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# Robot and Ball Localization in Soccer Competition using Image Processing

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**Abstract:** This paper illustrates the implementation of computer vision algorithm for robot localization in completing Free Kick Challenge task of FIRA RoboWorld Cup and Summit. A marker patch is placed at robot's head and robot localization is determined using Roborealm software. Image from marker is processed using color and shape matching technique to estimate position and angle of the robot. Robotis Bioloid Premium robot is used in the challenge task. Robot's controller (CM-530) is interfaced to serial communication in Roborealm software using bluetooth connection using PC to control robot's movement.

**Key words:** *ball localization, image processing, roborealm software, robot localization*

## INTRODUCTION

In 1996, the Federation of International Sports Association (FIRA) was founded by Prof. Jong-Hwan Kim from KAIST, Korea. From the beginnings, FIRA's major goals is using sports as benchmark problems for state of the art research in robotics and other related areas [1]. FIRA consists of five main categories which is Androsot, Robosot, Simurosot, Mirosot and FIRA Air. This paper only focuses on Androsot category with sub-category Free Kick Challenge. Both hardware and software programming are involved in this work. In this paper, an attempt to integrate computer vision algorithms for robot and ball localization is studied and implemented. Robotis Bioloid Premium robot is used as hardware, meanwhile Roborealm software is used for object localization using image processing.

## HARDWARE AND SOFTWARE

### Field and Gameplay

This task is played indoor area. A black (non-reflective carpeted) flat and hard rectangular is used as a playground. The size is 340 cm x 180 cm inside, on carpet and surrounded by 5 cm thick and 1.8 cm high white sidewalls. All the sidewalls are painted in white and fixed to the carpet. A standard yellow tennis ball is used as the ball. Overhead camera Logitech HD Pro C930 or C920 web-camera model is used at the center of field, at a height of minimum 2.7 meters and maximum of 3.3 meters so as to capture the frames over the range of 420 cm x 230 cm on the playing field. All active distance sensors are not allowed from setting up on the robot to measure the relative distances among robots [2].

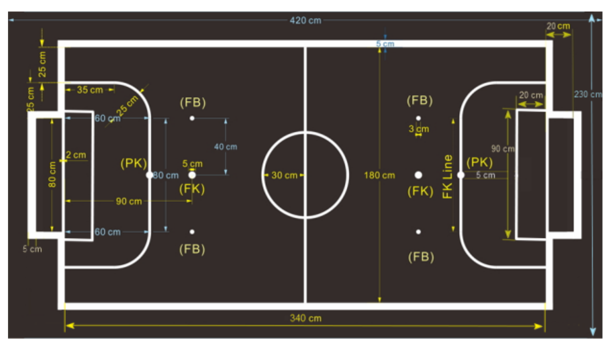


Fig. 1.1 Field size [2]

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Fig. 1.2 Logitech HD Pro C930 or C920 web-camera [2]

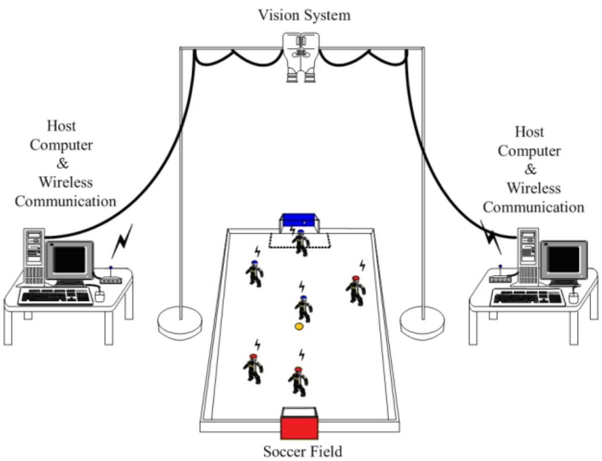



Fig. 1.3 Overall vision system [2]


Fig. 1.4 The stereo view of field [2]

**The Robot**

Robotis Bioloid Premium robot is used to perform the task because it meets the standard given in the competition's rules. Powered by 1000mAh LBS-10 11.1v Bioloid Premium lithium-polymer (LiPo) battery, the robot also has capabilities to self-adjusts posture while walking [3]. Its movement is controlled by Robotis CM-530 controller [4]. The controller can be interfaced to PC using both cable and wireless connection. There are two protocols of connection using wireless, which is Zigbee and Bluetooth communication. In this task, Bluetooth communication is used to interface with PC by using Robotis BT-210 serial Bluetooth module. This module creates serial profile port (SPP) in PC which is suitable for interfacing with Roborealm software. Using combination of 18 Dynamixel DC servo module, the robot can perform various human-like movement with great stability.

