Based on double threshold segmentation gait recognition method to design of motion control system for middle size league soccer robots

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Abstract

To achieve a soccer match where robots against human, the key issue for robots is to effectively identify human action. Through analyzing the characteristics of the human gait, and combing with the motion character of the meddle size league soccer robot, based on the tracking information of human skeleton captured by Kinect, a gait recognition method of double threshold segmentation is proposed in this paper. The gait recognition field is demarcated by acquiring the depth information of the human skeleton. The "go-forward" and "go-backward" and "piaffe" gait rules are developed, which can also generate motion commands to control the middle size league soccer robot to represent the gait. The experimental results show that the proposed method can realize motion recognition in real time, which has strong practical performance and can provide technical reserves for related research.

Keywords: Middle size league soccer robots; Threshold segmentation; Gait recognition; Motion control

1 Introduction

Middle size league soccer robot is an important research branch of robotics. It belongs to the third generation of intelligent robots which elegantly combining football game and robotic technology. Professor Alan Mackworth in Canada firstly developed a soccer robot with self-autonomously visual identification and decision-making ability in 1992 [1]. The IFSR (International Federation of Soccer Robot) was founded in 1997 and headquartered in Daejeon, South Korea. Currently middle size league soccer robot competition is one of the most important game of RoboCup, which representing the highest level of robot competitions [2 - 4]. In August 1972, the first session of RoboCup competition was held in Nagoya, Japan. Then RoboCup and related symposium are held annually.

Till present, the venue lights of middle size league soccer robot develops from a single light source condition gradually to normal ambient lighting, as shown in Figure 1. The team consists of more than 40 branches initially, and develops to more than 320 branches from over 80 countries now. The representative teams are Tech United Einhoven from Netherlands, CAMBADA from Portugal, MRL from Iran, RFC Stuttgart from Germany, etc. In China, the team from Shanghai Jiaotong University firstly participated in this competition in 2001, carried out related research on middle size league soccer robot. In 2002, the middle size league soccer robot competitions were added into Chinese robot competition. Subsequently, Tongji University, Shanghai University, South China University of Technology, Northeastern University, University of Defense Technology, Beijing Institute of Technology, Changshu Institute of Technology and other universities have participated in this event and the related research work.

FIGURE 1 The history of Venue environment

The goal of robot soccer game athletics is to launch a competition between human and soccer robot following the FIFA (International Federation of Football Association) official game rules [5]. To achieve this goal, the robot must with the functions not only under different lighting environments to recognize and identify the football field, but also to identify the football players and their actions. Currently, the former research has achieved fruitful results, while the latter is relatively little. Kinect can obtain high precision result on human identification and motion tracking, and it is less affected by the external light.

Above all, a Kinect-based human skeleton tracking by dual-threshold segmentation gait recognition method is proposed in this paper to design the motion control system for the middle size league soccer robot.

2 Related work

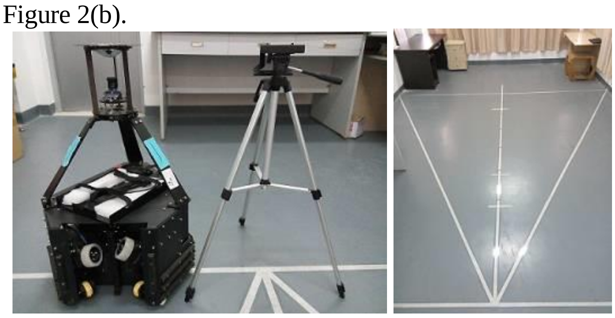
The somato-sensory technology of Kinect can effectively identify the position of the human's bones. When a person is fixed in one place, by the relative position of the hand bones between points, it can be adopted to develop the human robot interaction system to control the movement of the robot [6]. In football competition between robot and human, the robots need identify the person's motion to generate appropriate policy. The policy by perceiving only the change of hand position cannot meet the requirements. In this situation, it needs design a human robot interaction system to perceive the gait of human, such as “go-forward”, “go-backward” and “piaffe”.

