School of Engineering and Computer Science

BRAC University

Personal Health Care Companion – A Medication Assistant Robot

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Declaration

We hereby declare that we carried out the work reported in this thesis report, submitted by the authors listed for the degree of Bachelor of Science in Computer Science and Engineering to the Department of Computer Science and Engineering under the School of Engineering and Computer Science, BRAC University. We solemnly declare that to the best of our knowledge, no part of this report has been submitted here or elsewhere in a previous application for award of a degree. All sources of knowledge used have been duly acknowledged.

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Abstract

The purpose of the project is to build a robot which can act as a personal health care companion for elderly people. It will have some sensors to detect any possible injury and to erasure blood pressure, pulse rate and also gossiping, medicine alert etc. A motor stick can be attached to the robot which can help the elder people to walk. It will also have some Artificial Intelligence to interact with the user using face detection and voice command system.

Keywords

Medical Assistant, Robotics, Image Processing, Voice Recognition, Medicine Serving, OCR.

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Personal Health Care Companion – A Medication Assistant Robot

1 Introduction

1.1 Motivation

In this modern era, technological advancement is spreading its tentacles worldwide. Although majority of the people are being immensely benefited but description this some people especially the elder ones are still sufferers. This is because they are not that capable of doing normal activities due to their age and engulfed by natural types of diseases. There are so many medicine they need to take.

Personal Service Robotics is an emerging field in the recent world with a variety of application fields. Using service robots to take care of elderly and chronically ill people will be a bigger achievement. More than 5% of our total population is over 65 years or above in age who needs extra care. Our robot can take care of their health as well as accompany them in their lonely time. Some easy to do tasks like reminding the user to take their medicine in scheduled time, measure their body temperature, monitor their heart rate, alerting the doctor if needed, showing images of the dear ones etc. doing these jobs can play a vital role to give patients and elderly people proper treatment. If there is a robot to do these tasks, costs and expenses of our health sector might reduce and affordable to general people. Thus, to give proper and affordable treatments to the patients and elderly people, is our motive for this research.

1.2 Goal and Purpose

The main focuses of the system is help the elder person. They are more vernalable at their age. The Goal of the system is to serve the medicine to the patient especially those elder patient and become a good companion of their lonely life [1].

1.3 Research Methodology

Through our research on the project, we have reached to a conclusion that using MATLAB for the image processing is much faster, effective and accurate in our embedded hardware system. The program, we have implemented in our system which can detect the position of a medicine in a strip, uses the **Image Acquisition Library** and **Image Processing Toolbox**. The libraries of MATLAB are much easier and faster to program than other choices such as Microsoft Visual Studio Libraries and OpenCV Libraries. We have researched some algorithms for the medicine detection which has been used in industrial robots for object detection and found out that the best is **Circle Detection Algorithms** for the detection of medicine. We have integrating the processed images with the system using Arduino/Raspberry Pi uses the internal library of MATLAB which is much simpler than others.

2 Literature Review

In order to successfully carry out the thesis project and learn about the existing systems, we had to go through a lot of research papers and tried to expand our knowledge boundaries on different approaches and techniques of image processing and robot building. Some related works are mentioned in the following:

Socially Intelligent robot (Kerstin Dautenhahn, February 2007): This paper mainly talks about how the robot interacts with human socially. First part of this paper talks about HRI (Human Robot Interaction), discussing requirements on social skills for robots and introducing the conceptual space of HRI studies. Main focus of this paper is to develop social rules for robot behaviour (a ‘robotiquette’) that is comfortable and acceptable to humans. These ideas are quite intriguing and we thought this can be implemented [2].

Health Care Robotics: A Progress Report (Paolo Fiorini, Khaled Ali, Homayoun Seraji): In this article, how to design and evaluate mobile robot for health care assistance to the elderly and the handicapped is discussed briefly. They described how to build and implement the logics like The Manipulator Arm, The User Interface, Feedback to the user, etc. which also gave us some ideas for our research [3].

Towards Personal Service Robots for the Elderly (Nicholas Roy, Gregory Baltus, Dieter Fox, Francine Gemperle, Jennifer Goetz, Tad Hirsch DimitrisMargaritis, MikeMontemerlo, Joelle Pineau, Jamie Schulte, Sebastian Thrun) : This article momentarily emphases on cognitive prosthesis, safeguarding, systematic data collection, remote tele-medicine, social interaction, which gave us numerous ideas [1].

3 System Architecture

3.1 Overview of the System

Personal Health Care Companion is designed to provide medication assistance, particularly to the elderly people. In some extent, the system also provides user with basic health and environmental analysis. The system is developed as a form of a robot, hence the idea of incorporating some form of artificial intelligence along with traditional robotics was obvious. The architecture of the system, hereby, includes a structural mainframe consists of locomotion subsystem, medication assistant subsystem and alert and diagnosis subsystem.

Input: Inputs of the system controls most of the activities of the system and influence the outcome. The system takes inputs from user and environment, mostly using sensors. Some of these sensors continuously monitors for input and others provide on demand response essential to the system flow.

Processing: While some parts of the system are hierarchical, the general architecture of the system involves running concurrent subsystems. Besides simple computation and logical operations, the system performs complex operations such as image processing and voice recognition. Therefore, a processing unit capable of such complex operations needed to be included as a part of the system.

Communication: Successful system flow requires proper communication and organization among subsystems and processing units. While subsystems are designed to be independent of each other as much as possible, some communication are necessary among subsystems and processing units as the system involves sensing data from user, environment and inputs.

Power: Apart from subsystem components, processing unit and communication, power is one of the major area of concentration. So, the system architecture includes power management and regulation so that the system units may work without interruption.

Output: Outputs of the system are the successful execution of the process done by one or more subsystems. Results of the outputs include responses, movements or services such as medication alert, medicine serving process, etc.

3.2 Model of the System

3.2.1 Distribution of the System

The entire system comprises two major aspects, physical and logical units. On one hand, the physical structure involves mechanical, electrical and electronic components. On the other hand, logical part of the system includes logic operations, numeric calculations, data processing, etc. So, the distribution of the system is segmented as following,

Physical:

i. Mechanical

ii. Electrical

Logical:

i. Numerical and logical operation

ii. Image and voice data processing

Based on this architectural segmentation, the whole robot system is evolved through the development and integration of logic, hardware, software.

3.2.2 Model of the System

The core system is developed under three major wings or specialized units. These units are assigned to particular tasks. Results of one unit may help other units to perform dependent tasks. The following figure demonstrates a generalized subdivision of the current system components.

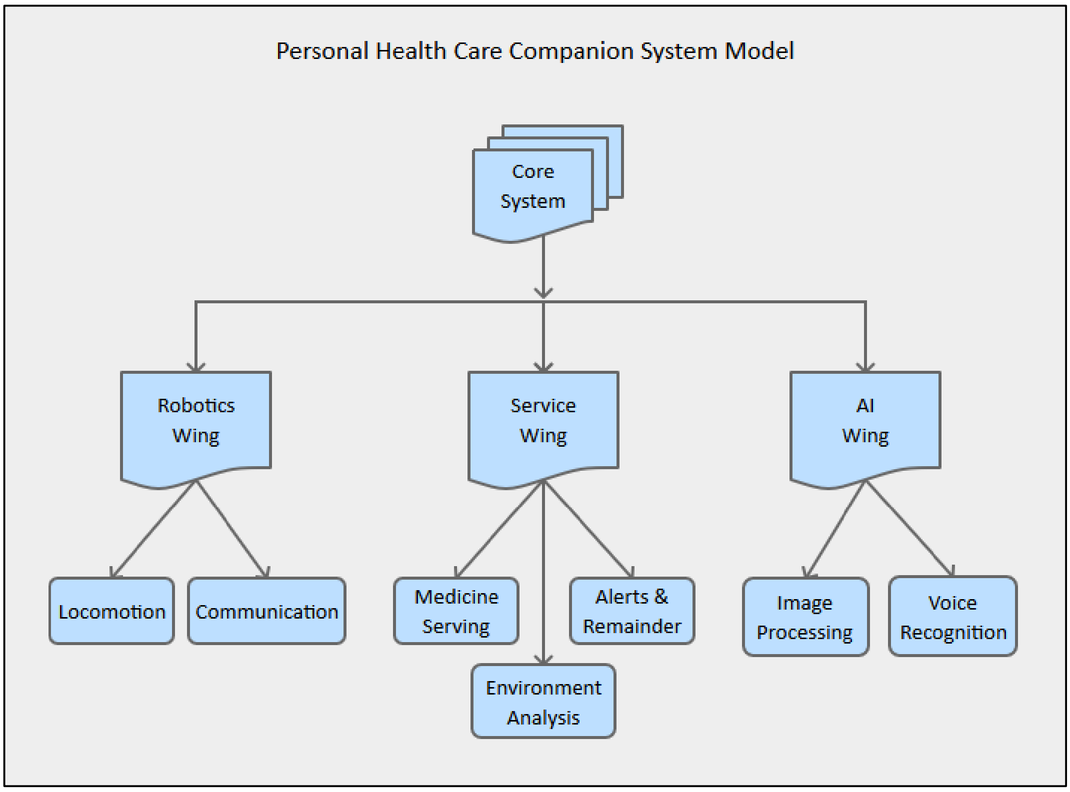


Figure 3.2-1 System model

Above figure also indicates the modularity of the system. Traditional robotics enables locomotion and communication. It also manages power distribution. Artificial intelligence provides intelligent use of sensor data, performs complex data processing and help performing autonomous actions. With the help of robotics and AI, major services are provided by the service wing. These services include medication reminder and physical serving of the medicine.

