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Analysis of Soccer Coach's Eye Gaze Behavior

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***Abstract*—How do people see a scene? To what do they pay attention in their field of view, and when? This depends on the observer's knowledge, experience, and so on. This study compares the eye movements of an expert and novices, and extracts the skill-based differences in their gaze behaviors. In this paper, we focus on the gaze behaviors of a soccer coach and non-professional people while watching a video of a soccer game, and analyze the relationships between the eye movements and dynamic salient objects, that is, the ball and the players, in the video. The results show that, when the ball and some players are near either of the goals, the expert pays attention not to them but to the many other players in the middle of the soccer field. The findings of this study will constitute novel stepping stones for modeling a skillful viewing technique and useful knowledge that can be taught to novices.**

I. Introduction

Human gaze behaviors change depending on cognitive factors [1], [2]. For instance, differences were found in the gaze behaviors of professionals and naive subjects when looking at a bonsai (a dwarf miniature potted tree) [3]. Naive subjects pass their gaze over the foliage and the branches and frequently change their point of fixation from one to another. Conversely, professionals look carefully at the root swelling, the trunk, the branches, and the pot, since these are the important points of a bonsai. In particular, to detect a gnarl, which is a major defect, they look at the root first. This example shows that the location, the order, and the duration of a person's gaze fixation differs depending on his or her knowledge and experience of the object, and even differs in different people looking at the same static object. In the last decade, some researchers focused on dynamic daily situations and analyzed the relationships between gaze behaviors, dynamic objects, and cognitive factors [4], [5].

The objective of this study is to reveal the expert's special skills when viewing a scene. In this paper, we focus on the skill-based differences in the gaze behavior of experts and inexperienced persons when watching dynamic objects, applying a method in which their eye movements are compared. These differences may be clearer when the observers are watching dynamic objects than when they are looking at static objects, because in the former case the observers' gaze behavior needs to be especially effective in order to understand the ever-changing situation. We analyze the gaze behaviors of a soccer coach watching a game of soccer. We expect that the coach, who is an expert, will manifest a gaze behavior that is significantly different from than that of others, because soccer, which is a team sport played on an open soccer pitch, involves the complex dynamics of visible objects, that is, the ball and the players, on an extensive sports field, and therefore requires special observational skills. As part of their training, novice coaches must be taught how to find the important points in the dynamics. However, the expert may find it difficult to teach this special ability to them verbally. The gaze behavior of the expert will reflect his unconscious knacks. We intend to extract implicit knowledge from the gaze behavior.

Soccer has been the subject of study in the research field of vision for years. Mark Williams et al. [6] investigated the difference in players' anticipation of the destination of a pass in an 11-a-side soccer game. Inexperienced players fixated more frequently on the ball and the player passing the ball, whereas experienced players fixated on significantly more locations than did their inexperienced counterparts. This result indicates that efficient visual search strategies are important for anticipating the destination of a passed ball.

Analysis of sports coaches' gaze behaviors has attracted academic attention. Moreno et al. [7] examined the visual search strategies employed by gymnastic coaches with different levels of expertise, and found that the fixations of the experts were longer duration than those of the novice coaches. However, the authors could not find any concrete search strategies.

In these studies, the context of the scene being watched by the observers whose gaze behavior was analyzed was not described, and their findings do not provide sufficient knowledge to facilitate the training of coaching novices, who would like to know to what they should pay attention in their field of view, and when. This is our main motivation for focusing on the relation between eye movements and dynamic objects. Our analysis approach has the potential to facilitate the investigation of the scenarios in which the differences in gaze behavior between expert and novice appear.

