Design of automatic mobile trolley using ultrasonic sensors

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Abstract. An automatic mobile trolley was a prototype of wheel robot that serves as a trolley or shopping cart. This paper proposed an automatic mobile trolley using ultrasonic sensors. It can follow human movement automatically. It did not need to be encouraged or withdrawn. It would make an easier shopping for people as customers. The trolley controlled by a microcontroller module unit. It can stop, turn right, turn left, forward and backward. It can follow wherever they go, during they were in range. Based on the test results, the trolley succeeded to move forward by 80%, move backward 80%, turn left, 70%, turn right 70%, and stop 80%.

1. Introduction
Shopping mall is a place where most people from all walks of life will get their daily needs ranging from food product, apparels, toiletries; gardening tools electrical appliances, and others. The numbers of small and large shopping malls keep on increasing over the years throughout the world due to the demand of the public. Thus, the level of advancement of shopping mall system and infrastructure also varies. There are still plenty of spaces for improvement in terms of providing quality shopping experience to the consumers. Consumers often face problems and inconvenience when shopping [1].

Nowadays, in mall for purchasing variety of items it requires trolley. Every time customer has to pull the trolley from rack to rack for collecting items [2]. It needs a lot of power to be done when shopping. But, trolleys in supermarkets were needed. A lot of goods in the shopping cart would be to push or pull, so the customers will limit the activity of the hand. When focused on pushing the trolley, buyers will often miss a lot of goods sold in supermarkets and only buy the important goods only, and of course this could harm the supermarket company [2-4].

The technology represents to retailers opportunity to reduce costs and to improve services, allowing to attend clients quickly, precisely and supplying personalised services [5]. All around the world, robots are entering the shopping centers, attesting that robotic technology is gaining ground. The rationale for this choice lies in the fact that retail shops need to offer trendy yet low-cost substitutes to e-commerce, reducing the operating costs of personnel management [6].

In order to give the best services, it had been need a trolley that can follow automatically human movement. The direction could be detected using transducers, sensors or other detector. For example, the detector may be sensitive to weight, heat, sound, dielectric constant, and so on [7,8]. Design was divided into several parts namely the design of hardware, hardware relationships, the initialization of sensors and auxiliaries, and software design. As various kinds of robots have been developed to
replace human works. Ultrasonic range sensors have been recently used for range detection and obstacle recognition in robots because of their low price, high efficiency, and relatively simple structure. While ultrasonic waves have better directivity than low-frequency waves in general, they are attenuated more rapidly. Ultrasonic sensor uses sound waves for its ranging and the speed of sound is influenced by a number of environmental parameters [7-9].

2. Sensor implementation
Detection and tracking of objects in the side-near-field have attracted much attention for the development of advanced driver assistance systems. Ultrasonic sensors applied the principle of 'time of flight' (TOF) to measure distance, which computed the travel time of ultrasonic echo reflected from the target [10]. Therefore, the performance of ultrasonic sensors highly depends on the reflective characteristics (e.g., shape, surface material) of the target surface [11].

Thus, an accurate and reliable model of ultrasonic sensors is of critical importance to the design of detection and tracking algorithms. In the literature, the models can be divided into two types based on their modeling principles: physical models and empirical models. The physical models are derived from the fundamentals of sensor working process, which simulated the errors based on the mechanisms of generation. For example, Kuc and Siegel designed a three-level model including geometric distance calculation, attenuation from reflection and transmission, and object recognition based on threshold methods [12-14].

In this design, we used sensors to control the distance and direction of user movement and location. Ultrasonic sensors were used as a detector. The ultrasonic sensor was also can be used as a directional detection [10-12]. Ultrasonic sensors are often used in automation tasks to measure distance, position changes, level measurement, such as presence detectors or in special applications. Some types allow you to adjust the sensitivity using a potentiometer or digitally. In the case of sensors that can be connected via the communication interface to the PC, it is possible to set detailed parameters of all the sensor's operating range and measured distances [15-17].

Three sensors were used to detect a person that walked in front of it. We used ultrasonic sensors type HCSR04. The sensors were installed in the front side of the trolley. Design of the sensors can be seen on figure 1. We assumed that the user will walk in front of the trolley, so that the sensors will detect the user and follow them wherever they go. Sensors detected the user based on the distance. So, we had to set the distance that sensors can detect first.

![Figure 1. Design of the trolley.](image-url)
Figure 2. Sensors and dc motors position.

We used 4 DC motor as the driver. Motors will run when the sensors got the right distance and detected somebody that walked in front of it. It will drive the trolley to move forward, backward, turn left, turn right and stop. In the design of the component connection adafruit motor shield mounted directly on Arduino (plugging) above it, and other power source components such as sensors and motors also comes from adafruit shield motor, so that the 9V-DC power from the outside is given to adafruit shield motor. We used Arduino as the controller. Arduino must be programmed first in order to perform its function. Arduino programming used the IDE (Integrated Development Environment) program. In order to the prototype could work properly, ultrasonic sensors were used to detect the user. It must be set the value and distance measure first. Error in setting the value and distance measure would cause error detection. The program was designed base on the flowchart in Figure 3.
Figure 3. Flowchart of trolley program.

