

## Automated medical surgical trolley

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### Article Info

#### Article history:

Received Aug 12, 2018

Revised Nov 20, 2018

Accepted Dec 26, 2018

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#### Keywords:

Arduino  
Automatic medical surgical  
trolley movement  
IP camera  
Operation theatre  
Surgical equipment

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### ABSTRACT

Operating theatre is a place in a hospital where surgical operations are conducted on patients by surgeons. In the operating theatre, the surgical equipment is placed on stainless steel table or on surgical instrument tray. However, during the operation accidents can occur where the surgical tools placed near to the surgeon could be accidentally be hit by them during the surgical operation. This may cause the surgical tools to fall on the floor which may lead to injuries. Hence, this paper presents an automatic medical surgical trolley for surgeons to grab operating tools easily. The proposed system is implemented for automatic medical surgical trolley movement using Arduino Uno R3. The invention provides an automatic medical surgical trolley which comprises automatic guidance, a wireless controller, an obstacle avoiding detection device, a touch screen controller via smart phone, an IP camera, a trolley, an integrated power supply and a processor. The trolley with stainless steel shelves is ideal for use in clinical environments and operation theatres. Medical equipment is loaded in the trolley, the wireless remote drives the trolley to move forwards and backwards. Automatic visual guidance is achieved via an IP camera attached to the trolley and a touch screen controller via a smart phone. A large amount of space and a large number of materials are saved, the workload of medical workers will be greatly relieved, and the working efficiency will be improved.

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## 1. INTRODUCTION

Operating theatre is a very busy area and a very clean area which is always called as a “sterile”. The surgical equipment tray is designed in order to lay all the surgical tools on it. The procedure’s flow will become smoother if the equipment they need all in one easy to access on the tray. Recently, there are many careless cases occurred in the hospital for instance in the operating theatre [1], [2].

The messy condition of the operating tools on the tray and the position of the tray next to surgeon could make the surgeon feel uncomfortable and suffocating which could lead the surgeon concentration to be disturbed. Safety is one of the important things to consider especially at the workplace because without it, the serious injuries or death could take place [3]. Workers injuries could affect the quality of the company or business state due to it will cause the insurance rate increased, other employees may be distracted and the productivity will be lost due to the accident. Accidents occur is because one choosing the wrong method of procedure or due to poor execution [4], [5].

Accidents can occur anytime and anywhere such as in the operating theatre. For instance, the usual cases happened in the operating room are anesthesia mistakes, operations on the wrong side of the body part and the surgical tools left inside patient’s body which lead to loss of a patient’s life [6]. The injuries not only

could happen to patients but to surgeons and other people inside the operating room as well. For example, the surgical tools placed near to surgeon could be accidentally be hit by them during surgical operation.

Many researchers have studied on smart trolley but many have been applied in supermarket. Reference [7] proposed smart trolley in mega mall where the component used are optical sensor as the sensor to detect obstacles and AtmelAT89V51 microcontroller. Reference [8] proposed smart trolley using RFID to speed up the purchase of product. The smart trolley will detect the items using tag card and the tag card will send information about the total price to the counter during payment.

Reference [9] proposed a smart trolley follower that follows and track line using vision based technique. The component used in this project is the ATmega microcontroller and blobbing technique as the tracking and detecting sensor. Reference [10] proposed a trolley that follows customer during shopping activities. The component used is the IR transmitter, IR receiver with a microcontroller. Reference [11] proposed a shopping trolley that can follow customer during shopping with giving information of the item located in the mall. The component proposed are the Arduino Mega as a microcontroller with ultrasonic sensor as the object detector. The RFID technology and Bluetooth module are proposed as the receiver for the instructor.

In this paper, automatic medical surgical trolley movement is designed to assist the surgeon and nurse in the operation theatre. This project involved the implementation of hardware and software design. The Arduino Uno R3 is implemented as the microcontroller for the hardware design that control the input and output instruction. Ultrasonic sensor is used as the obstacles detector to avoid trolley collide with object during the movement. Power window motor is used as the movement component in this project. The IP camera with Wi-Fi module is applied as a monitor system for the nurse to put medical equipment during the surgery is conducted.

This paper contains five section. Section 2 proposed the flow process of the proposed methodology in detail. Section 3 discussed the result of the implementation of hardware and software development toward the automatic medical surgical trolley and Section 4 conclude the work presented.