3.3 Block Diagram of the System

Block diagram mainly represent the major functionalism of the system and how it works is a very simple way. In below figure shows the whole system of the project. The block diagram combined in five components.

1. Input System
2. Core System
3. Communication Unit
4. Power Unit
5. Output System

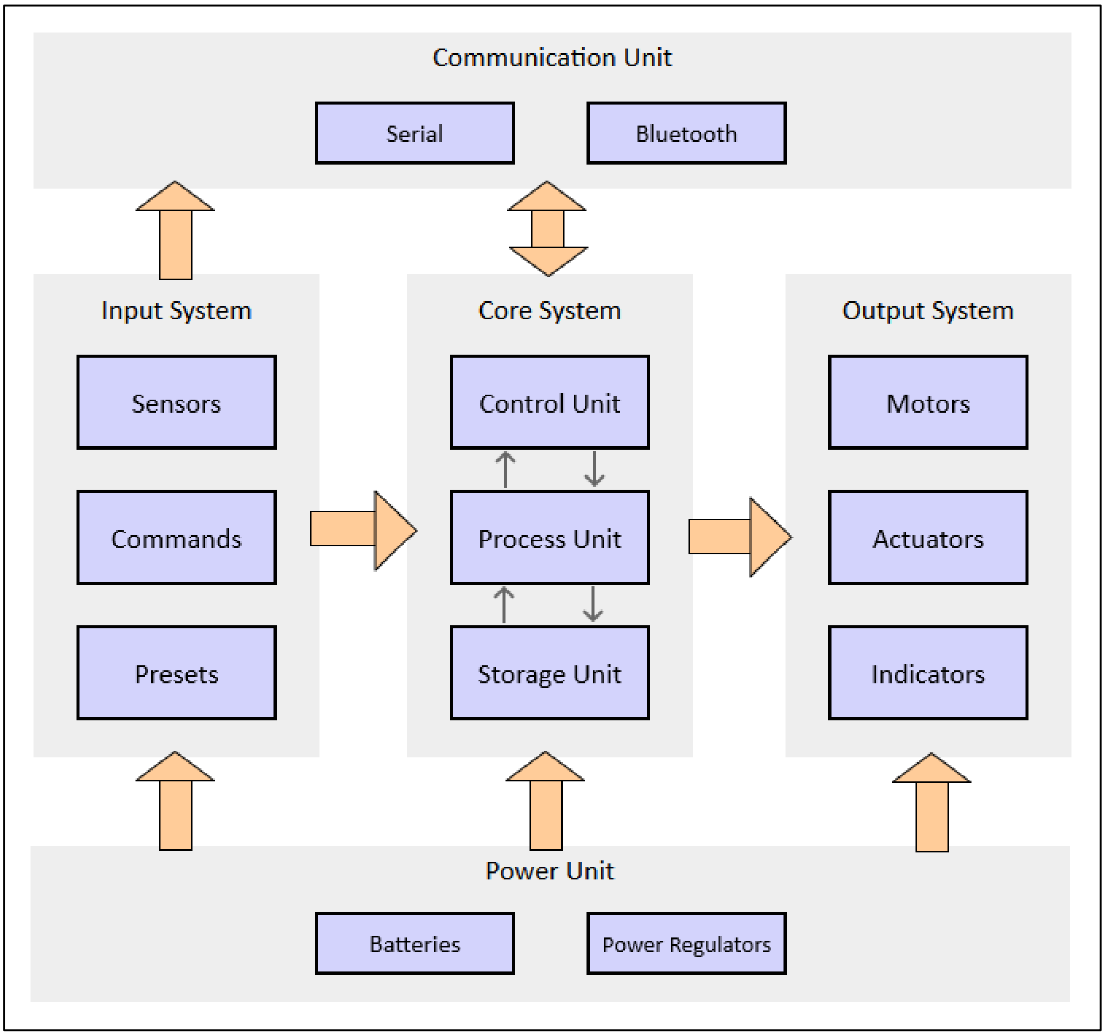


Figure 3.3.1: Main block diagram

3.3.1 Input System

Input System is one of the major components of the system. With the help of Power Unit and Communication Unit, the Input System established the link with the Core System for processing the inputs. Input system is segmented in following parts

1. **Sensors:** Sensors mainly used for collecting data quickly. The sensors that helped this project is given below
   a. *Camera:* Image processing has been used for detecting the medicine. For performing image processing, the input sensor has been use is webcam camera.
   b. *Microphone:* This project includes voice command option which help the device to move around or give the medicine from the medicine stip. The microphone has been used for capturing the voice input.
   c. *Switches:* One servo motor and two actuator have been used in this device. The servo motor use for rotation. One of the actuator use for push the medicine from the medicine strip and another one is to up-down the medicine carrier. From the switch’s input the core system able to control the rotation and the up-down measurement.
2. **Commands:** The device take input from users and also from the PC/Laptop. The commands can go through the communication unit to Core System or directly to Core system for processing the input. This commands input plays a major role in output System.
3. **Presets:** There are some per-defined commands in the input system which helps the main system to work automatically. This pre-define commands go to the control unit of the core system as input. Here this pre-defined command input named as presets.

3.3.2 Core System

Core System are the main part of the system. The Core system have been connected with every other units of the system. Fundamentally core system process the inputs from input system and show the output in output system. Communication Unit and power unit support the core system for processing. This parts also handle the logical operation. The core system is built by thee following parts

1. **Control Unit:** Control unit holds the main controller of the system. Here the Arduino Mega is the controller of the control unit as well as the main system. Control unit mainly control the rotation of the motor as well as the actuators length based on the inputs.

2. **Process Unit:** Arduino is in the process unit because it handle minor processes and some logical processes. There is one extra process unit has been used to control the system which is PC. This system need to process image data and voice data and arduino mega is not capable to process these data. This is why the PC has been used for processing the data. Process unit and control unit have communion with each other and it communicate in serial way.
3. **Storage Unit:** There are some third party software have been used in this system and MATLAB and Visual Studio are two of them. Those software save some data so that it can use it when the software work next time. Therefore there is a communication between the software and the storage unit.

3.3.3 Communication Unit

Communication unit manly plays the supporting role in this main system. Mainly Arduino and PC perform the communication in this unit

1. **Serial:** Most of the communication performed in this project use Serial communication. Arduino and PC communicate each other in serial. Input System use serial communication for permit the input in Core system.
2. **Bluetooth:** Bluetooth is one of the source of communication between Input System and Core System. Here Bluetooth mainly used for performing the wireless communication. Voice input from the input system go to the Process Unit of the Core System via Bluetooth.

3.3.4 Power Unit

Input system, Core system and Output System need Power to perform individual's duty. Without the power, the system does not work. Therefore, Power Unit provide the power to active the other units.

1. **Batteries:** The main source of power of our system is DC battery.
2. **Power Regulators:** In this system, some component need fixed amount of power. If the power limit cross the maximum limit then it will hamper the circuits as well as the whole system. For that reason, power regulator has been used.

3.3.5 Output System

There has to be some output in this system. According to the inputs, the outputs are performed with the help of control and process unit.

1. **Motors:** The motors are performed according to the commands from the input system. According to the inputs, the motors from the wheel will go forward or backwards and left or right as output. The Serco motor will rotate the medicine holder when the input command is “serve the medicine”.
2. **Actuators:** One output is push the medicine and another output is finding the right medicine position and both of the output performed my two actuators
3. **Indicators:** There are some indicator like Green LEDs, Red LEDs. Its show some of the outputs like, medicine strip is empty, device is moving, actuators or motor are working etc.

4 Design and Simulation

4.1 Model Designing

For turning an idea into a workable object there is a need of good design. It has been said that sketches is a good source of clever reauselt [4]. The device is created after designing and changing the sketch and mdel. For designing the model, Audodesk 3DS MAX software has been used. This software has lots of advantages and easy to understand. This software have x,y and z-axis for building 3D model [5].

