Quantification of Visual Search Motion During Basketball in VR Simulation

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Abstract: In basketball, players must be able to make good decisions in complex and rapidly changing situations. An important element of situational judgment is visual search motion. We propose to quantify the visual search motion of a basketball player during play. In the proposed method, the experience of playing basketball is realized on a VR simulation. The player wears a head-mounted display to experience the playing situation. We prepared scenarios that considered the characteristics of the basketball game and the characteristics of the head-mounted display and measured the visual search motion on the prototype system. Experiments were conducted on defensive players, and the results show that the measurement results of visual search motion are useful for discussing the characteristics of players.

1 INTRODUCTION

In basketball, players are required to make accurate judgments in response to complex and rapidly changing surroundings (Bjurwill, 1993) (Albernethy, 1993). One of the most important elements for making judgments is the visual search movement.

Visual search movements are performed when it is necessary to grasp the positions of multiple objects, such as a ball or other players. If visual search movements can be quantified, it will be possible to discuss whether or not the players acted appropriately to the situation together with their movements based on visual search movements.

In this study, we propose to quantify the visual search motion of basketball players during play.

For quantification of visual search motion, it is essential to obtain the following information. The basic information is the position and posture of the athlete's head. Information on the direction of the player's line of sight and the object he/she is gazing at are also necessary. In order to obtain this information in a real environment, it is necessary to know all the circumstances surrounding the players.

The proposed method realizes the experience of playing basketball on a VR simulation. The VR simulation allows us to manage all the situations surrounding the players. The player wears a head-mounted display (HMD) to experience the playing situation. By using an HMD that can measure the position and posture of the player's head and the direction of the player's line of sight, the system can obtain all information during the play.

The experience of playing on a VR simulation with an HMD cannot match the experience of playing in reality. Therefore, it is necessary to carefully consider the scenario to be used when measuring visual search motion, taking into account the characteristics of the basketball game and the field of view of the HMD. For this purpose, we will develop scenarios with the advice of an experienced head coach of a basketball team.

By quantifying visual search movements, it is possible to investigate the characteristics of players in a playing situation. As an example, in a scenario where defensive movements are required, we calculate basketball-specific motions from the results of visual search motion measurements. From the results, we

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show that it is possible to discuss the characteristics of the players.

2 RELATED WORKS

In an effort to quantify the visual search motion of basketball players in a real environment, measurement of rotational head and eye movements using a gyro sensor and an IR camera has already been proposed (Vickers, 2019) (Maarseveen, 2017). They quantified the differences in visual search motion for each selection when offensive players wearing eye-tracking sensors were in possession of the ball in Pick-and-Roll. In other sports, for example, in soccer, Aksum et al. (Aksum, 2021) quantified the visual search motion for each Ball Action of players wearing eye tracking sensors in soccer.

In such efforts in real environments, it is difficult to analyze the relationship between visual search movements and the surrounding situation because the surrounding situation is sometimes unknown.

As an approach to visual search motion using virtual environments, Ferrer et al. proposed a method to quantify visual search motion for passing in soccer games (Ferrer, 2020). In this method, a playing situation is prepared on a VR simulation and the direction of the head of a player wearing an HMD is measured. Because of the short time between the visual search motion and the passing action, the analysis of the visual search motion has not been addressed. (Wood, 2020) reported the effect of practice with visual search motion on a VR simulation.

3 QUANTIFICATION OF VISUAL SEARCH MOTION

In this study, we quantify the visual search motion of basketball players during play. The following information is used in the quantification of visual search motion.

The basic information is the position and posture of the player's head. This information is expressed in the court coordinate system. Next is the direction of the player's line of sight. This is represented by the average of the direction vectors of both eyes starting from the average of the eye positions of both eyes.

If there is a ball or another player at the gazing point, it becomes the gazing object. The walls and floors of the building where the basketball game is played are also considered as gazing objects. If the gaze vectors of the two eyes are nearly parallel, the object whose gaze vectors collide first is considered to be the gazing object.