Fig. 1.5 Robotis Bioloid Premium [3]


Fig. 1.6 CM-530 Controller [4]

Fig. 1.7 BT-210 Bluetooth Module

**Roborealm Software**

Roborealm software is used for robot and ball's localization in this work by tracking colored patch at the robot's head and ball's color [5]. By using Logitech HD Pro C930 or C920 web-camera at the center of field, this software analyzes and process the acquired images, within specific frame per second (fps), and send the needed commands to the robot's controller by Bluetooth communication. As a windows based software, Roborealm plays important role to simplify computer programming by providing pre-programmed modules for user. These modules can be used to ease the image processing by using easy click interface. The main goal of using RoboRealm is to translate visual input into a motion command that can be used to move the robot based on what a machine perceives [6][7].

## METHODOLOGY

Initially, the robot is placed at the start position. Logitech camera which is fixed at the center of field captures images of the whole field through USB cable connected to the PC. Roborealm identifies x and y coordinates of every object detected and send the signal to the robot through Bluetooth communication. Robot's controller receives signal and send to actuator for movement toward the ball.

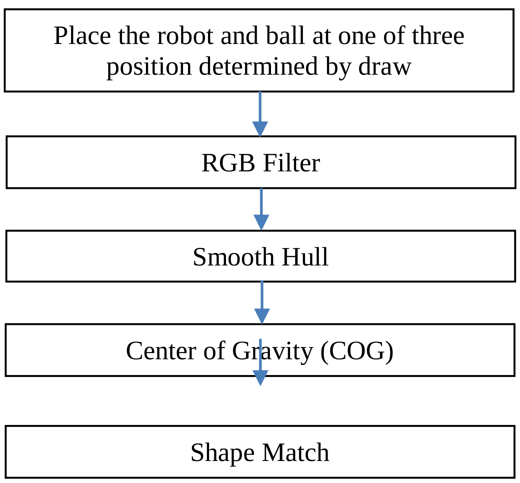



Fig. 2.0 Steps taken in the robot and ball localization

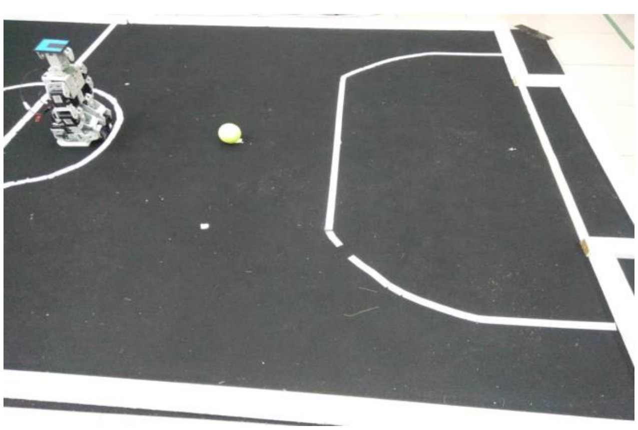


Fig. 2.1 Robot and ball position at the field

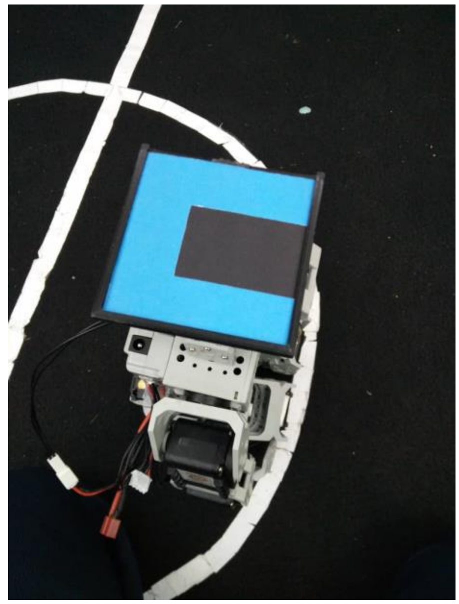


Fig. 2.2 'U' shape patch marker placed at the top of robot for localization

Fig. 2.3 Robot and ball position from camera view

### RGB Filter

RGB filters use RGB values to focus on the primary RGB color. Depending on the color selected, this filter will reduce all pixels that are not the selected color. This functionality differs from RGB Channels in white pixels as well, although they may contain selected colors. For example, if red is chosen,

$$R = ((R - B) + (R - G)) \qquad (1)$$

$$G = 0$$
$$B = 0$$

