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Obstacle-avoiding robot with IR and PIR motion sensors

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Abstract. Obstacle avoiding robot was designed, constructed and programmed which may be potentially used for educational and research purposes. The developed robot will move in a particular direction once the infrared (IR) and the PIR passive infrared (PIR) sensors sense a signal while avoiding the obstacles in its path. The robot can also perform desired tasks in unstructured environments without continuous human guidance. The hardware was integrated in one application board as embedded system design. The software was developed using C++ and compiled by Arduino IDE 1.6.5. The main objective of this project is to provide simple guidelines to the polytechnic students and beginners who are interested in this type of research. It is hoped that this robot could benefit students who wish to carry out research on IR and PIR sensors.

1. Introduction

Many robots for automation and navigation have been developed in recent years like wall-following, edge-following, human following and obstacle avoiding robots. The obstacle avoiding robot will evade obstacles it encounters in its path towards its operational goal. Due to the reliability, accessibility and cost effectiveness of using mobile robot in industry and technical applications, the obstacle avoiding robots are very important in factory floor. On the other hand, Unmanned Aerial Vehicles (UAVs) are playing a vital role in defence as well as civilian applications [14]. The military applications include reconnaissance, surveillance, battle damage assessment and communications. Meanwhile, civilian applications include disaster management, remote sensing, traffic monitoring, etc. Many of the UAVs applications need the capability to navigate in urban environment or unknown terrains that have many obstacles of different types and sizes. Basic requirement of autonomous UAVs is to detect obstacles in its path and avoid them. This paper proposed an example of the obstacle avoiding robot algorithm and design of the robot base using IR and PIR sensors. The developed robot can be used as a platform for several applications in educational, research or industrial.

The behaviour of a mobile robot is dictated by the interaction between the program running on the robot (the 'task'), physical hardware of the robot (the way its sensors and motor work) and the terrain (environment) [4]. These three fundamental components are as shown in Figure 1. The development in this paper is aimed to highlight the hardware and software implementation to design an autonomous platform. It serves to achieve research purposes like developing software modules to realize obstacle avoidance and investigating the interaction between the robot task and terrain. This platform serves for achieving educational purposes to reveal the latest technology for different sensors and actuators that is used in mobile robot design [19]. Besides that, it also provides the opportunity to study on how to program the microcontroller chip to acquire sensors data and react autonomously with environment in order to perform tasks.

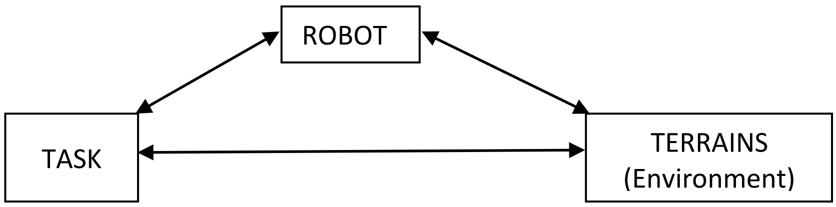

Figure 1. Obstacle avoidance fundamental component

2. Literature review

Robots need miscellaneous of sensors to obtain information about the world around them. Sensors will help detect position, velocity, acceleration and range for the object in the robot's workspace. There is a variety of sensors used to detect the range of an object. One of the most common range finders is the ultrasonic transducer. Vision systems are also used to greatly improve the robot's versatility, speed and accuracy for its complex and difficult task. Varun *et al.* [13] developed obstacle avoidance equipped with pan-tilt mounted vision system. In this case, the robot uses histograms of images obtained from a monocular and monochrome camera to detect and avoid obstacles in a dynamic environment. Kim *et al.* [1] presented the detection of moving obstacles (particularly walking humans) using single camera attached to a mobile robot. Detection of object that moves near the robot is searched by block-based motion estimation. Shoval *et al.* [8] described the use of mobile robot obstacle avoidance system as a guidance device for blind and visually impaired people. Electronic signals are sent to a mobile robot's motor controllers and auditory signals can guide the blind traveller around the obstacles. Kumar [3] proposed an alternative design for cost effective and simplified version of the obstacle avoidance robot using three ultrasonic sensors. Borenstein *et al.* [9] built a mobile robot system, capable of performing various tasks for the physically disabled people. The developed robot uses ultrasonic range finder for detection and mapping to avoid collision with the unexpected obstacles. Sathiyanaranayan *et al.* [10] developed self-controlled robots for military purposes. It uses GPS and magnetic compass, and adjusts strategies based on the surroundings using path planning and obstacle detection algorithms. Bhanu *et al.* [12] built a system for obstacle detection during rotorcraft low altitude flight. The requirements of an obstacle detection system for rotorcraft in low altitude flight based on various rotorcraft motion constraints is analysed in details. Huballi *et al.* [11] discussed on Smart Distance Measurement using IR sensor. From the research, they found that a major drawback of IR based sensors is their capability of detecting only in short distance.

