A Miniature Humanoid Robot That Can Play Soccor

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Abstract: An intelligent miniature humanoid robot system is designed and implemented as a platform for researching walking algorithm. The robot system consists of a mechanical robot body, a control system, a sensor system, and a human interface system. The robot has 6 dofs per leg, 3 dofs per arm, and 2 dofs for a neck, so it has total of 20 dofs to have dexterous motion capability. For the control system, a supervisory controller runs on a remote host computer to plan high level robot actions based on the vision sensor data, a main controller implemented with a DSP chip generates walking trajectories for the robot to perform the commanded action, and an auxiliary controller implemented with an FPGA chip controls 20 actuators. The robot has three types of sensors. A two-axis acceleration sensor and eight force sensing resistors for acquiring information on walking status of the robot, and a color CCD camera for acquiring information on the surroundings. As an example of an intelligent robot action, some experiments on playing soccer are performed.

Keywords: Humanoid robot, Biped walking, Camera calibration, Playing soccer

1. INTRODUCTION

In recent days, many researchers pay much attention to the humanoid robot system[1-4]. While most of the research are for a human-size robot, some researchers are interested in miniature humanoid robots[5-7]. Though miniature humanoid robots have some drawbacks such as limited load carrying capability, they also have some merits. The most important one is that they can be implemented easily compared with human-size robots so that researchers can focus their attention more on the software part for the research on humanoid robots.

In this paper, we introduce an intelligent miniature humanoid robot system which is designed and implemented as a platform for researching humanoid robots. The robot has 6 dofs per leg to have dexterous walking capability. It also has 2 dofs for a neck on which a color CCD camera is attached, so the robot can acquire information on the surroundings to perform some intelligent actions.

In section 2, the overall robot system is introduced in detail. Section 3 shows an example for an intelligent robot action, playing soccer. For the application of playing soccer, the robot uses vision sensor, so camera calibrations, image processing method, and an algorithm for playing soccer are studied. In section 4, we show some experiments performed on camera calibration and playing soccer. In section 5, some concluding remarks are mentioned.

2. THE HUMANOID ROBOT SYSTEM

2.1 The overall system

The intelligent miniature humanoid robot system consists of four sub-systems, a mechanical robot body with total of 20 dofs, a hierarchical control system, a sensor system with three different kinds of sensors, and a graphic human interface system for ease of developments. Figure 1 shows the overall humanoid robot system.

2.2 The robot body and controller

The miniature humanoid robot is 37.5 cm tall, weighs 1800g. It has 6 dofs per leg, 3 dofs per arm, and 2 dofs for a neck, so it has total of 20 dofs. RC servo motors are used as actuators. The joint structure for the leg is yaw-roll-pitch-pitch-pitch-roll, which enables the robot perform various walking motions. Figure 2 and figure 3 show the appearance and dimensions of the robot body respectively.

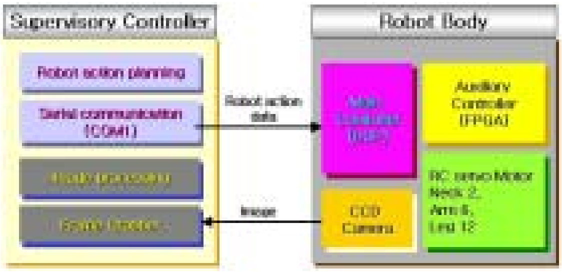


Fig. 1 The overall robot system.

Fig. 2 The appearance of the robot

The robot controller consists of three parts; The first one is a supervisory controller, which runs on a remote host computer and plans high level robot actions based on the vision sensor data. The second one is a main controller which is implemented with a DSP chip. The main controller communicates with the supervisory controller via wireless communication module, generates walking trajectories for the robot, and interfaces sensors such as force sensing resistors and a 2-axis acceleration sensor. The last one is an auxiliary controller, which generates periodic pulses to control 20 RC servo motors according to the robot joint data given from the main controller. Figure 4 shows the control system and the vision sensor for the robot.