## **2. RESEARCH METHOD**

### **2.1. Proposed method**

The flow process of this automatic medical surgical trolley involved the implementation of hardware and software development is shown in Figure 1. The flow process begin with the input signal is transmitted to the Arduino Uno R3. The input signal transfer information to the Arduino and then transfer to the relay to give output to the power window motor. Once the signal is received, the automatic medical surgical trolley starts to move according to the instruction given. The power window motor will move the trolley backward or forward based on the ultrasonic sensor. Once the ultrasonic sensor detect object in front of it, it will stop moving until another path is recognized. Then the trolley will start move. Otherwise it will just move until it reach the location given by the instructor.

### **2.2. Hardware implementation**

A hardware implementation is used that includes battery, wireless switch, smartphone, control unit, Arduino Uno R3, Relay, Ultrasonic sensor and motor. Figure 2 below shows the system architecture of this project. The system architecture used consists the power supply to power up the control unit. The wireless switch and smartphone is used as to send information to the control unit. The control unit will control the movement of the trolley based on the object detector, relay and motor. Table 1 shows the parameter and description for the project proposed.

### **2.3. Arduino uno R3**

Arduino is widely used as an open-source single-board microcontroller for the development platform which is flexible, easy-to-use hardware and software components [12]. In this study, Arduino Uno R3 with an onboard USB to serial chip is used to load code into on-board Atmega328 Microcontroller. This Arduino contains everything needed to support the microcontroller. To get started, user simply needs to connect Arduino Uno R3 to a computer with a USB cable. The Arduino consist 14 digital input/output pins which is used as a PWM outputs, 6 analog inputs, 6MHz crystal oscillator, a USB connection, a power jack an in-circuit system programming (ICSP) header and a reset button. The pin Connection of Arduino UNO R3 with Other Hardware as shown in Table 2.

