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Autonomous Soccer Robot Using Triple Infra-red Sensor for Ball Detection

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Abstract- **This research work describes about an autonomous microcontroller-based mobile robot for a robot soccer competition. The competition field as shown in the methodology is equipped with white lines to serve as the guidance path for competing robots. Two prototypes of soccer robot embedded with the Basic Stamp II microcontroller have been developed. Two servo motors were used as the drive train for the first prototype whereas the second prototype used two DC motors as its drive train. To sense the lines, light-dependent resistors (LDRs) supply the analog inputs for the microcontroller. The performances of both prototypes were evaluated. The DC motor-driven robot has produced better trajectory control over the servo motors and has brought the team into the final round.**

Keywords- **Soccer robot, Mobile robot Obstacle detection, Differential drive, Line following.**

I. INTRODUCTION

Robot soccer competition is a great and entertaining way to enhance the learning process in the field of robotics. Students would gain first hand experience in constructing and programming robots for competition, as well as allowing them to understand further the concept Mechatronics System Design [5].Realizing this, a robot soccer competition is organized in conjunction with the Mechatronics System Design course under the Engineering Faculty of the International Islamic University Malaysia (IIUM). This project-based course requires the students to build soccer robots and then to compete with each other. Their performances in this competition are measured and recorded as part of the evaluation scheme. Since it is very important to build some actual physical agents in order to address the full complexity of the tasks, we have been developing mobile robots to work specifically in a robotic soccer environment [1].

In this robot soccer competition, students are divided into groups of one, two, or three people and they are given freedom to design their own robots in terms of hardware and software used. For our group of two people, we opt to develop two prototypes of soccer robots with different kinds of drive trains. The performances of both robots are to be analyzed.

The common task of the onboard control system is to achieve the requested positioning using **a** set of control loops. The requirements include that many axes and sensors have to be synchronized, needing powerful real-time capabilities, under limited onboard batteries power [2].

The 2YOA21 sensor is able to unambiguously determine the range of objects between 5cm and 150cm. This marks a noticeable improvement over the older GP2D12 model, which was only able to detect objects between 8cm and 100cm. Also, the new sensor shows much less random fluctuation in the output signal than the original sensor did, eliminating the need to run averaging algorithms to obtain precise results [10].

II. METHODOLOGY

Fig 2.1. Robot soccer competition field

The rules of the robot soccer competition are as below:

1. Field size: 150 cm x 100 cm (see Figure 2.1)
2. Robot size:
   a. maximum width: 12 cm
   b. maximum length: 15 cm
   c. maximum height: -
3. Robot Control : Autonomous, On-board
4. Robot Starting: To be completed in 10 seconds.
5. Not to endanger spectators and damage game field.
6. Only ONE robot per team is allowed per game.
7. A robot is considered not working when there is no movement from the robot 20 seconds after the game starts.
8. Six balls will be placed strategically. Ball positions will be predetermined and are the same for both teams.
9. Two types of balls to be used:
   a. Orange Ping-pong balls
   b. White golf balls
10. Team Orange will have to push orange balls into the opponent's goal
11. Team White to push white balls onto the opponent's goal
12. Maximum game duration is 3 minutes: Referee has the right to stop the game if the robot not responding.

13. Robot that endanger spectator and damage the field will be disqualified.
14. Robot that push all own balls towards opponent goal at the fastest time will win the game.
15. In no team can push all balls towards opponent goal then the team that push the more balls farther will win the game.
16. If the goal scoring is even then the robot that scores more at a faster time will win the game.
17. If no robots can push balls towards opponent goal then the working robot wins the game.
18. If no robots can push balls towards the opponent's goal then both teams are considered 'lost'.
19. If both robots are not working then both teams are considered 'lost'.

III. MATERIALS

3.1 Robot Soccer Set-up

A. Mechanical Construction

The development of our first robot prototype of our soccer robot (see Figure 3.1) utilizes a plastic box as its main body together with two 80 mm wheels with each wheel attached to one Parallax servo. One Tamiya castor is mounted further up front to provide stability for the robot. The differential drive method is implemented to enable the robot to rotate clockwise and counter clockwise. This means that one motor would rotate while another stops to let the robot turns towards the desired angle of rotation.

