Development of Motion Analysis System for Quantitative Evaluation of Teamwork in Soccer Games

Tsuyoshi Taki, Jun-ichi Hasegawa and Teruo Fukumura

School of Computer and Cognitive Sciences, Chukyo University
101 Tokodate, Kaizu-cho, Toyota, Aichi 470-03 Japan
E-mail: taki@hasegawa.sccs.chukyo-u.ac.jp

ABSTRACT

In this paper, we present a motion analysis system of soccer games. The purpose of this system is to evaluate the teamwork quantitatively based on movement of all the players in a game. *Space management* and *cooperative movement* by players are two major factors for teamwork evaluation. To quantify them from motion images, we propose two new features; "minimum moving time pattern" and "dominant region". From experiments using actual game scenes, it is suggested that the proposed system can be a new tool for supporting to evaluate the teamwork.

1. INTRODUCTION

In any team sport, it is important to evaluate the teamwork of players as well as each individual work. A motion video of an actual game is very helpful for evaluating such cooperative work. However, motion image analysis by humans requires much time, a great deal of labor, and also it is hard to get objective results because each person has his own criteria in evaluation.

In this paper, we present a system for motion video analysis of soccer games. The purpose of this system is to evaluate the teamwork quantitatively based on movement of all players in a game. Recently, several studies on motion analysis for soccer or American football games have been reported [1]-[4], but there is no work except for Ref.[1] dealing with evaluation of such cooperative work of players.

2. SYSTEM OUTLINE

The system consists of 6 steps. In the first step, motion images of an actual soccer game taken by several video cameras are digitized. In the second step, static objects such as lines on the soccer field are extracted. In the third step, moving objects such as players, referees and the ball are tracked. Then, the positions of moving objects on the image space for each camera are transformed into, and merged on the soccer field space. In the final step, the teamwork is evaluated based on movement of players, and the results are visualized in the form of animation.

3. MOTION ANALYSIS

3.1. Camera Placement

In the telecasting of a soccer game, most scenes are local in that not all players appear in them, because the focus is on a player with the ball. However, it should be noted that not only movement of the player with the ball but also that of each player without the ball in the game are very important for teamwork evaluation. In this sense, game images from telecasting are not suitable for our purpose.

We use several cameras placed along the touchline on the field, so as to cover all players and all the soccer field as shown in Fig.1. For every camera, the optical axis is set to be perpendicular to the touchline and the zooming rate is fixed in order to simplify the problem of motion image processing. Fig.2 shows an example of an original game scene taken by the second camera from the left side in Fig.1.

3.2. Extraction of Field Lines and Players

Extraction of static objects such as field lines from the

0-7803-3258-X/96/$5.00 © 1996 IEEE

Authorized licensed use limited to: b-on: UNIVERSIDADE DO PORTO. Downloaded on July 12,2022 at 08:46:58 UTC from IEEE Xplore. Restrictions apply.

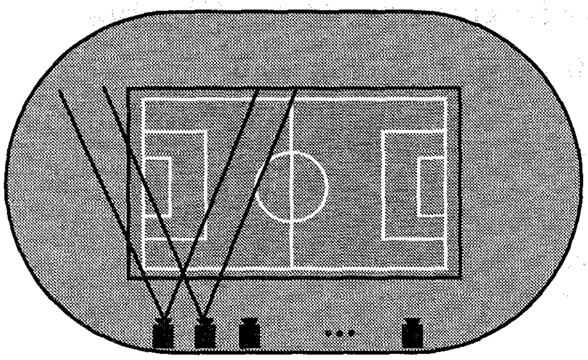

Fig.1 Camera placement

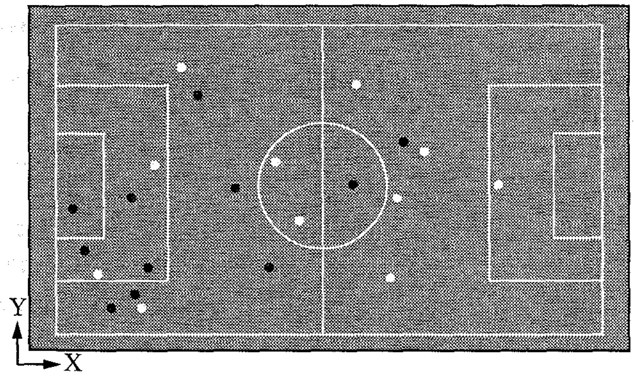

Fig.3 Position of players transformed into the soccer field plane.

