IOP Conf. Series: Materials Science and Engineering **260** (2017) 012030 doi:10.1088/1757-899X/260/1/012030

Time response for sensor sensed to actuator response for mobile robotic system

N S Amir and A A Shafie

Department of Mechatronics, Kulliyyah of Engineering, International Islamic University Malaysia, Jalan Gombak, 53100 Kuala Lumpur, Malaysia

E-mail:syamimi.amir25@gmail.com, aashafie@iium.edu.my

Abstract. Time and performance of a mobile robot are very important in completing the tasks given to achieve its ultimate goal. Tasks may need to be done within a time constraint to ensure smooth operation of a mobile robot and can result in better performance. The main purpose of this research was to improve the performance of a mobile robot so that it can complete the tasks given within time constraint. The problem that is needed to be solved is to minimize the time interval between sensor detection and actuator response. The research objective is to analyse the real time operating system performance of sensors and actuators on one microcontroller and on two microcontroller for a mobile robot. The task for a mobile robot for this research is line following with an obstacle avoidance. Three runs will be carried out for the task and the time between the sensors senses to the actuator responses were recorded. Overall, the results show that two microcontroller system have better response time compared to the one microcontroller system. For this research, the average difference of response time is very important to improve the internal performance between the occurrence of a task, sensors detection, decision making and actuator response of a mobile robot. This research helped to develop a mobile robot with a better performance and can complete task within the time constraint.

1. Introduction

Developing a mobile robot is a complex process. Robots have to simultaneously avoid an obstacles while performing the tasks to achieve goal. Tasks may need to be done within a time constraint. Since time and performance matters, robot controllers should be able to send command immediately to its devices. Time constraint is an important aspect to ensure good operation of mobile robot and can result in better performance [8]. With the rise in research and development of autonomous robots in the past decade, there has been an increased focus on control strategies for the robots to achieve robust and optimal performance [12].

The response time of an autonomous mobile robot is presented as an internal performance that characterize a robot regardless of a particular task. The response time is defined as the time between the occurrence of a task, its detection by a robot, the decision making, and the response [1]. This system response is important for mobile robot, especially when it needs to turn left or right immediately after its sensor detect an obstacle, for instance [2].

Real-time systems are computer systems that monitor, respond, or control to an external environment and it is connected to the computer system through sensors, actuators, and other input-output interfaces [3]. Since actuators perform actions in response to the sensed tasks, real-time communications and fast reaction are necessary [4]. Real time system have two types, hard real time system and soft real time system. Hard real time system is the system that should complete the task within the time constraint while soft real time system is a system that require performance assurances from the operating system [5]. In this research, the system analyse the time response starting from the detection of an obstacle by the sensor, until the actuator responds; thus it falls within the type of soft real time system.

Buttazzo et al. designed and implemented a software architecture for designing robots with real time constraint in their research. The architecture of the programming consists of four parts, namely action layer, control layer, communication layer and herd real-time kernel (HARTIK) which controls the other three layers. They concluded that their architecture provide a flexible framework for the development of robots [6].

Brega et al. conducted a case study that discussed the needs and requirements for real time robots in research, education and real world applications. They noted that the increasing complexity of mobile robots set higher requirements for the hardware of the mobile robots, software and the operating system [7].

Navigation of mobile robots is solved with microcontrollers with different memory capacities and operating speeds that can handle incoming and outgoing signals. The tasks of the robots may vary significantly, from simple tasks to the execution of complicated tasks. This fact determines the architecture and complexity used for the robot's navigation in maze solving [8].

2. Methodology

The experiment of this research was carried out with line following and obstacle avoidance tasks. Two identical mobile robot were used; both equipped with four sensors and two actuators. They differ in the number of microcontroller used because this research was carried out to compare the time response between sensor detection and actuators response for one and two microcontrollers used in a mobile robot.