II. Viewing experiments of game video to acquire eye movement data

We conducted experiments to acquire our participants' eye movement data while watching a soccer game video. The video showed a high school soccer club, which had played in the championships of the All Japan High School Soccer Tournament, playing an intrasquad game. The film was captured from the center of the side of the soccer field

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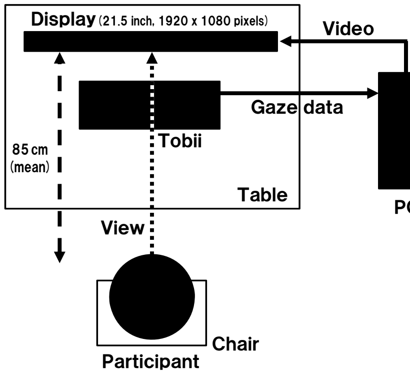

Fig. 1. Experimental environment.

using a wide-angle camera without zooming and panning, and thus, the whole of the field was within the view angle (video resolution: 1920*1080 pixels, video rate: 29.97 fps). The number of participants in the experiment was five, comprising one expert coach (male, 44 years old), who holds a Japan Football Association official approval S grade coaching license, and four coaching novices (males in their 20s). The experimenter instructed the participants to watch the video on a display monitor in full-screen mode (screen size: 21.5", screen resolution: 1920*1080 pixels) in the role of the coach of the designated team. We henceforth call the designated team the "own team" and the other the "opponent team." A Tobii X60 Eye Tracker (data rate: 60 Hz, accuracy: typical 0.5 degrees) was used to record eye movements as data sequences on the video display plane whose coordinate system comprised the horizontal axis x and the vertical axis y. Figure 1 shows a bird's-eye view of the experimental environment.

We upsampled temporarily the obtained data sequences of eye movements with linear interpolation, and then assigned exactly the gaze points $\boldsymbol{g} \in \mathbb{Z}^2$ on the display plane to each frame of video (29.97 fps) through downsampling. Additionally, the data sequences were smoothed using a discrete-time Gaussian filter ($\sigma = 1.66$, corresponds to 1 s time window) to reduce the effects of random fluctuations and involuntary micro eye movements. We annotated manually the coordinate sequence of the ball $\boldsymbol{b} \in \mathbb{Z}^2$ and the players $\boldsymbol{p_i} \in \mathbb{Z}^2 (i = 1, 2, \cdots, 22)$ on the display plane.

III. Methods of Analysis

A. Central Visual Field

The human eye detects the light reflected from an object and creates the image of the object on its inner surface, i.e., the retina. Not all the areas of the retina are equally sensitive. Thus, humans can see details clearly only in a limited range within the visual field. The resolution of human vision is highest at the *fovea centralis* of the retina, and decreases dramatically at the periphery. For example, at 10 degrees from the fovea, human eyesight is less than 20% of the maximum [8].

Gaze direction can be approximated from a line running through both the iris and the fovea. Humans have to move their eyes and turn their gaze toward an area of interest to gather information from the environment. Gaze behaviors are an important factor in identifying a human's cognitive state. In this study, we assume that the perception in the fovea is not only clear and high-resolution, but also a core factor of the visual perception activities [9].

In this paper, we define the central visual field as the combination of the foveal area (0-2 degrees from the fovea) and the para-foveal area (2-5 degrees from the fovea) [9], and we define a gaze directed to an object as one that captures the object within the central visual field. Strictly speaking, the central visual field is not circular, because (i) the foveal area itself is not circular, and (ii) the image we perceive is the combined result of both eyes. However, no method exists for measuring accurately the central visual field of an individual. Hence, we approximate the field as a circular area. The radius of the central visual field on the display is calculated as

$$R_{cm} = d \tan\left(\frac{\theta}{2} \times \frac{\pi}{180}\right), \quad (1)$$

$$R_{px} = R_{cm} \times \frac{w_{px}}{w_{cm}} \quad (2)$$

where R_{cm} represents the radius in centimeters, R_{px} represents the radius in pixels, θ represents the visual angle of foveal and para-foveal vision, w_{px} represents the width of the display, and w_{px} represents the horizontal resolution of the display. In the experimental environment, θ was 5 degrees, w_{px} was 1920 pixels, and w_{cm} was 47.6 cm. Equation 2 converts R_{cm} to R_{px}. **The central visual field is assumed to be a circular field with a radius of 150 pixels in this study.**

B. Data Sequence of Analysis

We extracted two analysis intervals: from the first kick-off in the game to a goal, and from the second kick-off to the end of the game. We excluded the out-of-play scenes, such as those immediately before a player threw the ball into the game or kicked a goal, from these intervals, because the observers' eye movements may have been desultory during these scenes, and each of these scenes showed monotonous visual changes. The total time duration of the intervals was 16 min 32 s out of a 20-min game.