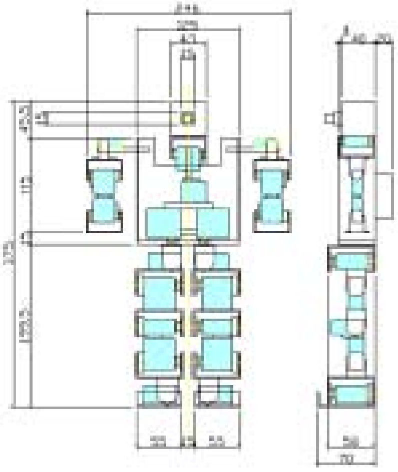


Fig. 3 The dimensions of the robot

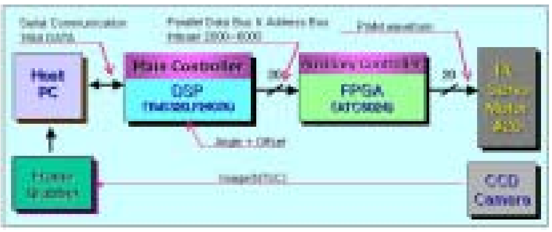


Fig. 4 The control system and the vision sensor

2.3 The sensor system

The sensor system has three types of sensors; 8 force sensing resistors, 4 of them attached underneath each foot, one 2-axis acceleration sensor on the body, and one color CCD camera on the neck. Force sensing resistors are used to acquire information on the walking status and a 2-axis acceleration sensor is used to check the flatness of the ground.

The CCD camera is used to acquire the information on the surroundings. The robot can perform intelligent actions such as climbing stairways, playing soccer autonomously with the information acquired by this vision sensor. The CCD image data are transmitted to the image processing unit that is on the remote host PC via 2.4 GHz wireless transmitter. Image processing unit is composed of a wireless receiver, a frame grabber, and image processing software. Some useful features are extracted from the color CCD image data and are sent to the supervisory controller. The supervisory controller then plans high-level robot actions and sends corresponding data to the main controller that is on the robot body via 433Mhz wireless communication module. A user graphic interface system is also implemented on the host PC, which can help the user to development robot walking patterns off-line, or to operate the robot manually. The specification of the vision system is shown in table 1.

Table 1 The specification of the vision system

Frame Grabber	Model	Meteor II
Camera	Image size	640 X 480
	Image device	1/3“ Interline CCD
Lens	Number of pixels	768×494
	Focal length	4.8mm

The robot has six dofs per each leg so that it can perform various walking patterns. The implemented basic robot walking patterns are (a) forward walking, (b) First half walking, (c) Last half walking, (d) side walking, (e) turning, and (f) kicking. These walking patterns except kicking are shown in figure 5. In that figure, only the right-hand side walking patterns are depicted. The robot can perform intelligent actions such as climbing stairs and playing soccer etc. by combining these basic walking patterns with the high-level action commands sent from the supervisory controller. The robot performs static walking so it has limited walking speed to avoid dynamic effects. Table 2 shows the walking parameters, within which the robot can perform each waking pattern stably.

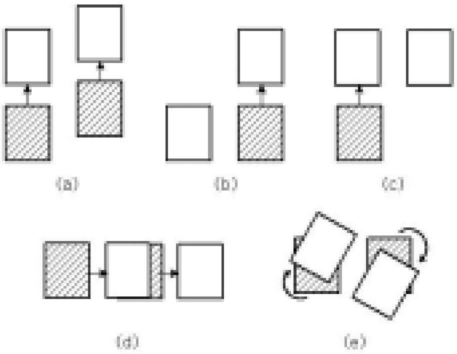


Fig. 5 The basic walking patterns

Table 2 The walking parameters for stable walking pattern

	time	Stride/angle
Forward walking	2 sec	8.6 cm
Side walking	4 sec	3.8 cm
Turning	4 sec	7 °

3. PLAYING SOCCER

3.1 Camera calibration

Linear and nonlinear distortion always exist in the CCD image data, so camera calibration must be done for the application such as playing soccer in which the world coordinates values of the interested objects must be known. Camera calibration is to determine a set of camera parameters that describe the mapping between 3-D reference coordinates and 2-D image coordinates[8]. For the camera calibration method, we use the method proposed by Bakstein[9]. In the proposed robot, only one color CCD camera is used, so generally it cannot reconstruct the 3-D coordinates values of the objects in the real world. However, in the application of playing soccer, we can assume that the value of the z axis for the objects be always some small value such as 0 because the interested area is the ground. In that case, we can obtain x and y coordinates values for the interested object such as a ball, or bottoms of goal posts etc.