4.1.1 Primary Design

First concept of our design is to pull the medicine form the medicine strip is from outside. The concept was there would be a pin which would rotate and the medicines were fixed. There is a device named Care-O-bot 3 which have similar concet with this project [6]. This help to find out the flaws of the device. This concept was not able to implement because of lack of proper equipment and design flaw.

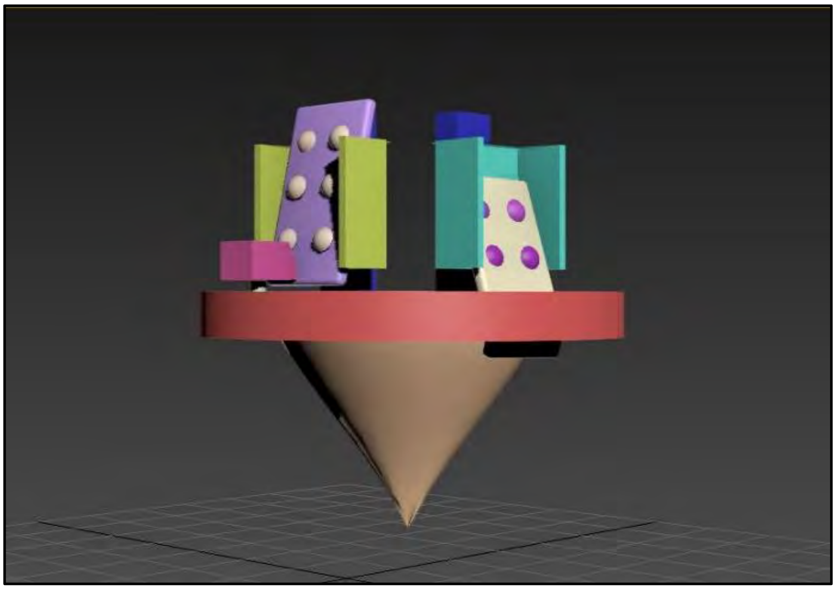


Figure 4.1-1 Medicines fall in tunnel

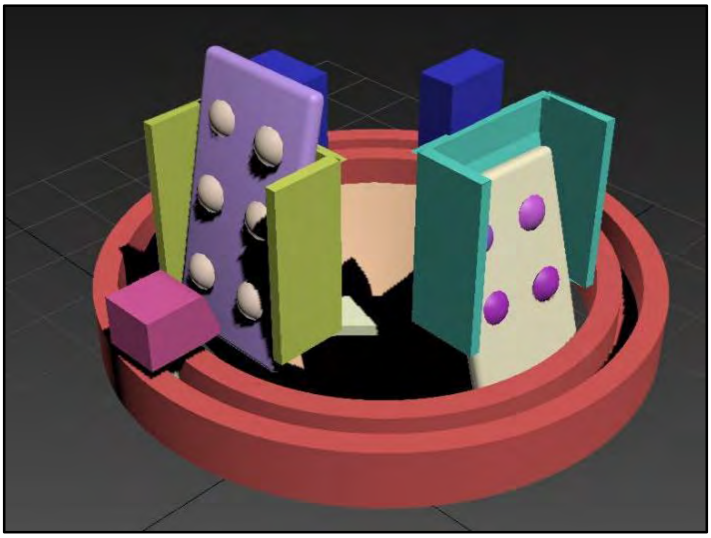


Figure 4.1-2 Push pin located outside

In the primary design there was a DC motor which actually used to rotate the medicine holder. Finally the DC motor replaced with steeper motor and the design had been changed.

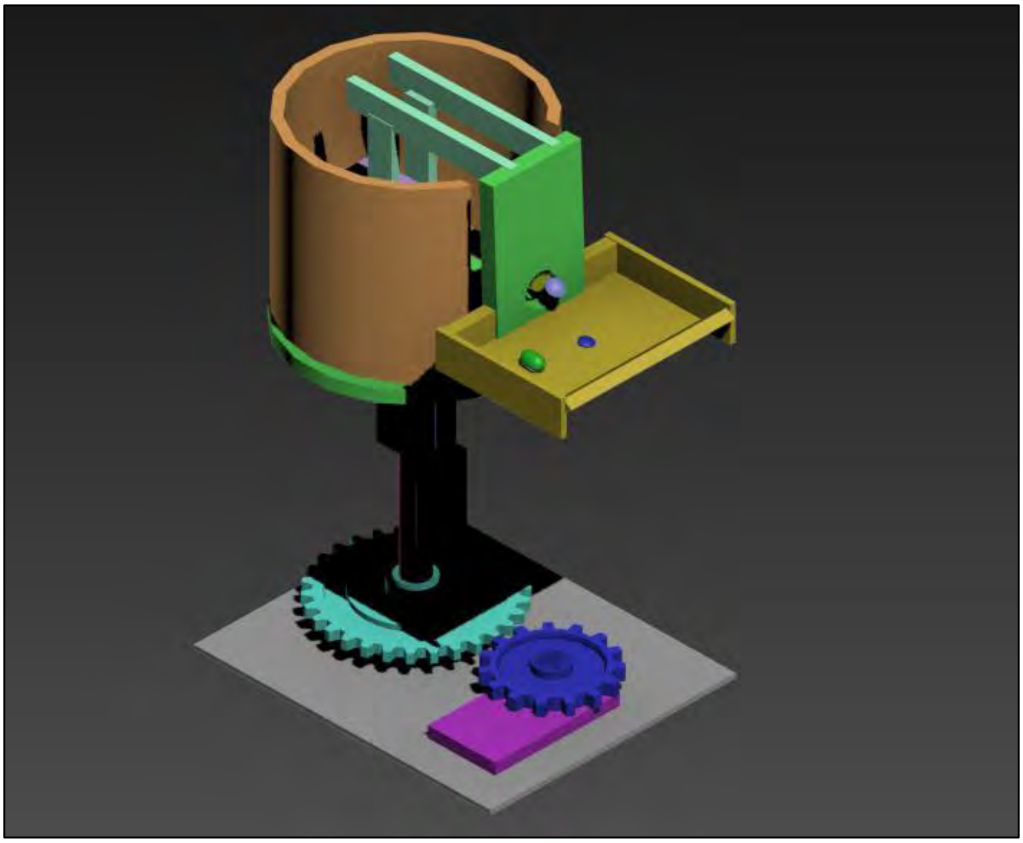


Figure 4.1-3 Rotation with a DC Motor

4.1.2 Conceptual Development

From the first concept's flaws, our supervisor came up with the idea of push medicine from the inside. For push method, an actuator has been used. The push actuator is fixed and the medicine holder will rotate and move up and down.