C. Gaze Percentage

In our measurements of the frequency of a participant's gaze to an object during the analysis intervals, we define the Gaze Percentage as

$$Gaze\,Percentage\,(\%) = \sum_t \frac{F(I_t \wedge G(\boldsymbol{g}_t, \boldsymbol{o}_t) \wedge \neg S(\Delta \boldsymbol{g}_t))}{F(I_t)} \times 100 \quad (3)$$

where $F(X)$ is 1 if the logical formula X is true, and otherwise 0, I_t represents whether or not the frame t is within the analysis intervals, $G(\boldsymbol{g}_t, \boldsymbol{o}_t)$ represents whether or not the gaze $\boldsymbol{g}_t$ is directed to the object $\boldsymbol{o}_t$ ($\boldsymbol{o} = \{\boldsymbol{b}, \boldsymbol{p}_i\}(i = 1, 2, \cdots, 22)$),

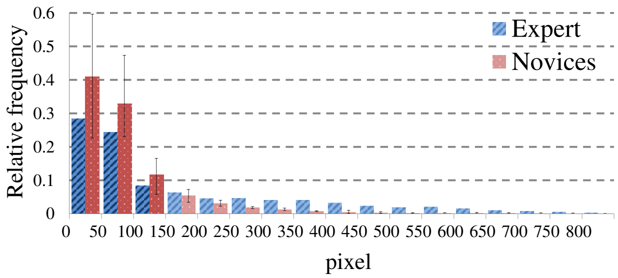

Fig. 2. Distance distribution between gaze points of experimental participants (expert/novices) and the ball positions on the display plane.

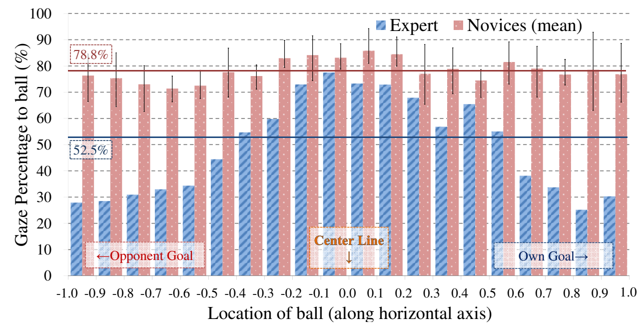

Fig. 3. Gaze Percentage to the ball calculated for each location where the ball was positioned.

and $S(\Delta \boldsymbol{g}_t)$ represents whether or not the eye movement $\Delta \boldsymbol{g}_t$ should be considered a saccade, which is a rapid movement of the eyes that occurs when changing focus from one point to another. Intervals featuring saccades were also excluded, because humans can hardly perceive what they see during a saccade due to saccade suppression [9]. The detection of saccades was conducted with reference to [10], [11].

IV. Analysis of Relationship between Gaze and Ball

The ball is the most important object in ball games. According to the findings introduced in Section I, we propose the following hypothesis: **The expert coach does not direct his overt attention to the ball as much as the novices do during soccer coaching**. This section confirms the hypothesis, and whether or not the Gaze Percentage of the observer to the ball varies with the context of the game. In this paper, we considered the location of the ball to be the context.

A. Distance between Gaze Points and Ball Positions

We first focused on the data typically used in gaze analysis, that is, the Euclidean distances between the gaze points $\boldsymbol{g}_t$ and the ball positions $\boldsymbol{b}_t$ on the display plane during the analysis intervals. Figure 2 shows the relative frequencies of the distances. The relative frequency of the expert was less than that of the novices within 0-150 pixels and had a long-tailed distribution. Conversely, the relative frequency of the novices within 50 pixels was more than 40%. This result indicates that the novices tended to look at the local area where the ball was located.