3. Sensors selection

The objective of having obstacle avoiding robot is to enable autonomous functioning without human supervision. A lot of sensors are available for obstacles detection such as ultrasonic sensor, infrared sensor, camera and LIDAR (laser based sensor system), which has been considered as one of the most accurate schemes for generating spatial information about the shape and surface characteristics of any object [18]. In this paper, infrared sensors are used to accomplish evading obstacle. IR and PIR sensors have been placed on prototype for obstacle detection as shown in Figure 2.

Accuracy with low cost is the constraint of this research, hence the IR sensor was selected for the design. Stereo camera vision does not perform well under some environment conditions such as plain wall, glass surfaces or poor lighting conditions whereas IR sensor can be used to improve the overall vision system of mobile robot [17]. IR sensors are widely used for measuring distances, so they can be used in robotics for obstacles avoidance. IR sensors are also faster in response time than ultrasonic sensors [17]. In addition, the power consumption of IR sensor is lower than ultrasonic sensors [11]. Active Infrared (IR) sensors can be an emitter and detector, which operate at the same wavelength. It is also known as photoelectric sensor working with reflective surfaces [15]. IR sensor can be categorized as retro-reflective sensors and diffuse reflection sensors. Retro-reflective sensors are proper for harsh environment conditions and have much larger detection range than the diffuse reflective sensor [15]. IR sensors use a specific light sensor that can detect a selective light wavelength in the IR spectrum. When an object is close to the sensor, the light from the LED bounces off the object and into the light sensor as shown in Figure 3.

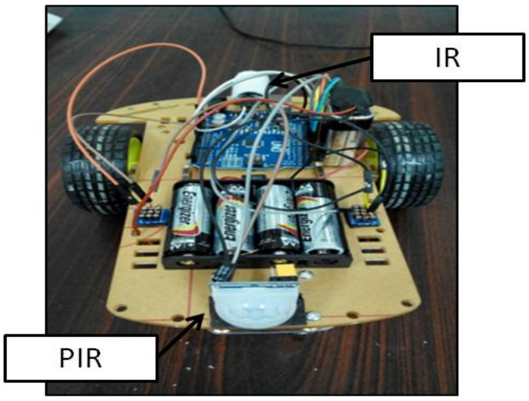

Figure 2. Position of IR and PIR sensor

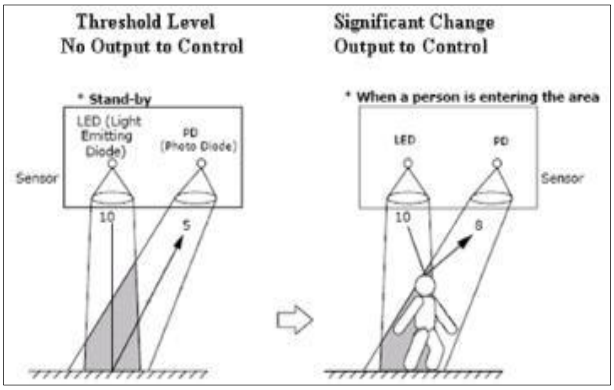

Figure 3. IR sensor object detection

3.1. IR and PIR sensors operation
Infrared sensors detect the object's distance with infrared radiation. When the beam detects an object, the light beam returns to the receiver with an angle after reflection. The method of triangulation is as shown in Figure 4. PIR sensors are also known as Pyroelectric Infrared sensor, Passive Infrared sensor or IR motion sensor, which detect the difference in temperature, thermal radiation, human body or an animal [15]. PIR sensor operates with the radiation of body heat as shown in Figure 5. The hotter the detected object, there will be more emission occurs in PIR sensor.