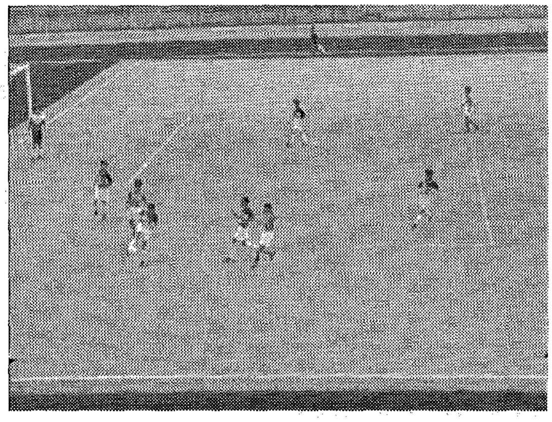

Fig.2 An example of game scenes

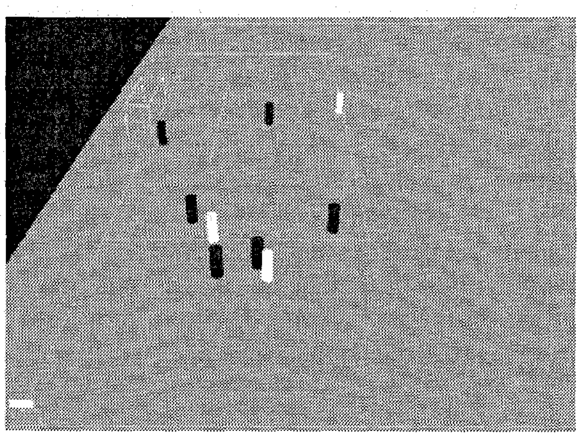

Fig.4 A reproduction of game scene

scenes is very simple because every camera is neither moving nor zooming. For example, the procedure of field lines extraction consists of thresholding and line detection based on Hough transformation.

The procedure for tracking players is as follows. At first, a body part of each player is located manually from the first frame as an initial template for the player. The center of the template is regarded as the center point of the player. Then, players are tracked frame by frame by correlation-based template matching. Each template is renewed at each frame. While the above tracking procedure works successfully for a player moving in isolation, it sometimes fails for a player occluded by another or a player falling down. In these cases, manual correction is performed.

Finally, a footing point for each player on the image is estimated from the center point of the player.

3.3. Transformation into Field Space

The footing point of each player extracted from each camera scene is transformed into the soccer field space, and merged on the space as shown in Fig.3. On the assumption that the soccer field is a plane and every player moves on the plane and the condition that the camera axis is perpendicular to the touchline, transformation from the image space into the field space results in the calculation of a simple ratio and cross ratio with regard to X and Y axis, respectively. The cross ratio for four points on a straight line is invariant to perspective view transformation. Fig.4 shows an example of game scenes reproduced by using positions of lines and players extracted from real scenes such as Fig.3. In the figure, each player is represented by a simple column.

Authorized licensed use limited to: b-on: UNIVERSIDADE DO PORTO. Downloaded on July 12,2022 at 08:46:58 UTC from IEEE Xplore. Restrictions apply.