2.1 Task

The tasks of this experiment is that the robot have to follow the line and make a correct decision at the junction until it reaches the finishing line. The mobile robot also have to avoid any obstacle in front of it. The time were recorded starting from the line detection until the actuator responds.

2.2 Measurement technique

The proposed system design is implemented on Arduino which consists of Atmel as processor running real time application, where the ultrasonic, sharp IR sensor and line sensor are the input which send the acquired data to the main microcontroller. The control module will make the decision when conditions are met.

One of the sensor used is ultrasonic sensor. It transmits ultrasonic wave towards external environment from the tranceiver, then the wave is reflected by the object and received by the sensor as shown in Figure 1. The time taken for the signal to travel is then calculated by the sensor and converted into a value that represents the distance between the sensor and the object in front of it [9].

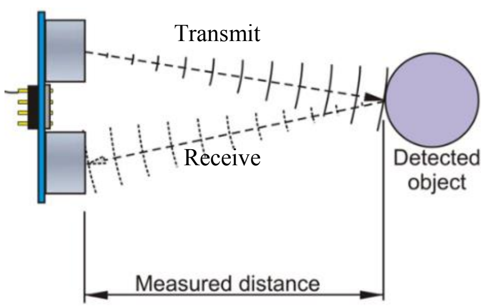

Figure 1. Principle of ultrasonic sensor [10]

Line sensor is also being used in this mobile robot. Basically, line sensor is similar with IR sensor which is made up of two components: a light transmitter and a light receiver. Different colours reflect different intensity of light from emitter to the receiver. Figure 2 shows the principle of IR sensor.

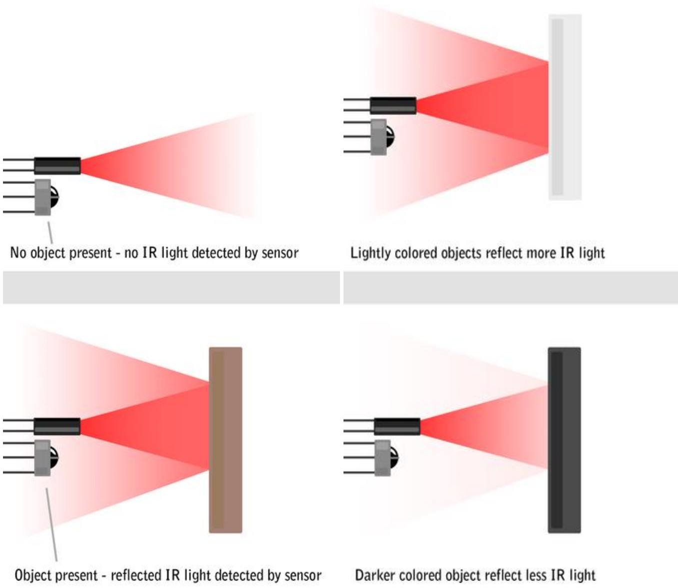

Figure 2. Principle of IR sensor [11]

The distance between the obstacle and mobile robot is calculated using Equation 1 for IR sensor and Equation 2 for ultrasonic sensor in order to get the distance in centimetre.

$$\text{Distance} = 6050/\ \text{sensor value} \quad (1)$$

$$\text{Distance} = \text{sensor value} / 58 \quad (2)$$

2.3 Hardware Setup

The proposed system is shown in Figure 3 and Figure 4. Figure 3 shows single microcontroller system whereas Figure 4 shows multiple microcontroller system. In both cases same application was executed on both platforms and response time is calculated.

