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LINE FOLLOWING ROBOT WITH HIGH RADIATION MATERIAL DETECTION CAPABILITY

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ABSTRACT

Advancement in technology have led to a rapid development in the design and manufacturing of robots, enabling them to provide human capabilities without the inherent shortcoming associated with human capabilities; such as boredom, fear, inefficiency etc. A mobile robot that can sense and observe the line drawn on the floor is the Line Follower Robot. The direction is usually predefined and can be either visible on a white surface with a high contrast colour like a black line or invisible like a magnetic field. Hence, with its Infrared Ray (IR) sensors mounted under the robot, this sort of robot can feel the line. Then, the information is conveyed by specific transition buses to the processor. The processor will determine the right commands and then send them to the driver, and the line follower robot will then follow the direction. Therefore, this paper focuses on the design of a mobile line following robot for detecting the high radiation level of a sample farmland and display on a 7-segment display by the aid of sensors to navigate through grid. The mobile line following robot must move through the squares and detect the high radiation levels and at the end provides us with information on the number of squares and detected high radiation levels. The robot's area of operation is limited to six squares each of dimension 60cm×60 cm. Silver coloured square spots with dimensions of 5 cm by 5 cm made of foil paper are used to indicate a high radiation level.

Keywords: Mobile Line Following Robot, Farmland, LDR Sensors, Infrared Ray, 7-Segment Display.

INTRODUCTION

The field of robotics has been hastily expanding in this 21st century due to advancement in science and technology. Rapid development in the design and manufacturing of robots enable them to offer human capabilities without the shortcoming associated from human such as slow response, vulnerability, inefficiency and forgetfulness. Mobile robots are one of those robots that can deliver human ability which in this case, it can move from one place to another. This provides a robot a much greater flexibility to perform complex and exciting tasks. Due to its mobility, this robot is used in many applications such as farm automation, hospital, education, entertainment, space exploration, military and security system (A.G. & Aisha, 2010).

Essentially, since the advent of the nuclear age, man has unwittingly produced environment in which access was limited largely due to the danger presented by excessive amounts of exposure to radiation, but also due to space limitations, and due to poisonous and combustible atmospheres. Robotic systems offer an optimal response to any of these challenges, removing the need for human entry to these locations and often supplying reports on the status of such locations that would otherwise not be accessible (Tsitsimpelis *et al.*, 2019).

Mobile robots can be grouped into few categories which one of it is autonomous robots. Autonomous robots are intelligent machines capable of performing tasks in the world by themselves, without explicit human control over their movements (G.A. Bekey, 2005). It is defined that, a robot is a machine that thinks, senses and acts. In artificial intelligence, such systems are known as "agents". Autonomous robots are distinguished from software agents that they are embodied and situated in real world. They receive information from the world through their sensors. For example, there are robots that can kick the ball, assembled parts, washing the airplanes, and etc. Autonomous robots are increasingly evident in many aspects of industry and everyday life (K. L. Su *et al.*, 2014).

The components of a basic autonomous robot are a controller, control software, sensors and actuators (S. Böttcher, 2006, J. E. Mckenzie, 2012). The designer defines the robot's starting point and the robot can then move with respect to this point along desired path with the aid of sensors. The controller is generally a microprocessor, embedded microcontroller or a personal computer (PC). Mobile control software can be either assembly level language or high-level languages such as C, C++, Pascal, FORTRAN or special real-time software. The sensors used are dependent upon the requirements of the robot. The actuators associated with the robot serves as final control elements in which information perceived by the sensors are processed and transformed into a desired a mechanical action (S. G. Tzafestas, 2014).

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LITERATURE REVIEW

An autonomous robot which detects and follows a line is called a line follower. The direction can be clear on a white surface like a black line, or it can be inverted or it can be opaque like a magnetic field. In the robot, a near loop control scheme is used. To remain on course when correcting the wrong moves using a feedback mechanism, the robot must sense a line and manoeuvres accordingly, creating a basic yet successful closed loop system (Pakdaman & Sanaatiyan, 2009). An Implementation of Autonomous Line Follower Robot was discussed. The idea of the robot which has been presented in this paper employs instructions from sensors and on-board logic circuits to achieve its physical movement. One of its significant attributes is controlling efficiently with very much accuracy. It does not use complex algorithms for line following applications (Kazi Mahmud *et al*., 2012).

