Design and Implementation of Humanoid Robot for Obstacle Avoidance

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ABSTRACT

In this paper, a path planning of humanoid robot for obstacle avoidance by using infrared sensors (IRs) is proposed. An autonomous humanoid robot TWNHR-3 is used to implement the proposed strategy. Four IR sensors are mounted on TWNHR-3 to detect obstacles. Based on the obtained information from IR sensors, a decision tree method is proposed to decide the behavior of robot so that the robot avoids obstacles and goes to the destination. Obstacle avoidance simulations and experiments of TWNHR-3 are presented to confirm its effectiveness.

Keywords: Humanoid robot, Autonomous mobile robot, Obstacle avoidance.

1 Introduction

Robot soccer games are teams organized by several robots to play soccer games under fixed restriction and rules. Two soccer alliances of the robot are the FIRA [1] and the RoboCup [2]. They hold the robot soccer match of world cup and international congress every year. In the FIRA Cup event, several main categories are organized: the **Mi**cro-**ro**bot **So**ccer **t**ournament (MiroSot), the **Simu**lated **ro**bot **So**ccer **t**ournament (SimuroSot), the **Robo**t **So**ccer **t**ournament (RoboSot), and the **Hu**manoid **ro**bot **So**ccer **t**ournament (HuroSot). In the HuroSot category, the humanoid robots have to detect all information from the game field and decide its strategy by itself.

There are many robots in the match field, so the robot must have the ability to avoid the collision with other robots and move to an appropriate destination. Obstacle avoidance is also a competition category in the FIRA Cup. The main idea of the competition category is testing the ability of obstacle avoidance of the robot. In this paper, an obstacle avoidance method based on the IR sensors is proposed for the autonomous humanoid robot. In general, vision sensors, ultrasonic sensors, and infrared sensors are usually used to detect obstacles in the soccer game [3-6].

Although the robot has been investigated for many years, there are still many issues to be studied, especially in the humanoid robot area [7-10]. Hardware and software architectures, walking gait generation and artificial intelligence are the main research field of humanoid robot. A compact size humanoid robot called TWNHR-3 developed by Intelligent Control Lab of Tamkang University for artificial intelligent research is considered in this paper. The objective of developing TWNHR-3 is to build a platform to investigate the walking gait generation and artificial intelligence. The work is focusing on the static and dynamic walking on even and uneven ground. More research on artificial intelligence is carried on with TWNHR-3 to make it an intelligent robot. Four infrared (IR) sensors and an electrical compass are installed in the robot to detect the environment including obstacles, the distances of the obstacles and terrestrial magnetism angle of the robot. Based on the obtained information from IR sensors and electrical compass, an obstacle avoidance method is proposed to determine the angle of robot so that the robot can avoid obstacles and go to a destination.

The rest of this paper is organized as follows: In Section 2, the architecture of the robot TWNHR-3 is described. In Section 3, the strategy of obstacle avoidance controller is described. In Section 4, some simulations and experiments results of the proposed strategy are described. Finally, in Section 5, some conclusions are made.

2 Architectures of TWNHR-3

TWNHR-3 is developed for realizing and analyzing the human movement and behaviors. Playing soccer game is the test platform to verify the ability of TWNHR-3. The robot needs to play a soccer game autonomously. In order to play a soccer game, three basic skills are designed and implemented on it: environment perception, move ability, and artificial intelligence. There are many robots in the match field, so the robot must have the ability to avoid the collision with other robots and move to an appropriate destination. Figure 1 shows the photograph of TWNHR-3. In the electronic design of the robot, 26 servomotors with high torques are used as actuators of the robot. In order to build a fully autonomous vision-based humanoid robot, a 16-bit DSP processor with a CMOS sensor is chosen to process the vision image of environment. The image of the field is captured by the CMOS sensor and the position information of the ball and goals is processed and extracted by the DSP processor. The digital compass and these four IR sensors are used for interaction with the environment and recognition of own situation. The IR sensors are mounted on the robot to detect obstacles. The positions of these four IR sensors are illustrated in Figure 2. The relative angle of goal direction and robot direction is shown in Figure 3. The digital compass is mounted on the body to detect the head direction of the robot and the goal direction respectively. In order to reduce the weight of robot, the concept of SOC design is applied in the complexity design of biped robot. The implemented FPGA chip can process the data obtained from the digital compass and generate desired pulses to control the angles of servomotors. Many functions are implemented on a FPGA chip to process the data and control the robot so that the weight of the robot is reduced. The system block diagram is described in Figure 4.