In order to obtain these values, we use an HMD that is capable of six-degree-of-freedom position and posture estimation. Furthermore, by using an HMD with an eye tracking function, we obtain the eye vectors of the left and right eyeballs.

For the VR simulation, an international standard basketball court is set up in the virtual space, and the ball and other players necessary for the game are placed in the court. Players wear HMDs to experience the VR simulation. In order to ensure a sense of immersion, a 3D model of the gymnasium is prepared that resembles a real gymnasium.

In the VR simulation, labels are assigned to the CG model to obtain the labels of objects that collide with the eye vectors. Players and balls other than the person experiencing the simulation are made to move according to the simulation program.

4 SCENARIO STUDY

4.1 Prerequisite

In order to quantify visual search motion, players wear HMDs while playing basketball.

Two limitations of wearing HMDs are listed below. First, the HMD with the eye tracking function must be firmly fixed on the head. Second, the field of view of the HMD is narrower than the normal field of view. Therefore, it is necessary to consider the influence of the difference in the field of view on the visual search motion.

Under these limitations, the player's experience should be a meaningful basketball play.

Based on the above, and based on the opinions of experienced basketball players and coaches, this study focuses on a scenario in which the players defend a goal. In goal defense, the defending player observes the movements of the attacking player through visual search movements and acts accordingly. In this type of action, there is almost no movement such as jumping, so the possibility of HMD misalignment is low. The difference in the field of vision can be mitigated by appropriately positioning the initial position of the defending players in relation to the attacking players.

4.2 Scenario

Taking advice from Kenji Yoshida, head coach of the University of Tsukuba men's basketball team, we will prepare three different scenarios.

The common assumption for all three scenarios is that there are three players, two offensive players and one defensive player, as shown in Figure 1. The participant in the experiment participates as a defensive player. At the beginning of the play, the attacking player who has the ball and is on the right side of the top, as seen from the direction with his back to the goal, is the ball man. The other attacking player on the left wing is the marksman. The arrangement of the two attackers and the defender is the same at the beginning of every scenario. It is difficult for the defender to see the two attackers at the same time.

In all scenarios, the defensive player should be close to the ball man at the start of the game in order to block a shot by the attacking player. The defender may try to anticipate and cut off the pass. In this case, the movement is a denial of the ball man reaching for the path of the pass from the ball man to the marksman in the initial position. On the other hand, since the two attackers are standing far from each other, the defender needs either a visual search motion by shaking his head from side to side or a visual improvement motion by trying to get them in his field of vision by moving back toward the goal.

Three scenarios for the attacker to score are described below. A scenario is divided into events along the time axis. The criteria for the division will also be described.

4.2.1 Scenario A

The first is scenario a, in which the ball man moves outside and shoots. Scenario a can be subdivided into three events. The first event is event 1, when the marksman moves outside the boundary of the field of view along the 3-point line. The next event is event 2 when the ball man passes to the marksman. Finally, the marksman shoots, which is the final Event 3. Figure 1 shows the scene at the end of Event 3. In each event, the defender is considered to either maintain his initial position or retreat toward the goal. Therefore, for each of the three events, there are two possible outcomes: either the defender stays in front of the goal without retreating, or he retreated. As a result,

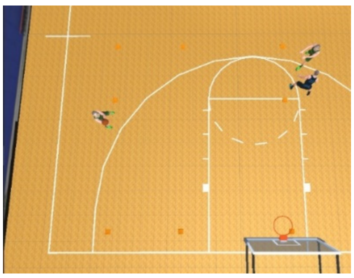


Figure 1: Scenario a.

there are six types of events. We label these events a1-front, a1-back, a2-front, a2-back, a3-front, a3-back.

