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Research paper

Area Estimation of an Object Using Multiple Infrared Scanning Method for Non-vision Robotic System

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Abstract

This paper presents an obstacle detection based on multiple scanning of a non-stationary and discrete sensor for a non-vision robotic navigation system in an unknown environment. In Simultaneous Localization and Mapping (SLAM), complicated computation and expensive equipment are often used by many researchers to obtain an accurate and absolute result. Therefore, in this project, a low-cost and narrowband discrete sensor, namely, an infrared sensor is utilized to visualize the object as well as estimate its dimension and area for accuracy testing. This sensor is mounted on a rotary joint, which is formed by two servo motors, which are served as the vertical and horizontal axes movement during the scanning operation. Then, the scanned data is stored in a database and 2D graphical image of the scanned object based on these detection data are tabulated by using MATLAB 2D scatter plot toolbox. It is found that the multiple scanned data based on the infrared sensor is not suitable for size determination of an object instead it is suitable for object visualization.

Keywords: *2D image representation; infrared scanning method; microcontroller platform; object area estimation.*

1. Introduction

Area and size estimation of an object or place are often used in robotics navigation and which in general, related to the Simultaneous Localization and Mapping (SLAM) technique or autonomous implementation. Various SLAM algorithms are implemented in the open-source robot operating system (ROS) libraries, often used together with the Point Cloud Library for 3D maps or visual features [1]. SLAM technology can allocate an object around it in a map and at the same time can help in object recognition and tracking for an unknown area. It is a combination of several elements such as calculation in the software and sensors for collecting information. There are many types of sensors that are existed for landmark observation in SLAM technique. Infrared sensor, however, has become a major concern in this work due to its low-cost budget, but at the same time can provide an accurate distance detection based on its narrow-band signal which contrasts to another distance sensor such as ultrasonic sensor [4][8][9]. However, there are some pros and cons in choosing this sensor for robotic application based on its abilities and strength [2]. The infrared sensor produces waves are not visible to the human eye. In the electromagnetic spectrum, infrared produces the radiation in between the visible and microwave regions. The infrared waves typically have wavelengths between 0.75 and 1000um. The wavelength of the infrared sensor has several stages. The first stage is in between 0.75 to 3 micrometers, which is known as the near infrared regions. The region in between 3 to 6 micrometers is known as mid region and the wavelength that is greater than 6 micrometers is called as far infrared regions [5]. On top of that, to obtain a good detection result by using the infrared sensor, the implementation of multiple sensors can increase the accuracy of the reading [6], and therefore a precise output can be obtained in future.

Previously, many researchers have demonstrated the implementation of infrared sensor as one of the object detections in obstacles avoidance. However, very few analyzed the feature of the detected objects such as its parameter, size, and area. One of the reasons is that more analysis work needs to be done including the mapping and localizing of the detected object that has been detected by the sensor [7]. Unfortunately, the size and dimension estimation processes are very significant to visualize the object with its actual size. By obtaining this kind of information from the sensor, more information can be obtained especially when dealing in an unknown environment [1][10].

Therefore, in this paper, the main objective is to provide the object visualization through the obstacle detection technique via an infrared sensor, which is very significant in Simultaneous Localization and Mapping method. Then, the second objective is to construct the image visualization of the detected obstacle based on the discrete detection through the infrared sensor and hence, the area estimation of the detected obstacle can be performed. Finally, the performance of the area estimation is executed and analyzed.

2. Methodology

Fig. 1 shows the overall flow of this project, starting from the hardware design stage until 2D data visualization using MATLAB. In the hardware platform design stage, it can be separated into two phases, namely, the Arduino development board and acrylic-based platform. The Arduino development platform consists of all electronics components which support the operating system while the acrylic based is the main robot platform that holds the servo motors and the infrared sensor. The main operation of this hardware platform is to send the input to organize the movement of the servo motors and receive the input from the infrared sensor during an object or obstacle distance measurement. Therefore, in this case, an Arduino Integrated Development Environment (IDE) software is used to script the execution code and run the debugged program on the ATmega328P microcontroller chip and so that the functions of the hardware components can be tested accordingly to the desired behaviour. Otherwise, the program needs to be troubleshot and reconstructed. To record the data received from the infrared sensor, the CoolTerm software is used [11]. These data are then being stored into several spreadsheets in the Microsoft Excel, which acts as the database, for further data processing. Finally, these data are plotted into a scattering 2D visual representation for testing and system validation through MATLAB software.