The Robotis kit is being used to develop our second prototype of soccer robot (see Figure 3.2). For this design, we have tried to maximize the ball collecting space of the robot so that all the three balls can be collected in a single trip. In order to do so, two screw castors are mounted at the farthest part of the left and right arms of the robot. In addition, the second prototype is being equipped with two SPG -20K DC motors as the drive train for the robot.

B. Circuitry Interfacing

For the on-board microcontroller of the robot, the Basic Stamp II (BS2) embedded on the Parallax Board of Education (BOE) is implemented as the board set provides easy interfacing with sensors and actuators [6]. Furthermore, the BS2 microcontroller can be easily programmed using the Pbasic 2.5 language through the Basic Stamp Editor v2.4.2.

In order to equip the robot with obstacle detection capability, the use of CMU camera is being considered. However, due to the high cost of obtaining such camera and the complexity involved in programming the vision system, this idea is abandoned in search of other more feasible method[4].

Therefore the approach of using three Sharp GP2Y0A21 analog distance sensors is being carried on since the inputs from the sensors are expected not to overly consume the limited processing power of the BS2 microcontroller

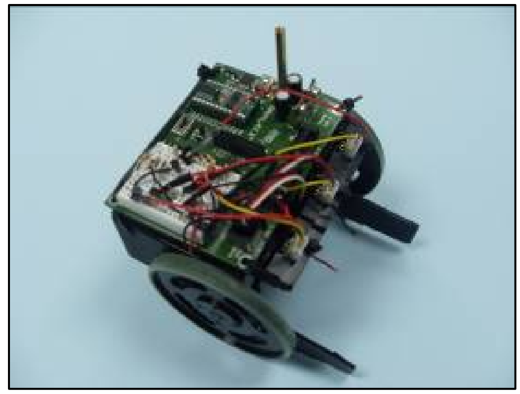

Fig 3.1. First soccer robot prototype with servo motors as drive train

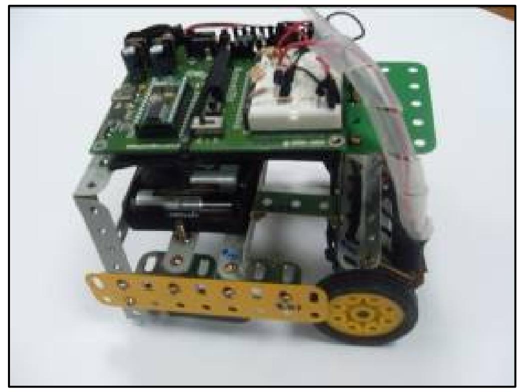

Fig 3.2. First soccer robot prototype with servo motors as drive train

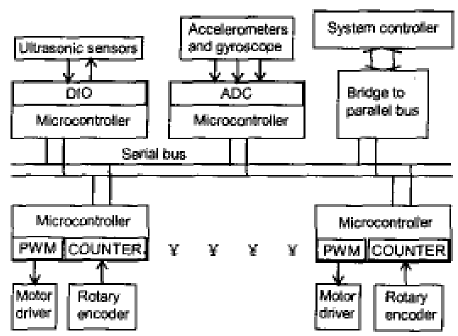

Fig 3.3: Microcontroller network for modular mobile robots

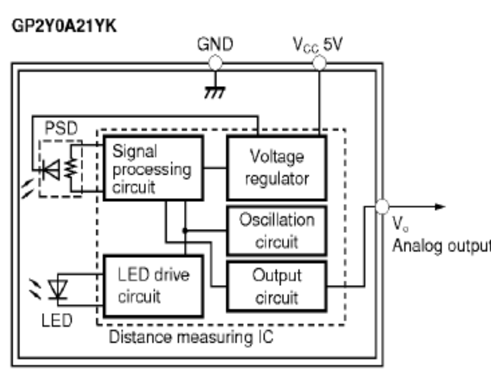

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Fig 3.4: Internal Block Diagram

The sensors are mounted onto the front side of the robot with each facing straightly towards the front. Such alignment will allow the robot to detect the presence of obstacles including the balls. A ball presence can be detected when only single sensor provide an extraneous input value as compared to the other two sensors. Whereas other kinds of obstacles like other robot or walls would provide input values that are of similar patterns between each other.

