

RoboBOX: A SMALL MOBILE ROBOT KIT FOR LEARNING ROBOTICS

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Abstract

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One of the important issues in meeting the challenges of globalization is preparing our future workforce. The current batch of students need only not to be excellent in their academic studies, but also need to be good in other skills such as being creative, innovative, and able to communicate well. The authors of this paper, has embarked on a unique project to develop a scheme in the area of robotics to provide a platform for the students to learn and explore beyond what they are taught in classrooms. Robotics is chosen as the area of study because it is acknowledged as a highly motivating activity for students. It is one of the unique areas where several fields in science and technology may overlap.

This paper reviews the development of a robotic kit, with the students as the main target user, as well as conducting robot competition for the students.

It is acknowledged that there are various robotic kits available. However, most of them are either too technically advanced or too expensive. We designed our robot kit with two design philosophies – affordable by all and can be used by all. The robot is also designed to be upgradeable where additional modules may be added to give extra functions or features. We have come up with the first prototype of the robot, which is named RoboBOX.

1. Introduction

RoboBOX is the name that is given to a small-sized mobile robot kit developed by Mobile Robotic Group of UNITEN (MRG). This name is given because of its boxy shape and size, and also to reflect the simplicity in design and easy to use.



Figure 1: RoboBOX

The target users of this robot kit are students and those who want to start learning about robotics. The kit is designed to be simple enough for the beginner and also flexible enough for more advance user. The basic or starter kit comes with basic components where the new user can build and use easily. This basic kit may be upgraded by adding additional modules, to give more functions and features, allowing the advance user to produce a more sophisticated and powerful robots.

What is a mobile robot? A simple explanation would be a type of robot that is able to move its entire body from one place to another on its own. Normally, it would have some sort of autonomous or self navigation system. Some examples of the more sophisticated mobile robot include the wall climbing robot[1], vacuum cleaner robot[2,3] and the robot that was send to explore Mars[4]. However, it this project, we focused on small and simple mobile robot for the use of students and beginner in robotics.

RoboBOX is categorized as a small-sized robot kit due to its size of around 20cm x 20cm x 20cm and the weight of around 200g. However, due to its 'upgradeability' the sizes and weight may change with the additional modules added.

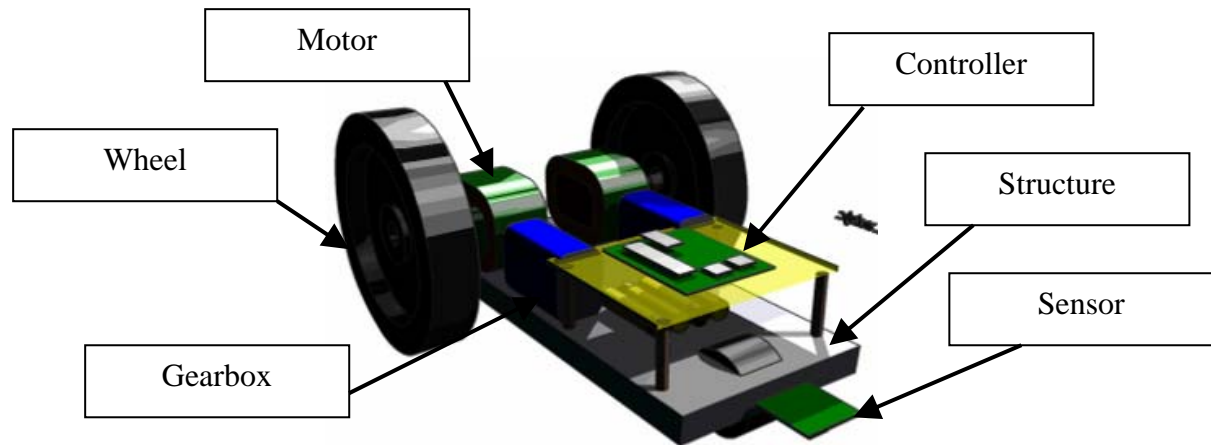


Figure 2: Basic component of a simple mobile robot

In this project, the robot is designed to be as simple as possible, yet flexible, where it has the capability to be upgraded to a more powerful robot and having a number of different functions.