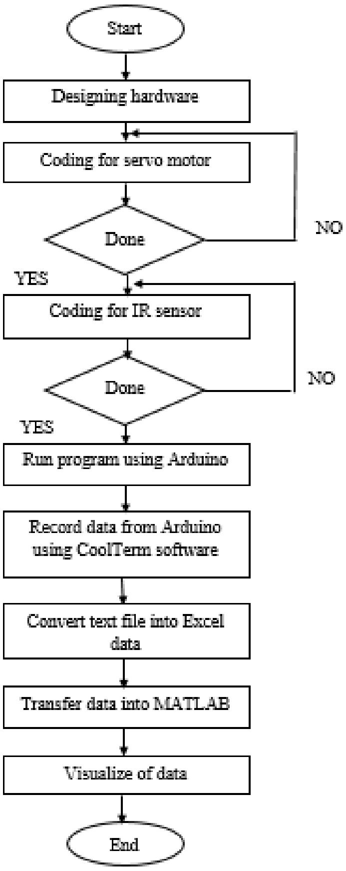


Fig. 1: Flowchart of the overall project.

2.1. Overall design

According to Fig. 2, the hardware development board consists of the Arduino development board that comprises of the rotation of two servo motors, in X and Z axes direction as well as the analog reading from the infrared sensor in measuring the distance of the detected object. The Arduino UNO hardware development board is the main controller and connected through a serial communication channel to the personal computer to collect and transmit data, vice versa. Meanwhile, in the personal computer (PC), the software such as MATLAB and Arduino IDE is the main software development platforms, which are mainly used to obtain the outputs of the sensor and process them.

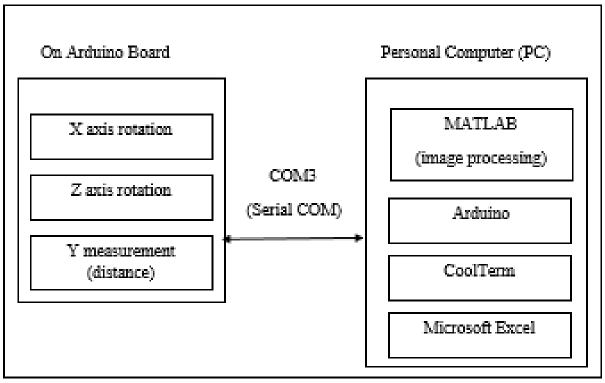


Fig. 2: Block diagram of overall system.

2.2. Hardware design

Hardware design connects several electronic components, which perform analog and logic operation in one whole system. Fig. 3 shows the hardware components in this design.

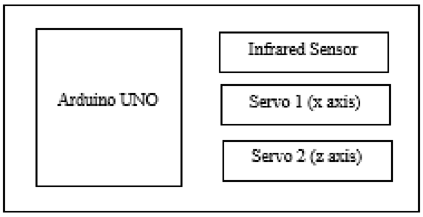


Fig. 3: Hardware design of the project.

Based on this hardware design, the Arduino UNO is the brain of the system which processes and governs all the inputs and outputs of the system. The only input that is required by this system is the distance measurement by the infrared sensor, which gives the data in centimetre value after the ADC module. This sensor is attached on the rotating joint that is created by using two servo motors that rotate in X and Z-axes as depicted in Fig. 4. For X-axis, namely Servo 1, rotates from 0 to 180 degrees while the Z-axis, which is Servo 2, rotates from 60 to 120 degrees. The infrared sensor is supplied by 5V from the Arduino development board [3]. On the other hand, the servo motors are connected to the external power source 240V, which has been reduced into 5V by using a voltage regulator. This is due to the fact that the servo motors require larger current approximately 1.8 Ampere to operate, Arduino alone cannot supply this much of current and therefore the power supply for these motors are separated from the main controller board.