B. Gaze Percentage

Next, we compared the Gaze Percentages of the expert and novices, as defined in Section III-C. Table 1 shows the Gaze Percentages to the ball. The Gaze Percentage of the expert was 52.5%, whereas the mean of the novices' was 78.8%. Thus, the Gaze Percentage of the expert was 20-30% lower than that of any of the novices. That is, the expert tended to look at the local area where the ball was located less frequently than did the novices. Based on these results, we consider that the expert gazed repeatedly to the ball and then at the area at a distance from the ball.

C. Difference of Gaze Percentage to the Ball Depending on Location of the Ball

As mentioned above, we confirmed that the expert did not gaze to the ball as much as the novices did. The question then arose whether the confirmed finding is true in any game situation.

Figure 3 shows the Gaze Percentages to the ball calculated for each location at which the ball was positioned. To define the location, the soccer field was divided into 20 equal parts of areas as shown in Figure 4. The Gaze Percentage of the expert for the middle of the soccer field was higher than for the area in front of either goal, whereas the Gaze Percentages of the novices did not differ depending on the location.

When the ball was located in the area in front of either goal, the expert gazed to the ball at about 30% frequency, which was quite low compared to the percentages of the novices. The game situation should make the participants more attentive to the location of the ball when it nears the goal. Nevertheless, the expert was more interested in other areas. We analyzed what the expert gazed to. As a result of the detailed analysis, we found that the expert frequently gazed to a cluster of the players in the middle of the soccer field in this situation. In an interview after the viewing experiment, the expert said that he kept paying attention to the defense line in order to manage a risky situation. On the other hand, when the ball was located in the middle of field, the expert gazed to the ball as much as the novices did. Having analyzed the relevant scenes in detail, we considered the following to be possible reasons for these results: (i) Most of the players of both teams were frequently concentrated in the middle of the field when the ball was located there, and (ii) scrambles to obtain possession of the ball tended to happen in the middle of the field.

Thus, the location of the ball can describe the game context. The expert changed his gaze behavior depending on the context.

V. Analysis of Relationship between Gaze and Players

In this section, we regard the field players as visual objects. The objective of this analysis was to resolve two issues: How does the expert gaze to the players, and in what way does the

TABLE I
GAZE PERCENTAGES TO THE BALL.

	Expert	Novices (mean)	Novice A	Novice B	Novice C	Novice D
Gaze Percentage	52.5%	78.8%	84.4%	73.3%	77.4%	80.1%

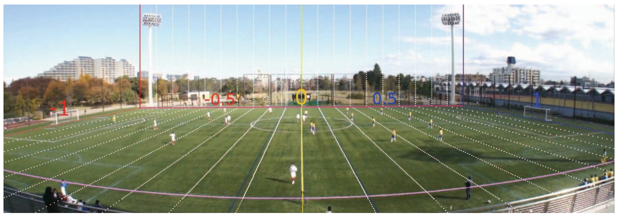

Fig. 4. Soccer field divided into 20 equal parts. The values shown in this figure represent the ID numbers of the partition lines.

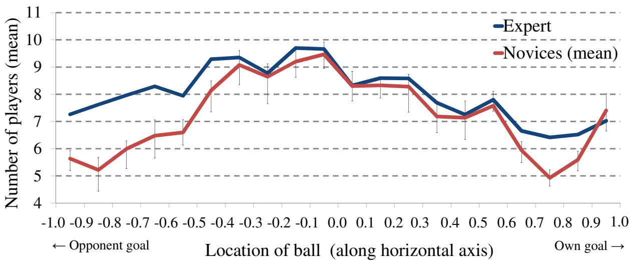

Fig. 5. Number of players located within the central visual field of the participants (expert/novices).

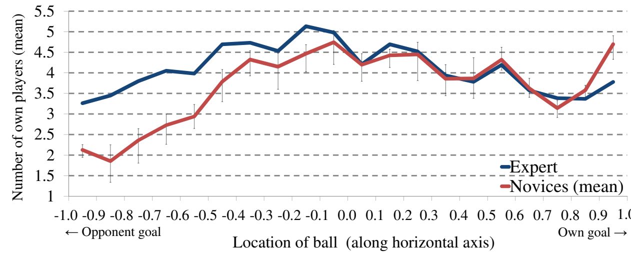

Fig. 6. Number of **own** team's players located within the central visual field of the participants (expert/novices).