For the biped walking robot to perform some meaningful actions in a restricted area, the localization problem must be solved. One method for the localization is to use some landmarks. In this application, we propose to use the two bottom points of the goal posts as landmarks. We can assume that the world coordinates values of the above-mentioned two landmarks are known.

For the robot to shoot the ball to the center of the goal posts, it needs to see the goal posts. Meanwhile, to cope with the limited resolution of the camera and to kick the ball accurately, the robot needs to see some interested narrow area. However, the robot has only one CCD camera, so it must have two views to deal with the above mentioned problem; One is a global view to find goal posts and localize itself and the other is a local view to acquire the accurate position of the ball. Thus, we need to perform two separate calibration processes. Figure 6 shows the calibration images used for the two calibration processes.

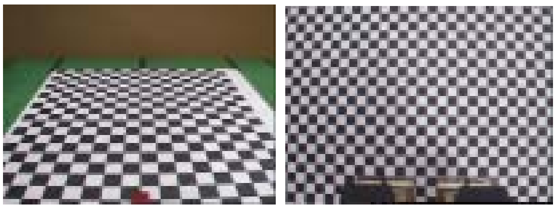

(a) (b)

Fig. 6 Camera calibration images. (a) the global view (b) the local view

3.2 Image processing

The robot uses color image data to extract features for the ball and goal posts that have different colors. We use HSI color space to reduce the light effects though the frame grabber uses RGB color space. Figure 7 shows the flow of image processing. The acquired RGB color data are transformed to HSI color data, then thresholded with the pre-determined minimum and maximum values of H and S, then labeled. Then the first pixel information such as the coordinate values of the center point, the size of the area etc. is acquired and stored. For the accurate results, edge detection and labeling is performed and the second pixel information is acquired and stored.

3.3 soccer algorithm

With two landmarks, the supervisory controller can determines the world coordinates values for the robot, the ball. The positions of the two bottom points of the goal posts are known. Therefore, relative relationships among the interested objects can also be known. The supervisory controller decides the sequence of the robot actions to kick the ball and then transmit the data to the main controller.

Next, we briefly explain the soccer algorithm. In figure 8, point A is the center of the goal posts, point B is the position of the ball, and the circle around point B is the neighborhood of the ball with given magnitude of radius. The algorithm for playing soccer is as follows; (1) The robot takes a global view to find the ball and goal posts, (2) the supervisory controller determines the world coordinates values of the interested objects and determines a series of robot action commands, (3) the robot generates a trajectory and approaches to the point near C, so that its frontal plane is perpendicular to the line formed by the two points A and B, (4) the robot takes a global view to find landmarks and corrects its position and orientation, (5) the robot takes a local view to find the accurate position of the ball, (6) the robot approaches and kicks the ball.