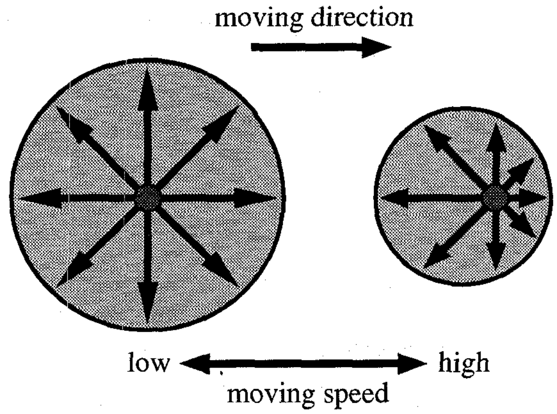

Fig.5 An acceleration model

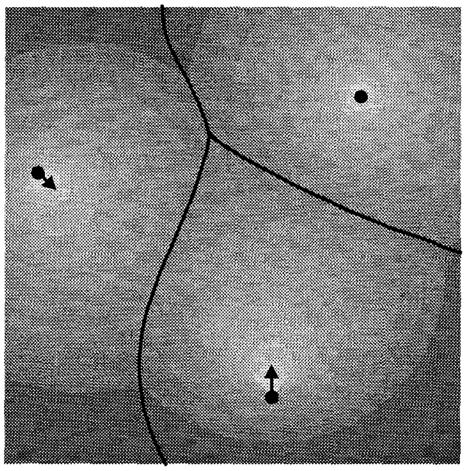

Fig.6 An example of dominant regions (partitioned by black line) for three players. (Dots and arrows indicate the positions and moving vectors of players, respectively. Gray tone represents the MMT for each player.)

4. TEAMWORK EVALUATION

4.1. Basic Idea

In a game of soccer, it is very important how to make and use space advantageous to one's own team in attacking, and how to remove spaces advantageous to the opponent team in defending. Such making and removing of spaces can be effectively performed by cooperative movement of players in the game. Therefore, *space management* and *cooperative movement* are the major factors for teamwork evaluation. To quantify them, we propose here two features; "minimum moving time pattern" and "dominant region", for each player at each moment in a game.

4.2. Minimum Moving Time Pattern

"Minimum moving time pattern" (MMT) of a player at any one moment is defined as a pattern in which each point has the minimum time to move from that player's current position to that point. To calculate a MMT at a moment, the position, the speed and the accelerating ability of the player at that moment are needed. The position and the speed can be estimated from images. The accelerating ability is modeled here as a set of acceleration patterns based on the physical ability of an average player. An acceleration pattern consist of all possible acceleration vectors. Our system uses an acceleration model as shown in Fig.5. In this model, the vector pattern varies with the speed of the player. This means that a human can accelerate in every direction with the same strength from standing still or moving at a very low speed, but as the moving speed become high, it becomes hard to accelerate in the moving direction.

4.3. Dominant Region

"Dominant region" of a player at any one moment is defined as a region where the player can arrive at earlier than all of the others. This can be obtained by a minimum operation for MMTs of all players. Denoting the MMT of the k-th player by $\mathbf{T}^{(\mathbf{k})} = \{t_{ij}^{(k)}\}$, the dominant region $\mathbf{S} = \{s_{ij}\}$ is obtained by

$$s_{ij} = k_0, \; t_{ij}^{(k_0)} = \min_k t_{ij}^{(k)} \quad (k = 1, 2, \cdots, K)$$

where K means the number of players. Fig.6 shows examples of MMTs (represented by the gray tone area) and dominant regions (partitioned by black lines) for three players calculated by using the acceleration pattern for low moving speed in Fig.5. In this figure, black arrows indicate a player's moving vectors. When dominant regions of all players of the same team are merged to a single region, each merged region is called "team dominant region". Fig.7 shows an example of team dominant regions obtained from an actual game scene. Furthermore, if the position and the moving vector of the ball are given, the dominant region of the

Authorized licensed use limited to: b-on: UNIVERSIDADE DO PORTO. Downloaded on July 12,2022 at 08:46:58 UTC from IEEE Xplore. Restrictions apply.

ball is also calculated. In the case that the ball is moving straight, its dominant region is given a set of line segments on the straight line.

4.4. Evaluation of Teamwork

It is possible to evaluate space making and cooperative movement of players by observing changes in the size and the location of each dominant region and team dominant region. Also, it is possible to evaluate pass cooperation by observing the relation between the dominant regions of players and the ball. For example, if a player moves so as to enlarge his own team dominant region, the movement has high quality. If the place where a player passes the ball is in the dominant region of another player on the same team, the quality of the pass cooperation is high. It can be said that if such a pass and movement are done cooperatively and successively, the series of plays have good teamwork.