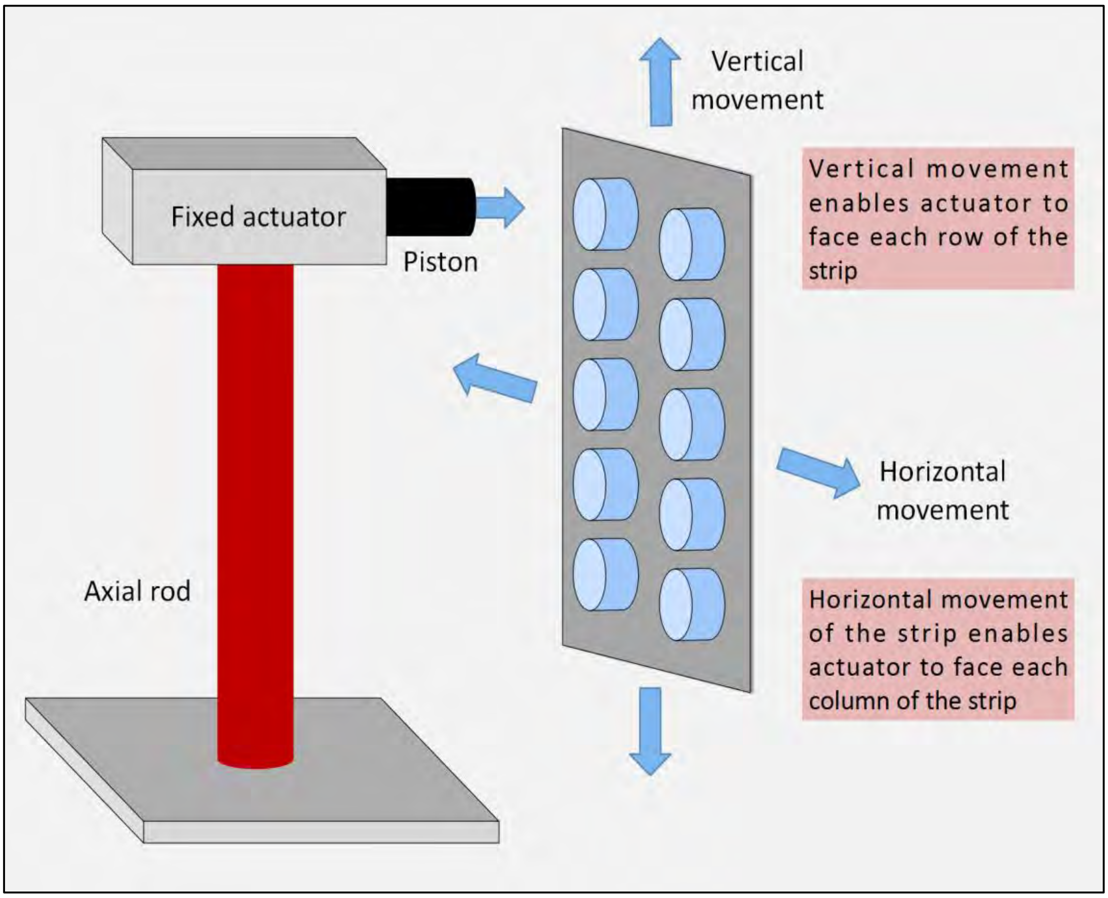


Figure 4.1-4 Medicine serving concept

4.1.3 Analogy of the Medicine Serving System

The main device placed on a square shaped metal plate. There was a rode which is fixed and connected the push actuator. Between them, there is a gear which rotate the medicine holder support with the help of stepper motor. The vertical actuator do the function of moving the medicine holder up and down for placing the medicine in the right place.

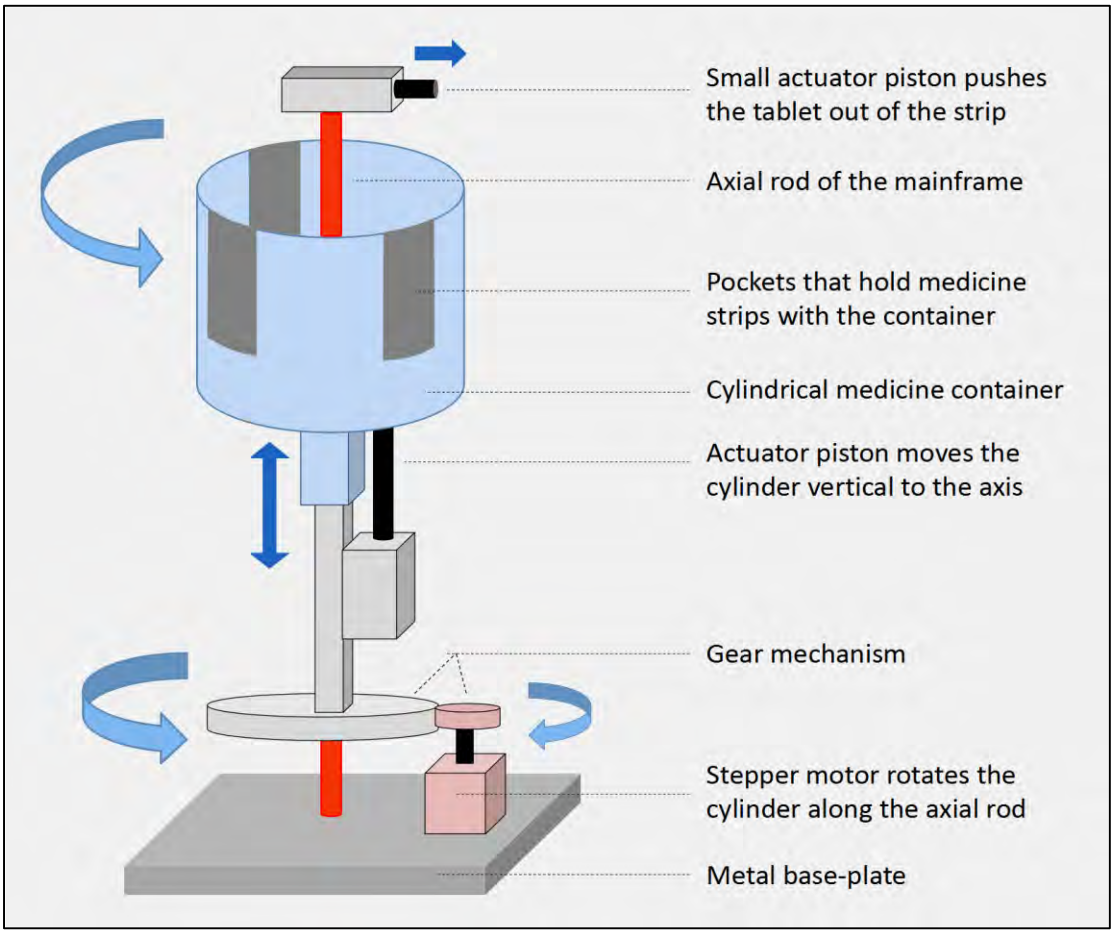


Figure 4.1-5 Analogy of the medicne serving subsystem.

4.1.4 Revised Design

The main goal of this thesis was to develop a device which can move and serve mdicine like household robot [7]. After the concept idea, the final device was made in the Autodesk CAD software.

Figure 4.1-6 Final device with boxed cover

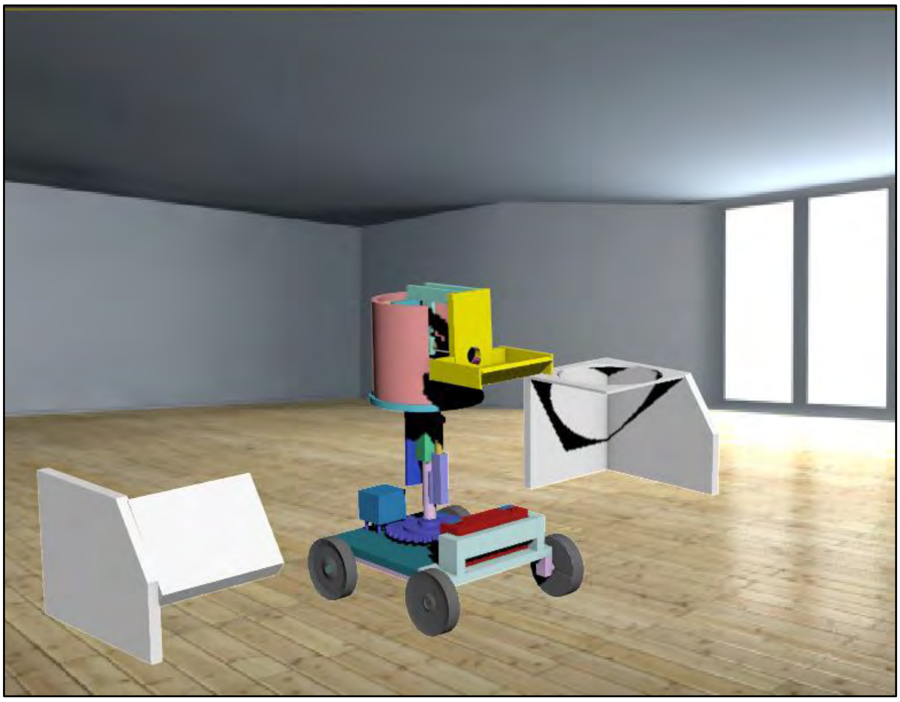


Figure 4.1-7 Final Device without the cover

Following figure demonstrates the revised design from various point of view.