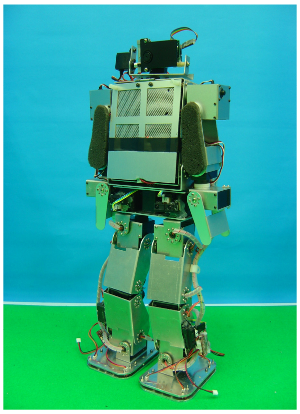

Figure 1: Four IR sensors and an electrical compass are mounted on the robot.

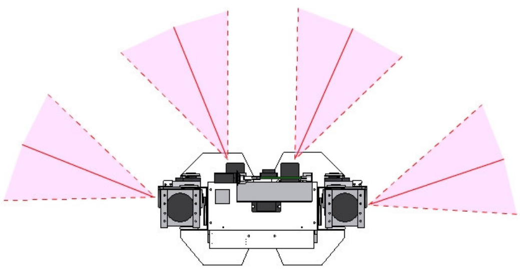

Figure 2: The detectable range of the IR sensors.

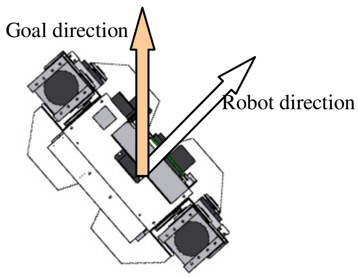

Figure 3: The diagram of the electrical compass.

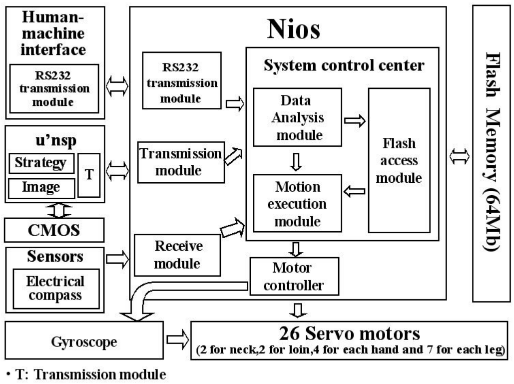

Figure 4: System block diagram of the robot in the electronic system design.

3 Decision tree of the obstacle avoidance

Obstacle avoidance is a competition category in the HuroSot league of FIRA Cup. There is a finish line marked on one side of the playing field. This side of the playing field is called the finish side. The opposite side of the playing field is called the start side. The two other sides are called side lines. A robot has crossed the finish line when either foot of the robot crosses the finish plane and touches the ground in the end zone. During the competition, the robot does not allow to touch any obstacles. Figure 5 shows the diagram of the obstacle run competition. The robot has to detect the location of obstacles and the direction of the goal line. An original implemented decide tree method base on the IR data is shown in Figure 6. The design of the decision tree method is based on the IR and electrical compass information. The behavior output of the decision tree is the robot's five basic movements including go forward, 30 degree right turn, 30 degree left turn, slip right, and slip left.

The robot strategy will check the relative behavior from the decision tree before robot move. TWNHR-3 will adjust the robot direction to face the goal direction, when robot is in the safe situation (B16). Once TWNHR-3 detects the obstacle via the IR sensors, the robot will do the relative behavior to avoid obstacles. TWNHR-3 is able to cross some obstacles by the proposed decision tree method. Figure 7 and Figure 8 illustrate the obstacle avoidance ability of the robot by MATLAB simulation results. In Figure 7, there is an obstacle on the robot's way to the goal line. When robot detects the obstacle, robot will choose the Behavior 10 (B10) to avoid the obstacle. The robot kept slipping to the right side, until there is no obstacle in front of the robot. The behavior interchanges B10 with B16 until robot is away from the obstacle. In Figure 8, there are two obstacles on the robot's way to the goal line. The robot also chooses the behavior from the proposed behavior strategy. At location "Safe point", the robot is already in the safe situation. Therefore, the robot chooses B16 turning to the goal direction. As the robot moving forward, robot detects the obstacle again. The behavior interchanges B10 with B16 until the robot is away from the obstacle. Figure 8 shows that the proposed method can successfully avoid obstacles.