The development of a line follower wheeled mobile robot was presented. In this project, LM3S811 which is ARM cortex-3 based microcontroller is chosen as the main controller to react towards the data received from infra-red line sensors to give fast, smooth, accurate and safe movement in partially structured environment. A dynamic PID control algorithm has been proposed to improve the navigation reliability of the wheeled mobile robot which uses differential drive locomotion system. The experimental results show that the dynamic PID algorithm can be performed under the system real-time requirements (Mustafa & Dilúad, 2012).

Mehran Pakdaman illustrated the process of design, implementation and testing TABAR, a small line follower robot designed for the line follower robot’s competition. The designed robot has eight infrared sensors on the bottom for detect line. Microcontroller ATMega16 and driver L298 were used to control direction and speed of motors. The robot is controlled by the microcontroller. In performs change the motor direction by giving signal to driver IC according to receives signals from sensors (Pakdaman & Sanaatiyan, 2009).

I. SYSTEM DESCRIPTION

A. Overview

The mobile robot is design to detect the dangerous radiation material in a farm land and display on 7 segment display. The robot is equipped with sensors to navigate through the farm land square grids. The mobile robot will be moving along all the six squares and detect the high radiation materials. At the end, it will provide the number of radiation material square detected by the mobile robot.

The sample farm land consists of a grid of six 60 cm x 60 cm squares. The grid consists of black tapes (1.8 cm width) separating the farm land into six squares. Squares with 5 cm x 5 cm size in the grid indicate high radiation material while the grid without the square indicates low/no radiation material. The high radiation material can be in any grid squares. It is a high light reflective material which randomly placed (see **Figures 1** and **9**).

Appropriate sensors and software are embedded to the robot to navigate through the grid to detect and collect data. The squares with high radiation material are stored in memory for later reporting. The robot is based on existing frame with 2 servos controlling the wheels. The diameter of the robot is 18 cm. The robot enters the grid from square 6 and exits from square 1. The Arduino ATmega328 microcontroller is used as an onboard microcontroller for the purpose of coordinating all the components based upon the desired objective. The entire system is powered by 9.0V DC source.

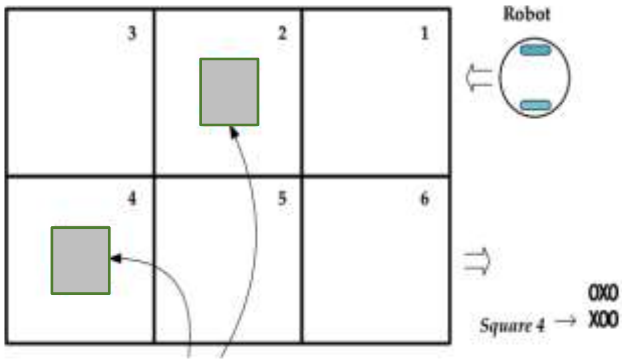


Figure 1: Farm Land Square Grids

B. Electronic Components

The electronic components used to complete the mobile robot are Infrared (IR) sensors (three units), Light Dependent Resistor (LDR) sensor (one unit), 7805 voltage regulators (one unit), push buttons (two units) and 7-segment display (one unit). Two IR sensors are used for the mobile robot to move following the grid lines of farm land, while the other one IR sensor is used for detecting which grid the mobile robot is situated (location of mobile robot).