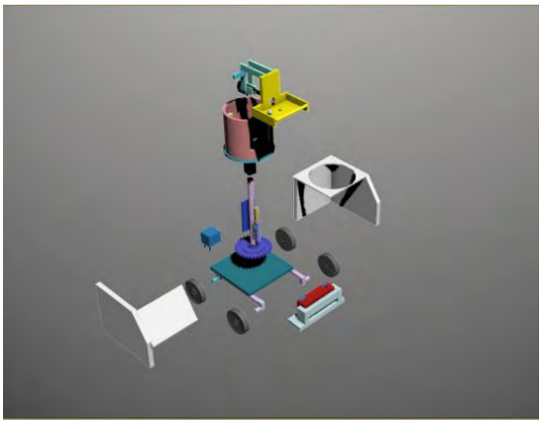
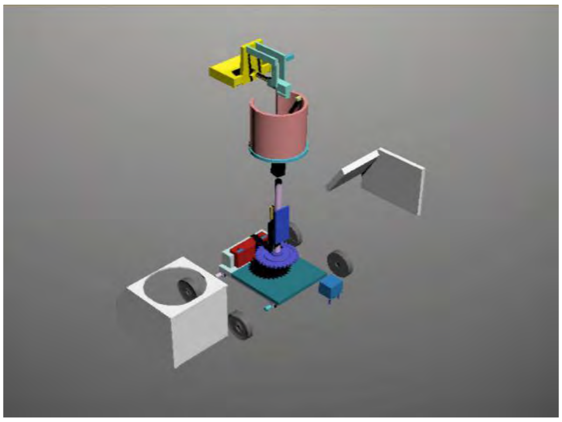
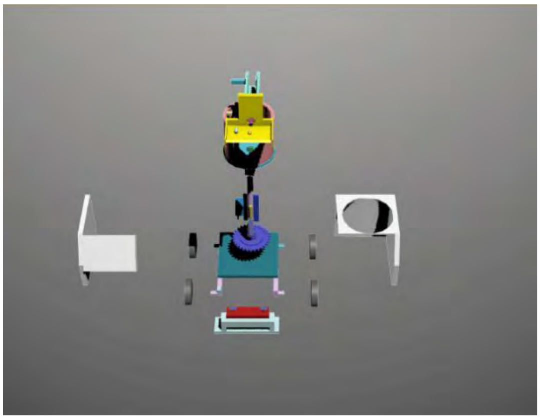
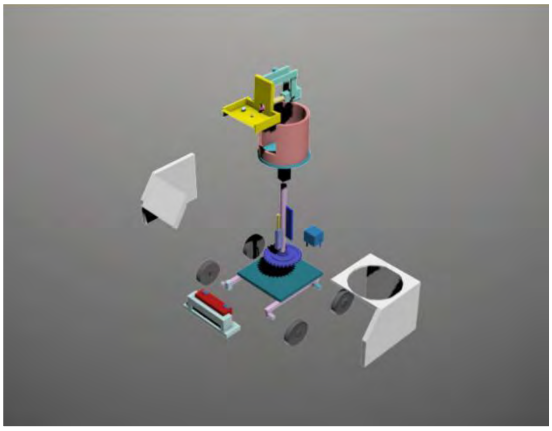
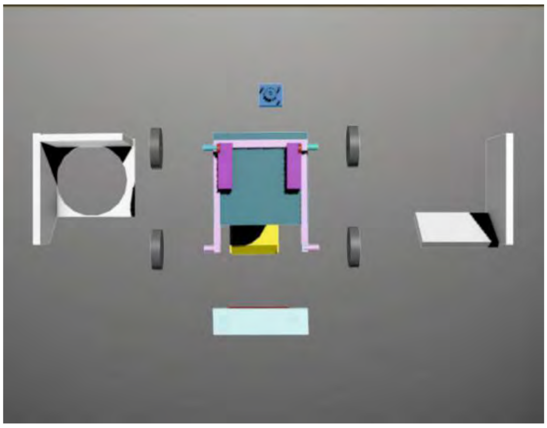
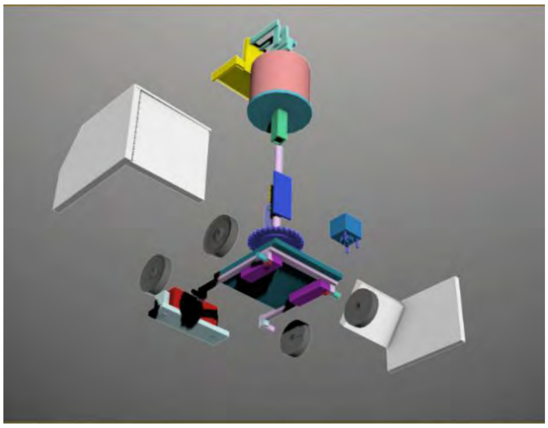
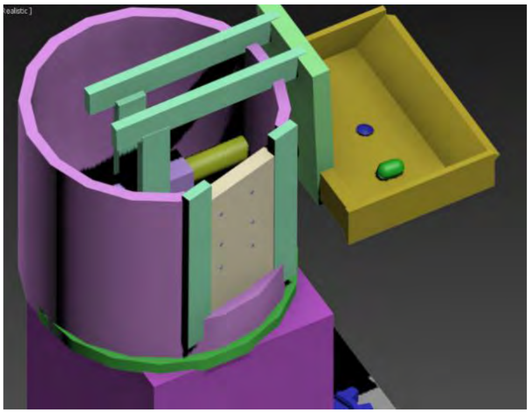
 *Angular Front-Right*	 *Angular back-left*
 *Upper Font*	 *Angular Front-Left*
 *Bottom*	 *Bottom Left*

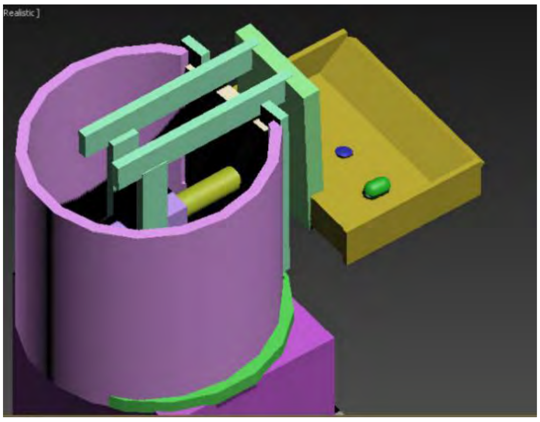
Figure 4.1-8 Revised design of the system

4.2 Simulation

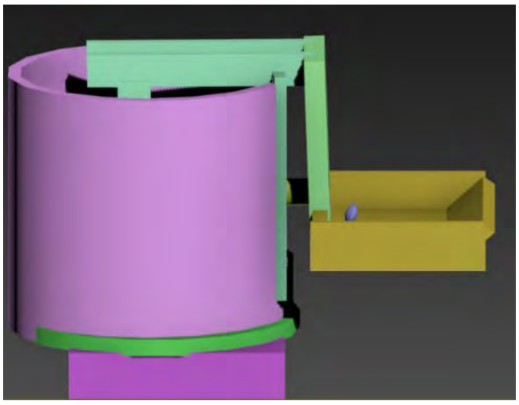
Following picture sequence simulates the medicine serving mechanism.



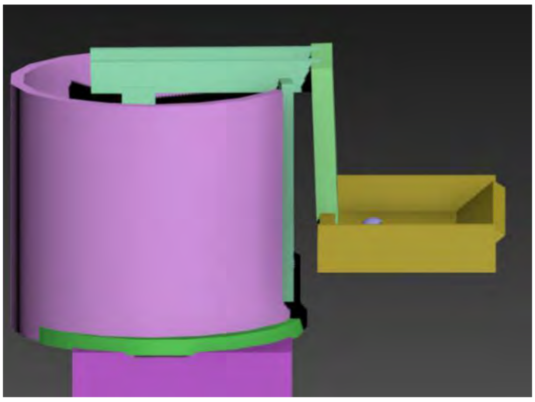
1. Medicine holder rotates



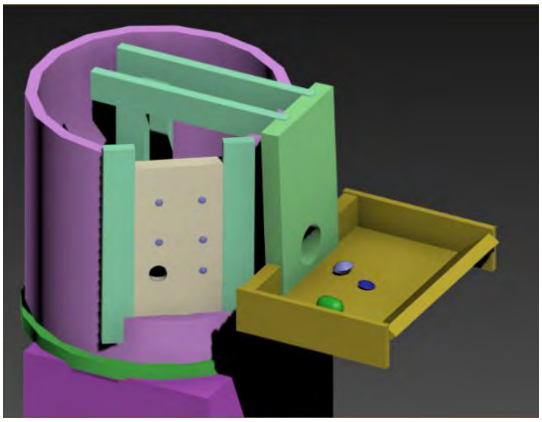
2. Adjusts in right place



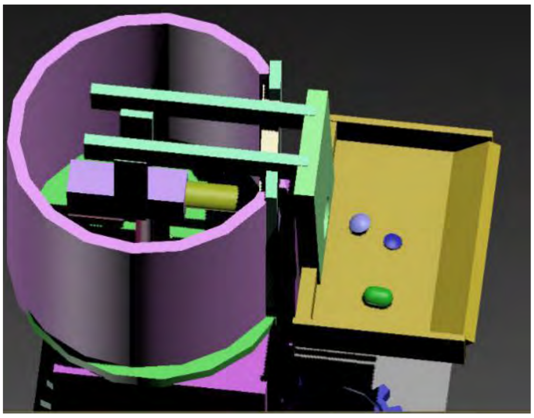
3. Pushes the medicine out



4. Actuator falls back



5. Medicine strip after the medicine fall out



6. Medicine in the tray

Figure 4.2-1 Simulation of medicne serving

4.3 System Flow

Generally, the system monitors medicine schedule and users' commands in parallel. It then executes as per the instructions generated by the user input or system input. Following flow chart shows the general working flow of the system.

