Design of a Robot Colony and its Application in Entertainment Robotics

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Abstract

Electrical engineering graduates need to be imbued with the knowledge of electronic design and software development. Furthermore, they have to be familiar with electronic components such as sensors, motors, logic devices, microprocessors and many others. This paper reports a project based learning initiative where autonomous mini-robots are developed for research, education and entertainment purposes. The objective of this work is hence two folds. One is to design and develop identical robots to perform a task cooperatively so that they can be used as a platform on multi-robotics research. Second, to expose students to a challenging engineering project where they can put theory in practice and learn various aspects of engineering. Results are presented in this paper.

Keywords: multi robots, robot competition, robots in education

1 Introduction

There is a paradigm shift in engineering education from conventional classroom teaching to hands on project based learning. Among the many possible engineering projects, robotic projects are very useful for students in learning engineering subjects. A major advantage is that students have to deal with an open ended problem and this way their creativity is stimulated. As project incorporates wide range of engineering fields, they can convert variety of theoretical study into practice. Furthermore, they learn team work.

It is expected that students' interest grows when there is fun factor during the learning process. Robot competitions were introduced for this purpose and have been popular for several years. It is now in the academic curriculum of many institutions. Recently, there are many international or local competitions organized regularly (see for instance [1, 2]). The benefits of robot competitions in engineering education are vastly discussed in the following references [3, 4].

In this study, we gave a multi robotics project to our final year students. The project aimed students' learning though the end product is a platform targeted for multi robotics research. As it will be presented in detail, this project involves building robots that can accomplish rather complex tasks. The fun factor introduced by programming these robots to compete in robot colony game which is organized by Singapore Robotic Games (SRG) society [2].

In this competition, a pair of self-contained autonomous mobile robots is expected to search and detect coloured pellets in a bounded area. Pellets must be collected and deposited to a designated pocket for each colour. There are two different coloured pellets available on the platform. The performance of each participating team is graded at the end of the run time of 6 minutes. The number of coloured pellets successfully collected in each designated pocket decides the winner [2].

In order to play this game, robots have to make strategies and decisions for dynamically changing situations and take actions autonomously in order to win the game. Such self-sufficiency introduces a higher level of technical complexity and it is an interesting challenge from engineering point of view. Furthermore, project has research value as many aspects of multi robotics, such as multi robot coordination, localization, mapping and communication [5, 6], are currently investigated by research community. A well known example in literature is robot soccer [7], which was initiated not only for engineering education but also to encourage developments in artificial intelligence and robotics fields. Currently, robot soccer has become an international event and conferences are being organized solely to discuss arising research issues.

This paper provides details on the hardware and the software aspects of the robots developed. Robots were built by third year electrical and electronics engineering diploma students. They have designed and realized the hardware, as well as the software and the strategies necessary to perform the task. In the following sections, we present the hardware, software components and discuss on students learning process.

2 Design of the Robots

2.1 Hardware

Dimensions of the current model of robots is 15cm×15cm× 20cm and it weighs less than 1.5 kg. It is operated with Li-ion batteries. It has 2-wheel drives and a rear balancing caster. A pair of stepper motor steers the robot. The stepper motor used in this design rotates at a standard step size of 1.8 degrees and provides an easy control of the distance that robot covered. The robot chassis is made of aluminium and its structure is flexible to stack electronic boards easily.

Each robot has a grabbing mechanism to secure pellets while carrying them to their target. Grabber consists of two solenoids each attached with a mechanical grabber and a pair of metallic obstructer. Each robot is capable of collecting up to three pellets at once. The main chassis of the robot and the working principle of grabber mechanism are illustrated in Figure 1.

A pellet is pushed into the slot, provided at the centre of the robot, by simply driving robot towards it. Optical sensors placed along the slot indicate the position of the pellet. In order to secure the pellet, a solenoid attached to the grabber latch is activated. This way pellet is tilted and pressed towards the rubber cushion at the opposite side. This mechanism provides a firm grip of pellets as well as minimizes their contact with the ground.