The definition of gait in Oxford Dictionary is “Manner of walking, bearing or carriage as one walks” [7]. The early classic definition of gait is: “A particular way or manner of moving on foot” [8]. Normally, gait analysis is the study of human walking. In the study, it needs analyze the viewer’s eyes and brain; some instruments are adopted to measure the body's motion state, the mechanical structure of limb, and muscle activity and so on. Gait is often adopted to present a cyclical form and status of limb activity when a person or an animal goes forward (such as walking, running, etc.). Gait recognition is a new emerging research field in recent years [9]. The early identification method is proposed by Niyogi and Adelso [10]. Cunado modeled thigh as a pendulum and got gait characteristic of frequency components from the tilt angle signal [11]. Wang W. presented a feature representation method based on kernel independent component analysis for gait recognition [12].

3 Human recognition in static environment

In order to obtain good recognition results, the Kinect is mounted on a tripod with the same height of the middle size league soccer robot adopted in this paper. Vision system calibration for target detection mainly refers to the process of determining camera parameters so as to get the best view field [13]. The experiments in this study are done in the static environment and dynamic environment; and the heights of the tripod and the middle size league soccer robot are 77 cm, as shown in Figure 2(a).

Gait recognition needs accurate information of lower limbs of the human. In this study, the skeleton model got by Kinect is evaluated by several experiments. Through marking the lines on the area where model is deformed, the valid domain for gait recognition is achieved, as shown in Figure 2(b).



a) Height calibration **b)** Effective view field

FIGURE 2 Setup of the experimental system

The corresponding steps are shown as follow:

1) The farthest distance is marked with a straight line, as shown in Figure 3, where the recognition rate is low, and the joints of lower limb have been severely deformed;

2) Inside the boundary shown in Figure 4, the Kinect can track the motion of the human; while outside the boundary, the body is not recognized correctly;

3) When the human standing on the position shown in Figure 5, the skeletal joint of the model by Kinect has been deformed, and it can be marked as the nearest distance;

4) The best hyperopia distance is shown in Figure 6, and if it becomes greater, the position information of the model skeletal point of lower limbs will start tremble.

FIGURE 3 Skeleton image (farthest distance)

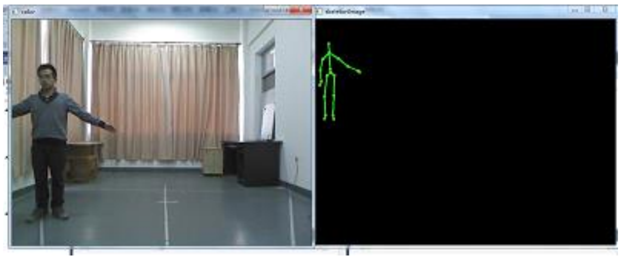


FIGURE 4 Skeleton image (at the edges)

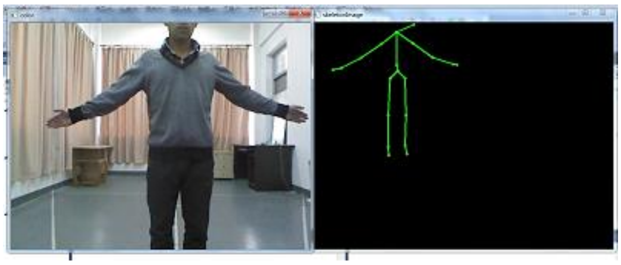


FIGURE 5 Skeleton image (less than 1.4m)

FIGURE 6 Skeleton image (3.3m)

Based on the static calibration results shown above, the effective view field of the robot is shown in Figure 7.

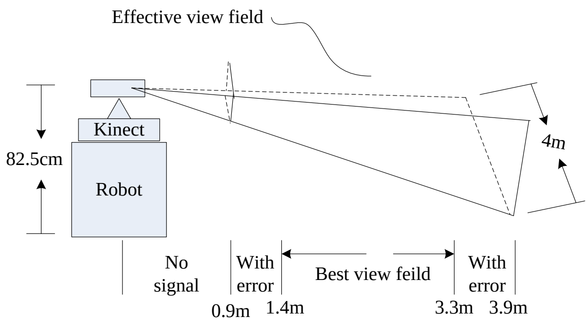


FIGURE 7 View field

4 Gait analyses

The main technologies for gait analysis are temporal measurement, kinematics analysis, dynamitic analysis and dynamic EMG. The kinematics-based technologies are footprint method, fixed point camera technology in a plane and three-dimensional information analysis system [14]. The traditional method of gait analysis is to take photos in the left view of the walker, and analysis the typical information of walking, such as step length, step frequency, etc. In this study, the depth information of all feature points of people during walking is extracted by Kinect to realize gait recognition. Comparing with the typical gait recognition method which adopting two-dimensional information from images, the data used in this research is three-dimensional feature information directly provided by Kinect per 30 ms, thus the gait recognition method proposed in this paper can improve the accuracy and speed.