R is then normalized with respect to the maximum red value. For ball localization, yellow color is chosen for RGB Filter module in Roborealm. Several parameters which is Minimum Intensity, Min Hue and Hue Hysteresis are tuned to filter out other color.

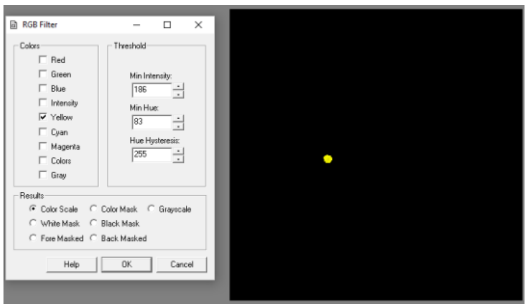



Fig. 2.4 RGB Filter for ball localization

Meanwhile, patch marker placed at the top of the robot is used for robot localization and angle estimation. Again, same technique is used to filter out blue from other color.

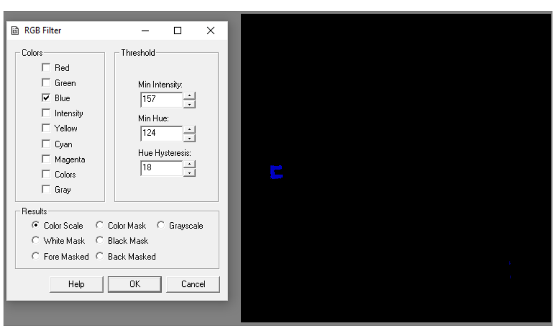



Fig. 2.5 RGB Filter for robot localization

**Smooth Hull**

The smooth hull module will smooth the shape of the blob. Blob shifts are averaged within the specified window. The final line is then weighted against the new and original outline. 100% weight replaces the average line. The result of this module is to smooth the perimeter of the blob without losing its edge.

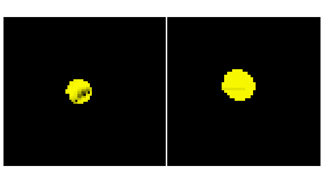


Fig. 2.6 Comparison of ball image before and after smooth hull application

**Center of Gravity (COG)**

The center of gravity module plays important rule to determine the coordinates of center of the object. This coordinate is represented using Cartesian coordinate system, which consist of x and y value. In Figure 2.6, the centroid of the ball is displayed consistently. This can be calculated as:

$$\frac{\sum_{k=n+1}^{n} x_n}{n} \tag{2}$$

$$\frac{\sum_{k=n+1}^{n} y_n}{n} \tag{3}$$

where $x_n$ and $y_n$ are the coordinates of the $n_{th}$ pixel in the desired object and $n$ is the total pixels in the desired object.

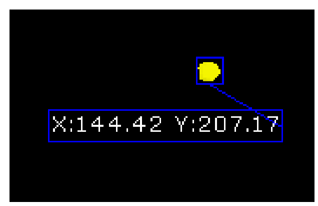



Fig. 2.7 Ball x and y coordinates

**Shape Match**

The shape matching property is used to recognize the shape using several images stored in database. It compares the probability of currently viewed object with the database by some statistical relationship. Shape matching modules will provide coordinates and orientation which is very important for determining the location of the robot in the field. The orientation value (radian format) will be used to estimate angle from robot to ball.

