Improvement of Manus Humanoid for Basketball and Marathon Events

Mai KaoJie, Kwang Khai Chun, Nitin Batra and Prahlad Vadakkepat
Electrical and Computer Engineering, National University of Singapore
4 Engineering Drive 3, Singapore 117576
{U0307803, U0303287, nitinbatra, prahlad}@nus.edu.sg

Abstract: *This paper discusses how the humanoid MaNUS is able to put a ball into a colored basket autonomously. The first part of the paper describes the design of the humanoid arms and head using Solidworks. The second section describes how stereo vision is incorporated into the humanoid system. The stereo vision incorporated allows the MaNUS to locate the ball in the 3-D space and grip the ball. The final part of this problem is to place the ball into a basket at a short distance away. This is achieved by using vision sensor to locate the basket and then by walking towards the basket using static walking gait. A programming technique making use of finite state machines is used to realize this. The humanoid is able to walk towards the basket with a ball in its hand and place the ball into the basket successfully. The final part of the project involves developing a line tracking and navigation system for the humanoid. The humanoid is successful in tracking colored lines without deviation for all scenarios including simple straight turns, gradual to sharp curves, zigzag lines, perpendicular lines and the combination of the various types of lines*

1. Introduction

The world of humanoid is fascinating. They are mimicking humans in the way human walks, swings the arms, and even along thinking. Sony's QRIO and Honda's Asimo are some of the best humanoids today that have some amazing intelligence that resembles human beings. Sony's QRIO had been known to be able to catch a ball from far thrown at him and Honda's Asimo is known to be able to walk up a small flight of stairs. There had also been research done along sports-playing robots such as soccer-kicking humanoid [1] and ping-pong playing robot [2]. They are interactive and entertaining, and there is going to be demand for such interactive robots in the future. Because of human's curiosity and fascination with robots, it is not hard to imagine there arrives a day where soccer is going to be played by 22 humanoids in a stadium-size football field.

A biped autonomous humanoid named MaNUS was developed in NUS in 2002 [3]. This work focuses on the design of a pair of hands and a head which holds 2 cameras for MaNUS. The humanoid is programmed to play basketball with these additional features.

2. Designing the Hands and Head

A few considerations are made in the design of hands. Firstly, it had to be light-weight. This is because the legs of the motor had to carry the weight of the upper body as well. Secondly, the degree of freedom for the hands is kept minimal to save computational complexity. With these considerations, the design is drawn out using Solidworks.

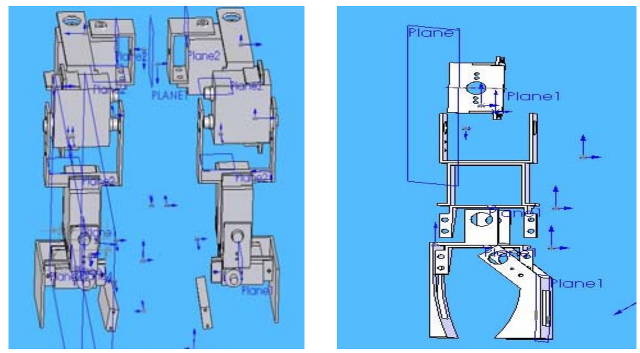

Figure 1: Two versions of hand designs

Two designs for the hand are considered: the second design is an improvement over the first. The two designs differ along the motors used in each joints and in the angles of rotation in some of the joints. Two types of motors are used: Hitec motor HS-5995TG and HS-5245MG. Each motor is able to provide a rotation of up to 140 degree. Each joint in the second design is briefly elaborated as follows.

Base shoulder

The base shoulder consists of roll and yaw axis. They cross at right angles and are both driven by DC servo motors. The servo motors used is Hitec motor TG5995, which has a motor torque of 30kg/cm. High torque motor are used because it has to move the weight of the whole arm.

Elbow

The elbow can move along the roll and the yaw axes. The servo motor used for the yaw axis is a smaller motor, Hitec motor 5245MG, which can carry a torque of 8kg/cm. A smaller motor is chosen for the yaw axis because it only carries the weight of the fingers; hence there is no need for a high torque motor which is comparably heavier. The high torque servo motor TG5995 is used for the roll axis.

Wrist

The wrist has only a roll axis of motion. A high torque servo motor is used for the wrist as the hands have to carry weights in the weightlifting event in the FIRA cup.

Finger

The finger has only the roll axis which is controlled by a small motor. The function of the finger is limited to grasping round or cylindrical object.

3. Overall Control System

The objective of the project consists of the 2 sub-tasks. Firstly, the humanoid has to locate and grab the ball. Secondly, it has to locate and walk towards the basket. The ball is then put into the basket. To achieve these objectives, 3 hardware components are needed, that is 1) Humanoid hands 2) The vision sensor and 3) The digital signal controller.