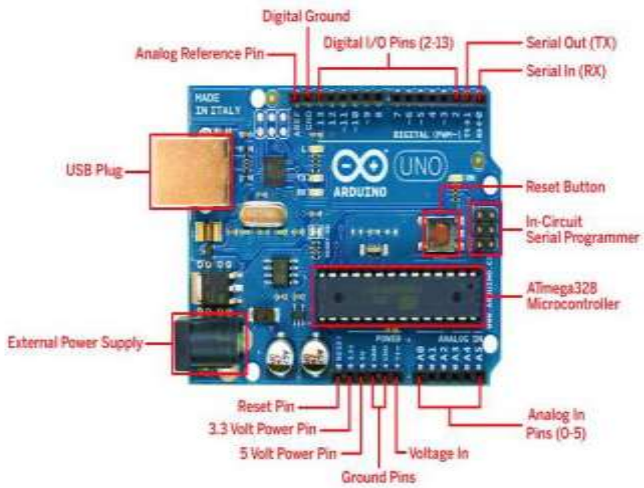
The LDR sensor is used to detect the high radiation material inside the farm land square. With the aid of coding, the number of radiation material will be counted. The two push buttons are for Start/Stop function (one unit). The 7-segment display helps to show the number of high radiation material as the mobile robot goes along the farm land. Finally, the 7805-voltage regulator is used for the power supply to the board and ensure it receive safe voltage supply.

C. Arduino with ATmega328 Microcontroller

The Arduino Uno is a microcontroller board based on the Atmel ATmega328 8-bit microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. This Arduino MCU board contains everything needed to support the microcontroller. And to get started, simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery [10].

The Uno can be programmed with the Arduino Software (Integrated Development Environment) which is a simplified version of the C / C++ programming language. The Arduino Uno provides users with the possibility to develop a program on any computer and download it to the board directly and it runs automatically. It also contains a Boot loader that allows the user to run new programs without the use of an external hardware programmer. The pin out configuration is shown in **Figure 2**.

Figure 2: Arduino Uno Pin Configuration



D. *Wheel Drive System*

The wheel drive system consists of two continuous rotational servomotors (GWS servo S03N STD). A servomotor is an assembled of a DC motor, gear assembly, and 5 potentiometers in conjunction with an intelligent circuit. The gears rotate based on a command desired by the operator.

A continuous servo motors is basically the modified version of the actual servos. They are made to rotate up to 360° by changing some mechanical connections of the basic servo motors.

Figure 3: GWS servo S03N STD

B. *Specifications*

The requirements are to design a mobile robot with appropriate sensors and software to navigate through the farm land grid to detect and collect data. The data is to be send to 7 segment display. The specifications for the robot systems are as follows:

a. The sample farm land consists of grids of six 60cm x 60cm squares.
b. The grids consist of black tapes (1.8cm width) separating the farm land into six squares.
c. Silver squares with dimension 5 cm x 5 cm in the grid indicate the presence of high radiation materials, while grids without silver squares indicate low/no radiation material.
d. Silver squares for the high radiation materials can be randomly placed in any grid.

II. DESIGN AND CONSTRUCTION

Overview

This chapter describes the technical details of the design which includes the hardware components; power condition circuit design, sensor connection, servo connection, and software development as well as platform arrangement. **Figure 4** shows the methodology flow followed during the hardware and software development.