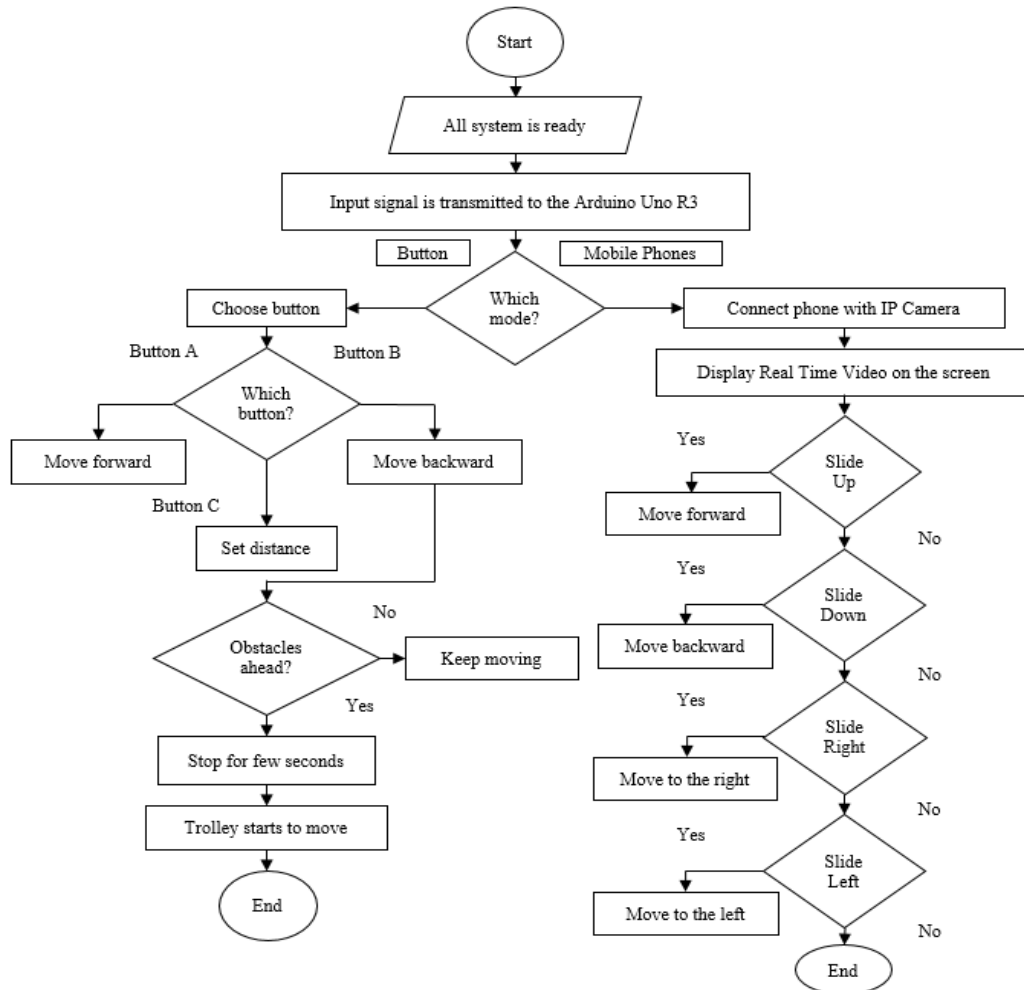


Figure 1. Proposed system design

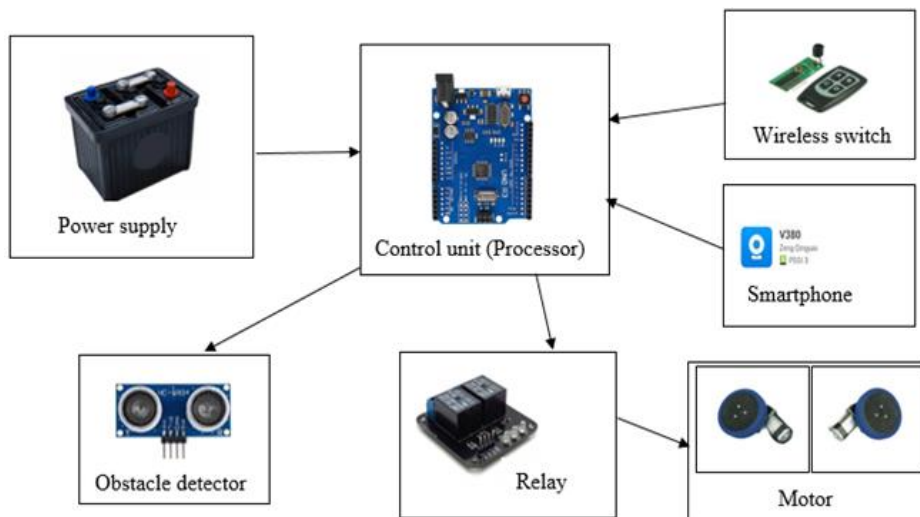


Figure 2. System architecture

Table 1. The Parameter and Description of Automatic Medical Surgical Trolley

Parameter	Description
Features	<ul style="list-style-type: none"> <li>a. Automatic visual guidance is achieved via an IP camera attached to the trolley and a touch screen controller via a smart phone.</li> <li>b. The trolley with stainless steel shelves is ideal for use in clinical environments and operating theatres.</li> <li>c. The automatic medical surgical trolley can avoid obstacles during the movement.</li> <li>d. The dimension of the trolley: 950 mm x 500 mm x 940 mm.</li> <li>e. The trolley can support up to a maximum weight of 20 kg for optimal operation.</li> <li>f. The trolley has 15 ampere load of power window motors supporting maximum speed of 15 RPM with no load.</li> <li>g. Battery power to supply power to the motor supporting maximum speed of 15 RPM with no load.</li> <li>h. The trolley has Wireless Switch Controller to drive the trolley forward and backward.</li> <li>i. Visual Guidance using IP Camera</li> <li>j. Touch Screen Controller using Mobile Phone</li> <li>k. Integrated Power Supply is attached together with the trolley.</li> </ul>
Platform	a. Arduino Uno R3, ATmega328 Microcontroller
Actuator and Driver	b. Relay & 60 ± 15RPM Rated Speed Power Window
Sensor	c. 5V DC Ultrasonic Sensor Module
Communication Technology	<ul style="list-style-type: none"> <li>d. IP camera with WiFi Module</li> <li>e. Mobile phones</li> <li>f. Wearable switch</li> </ul>
Algorithm	<ul style="list-style-type: none"> <li>a. A touch screen controller via a smart phone is used as an instructor for the automatic medical surgical trolley to move.</li> <li>b. The IP camera send information to the Arduino Uno R3 and the instructor.</li> <li>c. The power window motor allows the automatic medical surgical trolley to move according to the instruction given.</li> <li>d. Ultrasonic sensor is used and assists the power window to move and avoid the trolley from any obstacles.</li> </ul>