CMUcam2 camera

CMUcan2 developed by Carnegie Mellon University can track objects by its colours. A java console comes together with the camera. This console allows users to track the centroid of the object by its RGB value. A confidence level is generated which reflects how good are the RGB values in tracking the object. If there are nearby objects with similar RGB values and is seen by the camera, the confidence level reduces because the camera will use a window size which covers all possible objects that fit into these RBG values. Nearby objects with similar RBG values make the window bigger in size and hence lowering the confidence value.

DSP controller

Two controllers, Isopod and Servopod are used in the humanoid. These two controllers are used in two levels of controls. The Isopod does all the processing of the information from the sensors and is responsible for all decision making. The Servopod controls the leg and hand motors, and receives instructions from the Isopod.

A very important feature of this type of controllers is that it is able to run many sub-tasks together in real time mode. This is achieved because of the virtually parallel machine architecture (VPMA). This controller is appealing in the humanoid system design because there is a need to integrate many different tasks and run them in real-time.

The working mechanism of VPMA is such that smaller, independent machines can be constructed and then run in real-time mode. State machines run without halting the main program. This is useful in the MaNUS humanoid system, for example, in soccer ball kicking, there are generally 2 sub-tasks: One is to track the ball with the camera and the other to walk towards the ball by sending PWM signals to the servo-motors. These 2 sub-tasks are run concurrently without delaying the execution of either. This is virtually not possible without making use of state machines. Figure 3.2 shows how the whole control system is organized.

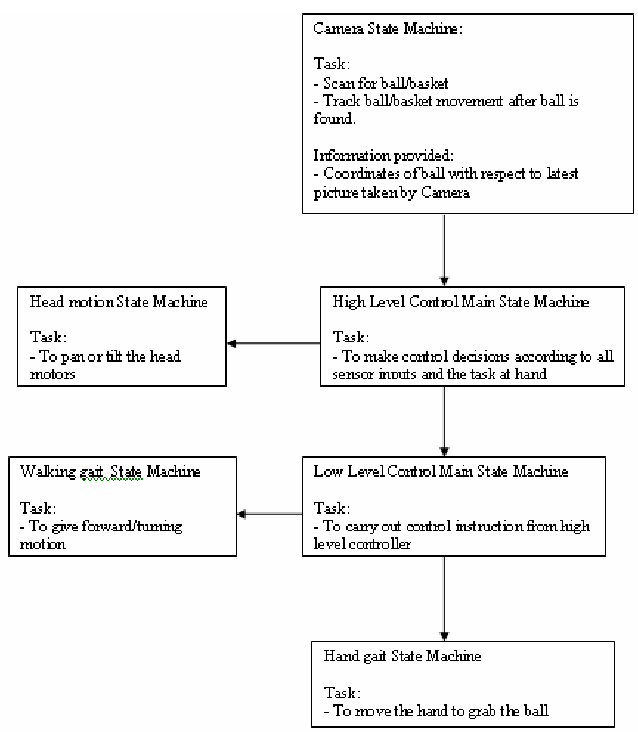

Figure 2: MaNUS: Overall control system

4. Algorithm to Walk towards the Basket

Once the ball is picked up, the humanoid has to move towards the basket to put the ball into the basket. Basket tracking algorithm is used to track the basket in real time mode. The direction to which the humanoid should head for is determined by the pitch and roll motors of the head. The basket is assumed to be of fixed height with a fixed radius. Hence there is no need for stereo-vision. A single camera is sufficient to locate the basket.

Tracking the basket

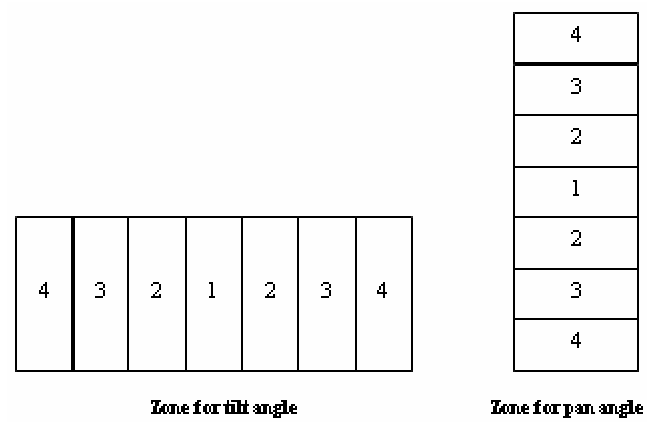

Figure 3: Image plane divided into 4 zones

The basket tracking algorithm is a robust algorithm whereby the cameras pans/tilts in such a way that the centroid of the basket always remains near the center of the image plane at all times (Zone 1). This algorithms is derived from the one used for tracking a ball. In Figure 3, if the image coordinates lie in zone 2, then the motor shifts back 1 degree until it is back to zone 1. If it is in zone 3, it shifts back by 5 degrees. If it is in zone 4, it shifts back by 10 degrees. The shifting here refers to either panning or tilting.