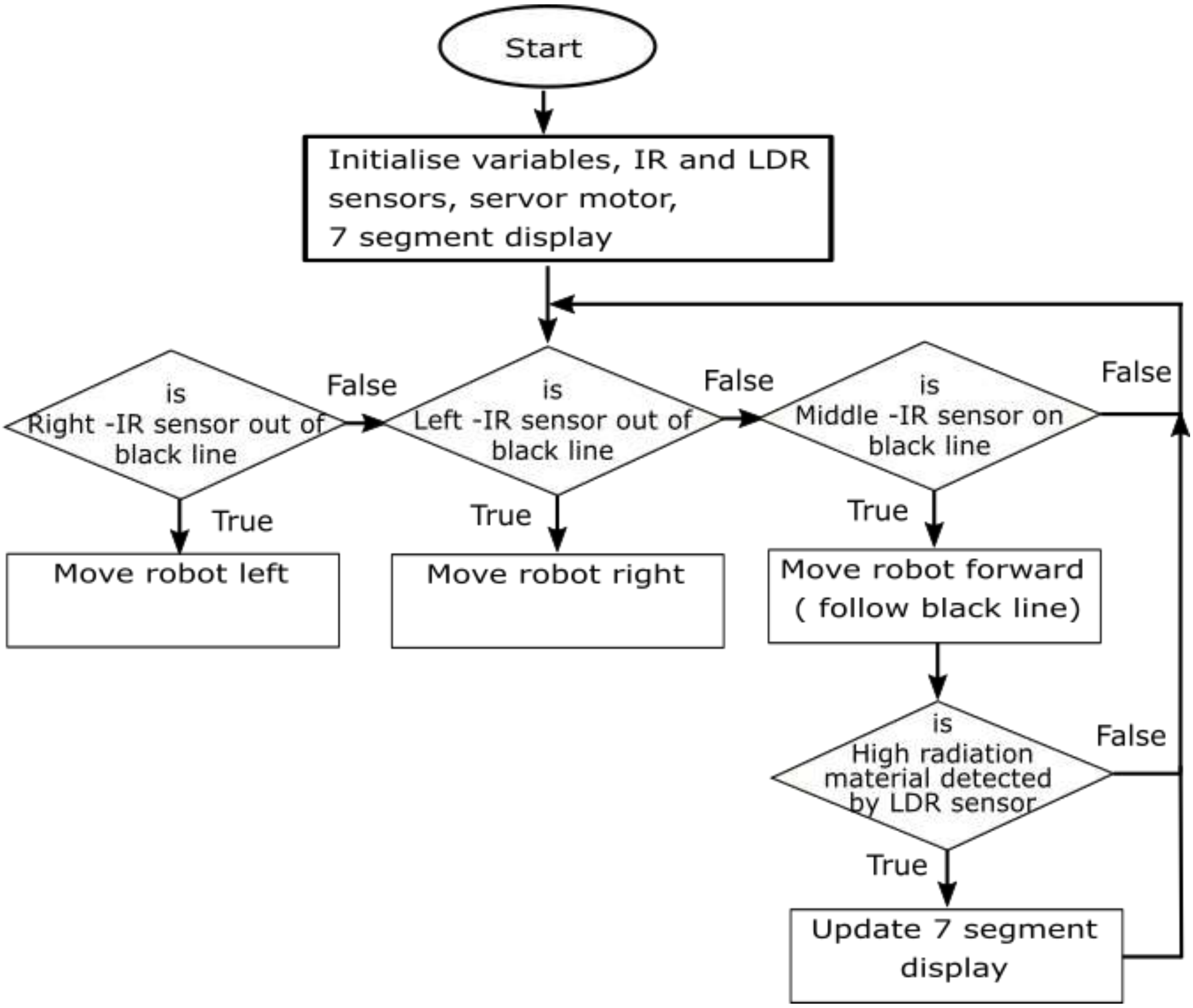


Figure 4: Design Flow Chart

B. High Radiation Materials Detection Using LDR Sensor

Light Dependent Resistor (LDR) sensor is used to detect the light intensity from the foil paper (which is used as high radiation material on the farm land). The detection will be used to count the number of high radiation materials exist in the farm land. LDR works in a simple principle that its resistance decreases with light falling on it.

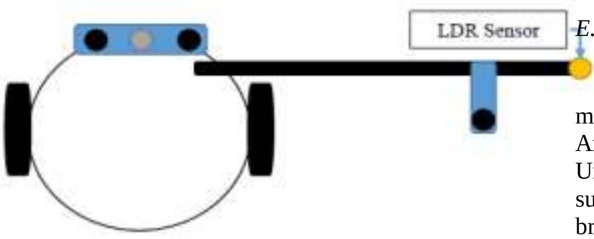


Figure 5: Mobile Robot with LDR Sensor

C. Line Following and Square Box Counter

Two IR sensors connected to pins A0 and A1 of Arduino board and placed side by side on the mobile robot. If the two of them are on the grid line (black tape), the mobile robot will move forward. If the left IR (LEFT-IR) sensor is out of the line (does not detect the black tape), the robot will move to the right and bring the mobile robot back on track (see **Figures 4**, **6 and 9**).

In other case, if the right IR (RIGHT-IR) sensor is out of the line, the mobile robot will move to the left and bring the robot back on track. With this configuration, the mobile robot has the ability to move precisely on the line with error correction capabilities. The third IR sensor (IR 3) is connected to pin A3 on Arduino board and is used to detect the location of the robot. It counts the number of square box (farm land grid) as the mobile robot passes through the grids.