Each robot is controlled by a TI320C2407 DSP with 32kWords of memory and operating at 40 MHz. This processor can deliver 40-MIPS performance and it operates at low-power (+3.3V). It has on chip 10-Bit Analog-to-Digital converters, PWMs, serial communications interface, up to 40 individually programmable general-purpose input/output pins.

Robots are equipped with variety of sensors to negotiate their environment. There are four optical proximity sensors on each robot. Three of these sensors are located at the front, along a semi-circle, to maximise the detection range. Positions of these sensors on the robot are highlighted with circles in Figure 2. Another proximity sensor is placed at the back to prevent back-to-back collision of robots. The sensor produces a voltage corresponding to the distance and the sensitivity to distance ranges between 10cm to 80cm. As proximity sensor produces a voltage proportional to the distance, using ADC of the Digital Signal Processor, robot is able to detect position of an obstruction quite accurately. Furthermore, at the front lower part of the robot, there are three different proximity sensors installed with short, medium, long range to detect the pellets.

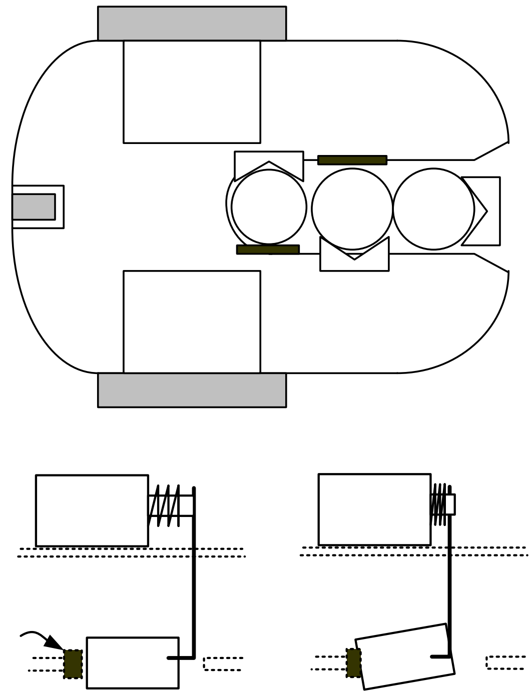

Figure 1: Robot chassis and the grabber mechanism.

Another sensor incorporated in the robot structure is a colour sensor to identify the pellet colour. The sensor used for this purpose produces Red, Green, Blue (RGB) values for a reflected light from an object approximately an inch distance. Built in ADC converters of the DSP processor are utilized to measure the voltages at these three components. The RGB values for each colour to be detected are experimentally found. Later, using a simple threshold method, robot can identify colour of a captured pellet easily.

There are two sets of infrared sensors attached at the front and the back of the robot. Each of these sensor arrays consists of three emitters and three receivers and they face to the ground. These sensors detect the boundaries of the platform.

Working principle of the robot can be summarized as follows: Firstly, the object sensor attached in front of the robot detects a pellet. The robot manoeuvres over and senses the pellet with the RGB colour sensor. Once the colour is determined, the pellet is held in place by the mechanical grabber. The second pellet is held in place in a similar fashion. The third pellet is checked and trapped by a pair of metallic obstructer, which is in front of the robot. In the following section, the program and the strategy developed will briefly be explained.

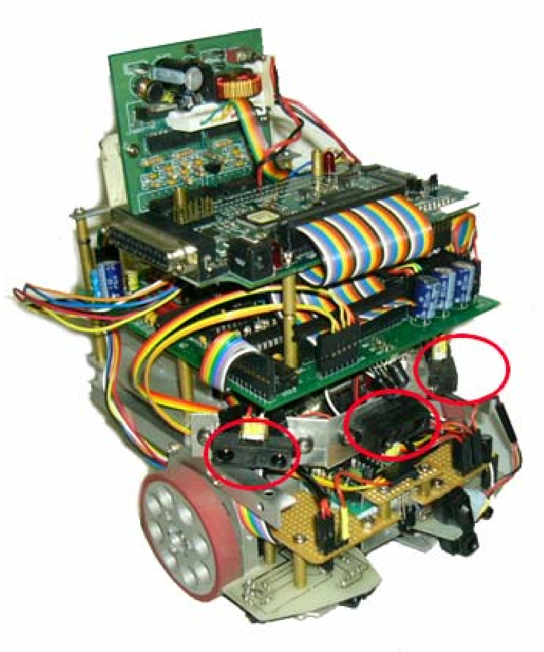

Figure 2: A picture of the robot. Highlighted areas show the position of proximity sensors.