In this paper, the body's hip, knees and ankles are taken as the main points for gait analysis. In three-dimensional space, the information of the trajectories is a 15-Dimentional vector data. In this experiment, the human faces the Kinect in the farthest position of best view field and starts to walk to the robot. The 15-Dimentional vector data of the hip, knees and ankles is recorded by Kinect as shown in Figure 8, Figure 9 and Figure 10.

Through the information shown in Figure 8, Figure 9 and Figure 10 we can know that when the swing leg moving up and down, in order to maintain balance, the body will swing in the X-axis; and in Y-axis direction the trajectory generates a cyclical peak; in the Z-axis direction, the data value gradually reduces; the knee and ankle trajectories have a stepped-shape because the foot stays in contact with the ground. Because the normal legs of human with good symmetry [15], the data of left leg can be taken as the example to present the character of walking gait. Kinect-data for left hip, left knee and left is selected to define the gait model in this paper. Model-based approach has the following advantages. Firstly, the model-based approach can provide the same model without parameter selection in stationary state and motion state [16]. Secondly, the method can accurately calculate the knee angle, which can help to understand and describe the nature of gait. These three feature points in space can constitute a triangle. According to the corresponding coordinates, we can find the length of three sides of the triangle. The knee angle is obtained by cosine theorem.

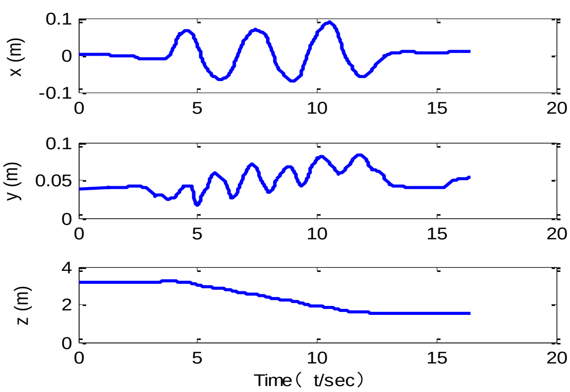
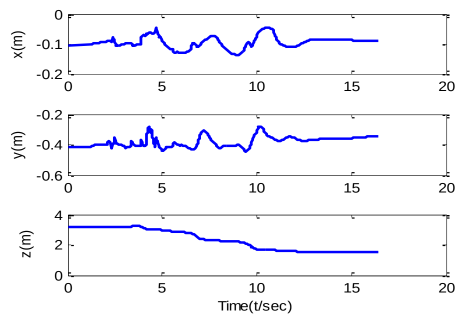
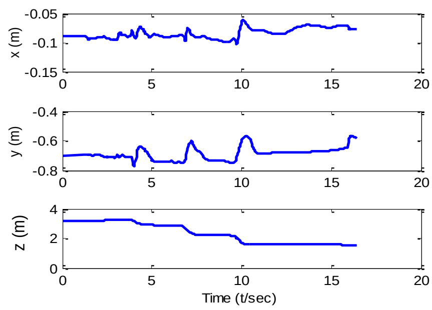


FIGURE 8 Trajectory of hip centre

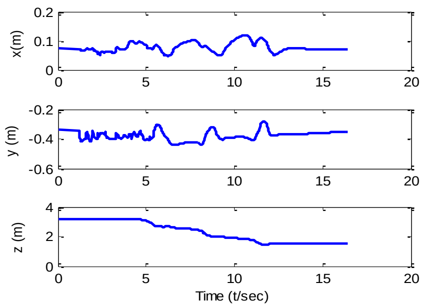


a) Left knee

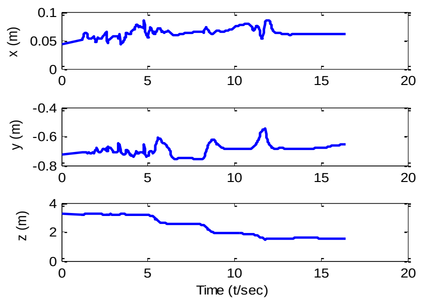


b) Right knee

FIGURE 9 Trajectories of both knees



a) Left ankle



b) Right ankle

FIGURE 10 Trajectories of both ankles

The “go-forward” experiment is carried out with above method. There are small changes in the x direction (front view), but the change is large (side view) in the y and z coordinate directions, so it can be reduced to YOZ plane to calculate knee angle represented by θ, as shown in Figure 11.The knee angle, as shown in Figure 12, presents the situation at the time of the legs upright, and the distance between the human and Kinect is 2.5m. The angle is not 180° (or π).