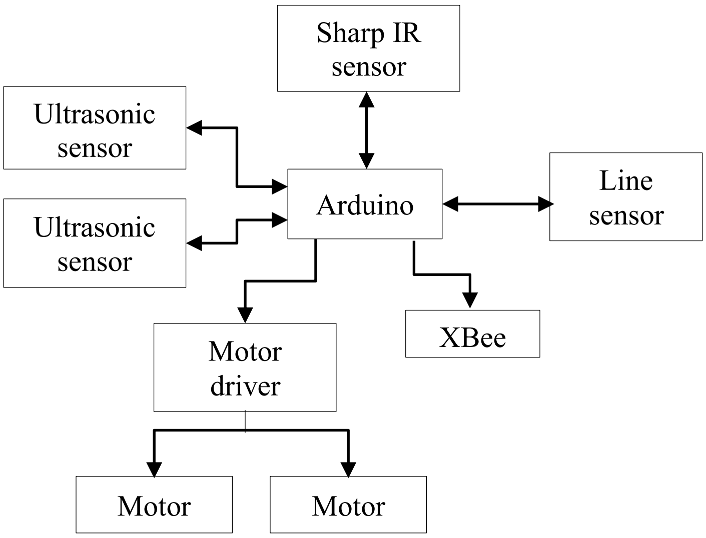

Figure 3. Block diagram of the overall single microcontroller designed system.

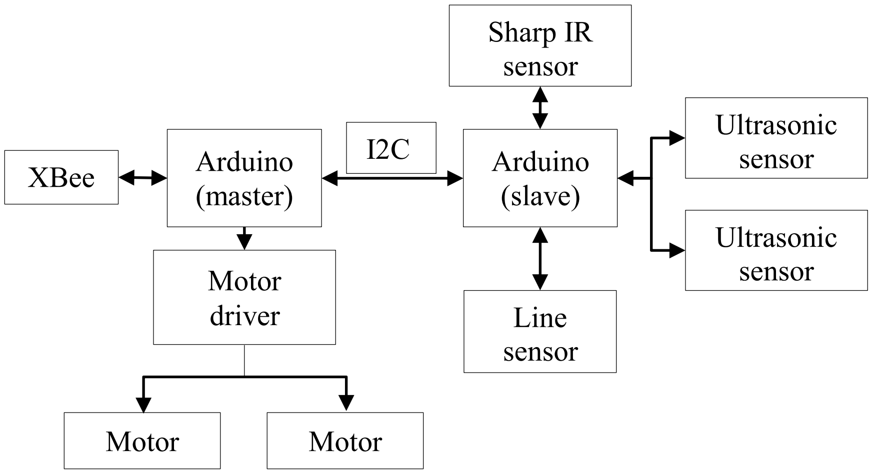

Figure 4. Block diagram of the overall multiple microcontroller designed system.

A microcontroller is a small computer on a single integrated circuit containing processor core, memory and programmable input/output peripherals. Microcontrollers are used in automatically controlled devices such as automobile engine control systems, remote controls and other embedded systems. Arduino microcontroller are used in this research because it consists of a standard programming language compiler and a boot loader that executes on the microcontroller. Furthermore, Arduino has a serial monitor that can show the data transmission when using serial communication. Thus, makes it easier to test the sensor since it show results or sensor values.

There are 3 sensors used in this research which are ultrasonic sensor, sharp IR sensor and line sensor. Two ultrasonic sensor are used to detect an obstacles at the right side and left side of the mobile robot while the sharp IR sensor is used to detect an obstacle in front of the mobile robot. The other sensor is line sensor that is used to detect line for line following task.

For this research, the data from the microcontroller at the mobile robot will be sending wirelessly from the mobile robot to the PC. Transmitter wireless module will send the time response between sensors sensed to the actuator response at the mobile robot to the PC and the receiver module will receive the data for a record. Wireless module that will be used in this research is XBee wireless module. Two XBee are needed in this research because one of the XBee act as a transmitter and the other one is a receiver. One XBee will be connected to the mobile robot and the other XBee will be connected to the PC.

Two DC motors at the mobile robot will act with the help of motor driver circuit. The motor driver is used to receive the signals from the control module in the form of binary logic and it will be supplied to the DC motors with sufficient voltage and current supply. The motor driver will also protect the control module from DC motors if it gets damaged.