Table 1: The behavior table of the decision tree

Behavior situation	Sensor situation	Obstacle situation	Decided movement
B1			Turn left
B2			Slip right
B3			Turn right
B4			Slip right
B5			Turn left
B6			Turn left
B7			Go straight
B8			Slip right
B9			Slip left
B10			Slip right
B11			Turn right
B12			Slip right
B13			Slip left
B14			Slip left
B15			Slip left
B16			Move to Goal line

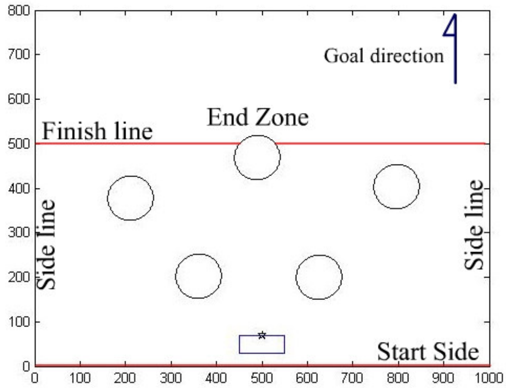

Figure 5: The diagram of the obstacle run competition.

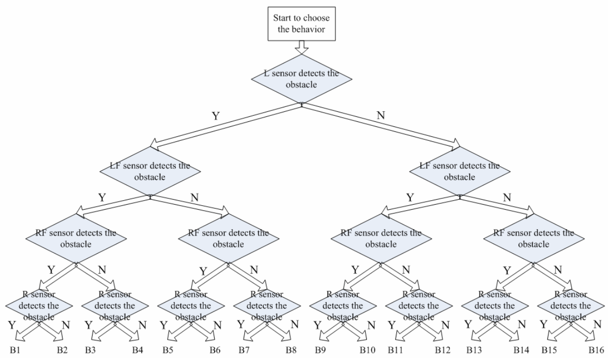

Figure 6: The decision tree of the obstacle avoidance strategy.

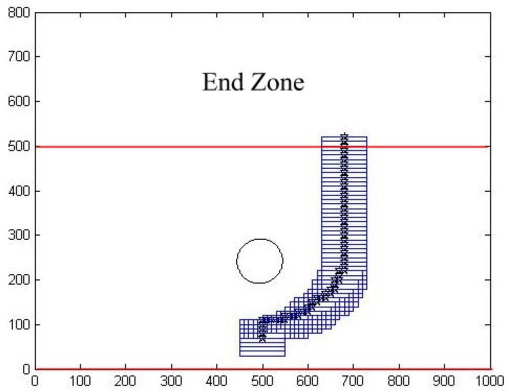

Figure 7: The simulation result of the robot avoids one obstacle.

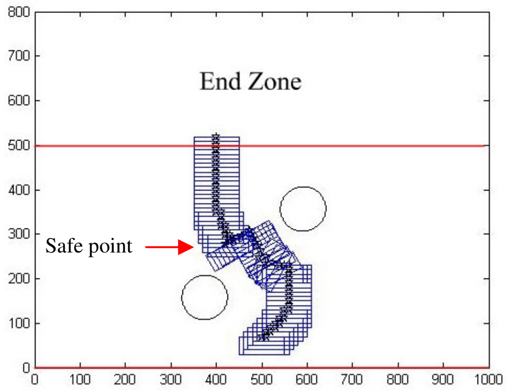

Figure 8: The simulation result of the robot avoids two obstacles.

4 Experiment results

The computer simulation results discussed in Section 3 show that the robot can effectively avoid obstacles and successfully arrive the goal line. In this section, the proposed strategy method on the TWNHR-3 in the real test ground is discussed. The dimensions of TWNHR-3 are: length, 460 mm; width, 250 mm; and weight, 3.1 kg. Two obstacles are on the robot's way to the goal line. Figure 9 shows that the proposed strategy method can let the robot successfully complete the test.

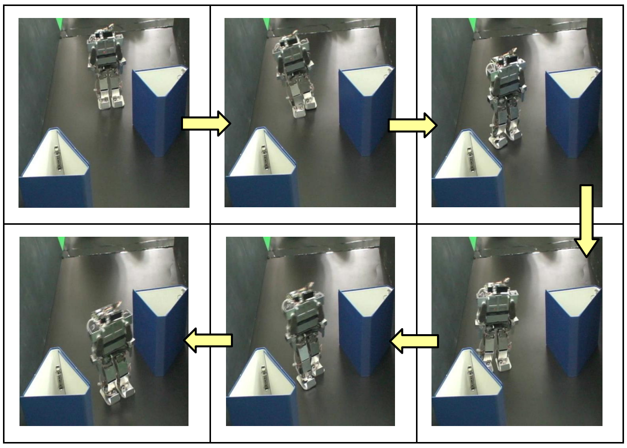

Figure 9: Six sequential image stills for real obstacle avoidance experiments

5 Conclusions

Four infrared sensors are installed in a humanoid robot to detect obstacles. Based on the obtained information from these four sensors, a decision tree method is proposed. From the simulation results, we can see that the robot can avoid obstacles and go to the destination based on the proposed method.

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