2. Robot platform in education

The use of robots, especially small mobile robots, in education has been growing worldwide for the past several years. It is used to educate the students from primary and secondary school children to university students. It is said that the popularity of robotics in education is because it offers an excellent platform for teaching various different engineering disciplines as well as the integration into systems [5]. Robotics is an interdisciplinary topic that requires the knowledge in mechanical, electronics, control and also computer programming.

In Massachusetts Institute of Technology (MIT), one of the courses in Electrical Engineering and Computer Science is known as 6.270 Autonomous Robot Design Competition [6]. This is a unique course where the registered students will become a participant in designing and building a robot that will play in a competition at the end of the course. The course is a hands-on, practical subject where the students need to apply what they have learnt. Other experiences using robots in different degree courses have been reported, for example, on software engineer project [7], hardware based vision [8], data structure courses [9], and freshman engineering course [10]

Robotics has also been used in primary and secondary level schools. Ruiz-del-Solar [11] has reported on his experiences and positive outcomes of working with school children using

robots as a tool to interest the students in science and technology. It is discovered that robotics is a highly motivating activity for children. A number of other experiences on using robots for school children are reported, for example, working with elementary school children [12] and K-12 school [13].

Various robotic-based competitions are organized annually. Most of the robotic-based competitions are considered educational as they target students as the participants, and having useful learning outcomes. It is reported that the students learn on various fields while working on robot contest [14]. Among popular international competitions are FIRA RoboCUP [15], Robosoccer [16], Robofesta (UK) [17] and FIRST robotic competition (USA) [18]. Robotic competitions are also organized nationally. For secondary school children, Robocup Junior [19] is organized annually by SIRIM and Ministry of Education (MOE). Robocon [20], which stands for Robot Contest, is organized annually since 2002 by RTM, MOE, Ministry of Science, Technology and Innovation (MOSTI) and SIRIM. Robocon is targeted specifically for tertiary level students.

In the local scene, it is noticeable that these kinds of robotics projects and competition have grown in interest in the past several years. As this is new to us, several issues and problems were encountered. Among the issues that have surfaced, are the availability of robot kits and hardware, facilities and knowledge. Since that this type of robotics projects are relatively new in Malaysia, not many people are expert in this area. Another big issue is the availability and cost of robot kit and hardware. It is acknowledged that, there are a number of robot kits available commercially in the market. However, most of them are either not available locally or too expensive. Another option is to self-develop the robot from scratch. However, this is not easy and too time consuming especially for the beginner or school children.

Among the popular robot kits are Elekit robot kit, LEGO Mindstorm robotic kit [21] and BEAM robotics [22] which are used in various competitions and also as a learning tools in classrooms [23-30].

3. The RoboBOX

Two main design objectives have been set when developing the robot kit. They are:

- (1) It may be used by all, where the kit easy enough to be used even by primary school children
- (2) It is affordable by all, where the cost shall be made to as minimum as possible

The first objective is very important, because the main target users are from primary school children. This would mean that the assembly should be easy enough, the number of components should be made to a minimum, sufficient resource and information shall be made available to them and also off-the-shelf and common components shall be used.

The second objective is to keep the cost as low as possible. One of the stumbling blocks in carrying out robotic project is the relatively high cost of hardware and components. Based on the price survey done on robot kits, a basic Lego Mindstorm set can cost between RM1000-1500, and an Elekit robot can cost around RM500. Therefore, in designing, the cost factor is one of the most important considerations. On the related issue, the components used shall be sources locally, meaning that the parts and components used are available in local shops. This is not only to keep the cost to minimum, but also to ensure that spare parts are easily available.

Apart from the two main design objectives, a few other elements are considered. Since that this kit is also targeted to be used by university student, it needs to be more flexible and modular so that it could be easily customized to suit different applications and competitions. This would give a more added value to the robot by making it to be upgradeable. The design follows modular concept, where additional modules can be added to give different functions.

