of sight to the opponent player in advance and to observe the power position to prepare for the counterattack of the opponent player at the same time. Taking advantage of this experience, we challenged an experiment to wirelessly capture the line-of-sight and body movements of four doubles players at the same time.

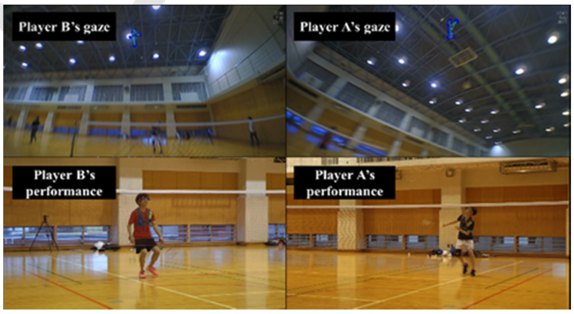

Figure 13: Example of edited 4K video.

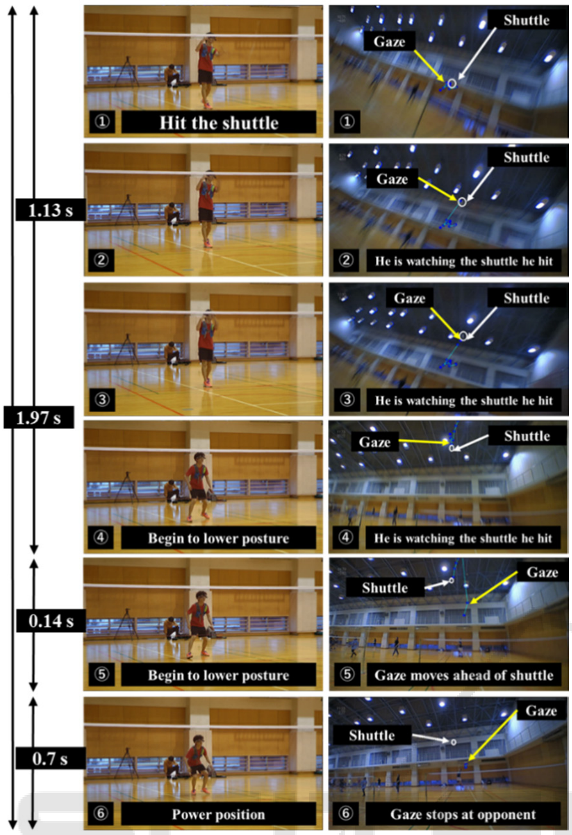

Figure 14: Player B's gaze and movement.

6 EXPERIMENT OF INDIACA

We conducted an experiment for the volleyball-like sport known as Indiaca, in which the player hits a shuttle called the Indiaca shuttle with a hand. Each of the two teams has four players, and the court is the same size as a badminton doubles court. Fig.15 shows the Indiaca shuttle. The Indiaca shuttle has feathered wings, and thus the speed of the shuttle's movements is moderated and anyone can enjoy playing regardless of their age or gender. Since Indiaca can be enjoyed by the elderly, it is attracting attention as a 'lifelong' sport. In addition, Indiaca world championships and World Cups have been held.

In the present study, the players were nine individuals who had participated in a practice session sponsored by the Japan Indiaca Association. In this experiment, not only the athletes' but also the referee's eye movements were measured. The referee is a veteran player who is also a director of the Japan Indiaca Association. The experiment was conducted in the arena of the Tokai University Takanawa Campus. Fig.16 shows the positions of the athletes and equipment and the range of use of the court during the experiment.

Figure 15: Indiaca shuttle.