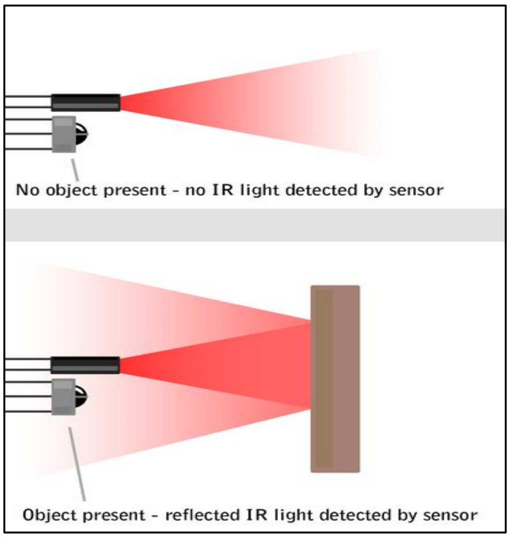

Figure 4. IR sensor working principle [15]

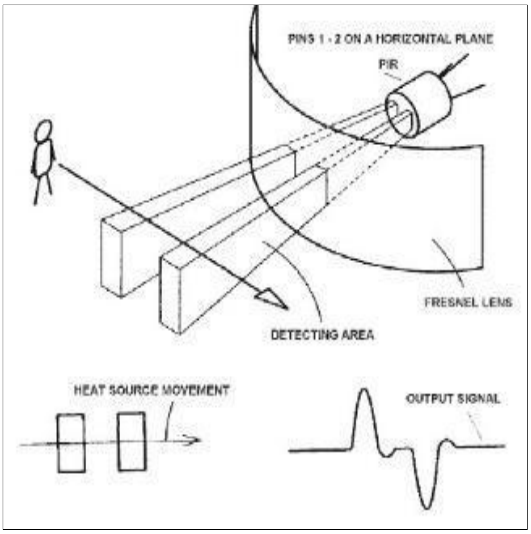

Figure 5. PIR sensor object detection

Object temperature calculation is based on Stefan-Boltzmann Law.

$$T_c = \sqrt{T_s^4 + \frac{\Phi}{A\sigma\varepsilon_s}},$$ [T_s = sensor's surface temperature T_c = object's temperature in Kelvin]

[Φ = magnitude of net thermal radiation flux Φ , ε = emissivity of the object]

PIR sensor relatively has a lower power consumption compared to IR sensor. PIR sensor also senses accurate detection in narrow areas and is compatible to work in microcontrollers [15]. The IR and PIR sensors can act as a transducer since they use infra-red signal as the input and convert it to analogue electrical output signal [15].

3.2. Limitation of IR and PIR sensor

Performance of IR sensors has been limited by their poor tolerance to light reflections such as ambient light or bright object colours. No object recognition at the dead zone area, for example Sharp GP2D12 IR distance sensor dead zone between 0 to 4 cm. IR sensors also give inaccurate detection result with transparent or bright colour materials. Detection results also depend on the weather conditions and the sensing reliability of IR sensors decreases with moisture and humidity. Furthermore, IR sensors can sense IR radiation from the sunlight, which can cause correctable or non-correctable errors at output. Besides that, if analogue IR sensor is used, signal losses will occur at the amplifier circuit. Meanwhile, PIR motion sensor needs a long calibration time and is sensitive to thermal radiation. Besides that, PIR sensor is insensitive to very slow motions or to objects in standing mode.