Putting the ball into a basket

The algorithm is designed in the following way:

1) Run the basket tracking algorithm. The outputs of this algorithm are the pan and tilt angles of the head motor.
2) Orient the humanoid until the center of the humanoid body is facing the basket.

3) Walk towards the basket. The head tilts as the humanoid walks forward.
4) The ball is already in the hands at around chest level. As the head starts tilting, the humanoid walks to a point when the ball blocks the vision of the basket.
5) Take one more step and use the wrist motor to release the ball.

5. Line Tracking and Navigation

The tracking of the colored line is achieved using the CMU camera attached at the head of the humanoid. The algorithm makes use of the information sent from the camera to the central processor. The humanoid first takes a shot of the colored track and that is sent to the controller for processing. The controller divides the camera shot into 5 vertical regions (A, B, C, D or E)

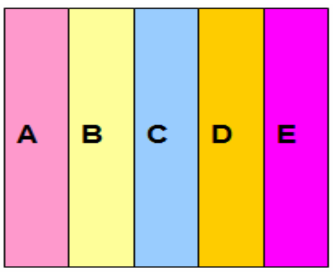

Figure 4: Camera shot divided into 5 zones

An Efficient Line Tracking Approach

In order to maximize the efficiency of line tracking, the algorithm is implemented such that the humanoid head is fixed in the central position. The humanoid only then needed to turn right or left to align itself to Zone C, the centre of the colored track. This direct and effective method eliminates the time taken to pan and tilt the camera to track the colored line before the aligning the humanoid.

Following the Colored Line

The humanoid makes a big left turn and a small left turn in Region A and B respectively. The humanoid continues to move forward in Region C. The humanoid then makes a small right turn and a big right turn in Region D and E respectively. These motions align the humanoid in such a way that the colored line is always at the centre of the camera image, and ensures that the robot is following the line.

6. Conclusion

New pair of hands is designed for the MaNUS humanoid. The pair of hands is designed to have the minimal required number of DOF with no redundancy, and is light-weighted. A different design of the hands is also designed which allows the humanoid to compete in various events in FIRA cup.

The head is redesigned to hold two cameras for stereo vision. It works with the concept of using 2 cameras to find out the disparity in the stereo-image pair. Camera calibration on each camera is done beforehand to map out each image coordinate to the real coordinate. With the camera calibration, the position of the ball can be determined with the disparity in the stereo images.

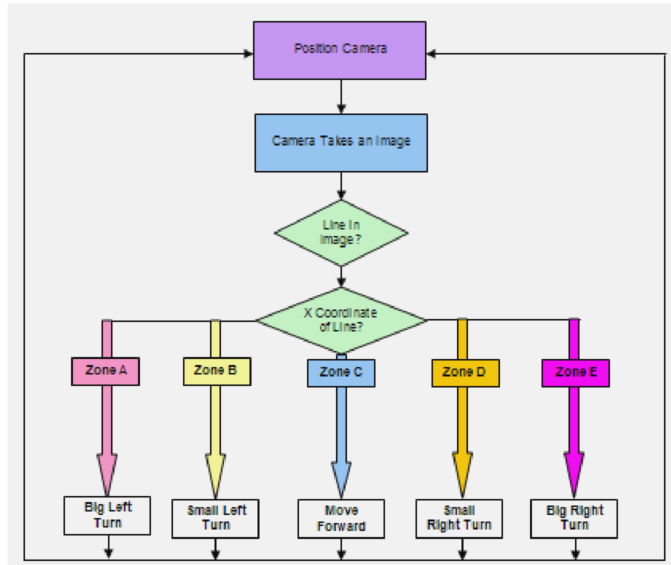

Figure 5: Flowchart for line tracking and navigation program

Algorithms are derived to allow the humanoid to play basketball. The algorithms are for tracking, locating and grasping the ball algorithm. Finally an algorithm to locate the basket and to deposit the ball into the basket is described.

With the developed algorithms, the humanoid can hold a ball, locate the basket, walk towards the basket and deposit the ball into the basket.

The line tracking and navigation system incorporated onto the humanoid is successfully implemented. The humanoid is able to track the colored line without much deviation for all scenarios including simple straight turns, gradual to sharp curves, zigzag lines, perpendicular lines and the combination of various types of tracks.

References

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