As for the line tracing sensors, three light dependent resistors (LDRs) are arranged in straight line and mounted below the motors and in parallel to their shafts. Three light emitting diodes are also mounted next to each of the LDR to provide uniform light source for the sensors.

C. Programming Algorithm

The issue of control manifests itself in at least two aspects of the Robot Design project: in the development of the robots higher-level strategy from a conceptual standpoint, and in the actual programming of that strategy into the machine through the process of writing computer code. In the conceptual area, the *algorithmic* control method is by far dominant over the *reactive* [3].

The LDR inputs can be monitored through the Basic Stamp Editor software. The black surface reading would show 0 value whereas the white lines shows values of more than 2000. This amount is used as the threshold value in sensing the lines and logic 1 or HIGH is applied to this case.

The combinations of the three LDR sensors are used to determine the appropriate movement for the robots. For example, if the robot's trajectory has diverted towards the left, the right sensor is in HIGH state and the right motor would stop rotating to enable the robot to move back on course.

D. Image Segmentation

The main purpose of image segmentation is to identify the target image from the original image[7]. It is an important part of target recognition and needs to be resolved firstly. This system uses an adaptive 2D Otsu image segmentation methodbased on genetic algorithm [8] .

IV. RESULTS

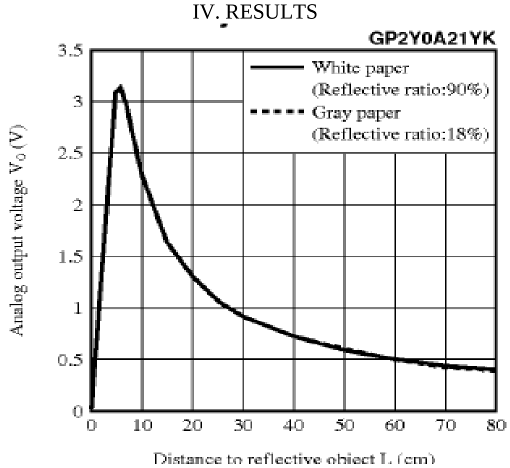

Fig.4.1: Analog Output Voltage vs. Distance to Reflective Object

To calculate the range (in centimeters) using the new IR sensor, use this equation:

$$Range = \left(\frac{3027.4}{IRValue}\right)^{1.2134}$$

where IRValue is the digital output signal from the sensor.

This equation was derived from the calibration curve shown below. The curve was created by plotting output values of the IR sensor versus distances to a stationary, flat object [10].

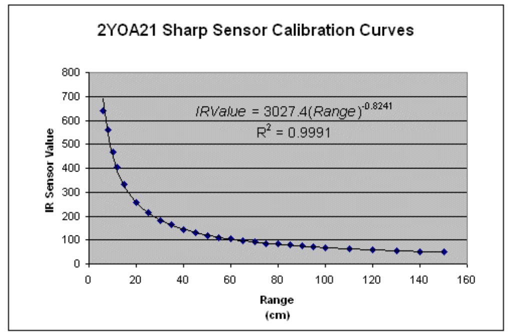

Fig 4.2: Here are the raw 2YOA21 sensor values at ranges between 0cm and 150cm.

Competition Results

The results of our soccer robot for the whole competition are as follows:

TABLE 3.1

Round	Results
Preliminary	0 – 0 (Won as opponent disqualified)
Quarter-Final	3 – 0 (Won)
Semi-Final	2 – 0 (Won)
Final	0 – 2 (Lost)

V. DISCUSSION

During the preliminary round, we use our first robot prototype which uses the Parallax servos. It has performed nicely in following the lines, but the speed is rather too slow to reach the opponent's goal post in time. The game is won, however, as the opponent's robot is declared to be disqualified due to their overly-sized robot.