4. Experiment set up

Circuit diagram of the obstacle avoiding robot is given in Figure 6. The hardware developed consists of Microcontroller Atmel ATMEGA 32, IR sensor, two DC motors as differential driving system, PIR (Passive Infra-Red) sensor and motor driver L293D. The microcontroller ATMEGA 32 is the central brain of the mobile robot. Figure 7 shows the chassis of the robot. The IR detector (rear) is connected to PD6 of ATMEGA32. If any object is located at the rear part of the robot frame, the IR sensor output will alert the microcontroller that an obstacle is detected. The IR sensor used as shown in Figure 8. PIR sensor (front) is connected to PD7 I/O pins. If any object is moving in front of the robot, the PIR sensor output will alert the microcontroller that an obstacle is detected. Motion sensor has 90 degrees field of view and it will be triggered when a warm object moves across the area it is facing. It is very sensitive and will trigger with just a hand movement. PIR motion sensor is shown in Figure 9.

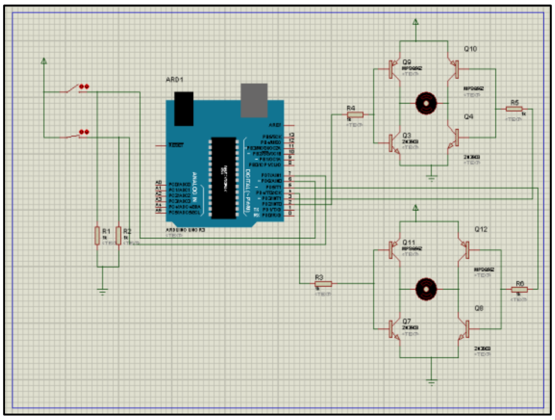

Figure 6. Circuit diagram of obstacle avoiding robot

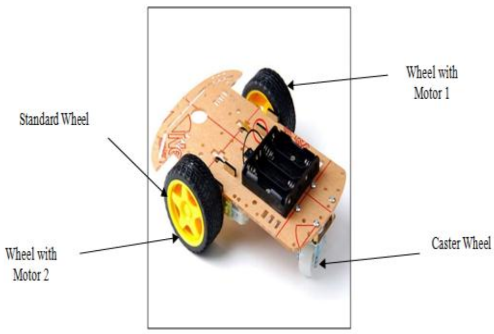

Figure 7. Chassis of obstacle avoiding robot

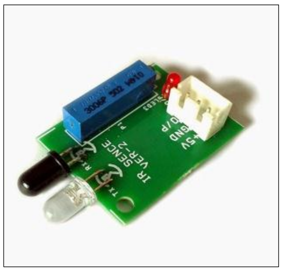

Figure 8. IR sensor

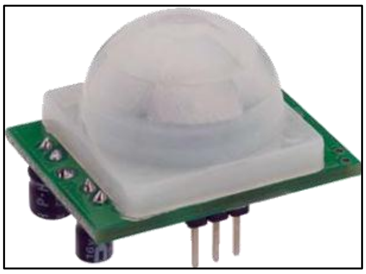

Figure 9. PIR sensor

Motor driver L293D (H-bridge) decides which motor will be moved or stopped in accordance to the incoming signal from the microcontroller ATmega32. The selected dimension of the mobile base is suitable to install sensors to interact with the environment. The wheel used in Figure 7 will provide sufficient traction and stability for the robot to cover all of the desired terrain. Standard wheel and caster wheel was used in this design. Standard wheel with rotation around motorized axle and rotation around the contact point. Meanwhile, caster wheel rotation around the offset steering joint and rotation around the contact point. The software is written using Arduino Integrated Development Environment or Arduino Software (IDE). It contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. Once the compile file (Hex code) is obtained, it can be downloaded into microcontroller.

5. Result

A brief overview of the software functions and the system architecture is shown in Figure 10. From the flowchart, the calling sequence and the relationship between the functions are visualized.