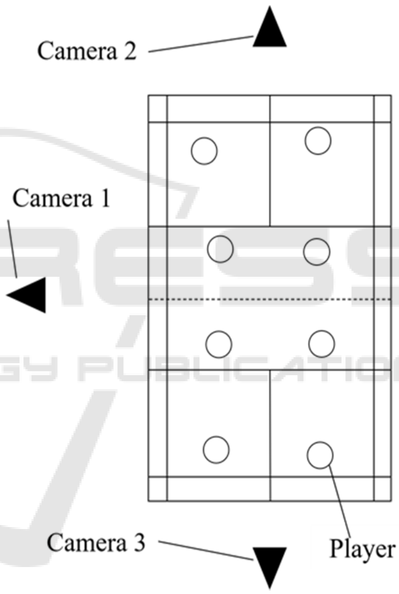

Figure 16: Placement of the players and devices.

7 RESULT OF INDIACA

After the experiment, we synthesized the line of sight data measured by the eye movement measuring device and the images obtained with the visual field cameras. We will describe the characteristic lines of sight of the players and the referee.

7.1 Player

We will first describe the line of sight of a player. Fig.17 shows the line of sight of a player who hits a serve. As shown in panel ①, the player is watching the shuttle before he hits, and in ②, he is watching the hit point of the serve. In ③, the shuttle is in the process of being launched toward the top of the parabola, and the players' points of view are moving to follow the shuttle's trajectory. In ④, the shuttle is at the apex of the parabola, and the serving player keeps watching the shuttle. Panel ⑤ is the time point at which the shuttle begins to fall. You can see that the player's line of sight is on his opponent player at the drop point faster than the shuttle falls. In panel ⑥, the opponent player tries to hit the shuttle back, and player whose eye movements are being measured watching that player.

7.2 Referee

We next describe the referee's line of sight. Fig.18 shows the scene where the team on the right side of the referee hits the serve. In panel ①, in which the server has the Indiaca shuttle, the referee is gazing at the server. At ②, the referee's line of sight was tracing the shuttle immediately after the serve was hit. He keeps his eyes on the shuttle until ③, just before the apex, but his gaze has shifted from ④ to the receiver player ahead of him, and his gaze remains stationary until the receiver player at ⑥ hits the shuttle. Indiaca is a sport played with four players on two teams, and it can be seen that the referee has determined which player the shuttle is heading for before the shuttle reaches the top of the serve.

In the 'smash' scene, we were able to measure the line of sight peculiar to the referee. Fig.19 shows the referee's line of sight during the smash. First, in ①, the team on the left side of the referee are trying to raise the toss from the player in the yellow circle to the player in the red circle. At this point, the referee has shifted his line of sight that was following the shuttle until immediately before to the player tossed. This is thought to be to confirm who can take this toss. After that, in ②, the referee's line of sight is moving to trace the raised toss. In ③, the shuttle approaches the apex of the parabola and the referee's line of sight moves ahead of the shuttle, but the destination is not the player who hits the smash, the player who blocks the smash. In ④, it can be seen that the red-circled player is in a position to hit the smash, but the referee is watching the net and checking whether the block player touches the net.