2.2 Software

All the programming is done using C language and compiled with Texas Instruments' code composers. We have developed libraries for the key functions of the robots such as: speed control, rotation, sensor reading, grabbing etc. Further developments on the software can easily be made by using these library calls.

The following pseudo code demonstrates the program developed to play robot colony game:

1. Move towards the centre of the field
2. Turn 360 degrees to search for surrounding pellets
3. Move towards the nearest detected pellet
4. Identify the colour of the pellet and grab the pellet
5. Continue search until the robot is filled with pellets
6. Move towards direction of the deposit stations depending on the colour of the last pellet
7. Deposit pellets
8. Repeat the process from 1

During searching and detection of pellets a combination of sensor reading is utilized. This method improves the reliability of the sensory data and consequently the performance of the robots. For short and medium distances, we employ infrared sensors and for longer distances, we employ optical proximity sensors. All these sensors are located at the front side, at the pellet level of the robot. The medium range infrared sensor is used to sense pellets that are at short range. The close range infrared sensor is used to fine-tune the direction of the robot when the pellets are very near. The optical proximity sensor is used to sense pellets that are at far. During a pivot move for searching pellets, robot utilizes medium range infrared sensor and the long range optical proximity sensor simultaneously. When either one of the sensor senses the pellet, the robot will move towards that direction. While moving forward, robot will turn on the close range infra red sensor to fine tune the direction of the robot. Robot's movement during search is depicted in Figure 3.

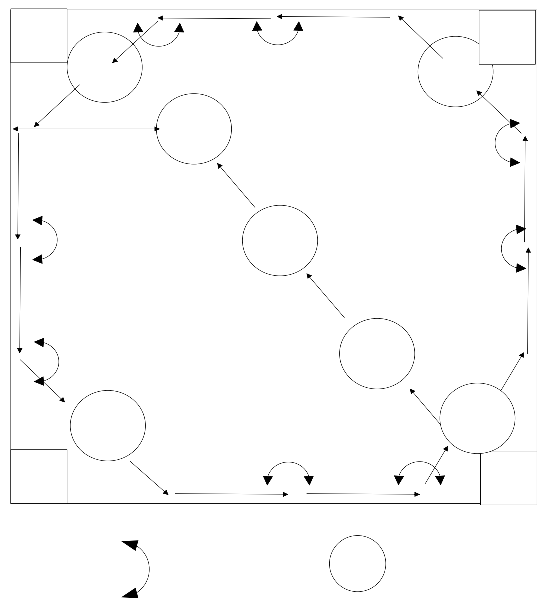

Figure 3: Robot movement during search.

Robot speed control: The robot is mobilized with a pair of stepper motors. The speed of the robot is variable and its control algorithm is available as a library function. The speed of the robot is then controlled dynamically depending on the situation of the game. For example, the robot will slow down when it senses another robot nearby or when it is near the edge of the board.

Anti Collision: The four optical range sensors located at the upper portion of the robot are mainly to prevent collision. Depending on which sensor is sensing and the range of the obstacle detected, the robot will behave accordingly. For example, if the sensor detects another robot at a very close range, it will retreat backwards for a certain distance. If the distance to obstacle is rather far, it will stop in its position and wait. To avoid a deadlock situation, we employ a priority scheme where one of the robots has higher privilege than the other. Hence, a situation where both robot sense each other and stop indefinitely is avoided.

Strategy for pellet depositing: The competition field is in square form and boundaries are highlighted with yellow lines. There are four small boxes at each corner where two of them are dedicated for pellet depositing. A robot can not differentiate the yellow box which indicates deposit station from any other yellow line in the field. Hence, there is a risk of misalignment during depositing of the pellets. When depositing pellets, a robot will align itself with the yellow line using its infrared sensors, before turning left and aligning itself again on the right. Only the right infrared sensors should sense the yellow line. Once both alignment sensors detect a yellow line again, it will assume that it is near the hole and will get ready to deposit by moving a fixed number of steps. We worked around this problem by using the timer of the DSP and robot's movement to measure the length of the line encountered. These operations and robots decision steps are illustrated in Figure 4.