As the basic RoboBOX kit is targeted to beginner, the basic function that the robot can do is to follow or track a line. This is one of the simplest functions that a robot can do. A line follower robot is able to move by following a given line (normally black line on white background) by itself.



Figure 3: RoboBOX as line follower robot

Basically the robot kit is divided into 4 main components, which are the structure, driving and steering system, electronics and power system. The structure is important to hold all other components. It will also determine the appearance of the robot. As the robot is mobile, it needs to have driving and steering mechanism. The robot will have the ability to move forward, turning to right and left, as well as spinning on one point. The electronics parts cover the control system and the sensor, which determine the behavior of the robot. The last but not least is the power supply. Without power the robot cannot move. DC power source is used to supply energy to the robot.



Figure 4: The components of RoboBOX

3.1 Mechanical structure

The structure is the casing to house and mounts all other components. Plastic box is chosen because of its low cost, easily available, sufficiently strong, and easy to be drilled. Different sizes of box can be used to make the structure. The only constraint is the size. It must be big enough to fit all components inside it. Transparent or semi-transparent plastic box is chosen mainly because the line sensors are placed inside the box.



Figure 5: Various shapes and sizes of the plastic box used as the structure

3.2 Driving and steering system

The robot is supported by two independent wheels and using differential steering system. This configuration is one of the most common and simple system for a mobile robot. Each wheel is connected by a driving shaft to a gearbox and motor. By having each wheel to be connected to different motors, this would allow the robot to move forward, backward, turning left and right. This is further illustrated in Figure 6.