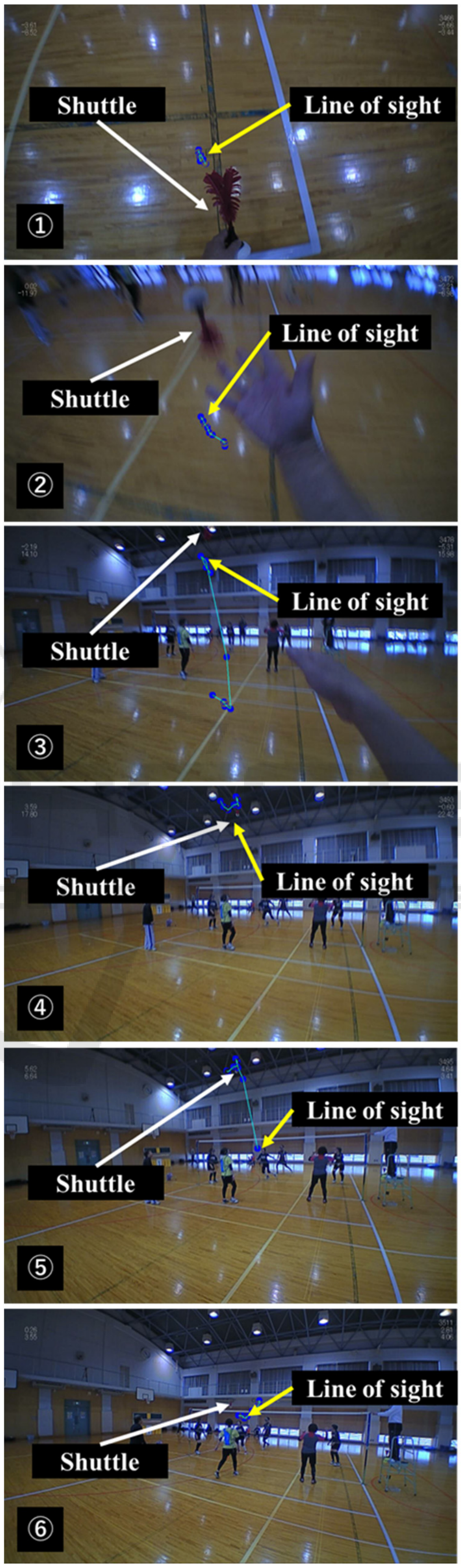

Figure 17: Player's line of sight (serve).

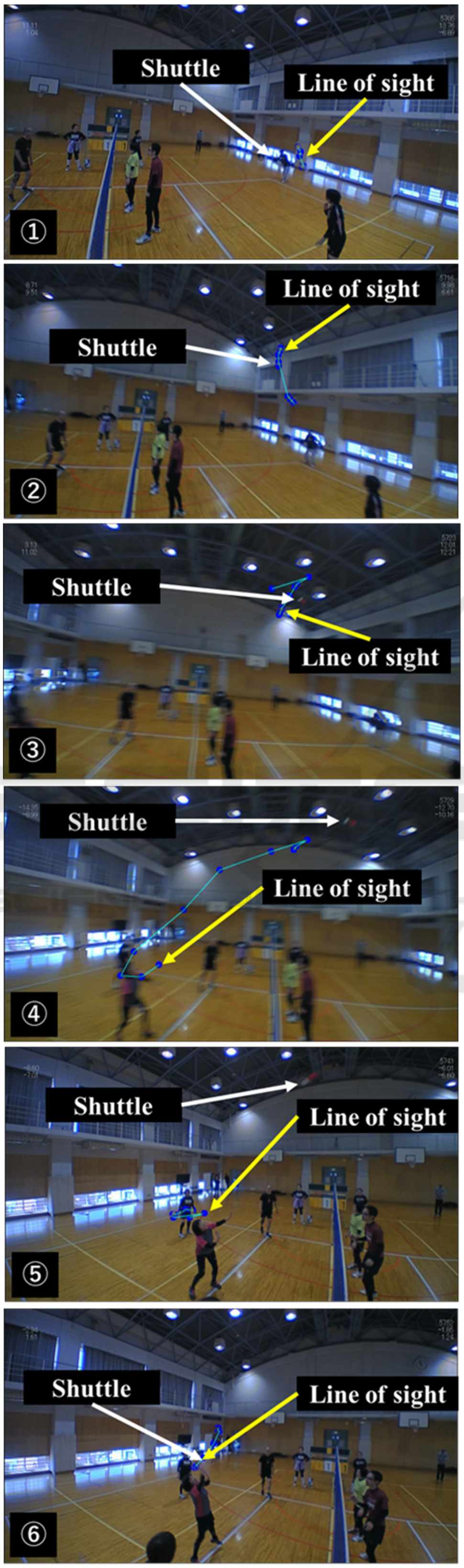

Figure 18: Referee's line of sight (serve).