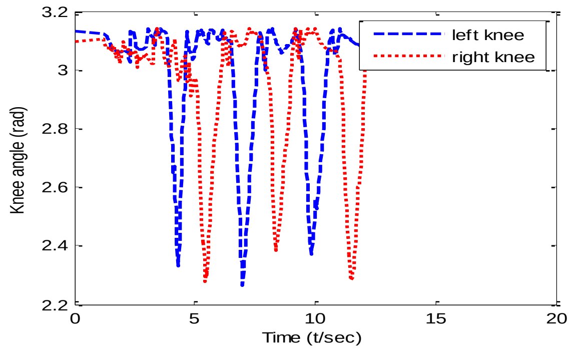


FIGURE 11 Knee angle

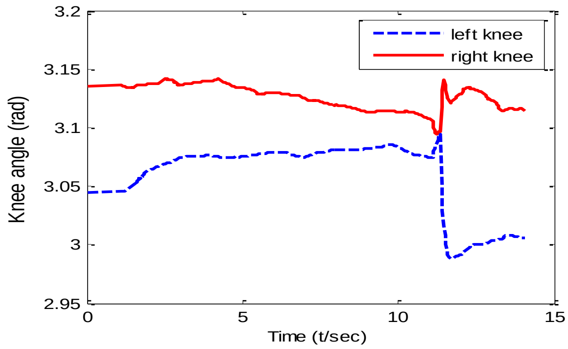


FIGURE 12 Knee angles of both upright legs

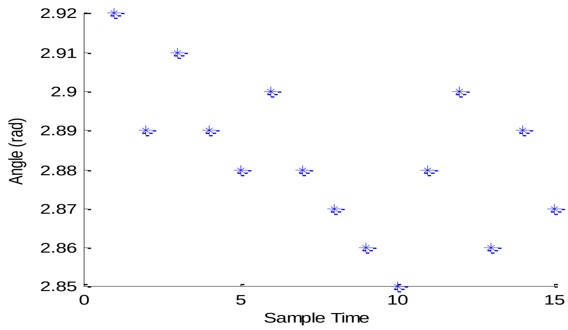


FIGURE 13 Knee angle in different experiments

From Figure 11 we can know that during "go-forward" experiment, before the process of feet up there will be some angle disturbance when people walk normally. The angles are recorded in 15 experiments, as shown in Figure 13. From the perspective of the go-forward process, after removing these disturbances it is state that the leg swings in the air. By the observation from Figure 13, we can obtain that the threshold value can be set at 2.8 *rad*. After filtering by this value, the knee angle (α) when the leg swinging in the air is obtained, as shown in Figure 14 and Figure 15.

After single-threshold filtering mentioned above, it cannot realize the gait recognition of "go-forward" by the value of α. Because the angle trajectory (θ) for "go-forward" has similarities with "piaffe", as shown in Figure 16.The Z coordinate of the hip bone point with Kinect distance is used to classify the gait is "go-forward", "go-backward" or "piaffe". The positional information of "piaffe "is shown in Figure 17.