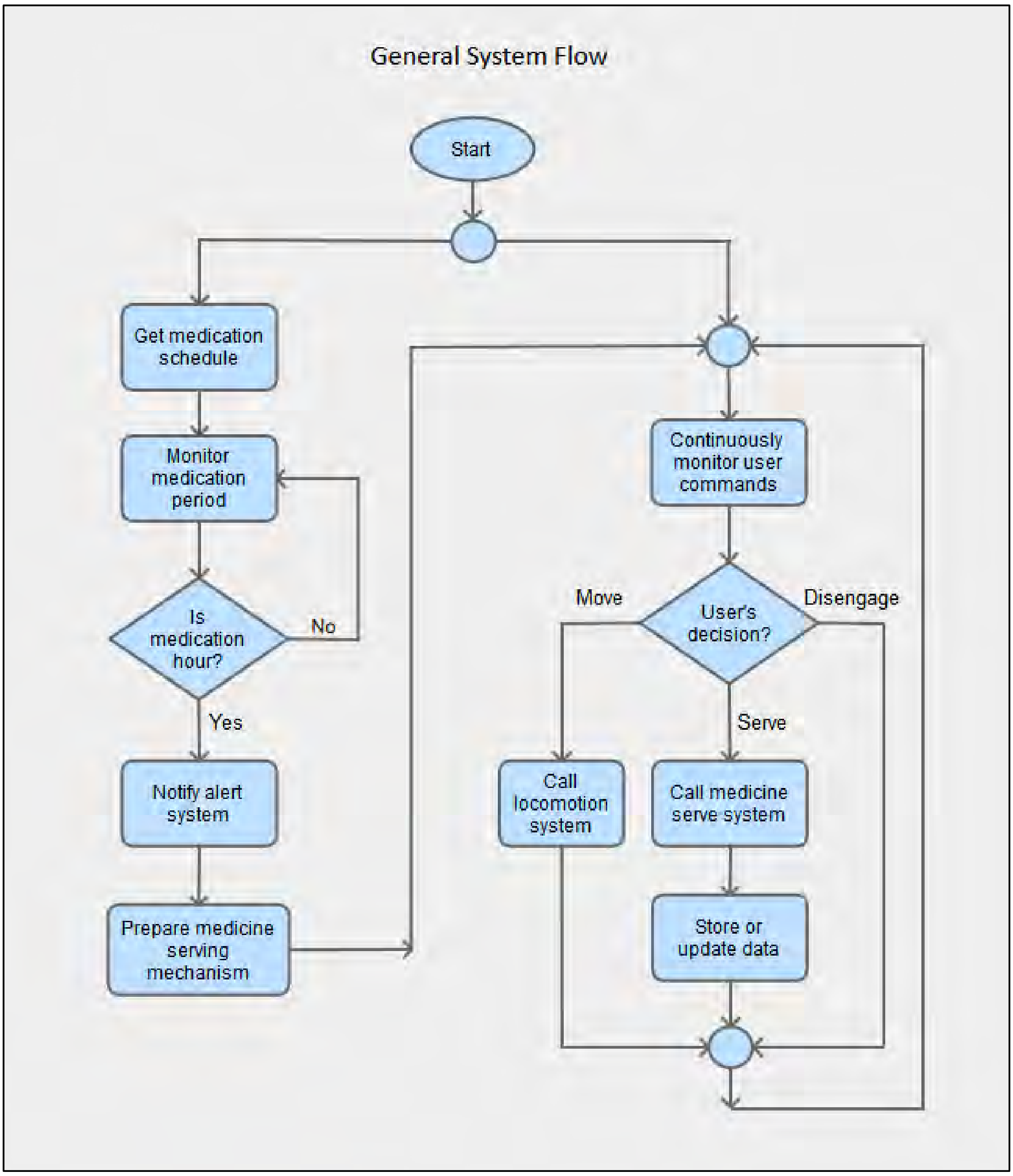


Figure 4.3-1 General flow of the system

4.3.1 Flow of the Medicine Serving Sub-System

As the medicne serving subsystem being the most important and major part of the system, a detailed flow of the mechanism is given below,

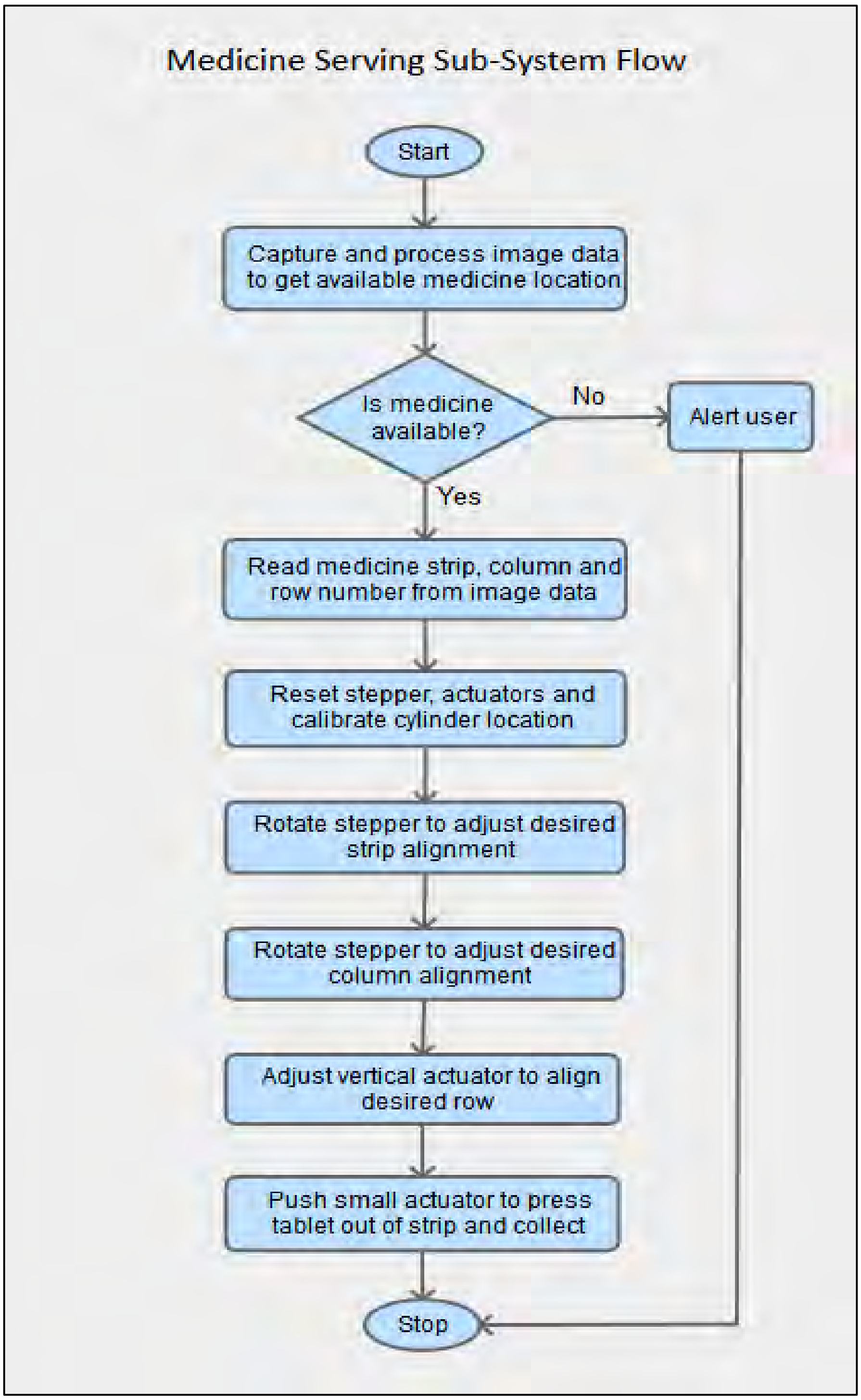


Figure 4.3-2 Flow of the medicine serving system

a

5 System Implementation

5.1 System Apparatus

This section contains the resources we have used to construct our robotic system. The variety of apparatuses were selected based on their dependability, obtainability and also financial feasibility. The important apparatus used to build the robot system are described in the following section.

5.1.1 List of Raw Materials Used

Cylindrical Medicine Strip Holder

For the medicine holder, we used a portion of carbon steel pipe. Carbon steel pipe is an alloy pipe that is solely made of steel and carbon. Unlike some other materials, carbon steel pipe doesn't need to be protected with preservatives, glues or pesticides, which makes them safer to handle and work with. As it will be holding medicinal strips, medicines can come to in touch with it, so there will be no chance of medicine deterioration. Carbon steel pipes are also resistant to corrosion. Carbon steel pipe offers great resistance to vibration and shock. Carbon steel, with its superior shock resistance, seems to hold up better than other pipes when loads are given. Carbon steel's high tensile strength makes it safe to use in situations with very high pressures. This means that they have a higher carrying capacity than pipes made of other materials that have the same diameter. Even if the user puts or leans on it, it will still be in one piece.