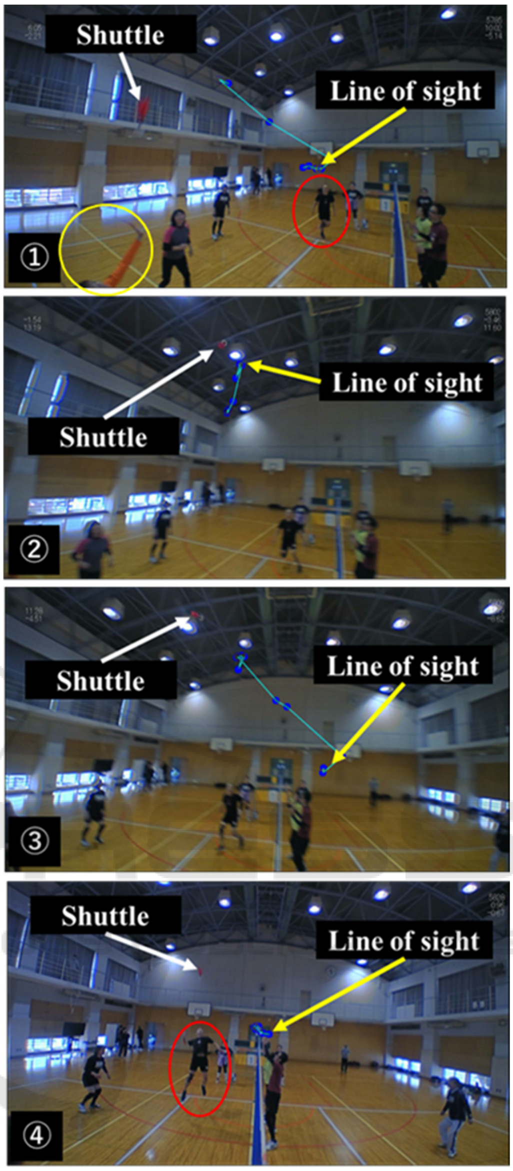

Figure 19: Referee's line of sight (smash).

8 EXPERIMENT OF DOUBLES BADMINTON

In this study, an experiment was conducted on badminton in doubles. Subjects were four members of the Tokai University Takanawa Campus Badminton Club. Four subjects were asked to wear a wireless eye movement measurement device and play a game. We measured the eye movements of the athletes during the competition and filmed their movements using three high-definition cameras. Fig.20 and Fig.21 show the scene during the experiment, and Fig.22 shows the layout of players and three cameras during the experiment.

Figure 20: Photo taken during measurement.

Figure 21: Photo taken during measurement.

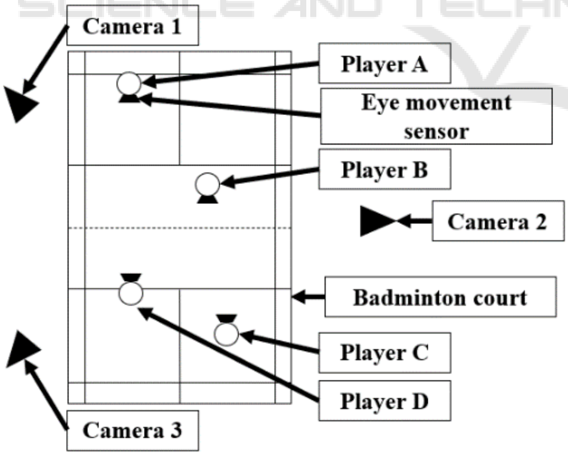

Figure 22: Arrangement of the equipment and players (doubles).

9 RESULT AND DISCUSSION OF DOUBLES BADMINTON

After the experiment, we combined the eye movement data with the videos from the field of view camera of the wireless eye movement measurement device. After that, the video was edited in 8K resolution to present simultaneously the videos from the field of view camera showing the eye movements of the four people and the videos from three video cameras. In this method, all the wipes can be displayed without losing their original resolution, since they are edited at 8K resolution. An example of the edited video frames is shown in Fig.23. In the center of the bottom row, an image of the entire court is presented, and broken lines represent the line of sight of each player identified by color. The position and orbit of the shuttle are shown with an illustration and a white broken line. This makes it possible to see at a glance who is looking where. On the left and right sides of the bottom row are images of the respective courts. On top of those images, the images of the players' line of sight on each wipe are presented. This time, the left team is Team A and the right team is Team B. The players are named as A1, A2, B1, and B2, respectively.