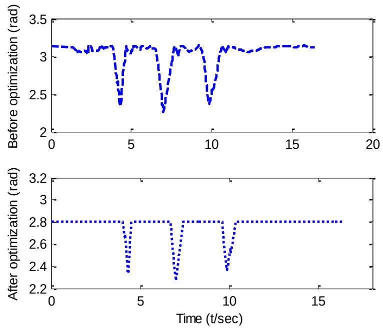


FIGURE 14 Angle of left knee joint

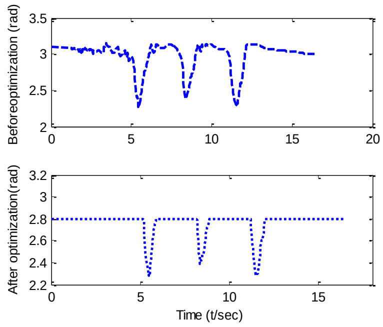


FIGURE 15 Angle of right knee joint

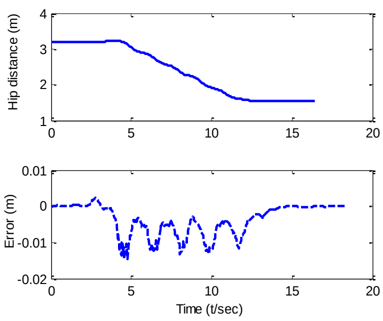


FIGURE 16 Hip distance information

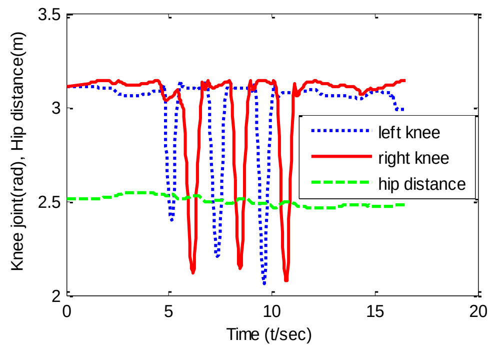


FIGURE 17 Angle of Knee and hip distance

From Figure 16 we can know that the minimum threshold of α between two adjacent frames is 0.005m during normal "go-forward" or "go-backward" gait, and in half cycle of the gait, there should be at least 20 times where the value of Z difference is larger than the minimum threshold. With the two threshold parameters α and θ, the proposed gait recognition method can calculate the step number of "go-forward" , "go-backward" and " piaffe " gait.

5 Experiments in dynamic environment with robot

Based on the proposed method, the human robot interaction system is developed for a middle size league soccer robot. The {"go-forward", "go-backward", " piaffe" }gait of the human will generate corresponding command {"1 ", " -1 ", "2"}to control the robot to go-forward, go-backward and stop. The Kinect is mounted on the top of the robot, and the experiments are done in real competition environment (lighting and venue), as shown in the follow.

5.1 GAIT RECOGNITION " GO-FORWARD " AND " GO-BACKWARD "

In this experiment, when human is in the view field of robot, the human robot interaction system starts the gait recognition process and when the human raises his right hand, it will generate an emergent stop command. Because there is an optimal view distance of vision system, some warning lines (white short) are marked on the venue, as shown in Figure 18.

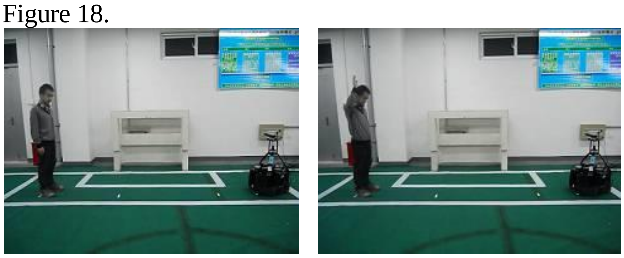
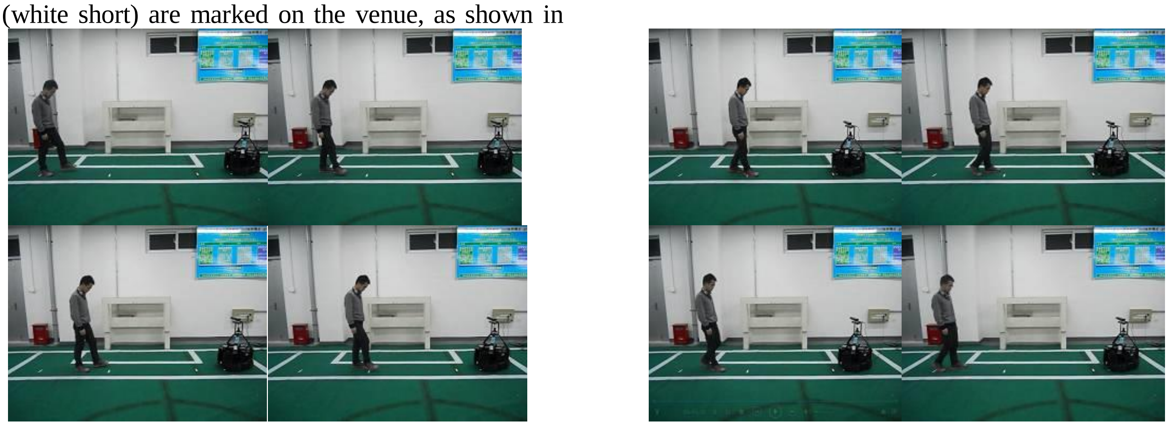


FIGURE 18 Setup of human robot interaction experiments

The experimental results are shown in Figure 19. The man firstly goes forward for 5 steps, as shown in Figure 19(a), then goes backward for 5 steps, as shown in Figure 19(b).