E. Hardware and Software Development

Figure 6 shows the illustration of fully functioning mobile robot. The battery bank is used to supply power to the Arduino Uno through the available power port on Arduino Uno. Then, both motors are powered by internal regulated 5V supply from Arduino UNO. The 7-segment LED (on the breadboard) is used to display the number of high radiation materials as per project requirements. Other components are explained in previous sections.

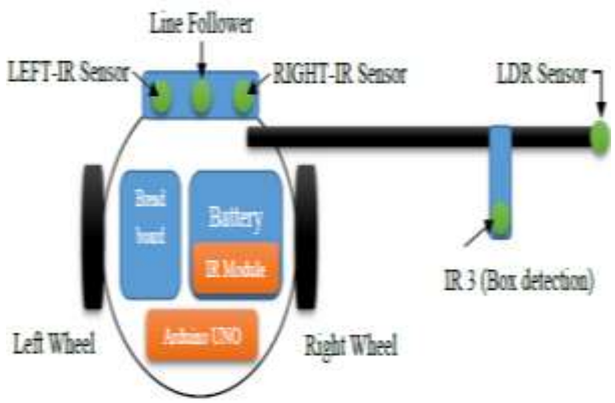


Figure 6: Illustration of Mobile Robot

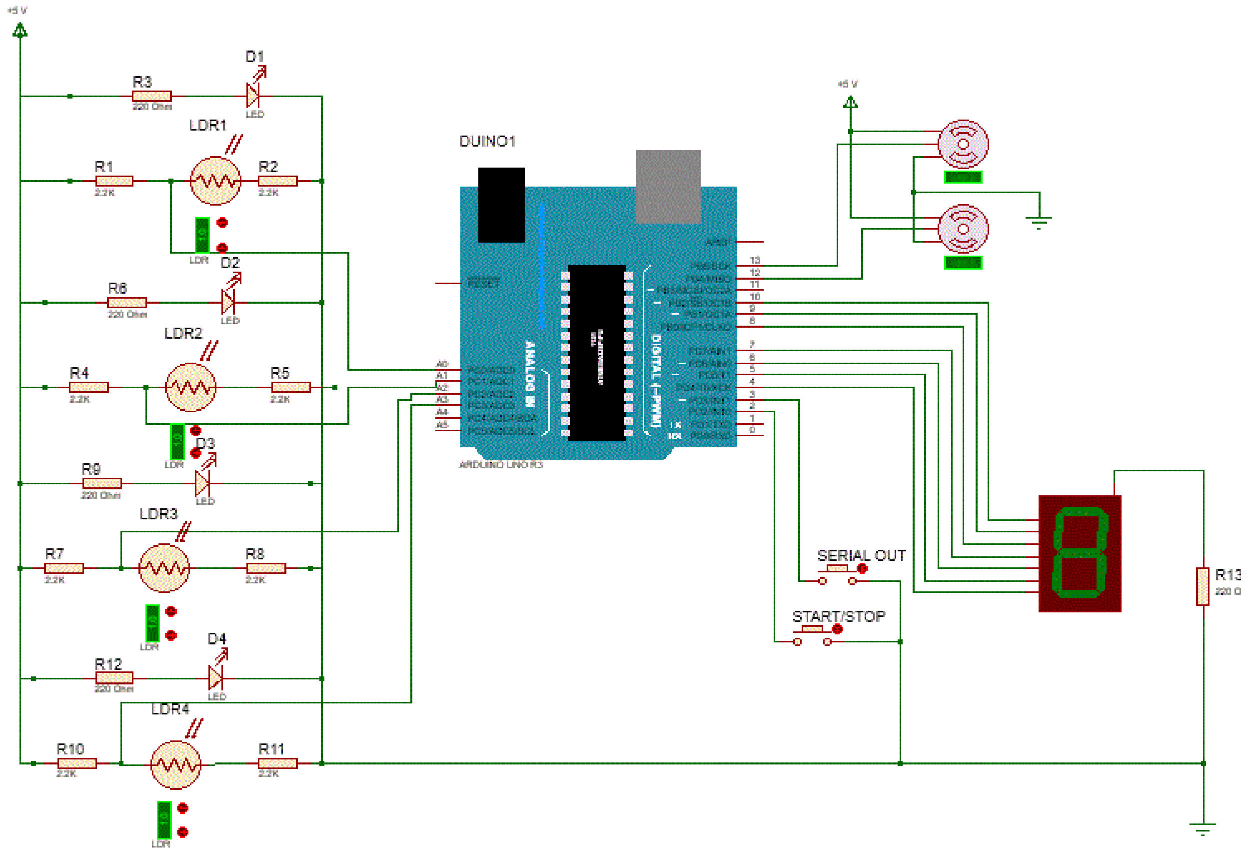


Figure 7: Full Circuit Connections of High Radiation Detection Mobile Robot

RESULTS AND DISCUSSION

A. Testing and Debugging

The testing and debugging of each module are done in two stages, serial display and onsite testing. During the first stage, each module is tested separately via serial monitor where the Arduino Uno board is programmed to display the states of each hardware connected to the board with three IR sensors, one LDR sensors, servos, seven-segment LED and the two pushbuttons. This is done module by-module to prevent the accumulation of problems throughout the entire program codes. Once all the modules are being tested separately, all the modules are combined in one script and tested again. Only then we proceed to the next stage where the robot is tested on the self-built platform according to the specifications in project outline. The fully assembled mobile robot is shown in **Figure 8**.