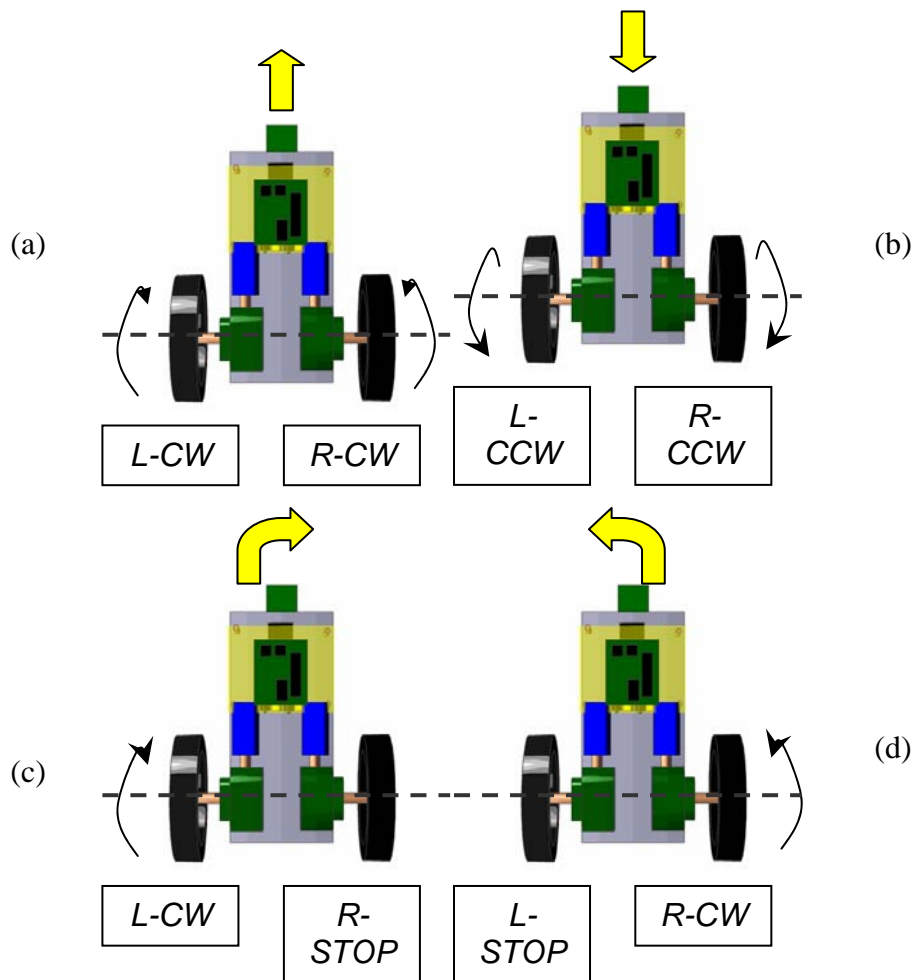


Figure 6: Top view of the robot showing how differential steering works.

(a) Moving forward (left and right wheel rotates clockwise) (b) Moving backward

(c) Turning right (d) Turning left

3.3 Electronics: Controller and Sensor

The electronics of the robot can be divided into two: motor control and sensor circuitry. The motor control circuit is used to control two small DC motors on the robot via an L293 chip that acts as a motor driver. For the students, they were given the L293B variant of the motor driver because it can withstand currents up to 1000mA per channel, which is more than enough to accommodate the motors that are supplied to the students. The L293 motor drivers will be controlled by signals given by the sensor circuitry.

On the sensor circuitry, two sets of sensors are used to detect the line, shown in Figure 11. Sensors used are the Cadmium-Sulfide (CdS) sensor or more commonly known as the Light Dependant Resistor (LDR). Readings from the LDR is amplified and digitized through a threshold comparator. The digital output from the comparator is the signal used to control the motor driver and thus driving the motors on the RoboBOX. The block diagram in Figure 7 shows how the electronic system is arranged.

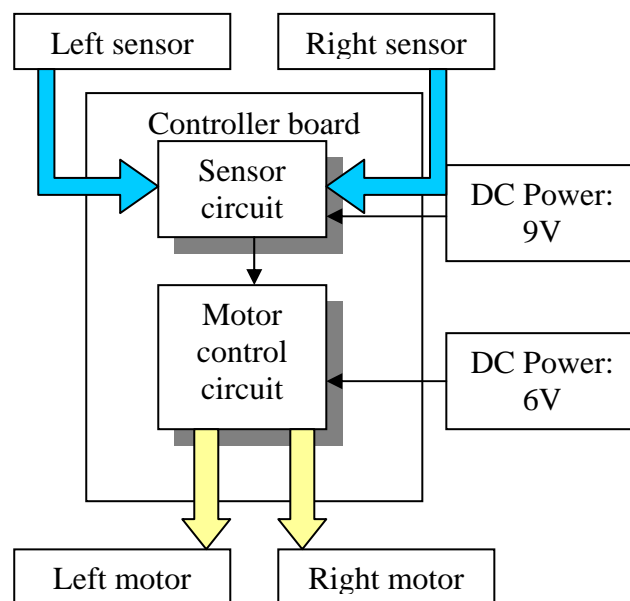


Figure 7: RoboBOX electronic system block diagram

For the basic kit, the circuit can either be built on a protoboard or soldered-on stripboard. Figure 8 illustrates the difference between the two. In terms of functionality, both circuits work exactly the same. However, esthetically the soldered-on version is smaller (fits better into the box) and is more robust.

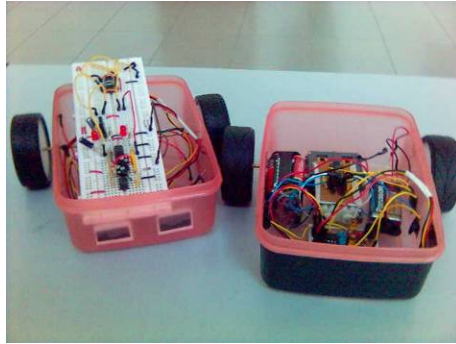


Figure 8: On the left – on protoboard, and on the right – soldered version

The circuit diagram, data sheet and components lists are prepared and provided to the student. Here, the student will have an opportunity to learn to read electrical diagrams.