4.2.2 Scenario B

The second is scenario b, in which the marksman shoots on the spot. Scenario b can be subdivided into two events. The first event is that the ball man passes to the marksman while the marksman is stationary on the spot. The second event is when the marksman shoots. Figure 2 shows the scene at the end of Event 2. As in scenario a, each event differs depending on whether the defender retreats to the goal or not. As a result, there are four different events. As in scenario a, we label the events.

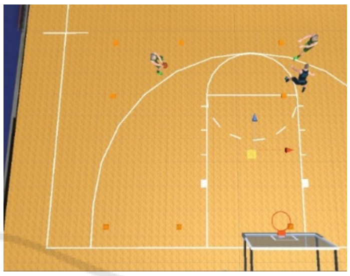


Figure 2: Scenario b.

4.2.3 Scenario C

The third is scenario c in which the ball man dribbles and shoots. Scenario c can be subdivided into three events. The first event is until the marksman begins to move. The next event is event 2, where the marksman starts to move and the ball man starts to drive. The last event, event 3, is until the marksman drives and shoots. Figure 3 shows the situation at the end of Event 3. If we take into account whether the defender retreats or not, we end up with six different events. The labeling is the same as in scenario a.

Figure 3: Scenario c.

5 ACTION INDEX

This section describes a method for obtaining the indices necessary to observe the visual search movements of the defensive players in the scenarios described in the previous section.

5.1 Event Switch

The factors of event switching can be divided into those based on the motion of the ball and the attacking players, and those based on the retreat of the defending players toward the goal. The former can be specified in time based on the description of the motion in the VR simulation. For the latter, the head position of the HMD is assumed to be the standing position of the defender, and when the distance from the standing position to the goal (goal distance) becomes less than a certain value, the player is judged to have retreated.

5.2 Head Shake

When the defender remains in the initial position and continues to defend, he cannot see the two attackers at the same time, and therefore, shaking his head to the left and right is a visual search motion. We call this action head shake.

We define the number of the head turns as follows to indicate the amount of head shake. When the head rotation angle returns to the original direction in a short period of time, if the variation of the head rotation angle exceeds a threshold value, one head turn is counted.

6 IMPLEMENTATION

To realize the proposed method, a VR simulation system is constructed. In addition, a system for experiencing the scenarios will be constructed.

6.1 VR Simulation System

The VR simulation system is built using Unity, a 3DCG integrated development environment. For the floor, ceiling, and four walls of the VR gymnasium, we used the texture of a photo of the interior of a real gymnasium used by the participants in the experiment to provide a sense of immersion. The attacking player is assumed to be 170 cm tall, assuming the height of an average Japanese male. The size of the ball and the court are based on the standards of the International Basketball Federation (FIBA, 2024). An overview of the VR gymnasium from a subject viewpoint in the simulation system is shown in Figure 4.

We will explain the mechanism of the movement required for the visual search exercise. We used Very Animation, a Unity Asset that allows the creation and editing of animations of objects. Several typical poses are prepared for the attacker's movements. A Unity feature called "Animation Blend" was used to complement the movements between the poses to reproduce the real game behavior. Timeline, a Unity feature that allows multiple objects to be controlled simultaneously, was used to accurately describe the layout of the positions of multiple players and the ball and their movements with respect to time.

Figure 4: A view of VR gymnasium from a subject viewpoint.

6.2 User Experience System

VIVE PRO EYE from VIVE Technologies, Inc. will be used as the HMD. Four base stations are used to estimate the position and orientation of the HMD. The wireless function is used to facilitate the movement of the participants in the experiment. This ensures that a 10m square area is available for the participants to move around. In order to provide an immersive experience for the participants, the system is set up in the gymnasium where the participants usually practice. Figure 5 shows an overview of the experience system.