Table 2. The pin Connection of Arduino UNO R3 with Other Hardware

Arduino Uno R3	Output
pinA0 (6x Analog IN)	Resistor R1
pinA1 (6x Analog IN)	Resistor R2
pinA2 (6x Analog IN)	Resistor R3
pinA3 (6x Analog IN)	Resistor R4
pin13 (14xDigital IN/OUT)	Ultrasonic sensor 1
pin12 (14xDigital IN/OUT)	Ultrasonic sensor 1
pin11 (14xDigital IN/OUT)	Ultrasonic sensor 2
pin10 (14xDigital IN/OUT)	Ultrasonic sensor 2
pin9 (14xDigital IN/OUT)	Relay
pin8 (14xDigital IN/OUT)	Relay
pin7 (14xDigital IN/OUT)	Relay
pin6 (14xDigital IN/OUT)	Relay
pin5 (14xDigital IN/OUT)	RF module receiver
pin4 (14xDigital IN/OUT)	RF module receiver
pin3 (14xDigital IN/OUT)	RF module receiver
pin2 (14xDigital IN/OUT)	RF module receiver

Connect to  


#### 2.4. Ultrasonic uno R3

Ultrasonic sensors are one of the favorable complementary sensors for indoor localization due to the small size, lightweight, and low cost [13]. It is used to measure the distance to an object by using sound waves. Ultrasonic sensors measure distance from a sound wave that has been sent at a specific frequency and listening for that sound wave to bounce back. This device has a stable performance and high accuracy ranging from 2cm to 450cm.

#### 2.5. Wireless switch

The wireless switch is to transmit and receive signal. The switch powers the receiver with 3.3-10Vdc and press the buttons on matching RF key fob remote. For the operation for the wireless switch, when button A is pressed, it activates the first pin on RF module (receiver). While when B button is pressed, it activates the second pin and so on for all four buttons. This is M4 momentary type acts like a push button and T4 toggle type acts like an alternating toggle switch.

## 2.6. Power window

The power window is used to open and close the motor windows by switch operation. The power window that is used has features like a car manufactured by Malaysian carmaker Proton which is Proton Wira Power Window Compatible, with voltage rating of 12Vdc, perfect fit with 5 inches' robot wheel with just 3 screws and can utilize up to 10A shield to drive the motor. The rated speed is  $60\pm 15$ RPM, while no load speed is  $85\pm 15$ RPM, the current with no load is less than 5A, rated current with load is maximum to 15A and stall current when trolley is locked is maximum to 28A at 12V. the power window rated torque is 30kg.cm (2.9N.m) while stall torque is  $100\pm 15$ kg.cm (~10N.m).

## 2.7. Relay

Relay is used to detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers. The function of relay is also to control a circuit by a low power signal or where several circuits must be controlled by one signal. Relay was used to switch and change contact. Relay switch is an electrically operated switch where the current flowing through the coil of the relay creates a magnetic field. This magnetic field attracts a lever and changes the switch contacts. The coil current of the relay can be off or on so the relays have two switch positions and most have double throw (changeover) switch contacts. The Input and Output Connection of Relay as shown in Table 3.

Table 3. The Input and Output Connection of Relay

Input of relay	Output of relay
Arduino Uno R3	Relay 3
Arduino Uno R3	Relay 4
Relay 3	Relay 1
Relay 4	Relay 2
Relay 1	Motor (of power window)
Relay 2	Motor (of power window)

## 2.8. Battery power

For instance, the proper operation of microcontrollers, depended on the voltage quality supplied to them [14]-[18]. Battery power is used to supply power to the trolley. To avoid from malfunction, the battery is set to 12-volt maximum voltage.

## 2.9. IP camera with wi-fi module

The IP camera with Wi-Fi module is used in this project to monitor the movement of the trolley. The IP camera is applied for the nurse to put medical equipment onto the medical surgical trolley while surgery is conducted [19]. In this way, the nurse can avoid interrupting the surgeon from going in and out from the operating theatre only to get any medical equipment that is needed while the operation is conducted. Figure 3 shows the apps from the smart phone to drive the trolley in real time video.