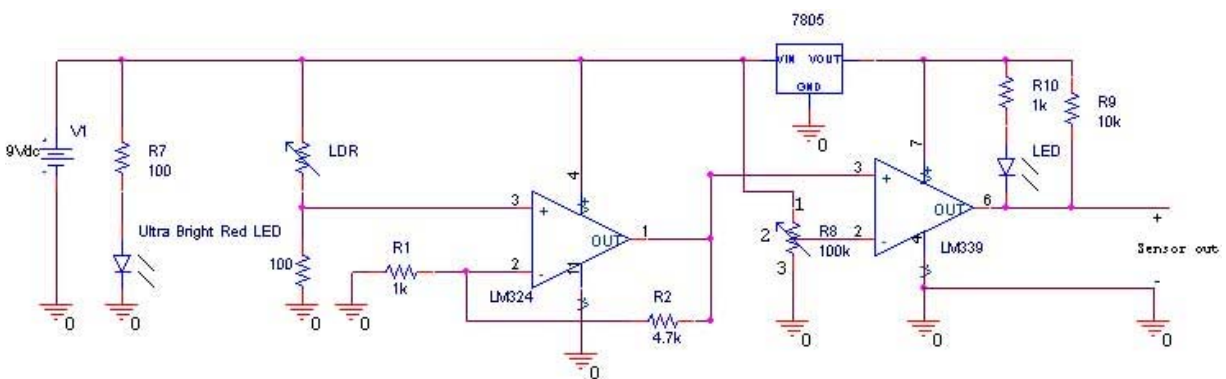


Figure 9: Basic Line sensor circuit

Also included and given to the students is a layout of the sensory circuit on a protoboard. However, from experiences conducted with the students, they will not refer to the electronic diagram when they are provided with this protoboard diagram.

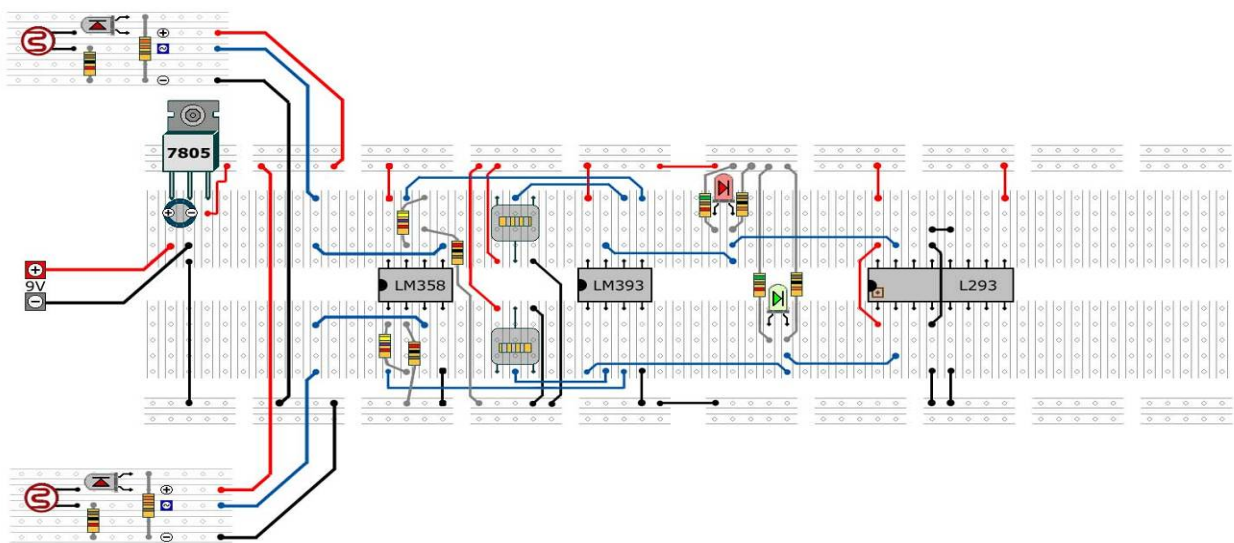


Figure 10: The layout of the components on the protoboard.