No matter the pressure that needs to be withstood, carbon steel pipes can be much thinner than other types of pipes. This means that they have a greater carrying capacity than other pipes. Which means, we can cut the pipes as we want and put more medicinal strips in it. Furthermore, carbon steel pipe is cheaper than copper, and its durability decreases costs needed for repairs or replacement.

Figure 5.1-1 Carbon steel pipe

Metallic Rod As Axis of Rotation

For keeping the whole structure together, we used 2 cm solid carbon fiber rod. These are extremely stiff, lightweight and have a very low coefficient of expansion. Carbon fiber rods have incredible linear strength due to the orientation of the carbon fibers. By using this rod as support, our whole structure has become very rigid and strong and was able to sustain proper weight. Also its size to weight ratio is feasible to the design, moreover it’s economic.

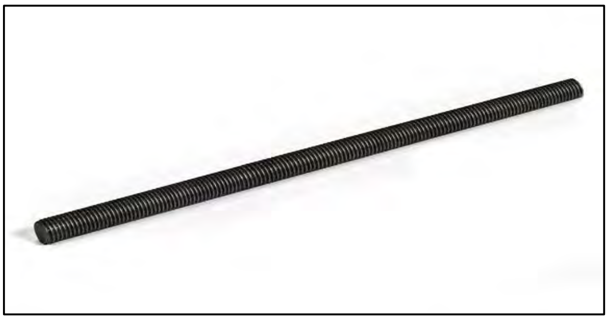


Figure 5.1-2 Carbon fiber rod

SS Rectangular Pipe for Frictional Rotation

The movable part has been built up using U.S.A Standard (304 Grade) stainless steel. It is the most widely used stainless steel with good performance. Its carbon content is lower and it is corrosion resistance. It is less susceptible to intergranular corrosion after welding and also non-magnetic. This is optimal for the design as the process includes numerous welding and non-magnetic property also proves vital in cases of interference with the electric motors being used. It has a density of 7.8x1000kg/m3 at 2 5℃. Elastic modulus at 190 - 210 GPa and tensile strength around 515 Mpa [8]. Because of it rigidness it was able to hold the weight of the cylindrical medicine strip holder, as well as was able to rotate properly along the carbon rod. The welding resistant property proved extremely crucial. This allowed the solid attachment of the body parts, preventing undesired vibration and friction among the parts. As this part of the structure will move frequently, this is quiet important that only this rectangular pipe moves and the other parts stay rigidly.

Also the lightweight property makes it ideal for our actuator to operate on it releasing it from requiring heavy current.

Figure 5.1-3 SS Rectangular Pipe

Mechanical Gears

A spur gear is welded at the bottom of the stainless steel rectangular pipe, so that using a small stepper motor the whole can rotate. The pitch circles of meshing gears roll on with stepper's shaft without slipping. The velocity *v* of the point of contact on the pitch circles is the same on both gears, and is given by

$$v = r_A\omega_A = r_B\omega_B,$$

where input gear *A* (Stepper's shaft) has radius r_A and meshes with output gear *B* (Spur gear) of radius r_B, therefore,

$$\frac{\omega_A}{\omega_B} = \frac{r_B}{r_A} = \frac{N_B}{N_A}.$$

where N_A is the number of teeth on the input gear and N_B is the number of teeth on the output gear. The mechanical advantage of a pair of meshing gears for which the input gear has N_A teeth and the output gear has N_B teeth is given by

$$MA = \frac{r_B}{r_A} = \frac{N_B}{N_A}.$$

This shows that if the output gear G_B has more teeth than the input gear G_A, then the gear train *amplifies* the input torque [9]. Using these equations, we used the stepper to rotate the gear, so that it can rotate the whole infrastructure.

Figure 5.1-4 Mechanical gear and stepper shaft

Base Plate

A solid piece of Aluminum which consists enough strength and sturdiness to serve as the surface, is our base plate. This base plate serves as the ground for the whole structure. Below it, two stainless steel pipe are welded so that the base plate can also serve as the chassis.

Figure 5.1-5 Metal base plate

Polyurethane (Rubber) Wheels

These have a diameter of 18 cm, providing a suitable height of the robot. These four wheels bear all the weight of the machine.

Figure 5.1-6 Polyurethane wheel

5.1.2 Resource Collection and Availability

To build anything there is need of vast resources and its availability. This thesis project requires lots of impetrated materials which is located in different part of Bangladesh and some of them are not available here. That is why there is a need to find the resources and find out the exact location.

The base of the system need to be strong to support the whole device. That is why it was required to find out the workshop where the metal plates were cut down and sold. The device required some other metal parts which support the Device. The metal base plate and other metal parts were bought from a workshop near Tejgaon, Dhaka.

For the medicine holder the system need perfect size to fit the push actuator. The medicine holder is a cylinder type and this type of material find in Bongshal, Dhaka.

The stepper motor is very expensive so that a second hand motor has been used in this system. Those motor was bought from Dholaikhal, Dhaka.

5.2 Hardware Components and Specifications

5.2.1 List of Hardware Components

12V Linear Actuators

Quantity - 2 (1 SS rectangular pipe + 1 Cylindrical Medicine Strip Holder)

- Input Voltage: 12 V
- Maximum Dynamic Load: 75 lb
- Maximum Speed: 1.0 inch/second
- Maximum Stroke Length: 6 inches

Stepper Motor

Quantity – 1 (Spur gear)

- Input Voltage: 4.8V
- Current Signal: 0.5 A
- Load Current: 2 A
- 1.8 Degree Rotation Per Step

12V Car Glass Lift DC Motor

Quantity - 2 (2 Rear Wheels)

- Input Voltage: 12 V
- Braking Torque: 26 Nm
- Working Torque: 5 Nm
- Working Speed: 6.7 rpm
- Working Current: 1.0 A

DC motors has been in use from 1879 and small DC motors has been used in all types of applications ranging from aircraft to automobiles. The advantages of DC motor know no bound. Advantages of DC drives include: High starting torque, easy installation, speed control over a wide range (both above and below the rated speed), quick starting, stopping, reversing, and acceleration, linear speed-torque curve and accurate step-less speed with constant torque. Our robotic system needs to move around, so this type of DC motor was essential. These type of motor carries the weight of the car's window, which gave us the idea to use these motor [10].

L298N Stepper Motor Driver Shield

Quantity - 1

- Operating Voltage: 5V
- Drive Voltage: 7V up to 35V
- Logic Voltage: 5V

This module is based on L298N,high voltage, high current dual full bridge driver which can be used to drive a stepper motor, relay coil inductive load; using standard logic level signal control; having two enable control end allow or prohibit the work has a logic device power supply input terminal, in the case regardless of the input signal affect the internal logic circuit portion to operate at a low voltage; can be an external sense resistor, the amount of change in feedback to the control circuit. This module integrates a built-in 5V power supply.

When ENA is HIGH, IN1 IN2 control OUT1 OUT2

When ENB is HIGH, IN3 IN4 control OUT3 OUT4

8 Channel 5V Relay Shield

Quantity - 1 (Two Actuators + Two DC Motors)

- Load Voltage: 12 VDC, 24VDC, 30VDC, 100VAC, 250VAC
- Trigger Voltage: 5V DC
- Load Current: 10A AC, 10A DC

Arduino Mega 2560

Quantity – 1

- Operating voltage: 5 V
- Input Voltage: 6 - 20 V (Recommended 7 - 12 V)
- Digital I/O Pins: 54
- Analog Input pins: 16
- DC Current per I/O pin: 40 mA
- Clock Rate: 16 MHz

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. For our thesis project, Arduino Mega enabled us to 2 DC motor, 2 actuators and 1 Stepper motor. The Mega was powered by a 9V battery and its digital pins were used to enable relays and actuators with precision. Also, with the help of Arduino we were able to establish voice enabled communication [11].

Push Switches

Quantity – 3 (On Actuators)

- Operating voltage: 5 V
- Operating current: 50mA

Miniature 2-PIN single pull single throw switches.

Battery

Quantity – 1

- Output Voltage: 12 V
- Capacity: 80 ah

Camera/Webcam

Quantity – 1

- Resolution: 8 MP
- Capture Mode: Still Photo, Video

In order to take picture for image processing we used an 8 megapixel USB web camera. This camera is flexible and can be fixed inside the structure and taken out anytime. With proper lighting it can take good pictures.

Microphone

Quantity – 1

- Type: Wired, Analog Audio

To take voice commands, we used microphones.