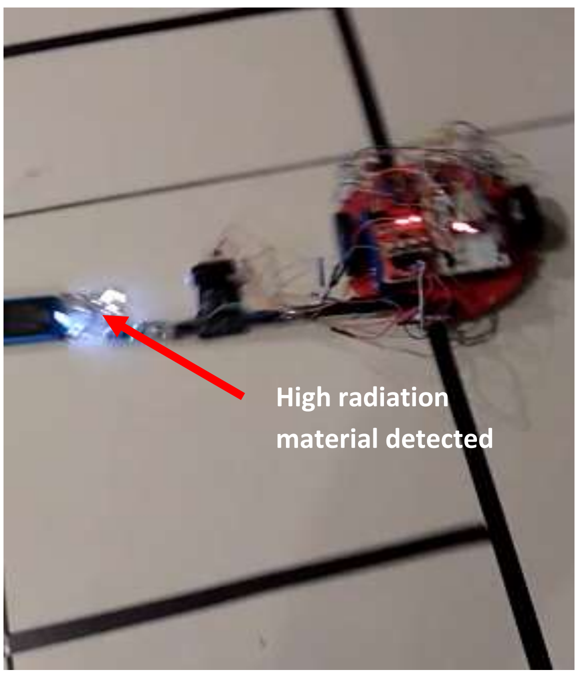


Figure 8: Fully Assembled Mobile Robot Sensing the High Radiation Material

B. Line Following

The movement of the servo motors is based on the reading of the IRs. Three IR sensors (IR0, IR1, IR2) are placed in front to detect the black colour for line following (i.e. moving robot forward). The robot is programmed so that it will make a 90-degree left turn at third and fourth square boxes when front IRs didn't detect any black colour (means robot mobile is located at square box's corner, see **Figure 9**). The square detection is done by an LDR sensor. Every time the robot crosses the boundary of square box, IR3 should detect the black line and increase the SQUARECOUNT by 1.

Figure 9: Screenshots Mobile Robot in Operation

CONCLUSION

Objectives of the design have been accomplished (see **Figures 4, 6 8** and **9)**. The mobile line following robot was able to move through all the six squares (i.e. the sample farm land) and sense all the high radiation materials existed in the farm land. The number of high radiation materials is displayed on seven segment display at the end of the work. The developed robot has proven to have achieved its objective with less complexity in terms of hardware design as compared to other robots in literature review. The LM324 comparator and motor driver circuits were eliminated as the microcontroller program and the servo motor used were able to handle the design, thereby making the robot less complex.

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