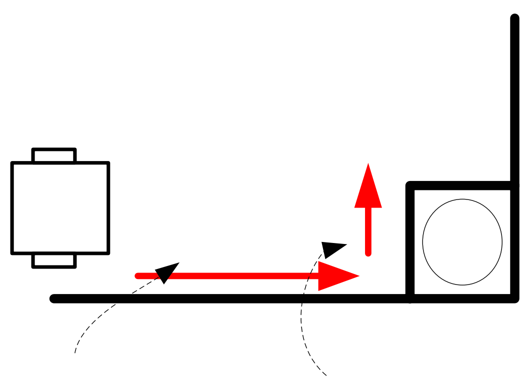

Figure 4: Robot detecting a deposit station.

3 Performance

It is important to note that in this application, we implement a navigation algorithm based on the knowledge about the robot's environment. It employs an evidence based strategy to navigate instead of conventional coordinate based method. That is sensory information processed and used to obtain a description of the robot's environment. A decision is made by comparing the world model known to robot and the sensory information. Although, the software developed for this robot is for game playing, the fundamental idea explored is a human like navigation. Human beings interpret their environment to travel from one point to another.

We conducted a series of experiments in order to measure the performance of robots in a more tangible manner. We run the robots for 6 minutes as defined in the game regulations. We repeat these experiments ten times. Table 1 shows detailed results of the experiments conducted. We observe that robots can pick up approximately 40 pellets on the average. Percentage of wrong pellet collection was %4. During operation, robots may entangle or go out of the field or encounter some other difficulties, in which case a reset is necessary. Number of resets performed during each trial is also recorded as a performance indicator. Figure 5 shows a picture of two robots on the field working together to complete the task.

Table 1: Performance results during the test trials.

Trial	Pellets collected	Wrong pellets	Number of resets
1	40	5	4
2	43	3	3
3	41	0	2
4	43	4	3
5	42	0	2
6	45	0	2
7	38	0	3
8	40	0	2
9	42	0	3
10	39	2	1
Average:	41.3	1.4	2.5

Figure 5: Robot pair collaborating to dispose all the pellets on the board to designated locations.

4 Learning experience

The project presented here integrates many aspects of an engineering application and it is primarily used to cultivate a problem based learning approach to engineering students. The duration of their project is about nine months, beginning at July and completed in March of the following year. Students who took up this project were aware of C programming and they did not need any refreshing for their programming skills. However, they needed assistance to program a digital signal processor as they have no experience with this processor. They did not face a major difficulty in their first four months while they were building up the basic theory.

Through out this project they have encountered many challenges and learned to overcome them. For instance, the grabber mechanism is purely designed by the students. Their initial design was grabbing a single pellet. However, they progress well in their design and built a multiple pellet grabbing mechanism at the end. Through out the project they transferred their theory in signal processing, control theory, and programming into practice. In addition, they have learned materials that are not included in their curriculum such as basics of artificial intelligence. In conclusion, students learning experience was thriving and project reached the objectives.

5 Summary

In this paper, we present design of a multi-robot system which is the result of a project based learning initiative. The robots are equipped with a high performance processor, various types of sensors and simple grabber mechanism. Robots are robust and perform well. Currently, they are programmed to play a robotics game for competition, though, design is generic and they can also be used for research and experiment purposes. Furthermore, this study enhanced student's problem solving skills and they gained a vast experience in realizing engineering projects. Lately, we have included an RF module and a communication protocol so that more complex algorithms can be implemented on these robots. In future, we are planning to develop simpler and smaller version robots in order to conduct experiments in artificial intelligence and multi-robotics fields.

6 Acknowledgements

Author wishes to acknowledge valuable contributions of his students Albert Ho, Shen Yunting, Mervyn Khoo, Ha Lai Tuck and Loh Jing Da.

7 References

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