The distance measure must be set on the sensor to detect the customer in front of it. When the value on ultrasonic sensor was 0 cm or not detecting would make the automatic trolley turned on at the beginning. When value on sensor $\leq 20$ cm; sensor $2 < 20$ cm and sensor $3 < 20$ cm, the trolley would move straight. When the value on sensor $1 > 20$ cm and $< 40$ cm, sensor $2 > 20$ cm or $< 40$ cm and sensor $3 = 0$ cm, the trolley would move to the right. When the value on sensor $1 = 0$ cm, sensor $2 > 20$ cm or $< 40$ cm, sensor $3 > 20$ cm or $< 40$ cm, the trolley would move to the left. When value on sensor $1$ and Sensor $3 = 0$ cm, sensor $2 > 20$ cm or $< 40$ cm, the trolley would stop (at rest but still detect). When value on Sensor $1$ and Sensor $3 = 0$ cm, sensor $2 > 40$ cm, the trolley would move forward. When the value on sensor $1 > 40$ cm, Sensor $3 = 0$ cm and sensor $2 > 40$ cm, the trolley would move forward. When value on sensor $1 = 0$ cm, Sensor $3 > 40$ cm and sensor $2 > 40$ cm, the trolley would move forward.

3. System Design

The program was designed so that the trolley can move forward based on the distance data from the sensor results. The program was built for 5 types of processes, that were forward, backward, and stop, left, and right. The program logic for forward, backward, right backward, and backward left using desbin logic, whereas to stop using if logic. The logic designed on the trolley was to make forward movement, change direction to the right, change direction left and backwards. Forward was when the trolley was over a distance of 40 cm, stops when the distance was more than 30 cm and smaller than 39 cm, and backward when the distance was less than 20 cm. The trolley could go forward, backward, stop, right backward, and backward left when it met the condition above. The variables in this program were US1, US2, US3, Jmin, bit1backward, bit2backward, bit3backward. Jmin was the minimum distance, bitbackward was the data of the form 1 and 0 (binary) obtained from the measurement sensor. If the distance is smaller or equal to Jmin, then bitbackward = 1; if the distance is greater or equal to 41, then bitbackward = 0.

The working principle of the ultrasonic sensor was transmit or sent a beam of ultrasonic waves, and then measured the time required until the arrival of the reflection of the object [18-20]. Arduino was used as the controller. Arduino was an open source electronic platform on hardware and software that was flexible and easy to use in creating interactive objects or environments [21]. Trolley prototype used the base material of mica plastic (acrylic), and used dc motors as its actuator. We could see the simple block diagram of automatic trolley working principle in figure 4.

Figure 4. Block diagram of automatic trolley.

By prototyping this method, developers and customers could interact with each other during the system creation process. Frequently, a customer simply defines in general what it wanted without specifying what output was required, what processing and data were needed. On the other hand,
developers were less concerned about the efficiency of algorithms, operating system capabilities and interfaces that connect human and computer. It took good cooperation between them, so that developers would know exactly what the customer want.

4. Result and Discussions

4.1 Ultrasonic Sensor Test
This test was performed to find out whether the ping sensor had succeeded to detect the distance. Testing was done by adding newping library on Arduino idea software, first sensor was declared as US1, second sensor was declared as US2, third sensor was declared as US3. The measurement results were obtained in centimetre. The test was done to obtain the distance value. It was done by closed and kept the position of the object in front of the sensor, to know the sensitivity when given a barrier object. A few test was done for the same distance.

Testing for sensor sensitivity level was done by comparing the sensor measurement results with the actual distance of the object using a ruler. The results could be seen in Table 1.

| NO. | MEASUREMENT USING RULER (CM) | MEASUREMENT USING SENSOR (CM) |
|-----|------------------------------|------------------------------|
| 1.  | 7                            | 6                            |
| 2.  | 5                            | 4                            |
| 3.  | 20                           | 20                           |
| 4.  | 30                           | 30                           |
| 5.  | 40                           | 40                           |

4.2 Trolley Test
Overall, the trolley testing on the initial condition when the trolley was activated, the trolley would measure the distance to the object in front of the middle, front left and front right trolley by using ultrasonic sensors located on the center of front right and left trolley body. And then, the distance would be displayed on the computer monitor serial program through Arduino module unit. The trolley test results were shown in Table 2.

| Number | Logical | Trolley Design | Result (%) |
|--------|---------|----------------|------------|
| 1      | Forward | All motor forward | 80 %       |
| 2      | Backward| All motor backward | 80 %       |
| 3      | Turn Left| Motor 1 and 3 move backward, motor 2 and 4 move forward | 70 %       |
| 4      | Turn Right| Motor 2 and 4 move backward, motor 1 and 3 move forward | 70 %       |
| 5      | Stop    | All motor stop   | 80 %       |

5. Conclusion
The trolley design could follow the human movement in front of it. It was controlled by the distance and follows the user. Arduino module unit could control the trolley Arduino can control the Trolley to
move forward, backward, turn right, turn left and stop. Based on the test results, the trolley succeeded to move forward by 80%, move back 80%, turn left, 70%, turn right 70%, and stop 80%. Trolley can follow human movement but cannot increase speed and distinguish who was its owner. The optimal measurement range of sensor measurement was obtained at a distance of 20 cm upwards to the end of the distance (in this case limited to 100 cm).

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