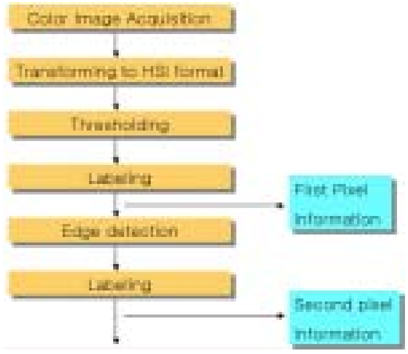


Fig. 7 The sequence of the image processing

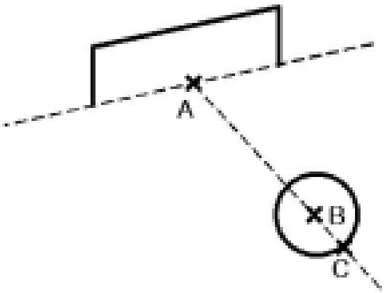


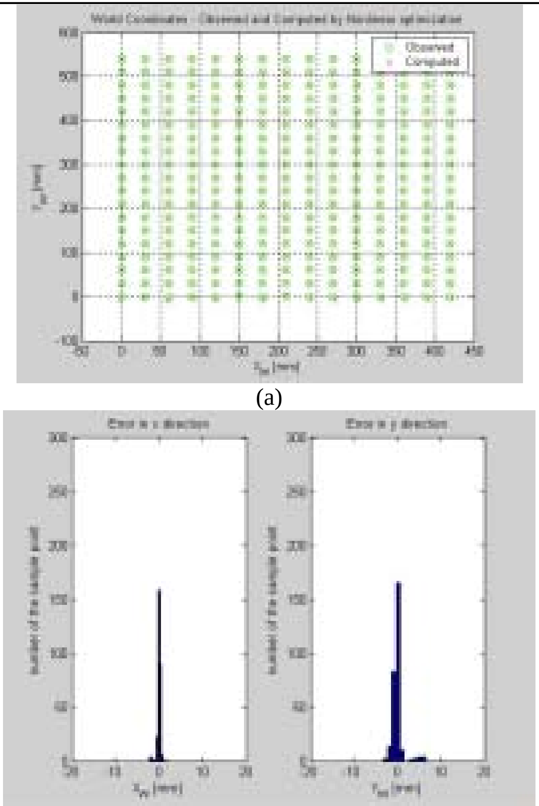
Fig. 8 The goal posts and the ball

4. EXPERIMENTS

4.1 Camera calibration

Two camera calibrations for the global view and the local view have been performed by the aid of the matlab toolbox[9]. Figure 9 shows the results for the calibration for the global view. The errors between the observed and computed values are small enough for the application of playing soccer. However, the calibrated area is relatively small in the global view because the robot must view the whole area including the goal posts. So, the points outside the calibrated area, large error is inevitable. The local view shows relatively small errors compared with the global view.

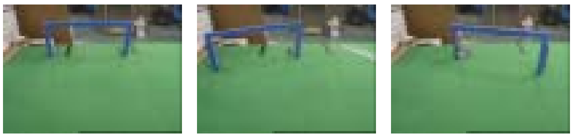
For the global view, the experiments to find the position and orientation of the goal posts are performed. Several locations of goal posts are shown in figure 10 and the experimental results are shown in table 3. For the local view, the six goal positions in figure 11 are observed and computed and the results are shown in table 4, which shows that the error between two values are small enough for the robot to kick the ball.



(a)

(b)

Fig. 9 Calibration results for the global view (a) Coordinate values for the observed and computed (b) Histogram for the errors in X and Y coordinates.



(a) (b) (c)

Fig. 10 The goal posts in the global view

Table 3. Angles and distances of the robot viewed in the center of the goal posts

	Observed		Computed	
Position	Angle(°)	Distance(Cm)	Angle(°)	Distance(Cm)
1	-3.82	77.38	-4.98	77.38
2	-18.75	71.25	-18.59	68.55
3	13.67	67.23	10.10	65.73

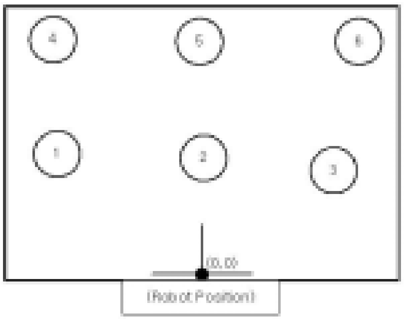


Fig. 11 Six positions of a ball in the local view

Table 4. Angles and distances viewed in the robot coordinates

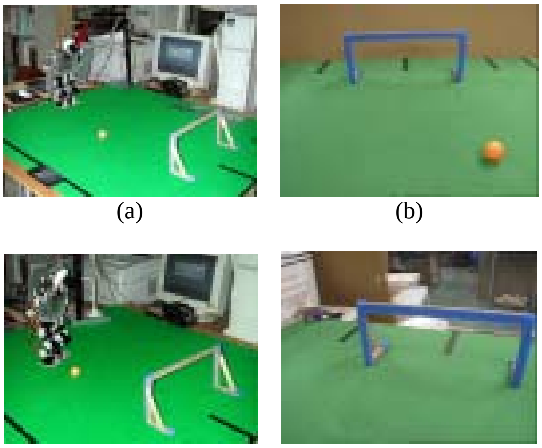
	Observed		Computed	
Position	Angle(°)	Distance(Cm)	Angle(°)	Distance(Cm)
1	160.2	10.66	158.1	9.23
2	93.2	7.53	88.47	7.50
3	24.8	9.40	20.9	9.53
4	129.9	14.65	127.0	13.64
5	96.0	12.22	93.3	12.21
6	52.9	13.07	48.0	14.8