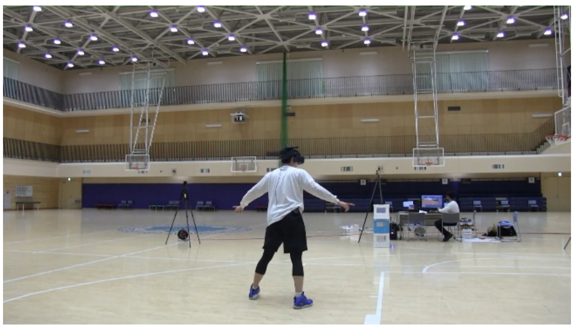


Figure 5: Overview of the proposed experience system in the university gymnasium at University of Tsukuba.

6.3 Measurement

The accuracy of the measurement of the motion of the participants in the experiment is determined by the accuracy of the VIVE PRO EYE. The position and orientation of the HMD are measured at 70 Hz or higher, but the data are recorded at 30 Hz for synchronization. The horizontal position of the HMD can be measured with an accuracy of $1.8 \times 10^{-3}\ m$ (Holzwarth, 2021). The direction vector of the HMD can be measured with an accuracy of 0.8° (Bauer, 2021). The eye detection in the HMD can be measured at 120Hz, but is recorded at 30Hz for data synchronization. The data is recorded at 30Hz. The eye vectors can be measured with an average accuracy of 6.21° (SD 0.77°) (Sipatchin, 2021).

As for the gazing objects, the eye vectors and collision judgments are performed for the floor, ceiling, and four walls of the VR gymnasium, as well as for the ball and the attacking player, and the target labels and the time when the collision occurred are recorded. For the attacking player, collision judgments are made separately for each joint, so it is possible to examine which part of the opponent's body the player was looking at.

Next, we will explain how to prepare the participants for safe defensive actions. In the experiment, the movable area is 5.45m in depth and 7.00m in width. The boundaries of the movable area are displayed during the experience in a way that does not spoil the sense of realism.

Next, the experimental subject is given time to practice until he/she can perform the desired defensive action in the actionable area of the VR gymnasium. During the practice, the players of the prepared scenario are reversed in the center of the court. During the practice time, the two attacking players exchange passes without moving from their initial positions. The experimental subjects are asked to "follow the offensive player on the left one-on-one. Practice to move smoothly to position 1 or 2, etc." They are told: "Please assume that the offensive player is aiming at the goal as in a game. Position 1 is the position where, when the marksman has the ball, the defenseman is in a straight line between the marksman and the goal and can immediately go for a block if the marksman moves to shoot. . The experimental subjects continued to practice until they self-reported that they were able to perform the defensive action within the area of possible movement. Thereafter, six trials are conducted.

7 EXPERIMENTS

7.1 Procedure

First, explain that there are two attacking players in the experiment and that the goal of the experiment is for the participant to interfere with the attacking shot as a defensive player. Explain that there will be six trials. We do not tell them how many different offensive scenarios the attackers have prepared. The experimenter is allowed two trials for each of the three scenarios so that the number of trials is not biased toward any of the three scenarios. The order in which the scenarios are presented is determined for each participant so as to counteract the order effect.

Next, we calibrate the eye gaze measurement for each participant in the experiment. In order to check the accuracy of the eye tracking, the participants are asked to look at a basketball in the VR gymnasium and erase it. The participant's gazing point is indicated by a pink sphere. When the sphere collides with the ball, the ball disappears.

7.2 Execution

Ten members of the University of Tsukuba men's basketball team, ranging in age from 19 to 21, participated in the experiment as participants A through J. The experience system was set up in the gymnasium used by the basketball team for practice (Figure 5). The time required for the trials of scenarios a, b, and c was 8.20, 4.90, and 8.30 seconds, respectively. In all scenarios, the initial positions of the two attackers and the defender are the same, and the attacker stands 93.2° open from the defender.

Based on the positioning of the players in the prepared scenarios, we set the threshold value of the pivoting judgment to 20°. When the goal distance of the participant in the experiment was less than 4.8m, the participant in the experiment was considered to have retreated, and an event switch was considered to have occurred. Figure 6 shows the measurement of the head rotation angle for experimental participant A in scenario c. In this example, the number of pivots is 6. Figure 7 shows the goal distance for participant E in scenario b.