3.4 Power supply

Off-the-shelf, standard batteries are used. Four 1.5V AA-sized batteries are used to power the motors and one 9V battery is used to power other electronic parts as well as the sensors. As the weight of the batteries is significantly high relative to the weight of the robot, the placement of them will affect the movement and balance of the robot.

3.5 RoboBOX components

The components for basic or starter kit include twin gearbox motor system, drive shaft, plastic wheel, plastic box, line sensors, mounting bracket and connecting wires.

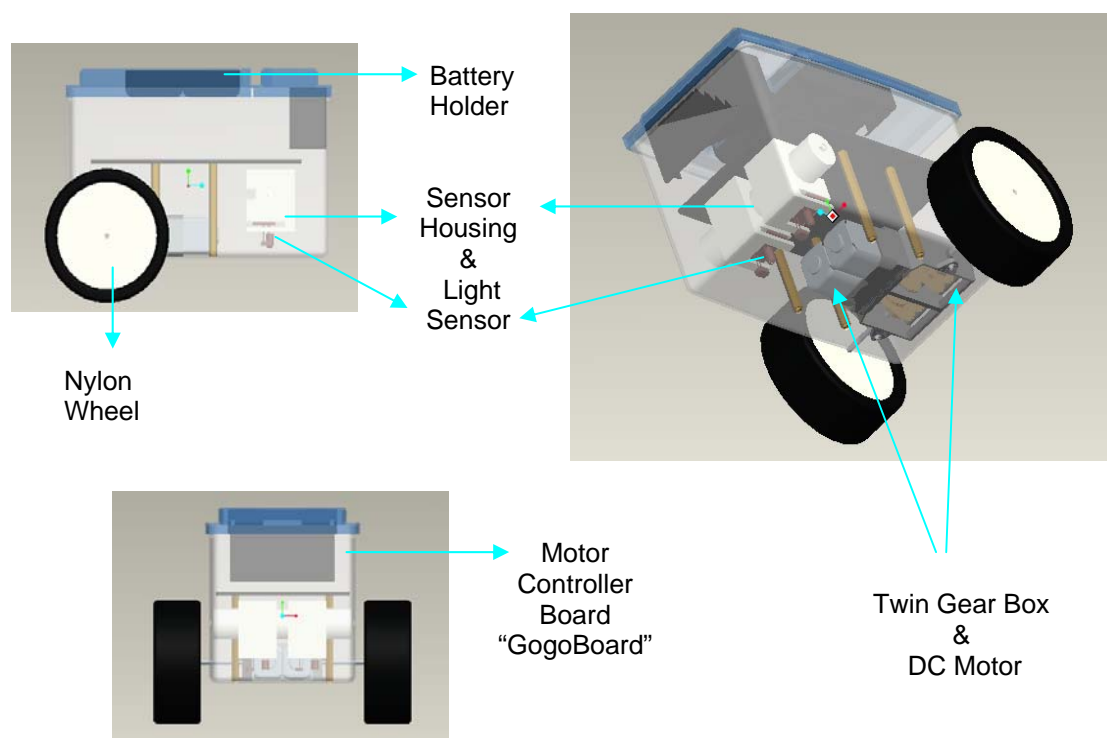


Figure 11: 3D model of the RoboBOX, showing the major components

3.6 RoboBOX Configurations

The main idea of RoboBOX design is to provide a general platform for robotics kit construction. All the components are packaged into module form to allow upgrade and reconfiguration of the system. A lunch box design as the main housing is to provide a general and easily available platform to house all the components. It allows the user's own creativity

to utilize daily products to build robots. The first version in RoboBOX series, a line follower robot design has been adopted for the basic RoboBOX kit called RaceBOX. It consists of a logic controller circuit, visible light sensors, driving system and power supply.