2.4 Software Setup / Algorithm Used For The Functioning Of The Robot

Arduino has general purpose input and output pins where these pins can be used by the ultrasonic sensor and DC motor. In this research, the ultrasonic sensor is triggered and once an echo is generated, the time will start. A signal is generated based on the threshold value to the DC motor driver then the timer is stopped. The time value between the sensors sense to the output response gives the response time of mobile robot. The structure of the propose architecture is shown in Figure 5.

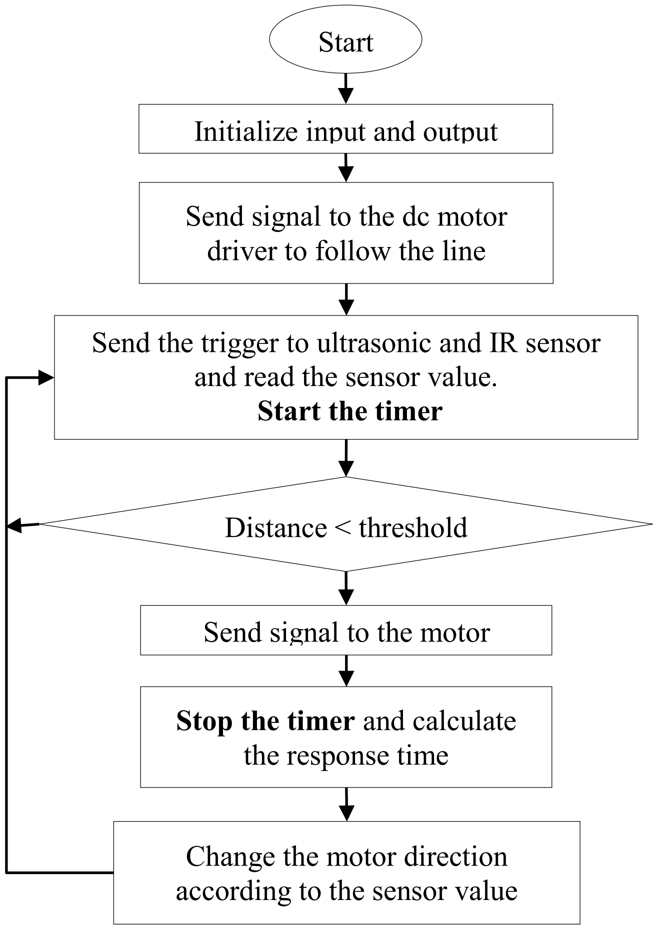

Figure 5. Flow chart of the system.

Experiments were performed to measure the time response from sensor sense to the actuator respond. These date can be collected via the command line in the programming. An obstacle avoidance was used to measure the time response and task performance. The program structure has five standards in the obstacle avoidance behaviour. The number of standards are determined by the possibility of sensors detection in the environment. The standards are used to control the speed and steering angle of the motor as shown in Table 1. However, if all sensors detect the obstacle, the mobile robot will turn back. In this research, the number of rule are five based on the combination of three sensors as an input with a steering angle manipulation.

Table 1. Obstacle avoidance behaviour standard base.

Sensor 1 (left)	**Sensor 2 (front)**	**Sensor 3 (right)**	**Steering angle**
Not detect	Detect	Not detect	Straight
Not detect	Detect	Detect	Turn left
Detect	Detect	Not detect	Turn right
Detect	Detect	Detect	Turn back right
Not detect	Not detect	Not detect	Straight

Two different experiments were conducted: those using 1 microcontroller and using two microcontroller in a robot. Each set of experiments had total of three runs and all trials have same obstacle and same tasks.

3. Results

In this paper, evaluation is conducted to analyse the mobile robot performance based on number of microcontroller. The proposed system is provided with an algorithm that helps in obstacle avoidance in a new environment. The data that are needed to be pre-defined are the sensor distance, speed and steering angle. Since these information are used for the obstacle avoidance to check whether the system generates correct output depending on the value it received from the ultrasonic and sharp IR sensor.