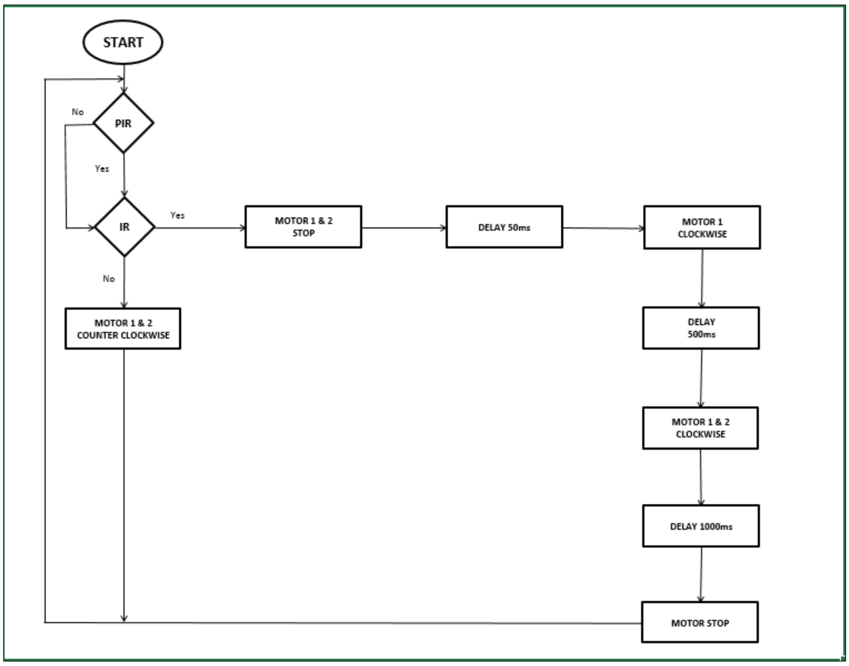

Figure 10. Flow chart of the obstacle avoidance robot movement

The working principle of the robot is transmitting sensed signal to the microcontroller to control the DC motors for obstacle avoidance. The H-bridge L293D controls the direction of the motors to move either clockwise or anti-clockwise directions as provided by the microcontroller. Figure 10 shows that, if PIR sensor detect a moving object while IR sensor does not detect any object, the robot will move backward (motor 1 and motor 2 counter clockwise). On the other hand, if PIR detect object and IR sensor also detect object, the robot will stop (motor 1 and motor 2 OFF). After 50 ms, motor 1 will move clockwise and the robot will turn left. After 500 ms, the robot will move forward (motor 1 and motor 2 clockwise) and after 1000ms, both motors will stop. From the flow chart in Figure 10, it shows that the IR and PIR sensors are very effective in sensing signals in their path for the obstacle avoiding robots to evade obstacles in its path.

7. Discussion and conclusion

The developed robot platform was not designed for specific task but as a general wheeled autonomous platform. It can therefore be used for educational, research or industrial implementation. Students can use it to learn the microcontroller programming using C++, Arduino Uno 1.6.5 compiler, IR and PIR sensors characteristics, motor driving circuit and signal condition circuit design. Research on obstacle avoidance robot at the polytechnic level can help students to develop communication, technical skills and teamwork. The design of such robot is very flexible and various methods can be adapted for another implementation. From this paper, it shows that PIR sensors are more sensitive compared to IR sensors while detecting human being.

8. Limitation and further improvement

The robot has been successful in avoiding obstacle but it also has certain limitations as well. Further improvement can be achieved by adding sensors on the left and right side of the robot. Besides that, computer vision with camera features can be implemented for monitoring applications. For further improvement, to implement an obstacle avoidance in aerospace, well-suited sensors should be used to gather the accurate information about the environment and obstacles. The laser based (LIDAR) sensor system is robust especially in off-road outdoor environments [18]. LIDAR based mapping gives most accurate scheme for generating information about the shape and surface characteristics of any object. The recent advancement in LIDAR technologies allows researchers and practitioners to examine the environment with higher precision, accuracy and flexibility than before. LIDAR sensor is considered as an effective solution to the problem of obstacle detection and recognition. However, the obstacle avoidance poses challenges to the image processing using LIDAR sensor.

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