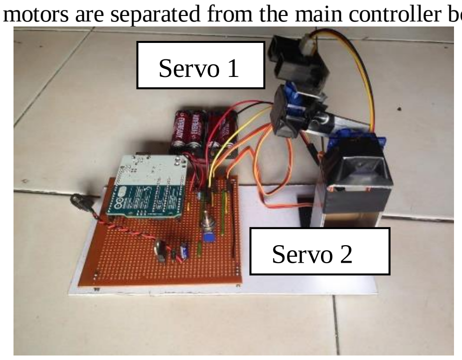


Fig. 4: Hardware design of the rotating infrared sensor for multiple scanning operations.

3. Software design

Software design consists of the controller and function modules that contain the instruction sets to all hardware components to perform the whole process in this system. This process governs the project to be executed in a sequential manner to obtain the desired output. Fig. 5 shows the software developments of this project.

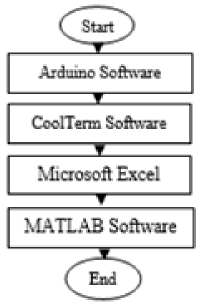


Fig. 5: Software design development to govern all the control signals to the execution of hardware components in order.

According to Fig. 5, the flowchart shows the algorithm categories that have been used in this project. There are two types of data that are important to be produced in this, namely, the area size estimation and the physical visualization of the detected objects. The C code in the Arduino IDE is used to script the functions of the rotation movements and reading the input from the infrared sensor. As the output of the program cannot be recorded in the serial output display in the Arduino IDE software, therefore, the CoolTerm software is used. Initially, the data is recorded in the text file. Later, the Microsoft Excel software is called to extract the data from this file into rows and columns for a better data arrangement. Finally, the extracted data from the *.xls* file is imported to the MATLAB software to be plotted.

2.4. Control algorithm

Fig. 6 shows the detail control flows in the program. According to this figure, the flow of control module begins by including the libraries needed to run the instruction program such as the servo and infrared distance sensor. The input is then being initialized by setting up the servo, position x into 0° and the other servo, position z into 60° for multiple axis movements [12]. The servo, position x instructed to rotate from 0° to 180° and vice versa, while, the other servo, position z instructed to rotate from 60° to 120°. Next, the port was set up by determining the pin-attach to the input (infrared distance sensor) and output (servo motors) to be connected to the microcontroller (Arduino Uno). Open serial port for output display. The flowchart continues by the servo, position z starts to increment by +1° for every rotation made by the other servo, position x. The servo, position x is also always in the increment of +1° from 0° to 180°. During the rotation of both servos, position x and z, infrared distance sensor will start to measure the distance being sense. If the distance measure y is larger than 100cm, the program will loop again. Detection distance below 100cm resulted in the output data. The output data are then being printed. The instruction now checks whether the servo position x meet the degree of 180, if 'yes', servo position x, will start to rotate from 180° to 0° by a decrement of -1°. If 'no', the rotation of servo position x, will continue to move until it reaches 180°. Same goes to the infrared distance sensor, it starts to measure distance during the decrement of position servo x. again, if the distance measure, y is larger than 100cm, the program will loop. Detection distance below 100cm resulted as the output data and being printed. The instruction now checks whether the servo position x meet the degree of 0, if 'yes', servo position z, will start to increment of +1°. If 'no', the rotation of servo position x, will continue to move until it reaches 0°. The instruction, set to loop until the position of servo z, reaches 120°. If 'yes' the program will end but if 'no', the rotation of servo position z will continue to increment until it reaches 120°.
From the data obtained in the Arduino software, the data will undergo the image processing technique in the MATLAB software. The purpose of this process is to visualize the obstacle read by the infrared sensor into a 2D scatter plot, hence we can calculate the area of the detected obstacle.

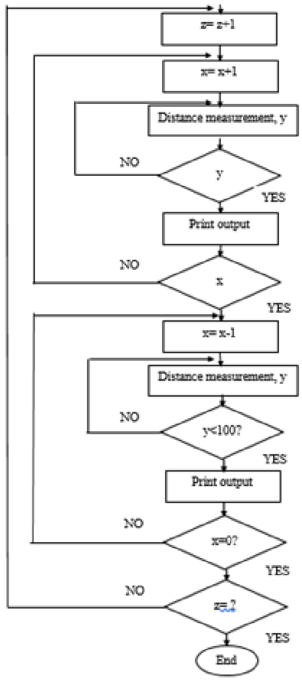


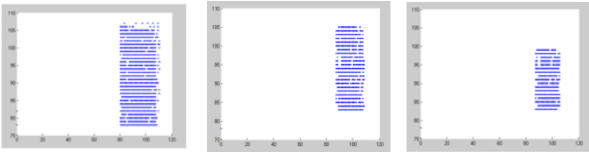
Fig. 6: Control algorithm flow in the Arduino hardware platform.