This section presents the results of the research about the calculation of the response time between sensors detection and output response in real environment. When using one microcontroller, the response time of the mobile robot is shown in Table 2. The response of the system was measured, the result shows that the response time from ultrasonic sensor or sharp IR sensor to DC motor are 50 ms to 53 ms.

Table 2. Time response for 1 microcontroller.

Obstacle	Test 1 (ms)	Test 2 (ms)	Test 3 (ms)
1	50.92	51.33	51.05
2	50.54	51	50.74
3	51	50.94	50.65
4	51.5	52.29	50.25
5	51.73	51.2	52.25
6	52.2	52.27	52.25
7	52.19	52.25	52.25
8	51.71	51.19	51.2

The same application was carried out for two microcontrollers and the response time of the system is shown in Table 3. The response of the system was measured, the result shows that 25 ms to 29 ms as the response time from ultrasonic sensor or sharp IR sensor to DC motor.

Table 3. Time response for 2 microcontroller.

Obstacle	Test 1 (ms)	Test 2 (ms)	Test 3 (ms)
1	26.5	26	26.62
2	25.94	26.76	26.59
3	26.19	27.56	26.65
4	26.63	26.65	26.64
5	27.29	28.07	25.94
6	27.2	28.67	27.53
7	27.56	28.2	28.07
8	27.53	27.67	26.69

The response time for different number of microcontroller from one microcontroller to two microcontroller was calculated and tabulated in graph shown in Figure 6. The graph shows the difference response between one microcontroller and two microcontroller, there was an average difference of 24.4 milliseconds. The timer should start and end accurately to calculate the distance between the obstacle detection and response time.

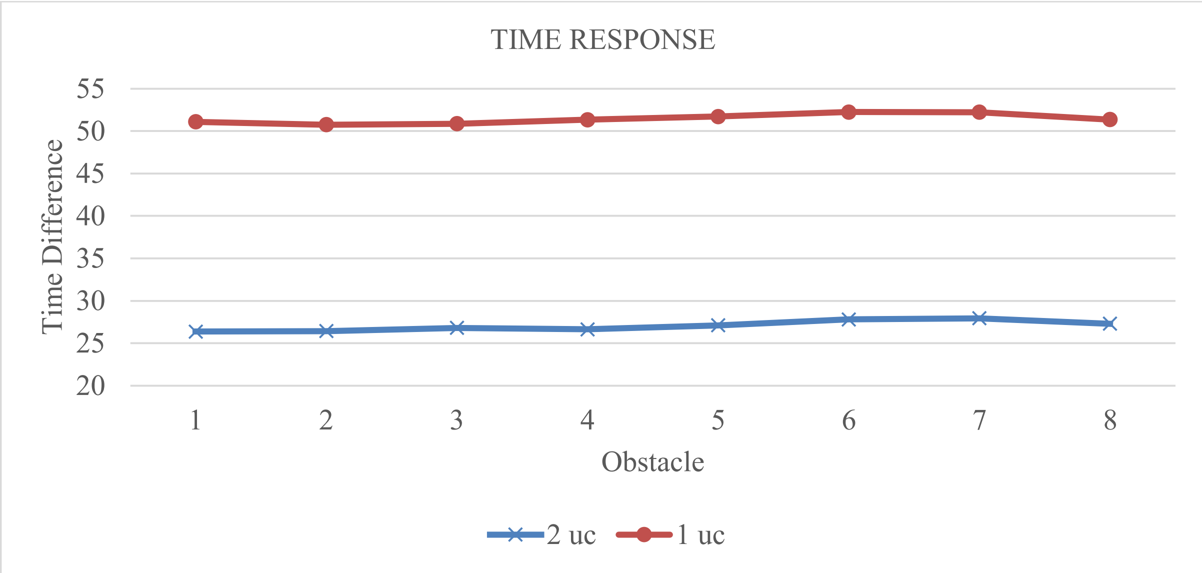

Figure 6. Graph of the difference response between one microcontroller and two microcontroller

T-test was applied to analyse the data collected. From the calculation, the u1 = 51.45351, δ1 = 0.569261, u2 = 27.0472, δ2 = 0.597558 and the T value is 83.6433.