The measurement record of each trial can be visualized. Figure 8 shows the scene. The position of the participant's head is indicated by the gray dots in the figure. The blue line indicates the frontal direction of the head, and the white and green lines indicate the edges of the HMD's field of view. The red line indicates the direction vector of the gaze, and the light blue dots indicate the gazing position. As shown in the subfigures, the gaze estimation is precise enough to examine the objects that the subject checked.

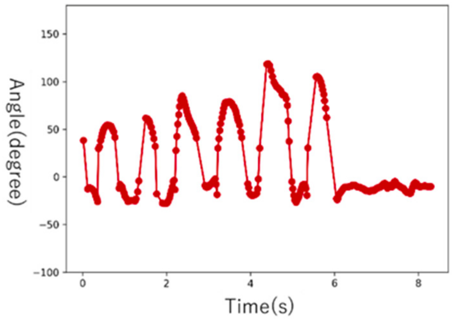


Figure 6: Head rotation angle for experimental participant A in scenario c.

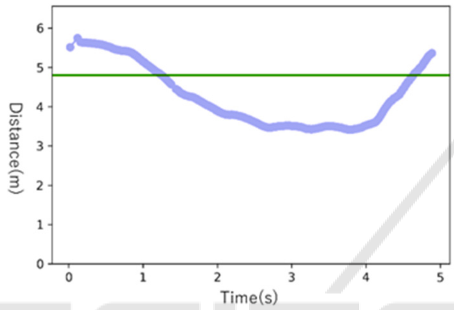


Figure 7: Goal distance in scenario b for experimental participant E.

7.3 Discussion

The characteristics of players are discussed based on the results of visual search movement measurements. The co-author of the discussion, Kenji Yoshida, is the head coach of the University of Tsukuba basketball team.

7.3.1 Adaptation to Multiple Scenarios

In terms of adaptation to the multiple scenarios in this study, focusing on a single participant, there are two possible directions: either the participant stays in the initial position and increases the number of pivots as the trial progresses, or the participant moves back toward the goal and performs pivots. The order of scenarios is scenario c, scenario a, and scenario b, in order of the number of pivots that should occur.

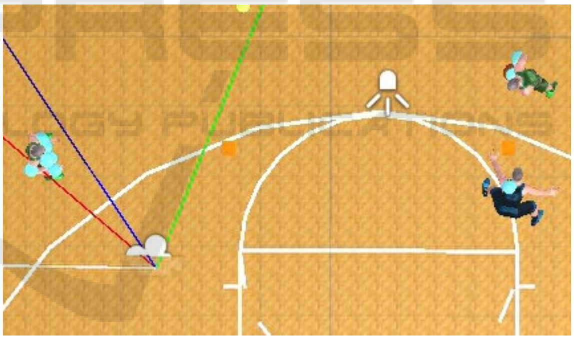
In Figure 9, we can see that participant B in the first trial had three shakes, but in the sixth trial, he had six shakes. It can be said that the participants did not know what kind of situation would come in the first trial, but as they repeated the trials, they became aware that there were multiple scenarios, and this reinforced the visual search movement.

In Figure 10, we observe that participant E was in the backward state for 2 out of 4 pivots in the first trial, but all 8 pivots were in the backward state in the sixth trial. It can be said that the subjects realized that there were multiple scenarios as they continued the trials, and performed the visual improvement exercise of retreating.

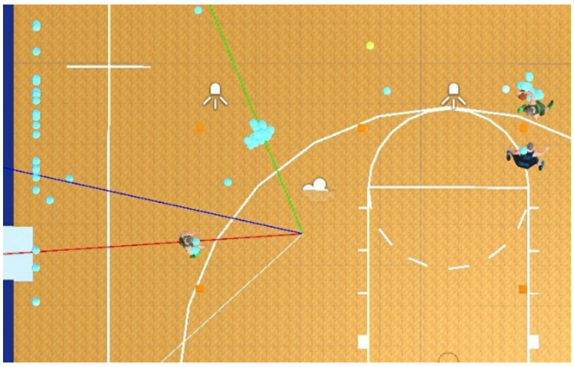
These are not defensive movements that should be judged as correct. They should be regarded as the manifestation of the characteristics of each player.