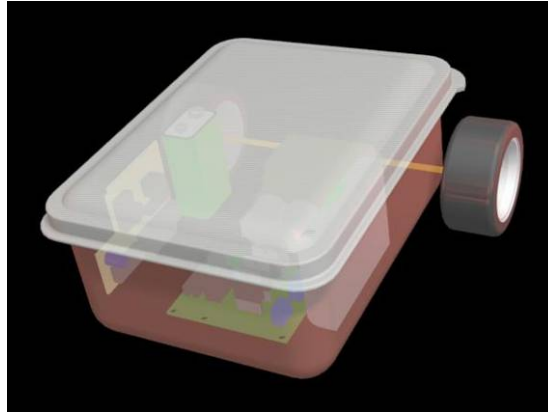


Figure 12: RaceBOX – Line Follower RoboBOX

With the same hardware, it can be transformed from wheels system to tank-treaded design in NaviBOX. By adding an IR proximity sensor, the same system can be enhanced with object avoidance capability.

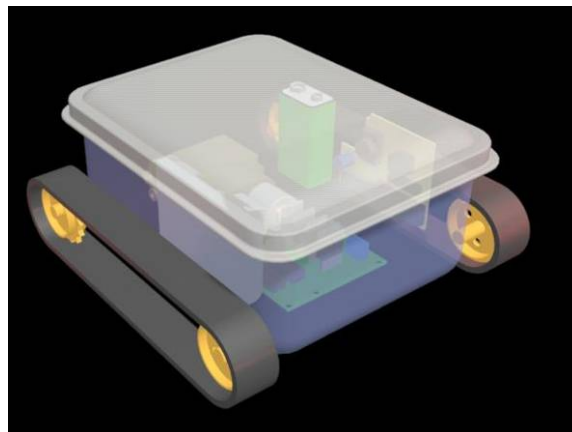


Figure13: NaviBOX – Object Avoidance RoboBOX

Currently, the latest version of RoboBOX is GoGoBOX – the integration of RoboBOX with an open source microcontroller, GoGoBoard. This combination further enhanced RoboBOX controller system to become reprogrammable.

The unlimited expandability of configuration with less demanding resources is the main concept of RoboBOX. Simple yet flexible design makes it a great tool for research and education. The only limitation is the creativity of the user.



Figure 14: Clockwise from upper left – First prototype of RoboBOX, Start/basic kit, RoboBOX components in unassembled form, GoGoBOX

5. Preliminary Evaluation and Discussions

5.1 RoboBOX Line Racing

A competition was held internally involving the robot kit. This competition is opened to any UNITEN students. It is organized mainly to gauge how well the robot would work and the students' response to it. Ten groups of students registered to participate in the competition. Each group consisted of three members. The students came from ME and EE department, from first until final year. The competition attracted both male and female students. Each group was provided with an unassembled RoboBOX Kit, as shown in Figure 15, one week before the competition.



Figure 15: RoboBOX components

A 'racing track' was designed using black masking tape on white polystyrene background as shown in Figure 16. The track consisted of several smooth curves and a couple of sharp curve to test the ability of the robot to navigate around the track. Each team was allowed to go along the track twice. Time was taken and the fastest time will win the game.



Figure 16: Track used in RoboBOX line racing

During the preparing and competition, it is observed that most groups were able to assemble and make the robot move within two to three days. There a few teams that was able to make the robot work within one night (before the game!). Even though most of them can make the robot moves, they faced a number of problems. For some, their robots were not reliable, where the robot did not work all the time and troubleshooting need to be done to find the cause. A lot of problems were caused in the circuitry system where the components were not place properly and securely when they were built. Another issue was to get the robot moving as fast as possible and at the same time completing the track. It is observed that if the robot moved too fast, it might miss the corners and run out of the track causing it to be disqualified. Fine tuning need to be done, and a lot of the students spend the whole night before the competition to get it right. It is observed that some of the factors affecting the performance of

the robot are the positioning of the sensors, the battery capacity, and the components and battery placement.