## 2.10. Software implementation

The software implementation is needed to control the Arduino Uno R3. Firstly, each command needs to be declared at the top of each coding. The first coding is declared to activate the ultrasonic sensor. Figure 4 shows the source code to power on the ultrasonic sensors. After the ultrasonic is configured successfully, the sensor will detect any obstacles in the maximum range of 400 to 500cm. The source code is built to the Arduino Uno R3 to control the movement of the trolley. The Arduino Uno R3 is then connected to the relay to move the motor in forward, reverse, right or left direction. This system is also designed to stop the trolley when the obstacles are detected by the sensors. Figure 5 shows the full source code of the software implementation.

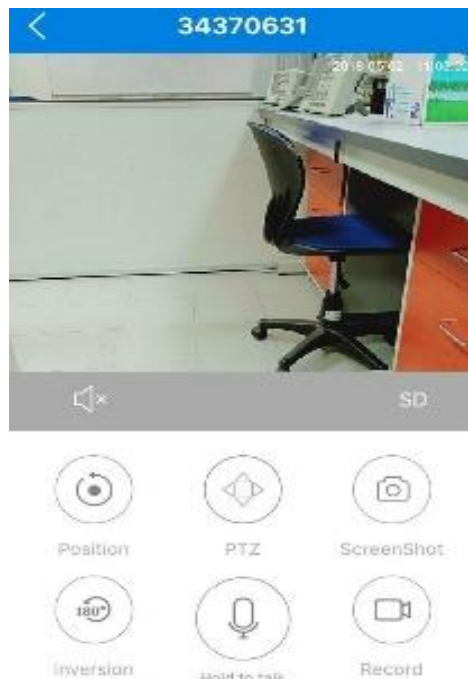


Figure 3. Apps to drive the trolley, with real-time video

```
#include <NewPing.h>2

#define TRIGGER_FRONT 11 // Arduino pin tied to trigger pin on the ultrasonic sensor.
#define ECHO_FRONT 10 // Arduino pin tied to echo pin on the ultrasonic sensor.

#define TRIGGER_BACK 13 // Arduino pin tied to trigger pin on the ultrasonic sensor.
#define ECHO_BACK 12 // Arduino pin tied to echo pin on the ultrasonic sensor.

#define MAX_DISTANCE 200 // Maximum distance we want to ping for (in centimeters). Maximum sensor distance is rated at 400-500cm.

NewPing sonarfront(TRIGGER_FRONT, ECHO_FRONT, MAX_DISTANCE); // NewPing setup of pins and maximum distance.
NewPing sonarback(TRIGGER_BACK, ECHO_BACK, MAX_DISTANCE);

//declare pin
const int inPinA = 2; // BUTION A
const int inPinB = 3; // BUTION B
const int inPinC = 4; // BUTION C
const int inPinD = 5; // BUTION D

const int Relay1 = 6; // left tyre forward
const int Relay2 = 7; // left tyre backward
const int Relay3 = 8; // right tyre forward
const int Relay4 = 9; // right tyre backward
```

Figure 4. Source code to declare the ultrasonic sensors and wireless switch

```

void loop()
{
  // ***** SETTING DELAY TROLLEY *****
  if (PinC = digitalRead(inPinC)) // Pin C for motor move right
  {
    Serial.println("\n *** SETTING MODE ***");
    Delayfront=0;
    Serial.print("\nDelay initial =");
    Serial.print(Delayfront);
    MotorForward();
    do
    {
      delay(100);
      Delayfront=Delayfront+1;
    }while (PinD == digitalRead(inPinD));
    Serial.print("\nDelay set =");
    Serial.print(Delayfront);
    MotorStop();
    ("\n *** SETTING DONE***");
  }

  // ***** MOTOR FORWARD *****

  if (PinA = digitalRead(inPinA)) // Pin A for motor move forward
  {
    Serial.println("\n BUTTON A PRESSED");
    DelayDetectforward();
  }

  // ***** MOTOR REVERSE*****

  if (PinB = digitalRead(inPinB)) // Pin A for motor move forward
  {
    Serial.println("\n BUTTON B PRESSED");
    DelayDetectreverse();
  }

  // ***** CAM MOVEMENT *****

  if (Cam1 = digitalRead(inCam1)) // Cam1 for motor move forward
  {
    do
    {
      Serial.println("trolley move front");
      MotorForward();
    }while (Cam1 = digitalRead(inCam1));
    Serial.println("trolley stop moving");
    MotorStop();
  }

  if (Cam2 = digitalRead(inCam2)) // Cam2 for motor move reverse
  {