During this experiment, the trajectories of knee angles and Z coordinates of hip are shown in Figure 20.

The robot motion commands executed in the experiment are shown in Figure 21.



a) Go-forward b) Go-backward

FIGURE 19 Experiment results

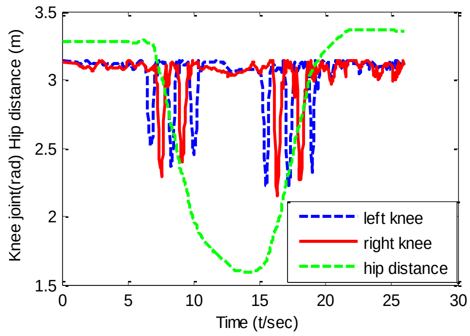


FIGURE 20 Go-forward and go-backward

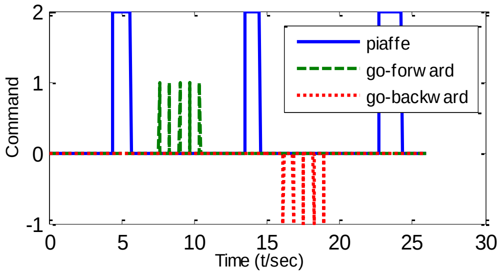


FIGURE 21 Command recognition

From Figure 20 and Figure 21 we can know that the values of knee angles and Z coordinate of Hip distance between Kinect are well captured by the system. With the proposed gait recognition method, the human robot interaction system can generate correct command to move the robot in real time.

5.2 GAIT RECOGNITION "PIAFFE"

In this experiment, the man firstly piaffes for a while, and starts to go forward to the warning line, then piaffes for a while again, finally starts to go backward. The values of knee angles and Z coordinate of Hip distance between Kinect captured by the system are shown in Figure 22. The corresponding commands are shown in Figure 23.

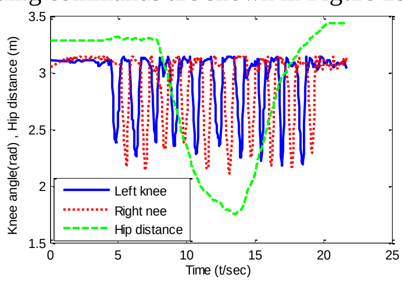


FIGURE 22 Angle and distance

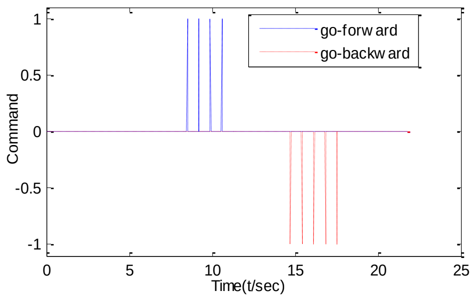


FIGURE 23 Command recognition

From Figure 22 and Figure 23, It could be recognized that when the man pilaffs', only the value θ changes and Z coordinate of hip distance between Kinect (α) does not reach the threshold; while when the man goes forward and backward, the two threshold (α,θ) reach the given thresholds, and the human robot interaction system generates "go-forward" and "go-backward" command to move the robot.

6 Conclusions

How to enable middle size league soccer robot to identify human, and effectively recognize the human gait is a key issue to achieve soccer match between the robot and the human. Based on dual-threshold segmentation of skeletal depth information captured by Kinect, a gait recognition method is proposed in this paper to develop the human robot interaction system for the middle size league soccer robots. The effective view field and best view field of the Kinect-based human robot interaction system are calibrated. The values of two thresholds are well achieved through the experiments in static environment for recognizing the gait of "go-forward", "go-backward" and "piaffe". The robot can represent corresponding motion captured by the developed system. The experimental results show that the proposed method can make the middle size league soccer robot to quickly and efficiently identify the human gait at the venue environment, and reproduce the corresponding actions.

This work provided a new method and technical reserves for the middle size league soccer robots to launch a football match against real players (human) in the near future.

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