For the next rounds, another robot is constructed with the servos replaced with DC motors. With this second prototype, we have managed to reach the final round of the tournament, but we lost to the opponent team which has a great soccer robot with great strategies. All is not lost actually, since our robot has actually brought a good fight for the opponent robot.

Finally, in the table below, we see that the range equation (at the top of this page) is not perfectly accurate, but it is quite well-behaved. For ranges greater than 6cm, the maximum error is only 4% and is most often less than 1%[10].

TABLE 4.1
COMPARISON OF RANGE EQUATION VALUES WITH ACTUAL VALUES

Comparison of Range Equation Values with Actual Ranges			
Range (cm)	IR Sensor Value	Calculated Range (cm)	% Error
6.0	638.1	6.61	10.2%
8.0	560.8	7.74	3.3%
10.0	467.1	9.66	3.4%
12.0	404.0	11.52	4.0%
15.0	333.5	14.53	3.1%
20.0	257.5	19.89	0.5%
25.0	214.0	24.90	0.4%
30.0	182.0	30.31	1.0%
35.0	162.6	34.75	0.7%
40.0	143.9	40.30	0.8%
45.0	131.1	45.13	0.3%
50.0	119.2	50.65	1.3%
55.0	111.2	55.10	0.2%
60.0	103.4	60.22	0.4%
65.0	95.3	66.45	2.2%
70.0	91.2	70.09	0.1%
75.0	85.0	76.34	1.8%
80.0	82.3	79.39	0.8%
85.0	78.7	83.82	1.4%
90.0	75.3	88.44	1.7%
95.0	71.0	94.98	0.0%
100.0	66.0	103.78	3.8%
110.0	62.9	110.01	0.0%
120.0	57.6	122.41	2.0%
130.0	55.0	129.47	0.4%
140.0	51.6	139.89	0.1%
150.0	50.3	144.29	3.8%

The interfacing of the Sharp analog sensors has come with the least success since the RCTIME command shows fluctuating values of the analog inputs without any consistent reading pattern.

The programming of the robot equipped with the Parallax servos requires continuous calling of the PULSOUT command in the PBasic 2.5 directive. This has caused the robot to move with a very slow speed (less than 30 RPM) when the PULSOUT command alternates with the calling of the sensor reading function within the programme algorithm.

For the second robot prototype, the use of two DC motors has enabled the robot to move at a higher speed of 45 RPM at 6 volt battery supply. The speed is considered to be sufficient enough for line tracing and ball collecting purposes for this tournament.

VI. RECOMMENDATION

Further improvements can be made by using a better microcontroller than BS2 like PIC16F877A which has better processing power, bigger memory and built-in pulse-width-modulation (PWM) function. Whilst decent DC motors plus with sufficient speed and high torque plus their drivers would enhance the mobility of the robot. It is also recommended that the Sharp GP2Y0A21 sensor is to be used with an analog-to-digital converter (ADC) chip in order to supply the BS2 microcontroller with a digital input.

The use of LDRs provides a great low-cost line-tracing sensor. However, it is prone to the ambient light and is also not fast enough in scanning the white lines. Quite many times the robot has diverted from the white lines and junctions since the readings from the LDRs are not fast enough. For such a speed-critical competition, perhaps it is better to implement the infrared sensors and detectors that come in one package like the QRD1114s.

Different configurations for the line tracing sensors could also provide better results in terms of effective scanning of the lines. Instead of three sensors, perhaps the configuration of five sensors being aligned in a semi circle shape might provide better line sensing capability for the robot.

VII. CONCLUSION

Further, we believe that robots can be useful in education of a number of other subjects. For instance, robots can be used as an educational tool for artificial life and biological investigations, as described in [9].

From this robot soccer competition, there are so much knowledge and experience obtained by just building a small-sized soccer robot. Robot soccer competition is indeed a great platform for students to enhance their robotics skills in terms of mechanical construction, circuit interfacing and programming. Besides that, the implementation of good strategies is undeniably important in determining the success of the game played.

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