```

Figure 5. Source code for overall system for automatic medical surgical trolley movement

### 3. RESULTS AND ANALYSIS

Arduino Uno R3 is used as the main microcontroller to interface with all hardware used in this project. A touch screen controller via a smart phone is used as an instructor for the automatic medical surgical trolley to move. An IP camera with Wi-Fi module is used as a transmitter and receiver data between a touch screen controller to monitor the movement of automatic medical surgical trolley in and out from the operating theatre. The power window motor allows the automatic medical surgical trolley to move according to the instruction given. Thus, the automatic medical surgical trolley can lead surgeons and nurses during surgery. In order to prevent the automatic medical surgical trolley colliding with other object, ultrasonic sensors are used to avoid collision. Figure 6 shows the automatic medical surgical trolley of this project.

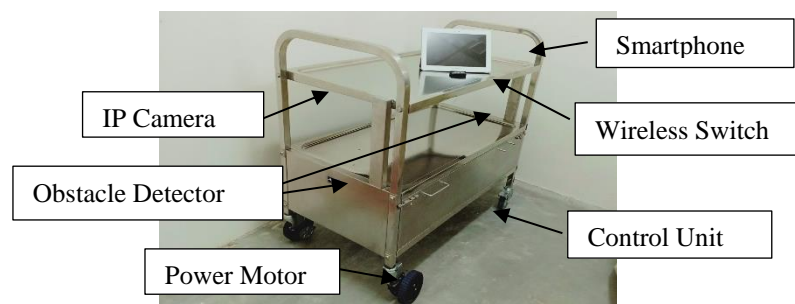


Figure 6. Automatic medical surgery movement

The welfare of operating within any engineering environment is of the prime importance. All experiment carried out were expected in a safe manner with no negative effect on health and wellbeing. Health and safety during producing this product is about measures designed to protect the health and safety of the general public who may be affected by these activities. Product safety is a term used to describe policies designed to protect people from risks associated with thousands of consumer products they buy and use every day. Therefore, safety and health measured has always been the consideration before producing this automatic medical surgical trolley.

Arduino Uno R3 is implemented as the main controller to interface with all hardware used in this project. It is used to process the input from the instructor and transmit data to the power window. The Arduino Uno R3 is a sensitive microcontroller where several precautions must be considered. The maximum voltage applied to the Arduino Uno R3 is 5.5 volt where it does not exceed 12 volts to avoid overload voltage and it is applied on direct current only. The input and output pins were not shortening to avoid overcurrent condition on both input and output pins. The pushbuttons or switches were connected to the Arduino Uno R3 using pull up and pulldown resistor. Figure 7 shows the schematic circuit of hardware and software implementation of automatic medical surgery trolley using Proteus. The schematic includes the connection of Arduino Uno R3 to ultrasonic sensor, relays and motor.