3. Result and Discussion

In this experiment, the detection of the object including the object visualization is unlimited to all types of shapes such as symmetrical and non-symmetrical but the area estimation calculation is limited to a symmetrical object only. The object area calculation for the asymmetrical object is quite tedious and more image processing technique is needed to transform the constructed image in MATLAB. In this work, the type of symmetrical shape object chosen in this experiment is the rectangle-shaped object. The rectangular shape is one of the examples for the symmetrical shape that can be detected and calculated as shown in Fig. 7.

Fig. 7: Experiment work for the rectangular shape.

Fig. 8 shows the actual symmetrical object (rectangle) that has been detected by the infrared sensor. The visualization of the object, Fig. 8(a), shows that the shape and size of the image are bigger compared to Fig. 8(b) and 8(c). This is because when the object is placed near the infrared sensor, the detection of the surface is better. Furthermore, more infrared signals are transmitted on the surface of the object. As a result, more data is available to construct the 2D image. When the object is placed far from the infrared sensor, it loses its ability to detect most part of the object's surface. Table 1 and 2 show the measured perimeter and percentage error of the height, width and area calculation of the detected rectangular object. From these tables, the shortest distance of the object from the sensor has a lower percentage error of the height and width. Others have given a very large error. It can be seen clearly in Fig. 9 that the further the distance between object and sensor, the higher the error percentage of the area calculation. It can be concluded that this sensor is best in detecting a rectangle object that is placed near to the sensor.



(a) (b) (c)

Fig. 8: 2D Visualization in MATLAB for the rectangular shape with the distance of (a) 30cm and (b) 40cm (c) 50cm from the infrared sensor.

Table 1: Percentage of error of height and width for the rectangle-shaped object

Distance from sensor (cm)	Actual Height (cm)	Actual Width (cm)	Estimated Value (Height)		Estimated Value (Width)		Height Error Percentage (%)	Width Error Percentage (%)
			Servo Degree (°)	Estimated Height (cm)	Servo Degree (°)	Estimated Height (cm)		
30	20.5	12	32	18.74	30	17.3	8.58	44.17
40			25	18.65	26	19.5	9.02	62.5
50			20	18.20	22	20.2	11.2	68.33

Table 2: Percentage of error for the area of the rectangle-shaped object

Distance (cm)	Actual Area (cm2)	Estimated Area (cm2)	Error Percentage (%)
30	246	324.2	31.8
40	246	363.7	47.8
50	246	367.6	49.5

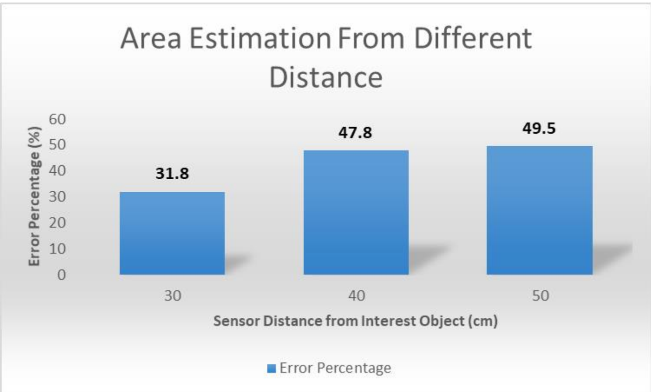


Fig. 9: Error percentage obtained from different distances between sensor and object of interest.

4. Conclusion

As a conclusion, the infrared scanning method is only suitable to estimate the size of the symmetrical object in near detection mean. Otherwise, a larger error will occur. Unfortunately, to use this sensor solely in object measurement is not advisable as the error is accumulated started from the first detection. This technique can be combined with another sensor such as a camera for a better size estimation method. Nevertheless, even though it is not suitable for size measurement, it shows that the infrared scanning method able to provide data to be mapped into a visual representation.

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