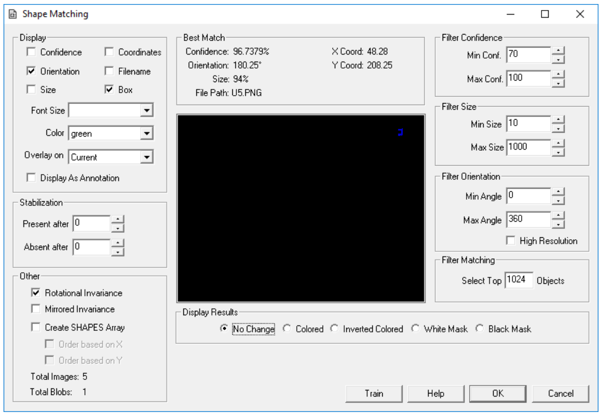



Fig. 2.8 Shape matching parameters

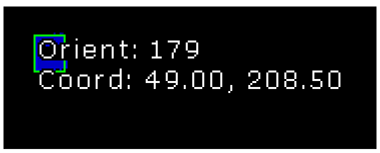



Fig. 2.9 Shape matching results

**Interfacing with CM-530 Controller**

To perform communication from Roborealm to CM-530 robot's controller, the serial module has been used. Bluetooth BT-210 is used to create Serial Port Profile (SPP) that allows connection from Roborealm serial module. Basically, Serial Port Profiles define the protocols and procedures that a device will use using Bluetooth for RS232 (or similar) serial cable emulation. The situations covered by this profile relate to legacy applications using Bluetooth instead of cables, through a series of port abstractions (which is operate system dependent).

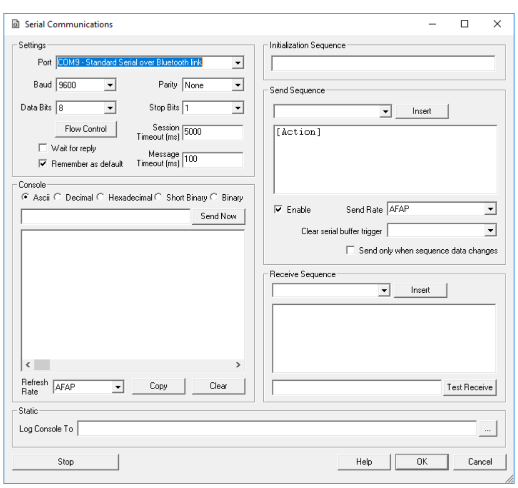
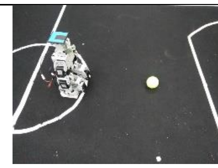
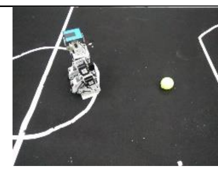
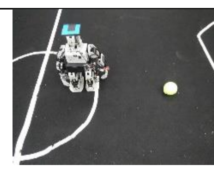
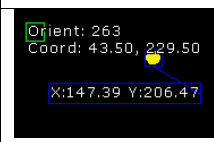
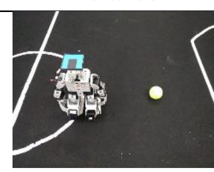



Fig. 2.10 Serial processing using SPP

## EXPERIMENTAL RESULTS

In this work, several position of ball and robots has been tested and the result of positioning are given in Table 1.

Table 1: Four position of robot tested

| Position | Actual Image | Robot position and orientation |
|---|---|---|
| 1 |  Robot facing forward |   Orient: 184 |
| 2 |  Robot facing backward |   Orient: 22 |
| 3 |  Robot facing leftside |   Orient: 263 |
| 4 |  Robot facing rightside |   Orient: 79 |

## CONCLUSION

Using image processing to determine robot and ball localization was achievable. For ease of the process, robot's patch identification through color filtering and removing unwanted objects was used. The experimental results show that the robot and ball's localization was successfully determined according to real position on the game field.

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