With this method, we can display the line of sight along the time line. Fig.24 shows an enlarged figure from Fig.23. In the scene in Fig.23, team A is the team to serve. The server A2 confirms the receiver B1 and then looks at the shuttle at hand and prepares for the serve. (green circle 1 and 2) On the other hand, receiver B1 is looking at server A2 and preparing for receive (blue circle 1). After that, we can confirm the eye movement following the shuttle that A2 hits (blue circle 2). In addition, just before the shuttle is hit, it is clear that eye movements are being performed to confirm the opponent's position (blue circle 3). B2 was gazing at server A2 in the same way as B1, and was following the shuttle with line of sight (yellow circle 2). However, it was confirmed that the eye movement was like leading the shuttle during the follow-up (yellow circle 3). On the other hand, A1 was alternately watching B1 and B2 of the opposing team (red circle 1 to 4). This is probably because he was trying to confirm the positions of both opponents. After that, when B1 hits the receive, A1 was gazing at B1 (red circle 5).

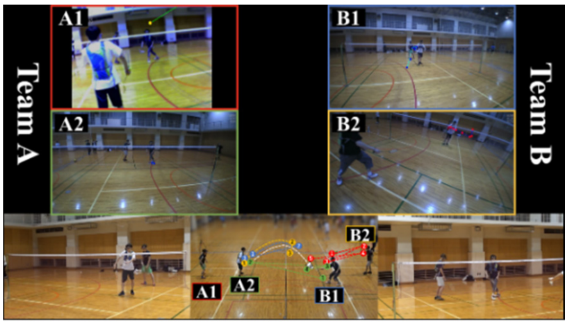

Figure 23: Examples of 8K edited video.

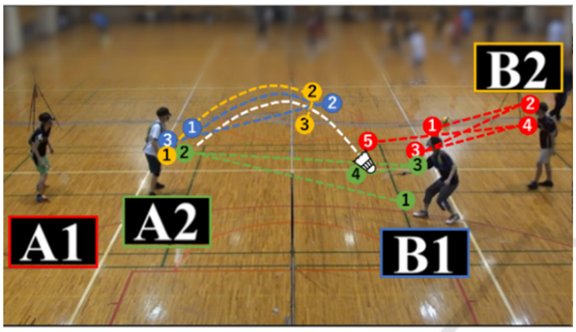

Figure 24: An enlarged figure (the center of the bottom row).

10 CONCLUSION

In the present study, we measured the eye movements of players during various types of sports to confirm the operability, accuracy and practicality of using a wireless eye movement measurement device. The device includes a new and optimized system for eye movement measurement during sports. In the dance experiment, accuracy was evaluated before and after high-speed rotation. The standard deviation before rotation for the 5-point calibration was x: -0.82±0.64 degrees, y: -0.72±0.69 degrees, and that after turning was x: 0.92±0.87 degrees, y: -1.71±1.75 degrees. In addition, we were able to clarify the spotting technique used by dancers during rotation by analyzing a combination of eye movements and body motions. In the badminton singles and indiaca experiments, measurement was found to be successful in court sports. By measuring the athletes' and referees' lines of sight during competition, it was possible to confirm their characteristic line-of-sight movements. Since the line of sight can be presented as a video, it can be interpreted clearly at a glance, and it is thought that this information can be used for training athletes and referees. In the badminton doubles experiment, we succeeded in simultaneously measuring the data of 4 different athletes. Up to now, there have been no cases in which the eye movements of four athletes during the competition have been measured at the same time, and this is considered to be the first case.

In the field of sports video, new content has been developed using various technologies, such as free-viewpoint video and game viewing using VR. Therefore, we proposed an editing method that takes advantage of the 8K resolution to present images without compromising the resolution of each image. In the proposed method, the player's line of sight and movement can be confirmed at the same time, and it is considered that the viewer can have a new viewing experience, such as bargaining with the opponent and cooperation with the teammate using the line of sight. Our proposed method is able to measure an athlete's line of sight and match it to his/her movement in actual competition and this is thought to have useful applications in coaching.