4.2 Playing soccer

Several experiments on playing soccer have been performed with various positions and orientations of a ball and the robot. In those experiments, we assume that only the robot, a ball, and goal posts are on the ground. One of the experiments is shown in Figure 12. At first, the robot is located as in (a) and the camera image for this case is shown in (b). The robot can view the goal posts and a ball simultaneously with the global view and the relative distances and angles between three objects can be computed. The computed and observed values are shown in table 5. With these values and the walking parameters for the robot shown in table 2, the next pointfor the robot to move is determined to be (19.0, 29.8) with angel of 24°. The sequence of the walking also determined to be 5 right side walks, 1 first walk, 3 forward walks, 1 last walk, followed by 3 left turns.

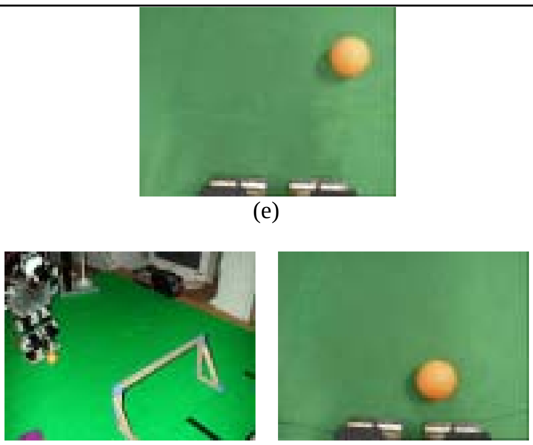
After taking these walks, the robot is positioned as shown in (c) and the images for the global view and for the local view are shown in (d) and (e) respectively. The coordinates values are shown in table 6. As discussed earlier, the errors in the local view are relatively small to kick the ball. The robot localize itself again at this point with the values obtained in the global view and the final approach is made. The final approach consists of 1 right side walk and 2 first and last walks. The final position of the robot is shown in (f) and the image taken in the local view at this point is shown in (g). At this point, the computed coordinate values of the ball in the robot coordinates are (1.22, 1.59) and the observed values are (2.0, 2.5). Though there exist errors both in x and y coordinate values of the ball, the magnitude is relatively small for the robot to kick the ball.

Even though the robot is able to kick the ball in the most of the experiments, more accurate and sophisticated method for reducing the errors generated in walking and camera calibration is required for better performance.



(a) (b)

(c) (d)



(e)

(f) (g)

Fig. 12. The scenes and images for a shooting experiment

Table 5. Positions and orientations of the objects in the robot coordinates at the initial position.

	Ball		The center of goal posts	
	Computed	Observed	Computed	Observed
X(cm)	14.94	16.0	-2.73	-3.0
Y(cm)	45.56	42.3	79.45	80.65
Distance(cm)	47.95	45.22	79.49	30.8
Angel(°)	71.84	69.28	91.97	93.0

Table 6. Positions and orientations of the objects in the robot coordinates at the intermediate position.

	Ball		The center of goal posts	
	Computed	Observed	Computed	Observed
X(cm)	6.36	6.8	2.41	0.6
Y(cm)	10.04	10.5	53.51	53.65
Distance(cm)	11.89	12.51	53.57	53.65
Angel(°)	57.64	57.07	87.42	89.36

5. Results

An intelligent miniature humanoid robot is designed and implemented. Several basic static walking patterns are generated and combined to perform more sophisticated robot action. As an example of an intelligent robot action, playing soccer is performed. To enable the robot to play soccer autonomously, camera calibrations are performed, self localization method with landmarks of the goal posts are proposed, and an algorithm for shooting the ball is proposed and experimented. The experimental results show that the robot is able to acquire relatively accurate positions of the interested objects such as a ball and the bottoms of the goal posts. However, a more accurate and sophisticated method for reducing the accumulated errors while on walking and the errors induced by the vision sensor is required for better performance.

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