As k = 8+8-2 = 14, tα = 2.145 (from critical value (t_{crit}) table [12]). The inequality 83.6433 > 2.145 holds, the null hypothesis H_0 (i.e. u1 = u2) is rejected, which means that the second experiment (2 microcontroller) performs significantly better than the first one, the probability of this statement to be erroneous is 0.05.

4. Conclusion

The overall research shows that ultrasonic sensor can detect the obstacle and communicate with control module to avoid the obstacle in 50 ms to 53 ms for one microcontroller and 25 ms to 29 ms for two microcontroller. The results show that two microcontroller system have better response time compared to the one microcontroller system and the probability of this statement to be erroneous is 0.05. The average difference between the response time of one and two microcontroller is 24.4 milliseconds. This response time is important in many real time applications especially maze solving.

References

[1] Baums A and Gordyushin A 2013 Response Time of a Mobile Robot *Automatic Control and Computer Sciences*, pp 352-358

[2] Atmadja W, Christian B and Kristofel L 2014 Real Time Operating System on Embedded Linux with Ultrasonic Sensor for Mobile Robot *International Conference on Industrial Automation, Information and Communications Technology (IAICT)*, Bali

[3] Shaw A 2001 Real-Time Systems and Software *Software Focus*, Middlesex, UK, John Wiley & Sons, Ltd., pp. vol **2**, Issue 2, p 81

[4] Ngai E C H, Lyu M R and Liu J 2006 A Real-Time Communication Framework for Wireless Sensor-Actuator Networks *IEEEAC*

IOP Conf. Series: Materials Science and Engineering **260** (2017) 012030 doi:10.1088/1757-899X/260/1/012030

[5] Murikipudi A, Prakash V and Vigneswaran T 2015 Performance Analysis of Real Time Operating System with General Purpose Operating System for Mobile Robotic System *Indian Journal of Science and Technology,* p 6

[6] McKenzie A, Dawson S, Hu F and Anderson M 2011 Using Sun's Java Real-Time SystemtoManage Behavior-Based Mobile Robot Controllers *Journal of Robotics,* p. 11

[7] Brega R, Tomatis N and Arras K O 2000 The Need for Autonomy and Real-Time in Mobile Robotics: A Case Study of X0/2 and Pygmalion *International Conference on Intelligent Robots and Systems*

[8] Matijevics I 2006 Microcontrollers, Actuators and Sensors in Mobile Robots *4th Serbian-Hungarian Joint Symposium on Intelligent Systems*, Subotica, Serbia

[9] Srinivasan K and Gu J 2007 Multiple Sensor Fusion in Mobile Robot Localization *Electrical and Computer Engineering Conference,* Canada

[10] Kelemen M, Virgala I, Kelemenová T, Miková Ľ, Frankovský P, Lipták T and Lörinc M 2015 Distance Measurement via Using of Ultrasonic Sensor *Journal of Automation and Control,* pp. 71-74

[11] Ismail R, Omar Z and Suaibun S 2016 Obstacle-avoiding robot with IR and PIR motion sensors *AEROTECH VI - Innovation in Aerospace Engineering and Technology*, Kuala Lumpur

[12] Nehmzow u 2006 Scientific Methods in Mobile Robotics (Quantitative Analysis of Agent Behaviour), united Kingdom: Springer

[13] Pandey A, Jha S and Chakravarty D 2016 Modeling and Control of an Autonomous Three Wheeled Mobile Robot with Front Steer *IEEE International Conference on Robotic Computing*

[14] Ahmad A, Rathore M M, Paul A, Hong W H and Seo H 2016 Context-Aware Mobile Sensors for Sensing Discrete Events in Smart Environment," *Journal of Sensors,* p. 10