In the future, we would like to examine more easy-to-understand editing methods and ask for opinions from sports instructors and others on how to apply them to sports science.

ACKNOWLEDGEMENTS

This work was supported in part by the Hoso Bunka Foundation (2018/2019 Grant Cycle). We would like to express our sincere gratitude to the badminton team at the Takanawa campus of Tokai University for their cooperation in this experiment.

REFERENCES

Canon Global, (September 17, 2019). *Free-viewpoint video generation system progresses to practical stage. Provides highlight scene video from Rugby World Cup 2019.* [News release], Retrieved August 27, 2020, from https://global.canon/ja/news/2019/20190917.html

Dehesdin, C., (2014). *Spin, Dance, Jump, Repeat!, Why don't figure skaters get dizzy?*, Retrieved September 26, from http://www.slate.com/articles/news_and_politics/explainer/2010/02/spin_dance_jump_repeat.html

Hüttermann, S., Noël, B., Memmert, D, (2018). Eye tracking in high-performance sports: Evaluation of its application in expert athletes, *IJCSS*, 17(2), 182-203

Japanese Olympic Committee[1], (n.d.). *National Training Center*, Retrieved September 26, from https://www.joc.or.jp/training/ntc/

Japanese Olympic Committee[2], (n.d.). *Japan Institute of Sports Sciences*, Retrieved September 26, from https://www.joc.or.jp/training/ntc/jiss.html

KDDI, (June 27, 2018). *Live watching professional baseba ll at your favorite angle, the world's first, succeeded in real-time distribution of free viewpoint video with "5G "* [News release], Retrieved August 27, 2020, from https://news.kddi.com/kddi/corporate/newsrelease/2018/06/27/3225.html

Kheradmand, A., (2016). *Why don't figure skaters get dizz y when they spin*, Retrieved September 26, from https://www.scientificamerican.com/article/why-don-t-figure-skaters-get-dizzy-when-they-spin/

Letzter, R., (2018). *The brutal neuroscience of figure skati ng: How spinning athletes overcome dizziness,* Retriev ed August 27, 2020, from https://www.livescience.com/61795-ice-skating-brain-spin-dizzy.html

Ministry of Internal Affairs and Communications, (n.d.). *4 K/8K broadcast information site*, Retrieved August 27, 2020, from https://www.soumu.go.jp/menu_seisaku/ictseisaku/housou_suishin/4k8k_suishin.html

MLB[1], (n.d.). *Statcast*, Retrieved September 26, from http://m.mlb.com/glossary/statcast

MLB[2], (n.d.). *Barrel*, Retrieved September 26, from http://m.mlb.com/glossary/statcast/barrel

Natsuhara, T., Nakayama, M., Kato, T., Hagano, T., Yoshida, T., Sasaki., R., Asai, T., (2015). Cognitive process that supports the execution of a path with tactical judgement in football, *Japan J. Phys. Educ. Hlthe. Sport Sci.*, 60 (1), 71-85

Nojiri, Y., (2007). Overview of super hi-vision, *The journal of the institute of image information and television engineers*, 61 (5), 599-602

Softbank, (March 25, 2019). *Launched VR platform applic ation "LiVR"* [News release], Retrieved August 27, 2020, from https://www.softbank.jp/corp/news/press/sbkk/2019/20190325_02/

Rodrigues, S. T., Vickers, J. N., Williams, A. M., (2002). Head eye and arm coordination in table tennis, *Jpurnal of Sports Sciences*, 20(3), 187-200

Takei scientific instruments Co., LTD., (2018). *Talk Eye L ite*, Retrieved August 27, 2020, from http://www.takei-si.co.jp/en/productinfo/detail/65.html

Wood., G. W., Wilson, M. R., (2010). Gaze behaviour and shooting strategies in football penalty kicks: Implication of a ‘keeper-dependent approach, *International Journal of Sport Psychology*, l41 (3), 293-312