At the end of the competition, the winner, first runner up and the best design robot were awarded with a small token of appreciation. Generally, it is observed that the students are satisfied and happy with the game. They have put a lot of effort in building the robot and making the robot moved as fast as possible. Most of them said that they would be interested to joint similar event in the future.

5.2 Measurement class project

During the previous special semester, a project-cum-competition was conducted. The competition is similar to the RoboBOX Line Racing competition held previously. However, the track is designed differently, where two teams will compete at one time, to reach to the centre of the track, as shown in Figure 17. The team that reached the centre first will be considered as the winner.

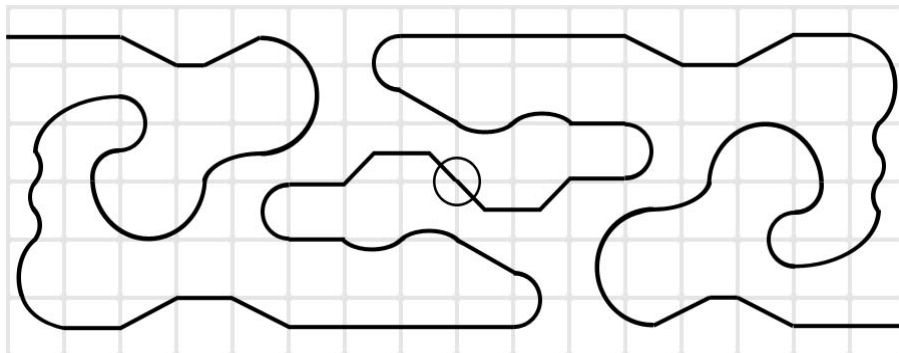


Figure 17: Track for EEEB211 Special Semester Project

This time, more information, resources and guide were given to the students to help them in building the robot. A briefing was given to give them a kick start. During this briefing they were inform how to build to robot, how the electronics system worked and also how to win.

A survey was given to the participants to obtain their feedback on the robot kit and the competition. In the survey, 70.5% indicate that this is the first time that they have involved in robotic project. The remaining indicates that they have involved in robotic project either during they school days or national level competitions such as Robocon and Robofest.

On the building of the robot kit, most of the students said that they would require a few days to completely assemble the robot. 11.8% said they only need a few hours to complete it, and 32.3% said they need about one day to finish. Once the robot has been assembled, most of the students said they need a few days to get the robot to be fully working.

Table 1: Time taken to assemble the robot.

Duration	Response
A few hours	11.8 %
About one day	32.3 %
A few days	52.9 %

On the response to the impact of this project or competition on the subject, 82.4% strongly agree that it makes the subject more interesting. Half of the students agreed that it makes the subject easier to understand and 57.9% agreed that this project is making them want to learn more on the subject.

Table 2: Impact of this project on the subject

Impact	Response (%)			
	Disagree	Neutral	Agree	Strongly agree
• Makes the subject more interesting	0	11.8	5.9	82.4
• Makes the subject easier to be understand	0	11.1	50.0	38.9
• Makes you want to learn more on the subject	0	10.5	57.9	31.6

The students were also asked how they feel about this project. Most of them indicated that it is interesting (84.6%), useful (61.5%), exciting (76.9%), fun (84.6%) and enjoyable (69.2%).

Conclusions

This paper reviews the development of a robot kit, that we called RoboBOX which aims to be an educational robot platform for learning robotics especially for school children. The main characteristics of this robot kit are easy to be used, cost effective, and using modular concept for flexibility of use. Teaching and learning can take place in groups of students by having projects or competitions employing the robot kit. In these projects, the practical or hands-on approach will offer exciting and challenging tasks which should help to develop engineering skills including design and problem solving, creativity and teamwork.

Based on the competitions and projects that were carried out, most of the students responded very positively to the use of the robot kit. It can be said that the projects gave them new and interesting challenge, which they could not obtain from a normal classroom. Most of them are able to assemble and make the robot work in a relatively short time.

All components used in the kit are sourced locally. The overall cost of the components is also kept to minimum, which is around RM100.

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