7.3.2 Unique Defence Motion

(a) At the beginning.



(b) Checking the left target.



(c) Facing to the left target as the targe moves.

Figure 8: Measurement visualization of visual search motion. Th time flows from (a) to (c). Note that the light blue balls (gazing object) are placed properly.

Looking at the cross-sectional results of the experiment, we can find players who perform characteristic defensive actions. The number of pivoting movements for all 10 participants for scenario a is shown in Figure 11. Participant J performs the pivoting without retreating. From this, the head coach states that we can read that this participant is faithfully performing the deny, the action that prevents the path of the ball.

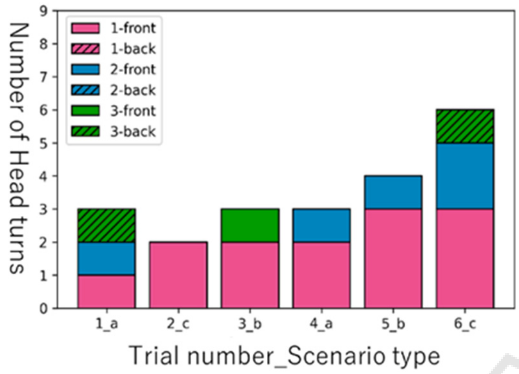


Figure 9: Number of head shakes per scenario for Participant B.

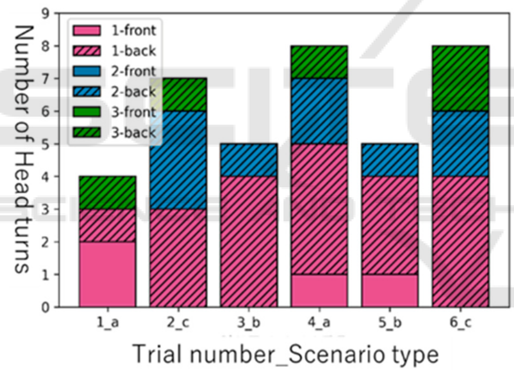


Figure 10: Number of head shakes per scenario for participant E.

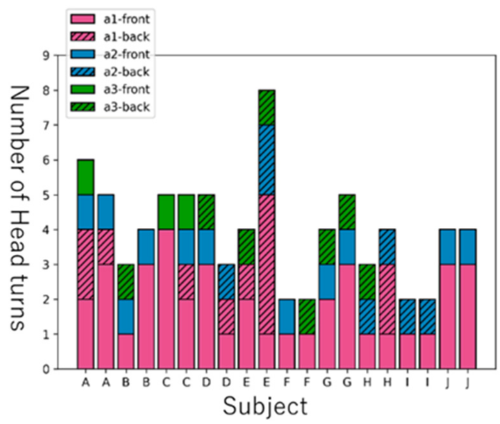


Figure 11: Distribution of head shake frequency in scenario a.

8 CONCLUSIONS

We proposed a method for quantifying the visual search motion of players during the game. We showed how to construct a VR simulation system that can manage all the situations surrounding the players and their experience system, so that the visual search motion can be measured.

By preparing a scenario that takes into account the characteristics of the basketball game and the characteristics of the HMD, we showed that the measurement of visual search motion is effective even on a VR system.

As an index to investigate the characteristics of visual search motion, the number of left and right pivots at each segment in the scenario was obtained. We conducted an experiment with members of the men's basketball team of the University of Tsukuba, and were able to discuss the characteristics of the relationship between the players' visual search movements and their defensive actions based on the results of the measurement of visual search movements.

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