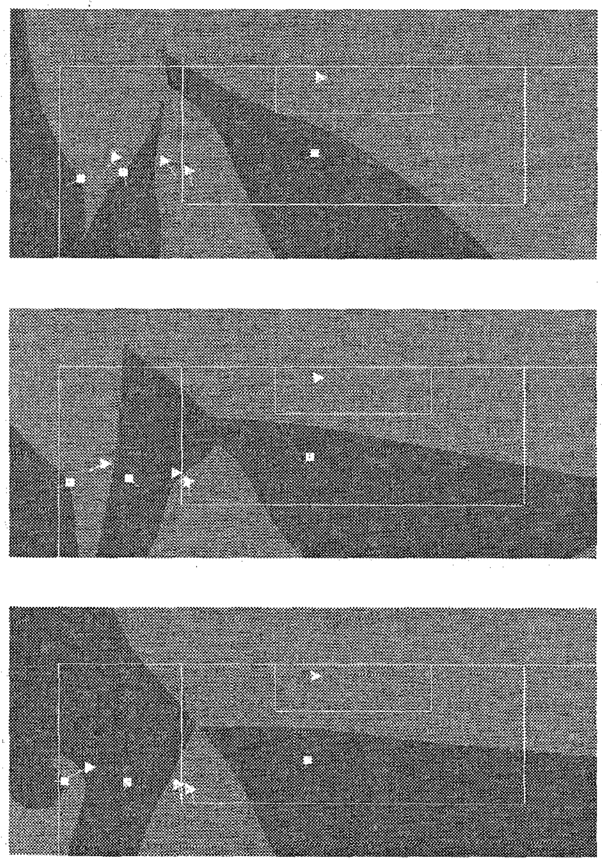

Fig.7 Examples of team dominant regions (light and dark gray regions) obtained successively at intervals of five frames. Each player is indicated by a small white square or triangle, with a white short segment representing the moving vector. We can see that regions with the players' movement are changing dynamically

5. CONCLUSION

In the paper, a motion analysis system for quantitative evaluation of teamwork in soccer games was proposed and applied to actual game scenes. As a result, it is suggested that the proposed system can assist team trainers and coaches of soccer who want to evaluate cooperative work of players in games. The basic idea of the system can be applied to other team sports such as basketball and handball. Also, it is possible that the system will become an amusement tool for game spectators by combining with virtual reality technology. Improvement of the automated tracking procedure and comparison of results by a human and the system in teamwork evaluation will be studied in future.

ACKNOWLEDGMENTS

The authors would like to thank Prof. Hiroyuki Taki, Chukyo Univ. and Mr. Kensaku Mori, Nagoya Univ. for helpful suggestions, and colleagues of our laboratory for discussion. This work was supported in part by the grant-in-aid of Artificial Intelligence Research Promotion Foundation, Japan.

REFERENCES

[1] T. Kawashima, K. Yoshino and Y. Aoki: "Qualitative Image Analysis of Group Behavior", Proc. IEEE Conf. on Computer Vision and Pattern Recognition, pp.690-693, 1994

[2] Y. Gong, T.S. Lim, H.C. Chuan, H. Zhang and M. Sakauchi: "Automatic Parsing of TV Soccer Program", Proc. 2nd Int. Conf. on Multimedia Computing and Systems, pp.167-174 , 1995

[3] A.F. Bobick: "Video Annotation: Computers Watching Video", Proc. 2nd Asian Conf. on Computer Vision, pp.I19-I23, 1995

[4] D. Yow, B.L. Yeo, M. Yeung and B. Liu: "Analysis and Presentation of Soccer Highlight from Digital Video", Proc. 2nd Asian Conf. on Computer Vision, pp.II499-II503, 1995

Authorized licensed use limited to: b-on: UNIVERSIDADE DO PORTO. Downloaded on July 12,2022 at 08:46:58 UTC from IEEE Xplore. Restrictions apply.