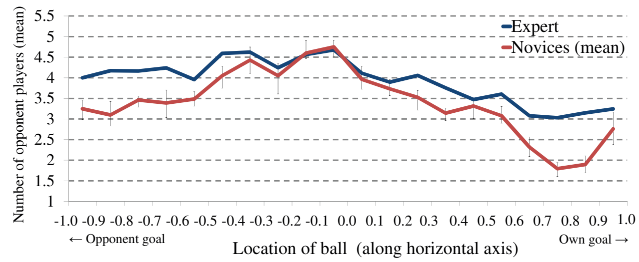

Fig. 7. Number of **opponent** team's players located within the central visual field of the participants (expert/novices).

expert's gaze behavior differ from that of the novice? We first focused on the number of players located within the central visual field.

Figure 5 shows the number of players in each area in which the ball was located. The expert gazed to more players than the novices did when the ball was located in the area in front of either goal. As previously mentioned in Section IV-C, the expert gazed to a cluster of players in the middle of the field when the ball was located in the area in front of either goal. This finding agrees with the tendency shown in Figure 5. In addition, the expert and the novices gazed to the same number of players when the ball was located in the middle of the field.

We then focused on the number of own/opponent team's players who were located within the participants' central visual field. As shown in Figure 6, the expert gazed to more of the own team's players than the novices did when the ball was located in the area in front of the opponent's goal. The novices gazed to the local area where a few of the own team's players were then located. When the ball was located in the area in front of either goal, especially the own team's goal, the expert gazed to more of the opponent team's players than the novices did, as shown in Figure 7.

Figure 8 shows the ratio of the own team's players (Figure 6) to the opponent team's players (Figure 7) located within the central visual field of the participants. The more the ratio exceeds 1.0, the more the own team players are contained in the central visual field. The ratio of the novices was low when the ball was located in the area in front of the opponent's goal and very high when the ball was located in the area in front of the own team's goal. We consider the reason for this to be that the closer the ball came to the goal, the greater was the number of players, whose role was to save the goal, at the periphery of the ball. Conversely, the ratio of the expert was more stable, being around 1.0. We consider that the expert frequently directed his gaze to the area where the numbers of own team players and opponent team players were equal.

The novices' gaze to players tended to depend on the location of ball, i.e., the context of the game. On the other hand, the expert's gaze to players did not excessively depend on the ball's location. In the post-experiment interview, the expert said that the balance of the number of defense and offense players is very important for sensing the signs of an opportunity to attack or a crisis among the defense players.

VI. CONCLUSIONS

We analyzed the skill-based difference of gaze behavior of participants viewing a game of soccer to reveal the expert coach's special viewing skills. We focused on the relationship between eye movements and dynamic objects. The expert gazed to the ball at high frequency when it was located in the middle of the soccer field, and at low frequency when it was

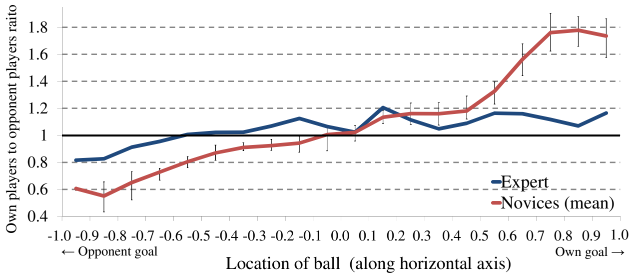

Fig. 8. Ratio of the own team's players to the opponent team's players who were located within the central visual field of the participants (expert/novices).

located in the area in front of either goal, whereas the novice gazed to the ball at high frequency regardless of where it was located. The expert gazed to the area where the number of both teams' players was similar in order to check the balance of the numbers.

This work will contribute to an expert coach's ability to transmit a skillful perspective to novice coaches and to help people understand that the way in which they view objects is different from that of others. The findings of this study will constitute novel stepping stones to modeling a skillful viewing technique, and provide useful knowledge for training novices.

In future works, to generalize the findings, we need to increase the size of the samples, especially that of the experts' gaze behavior. In addition, we will attempt to employ the dynamics of visual objects to describe a more detailed context.

Acknowledgments

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