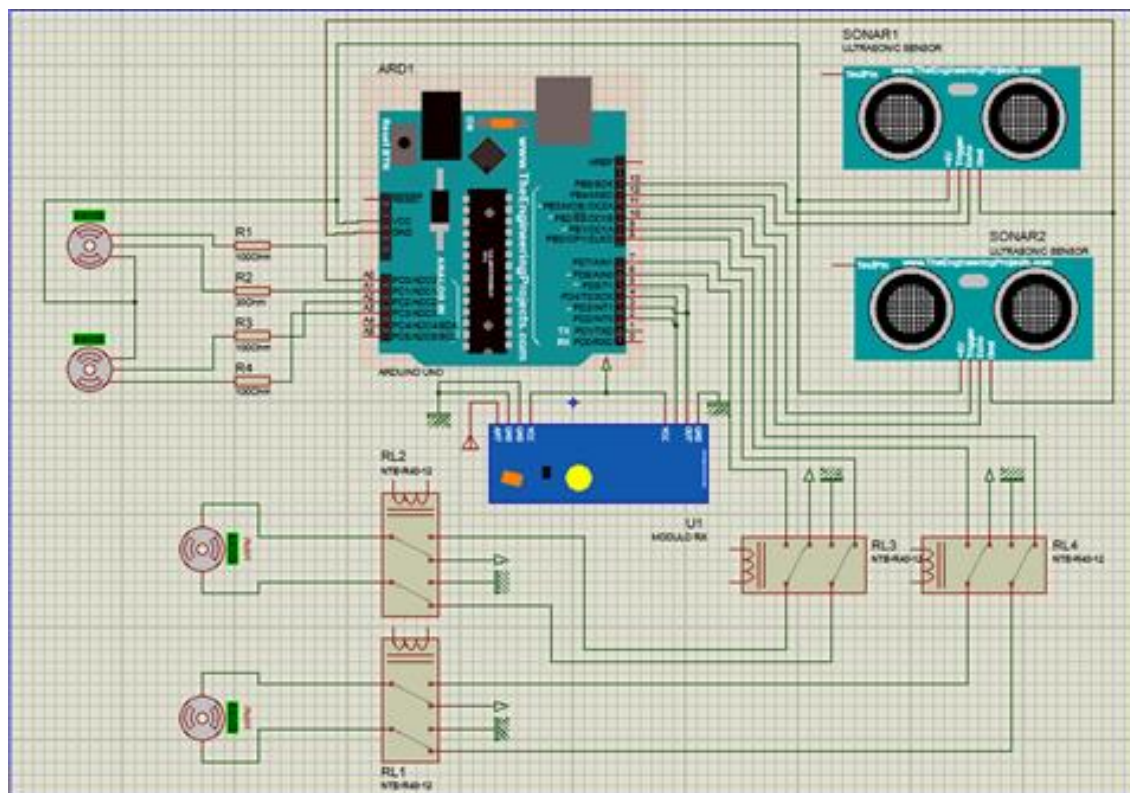


Figure 7. Schematic diagram for the hardware implementation of automatic medical surgery trolley movement

When the torque of the power window motor is decrease, inertia impact is reduced. This precaution is considered to avoid medical stuff fell down when the trolley moves and stop. The other precaution is considered is the tyre surface. The tyre surface was modified to have a higher grip so it can enable the trolley to move to the location without sliding to other place.

Several wires were used in connecting the battery with the relay and the power window motor. The end of each wire is implemented with the connector. The connectors used are made from reinforced insulation where the protection is provided by single or basic insulation but has the same protective properties as double insulation between two cables when connected. It is due to prevent from the current leakage. Thus, it can be last longer and it is a proper way to connect between two cables.



Last but not least, the automatic medical surgery trolley is made from aluminum sterilize for protection against germs and infection. A proper hygiene is a must in health-care environment since this product will be used in hospitality environment. Aluminum is a metal use widely in hospital because its property against rust. Thus, it is easy to clean. Besides that, Food Safe Coatings for Metal applied on the trolley since the product will be used to place surgery utensils and require extra protection against germ and rust. That is especially true if you work in health care, where poor hygiene can be matter of life and death.

#### 4. CONCLUSION

In conclusion, an automatic medical surgery trolley is developed to assist surgeons to reach medical equipment during surgical operation. The automatic medical surgery trolley system is developed with a microcontroller based on Atmega328 called Arduino Uno R3. The Arduino Uno R3 receive input signal and delivers output to the relay and power window motor to move the automatic medical surgery trolley. The automatic medical surgery trolley move based on the ultrasonic sensor where the sensor will move whenever no object is blocking the way through the location. An IP camera with Wi-Fi module is attach as the monitoring system for the nurse to move the trolley in and out from the operating theatre.

#### ACKNOWLEDGEMENTS

The authors would like to thank the Universiti Teknikal Malaysia Melaka (UTeM), Rehabilitation Engineering & Assistive Technology (REAT) research group under Center of Robotics & Industrial Automation (CeRIA), Advanced Digital Signal Processing (ADSP) Research Laboratory and Ministry of Science, Technology & Innovation (MOSTI) Malaysia for sponsoring this work under project 06-01-14-SF00119 L00025 and the use of the existing facilities to complete this project.

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