Figures of the major components used:

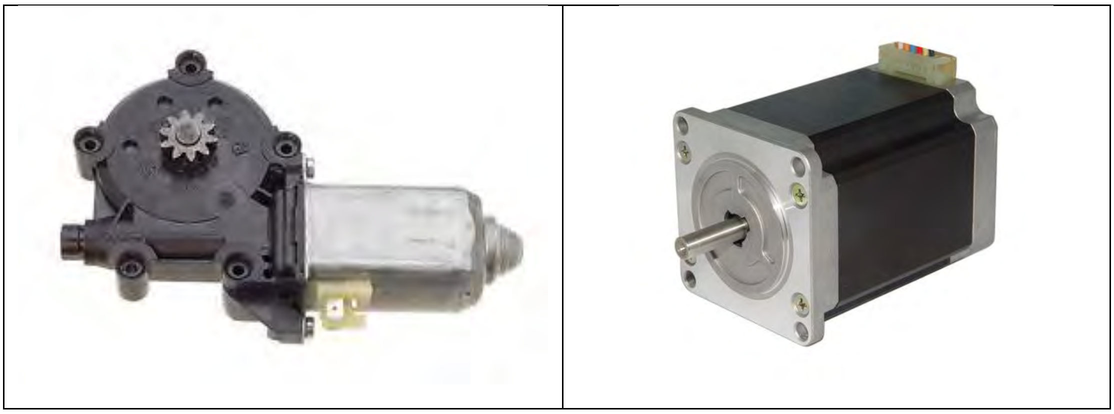


Figure 5.2-1 DC motor and stepper motor

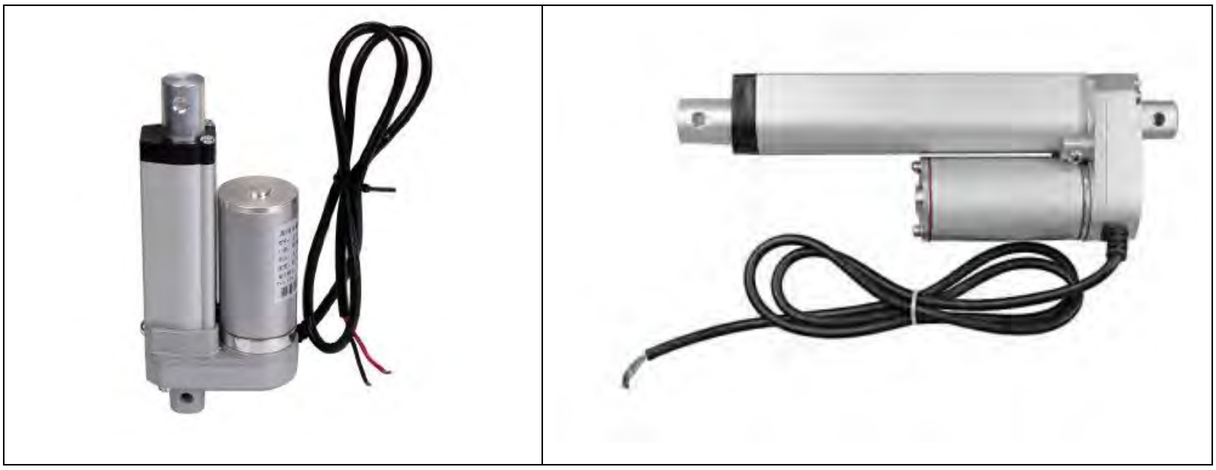


Figure 5.2-2 Small and medium size linear actuators

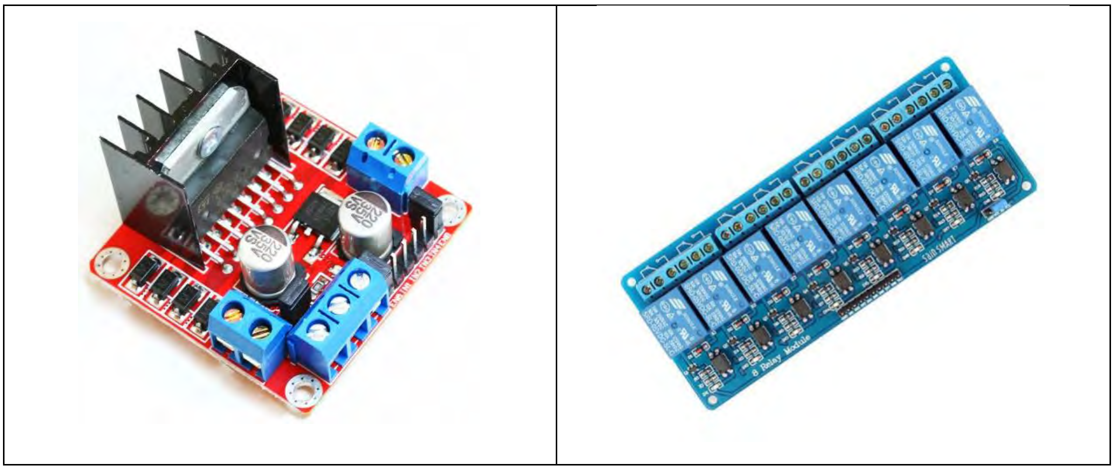


Figure 5.2-3 L298N stepper motor driver shield and relay shield

Figure 5.2-4 Arduino Mega 2560 and PC webcam

Figure 5.2-5 Push buttons and DC battery

5.3 Hardware Implementation

5.3.1 Mechanical Structure

Body

The main body consists a 22” inch (55.88 cm) metallic rod from the base plate. This is an ideal height for the machine as we must have a minimal height above the ground, so that the cylindrical holder is closer to the user’s hand. There is a stainless steel rectangular pipe, which is 20” inch (50.8 cm), along with the metallic rod in a way that the upper body can rotate or move upwards and downward using friction.

At the bottom of the metallic rod, there is an 8” inch (22cm) spur gear welded with rod, so that the whole structure can rotate with the help of a motor. In our case, we used a stepper motor for rotating the gear. The metallic rod, the rectangular pipe, the spur gear and the stepper motor all of them are situated on a 12’’ inch (30.48cm) base plate. There is also an aluminum sheet welded with the base plate to carry the battery. The metallic rod along with the spur gear is placed on the baseplate in a way that the whole structure is properly balanced and stabilized when the robot moves around. Also some space is kept around the metallic rod structure so that we can fix the circuit box there as well as it can rotate freely with the structure. It is very important to give the circuit box proper space and flexibility to ensure the circuit connection doesn’t get loose.

To go upward and downward, there is another metallic structure of 7” inch (17.78cm), which is made by metallic plates joined together to surround the stainless steel pipe. This metallic cover can go upward and downward along the stainless steel pipe with the assistance of a 12V linear actuator.

Figure 5.3-1 The main base of the body without wheels and box cover

Upper Body

The upper body has three parts; each part has separate tasks. The main part is cylindrical metallic pipe. The other two parts are the metallic cover and the tray.

Cylindrical Case

The upper body contains a 6” inch diameter cylindrical metallic pipe, which has three pockets to keep medicine strips in it. This round cylindrical metallic pipe is welded on the squared shape metallic pipe so that it can also rotate, move upward and downward with main body structure.

These three pockets were cut in the size of three different average medicine strips which are 4x3’’ inch, 5x4’’ inch, 6x5” inch. These measurement is taken from the three most popular and most used medicine strips to ensure efficiency.

Inside the case, there is another 12V linear actuator which is used to push the medicine out of the strips. The actuator is fixed on the metallic rod; it doesn’t rotate or moves upward or downward with the cylindrical case.

Figure 5.3-2 The cylindrical metallic pipe with medicine strips

Metallic Cover

An ‘U’- shaped metallic structure is welded on the liner actuator, which has come down at the front of the nose of the actuator with a hole in it, so that the actuator can push the medicine through it. Also there is some space between the metallic cover and the actuator so that the cylindrical pipe can move freely in between.

Figure 5.3-3 The metallic cover without the actuator

Tray

In front of the cylindrical case, there is a tray fixed with the metallic cover. This tray is used to hold the medicines that is pushed by the actuator. This tray is 2.5 feet above the ground. This height is appropriate for the patients so that they can take their medicine easily without bending too much.

Figure 5.3-4 Medicine Collector Tray

Chassis

The chassis contains four polyurethane wheels. The two front wheels are connected with the base plate by stainless steel pipes, one side welded with the wheel and other side with the base. The rear two wheels are welded with two 12V DC wiper motors. These motors are welded with the base using two round shaped metallic plates, cut according to the motors. One 12V battery is good enough to run these motors. The chassis carries the whole structure and can move forward, backward, left and right properly. The overall weight of the robot is 20 kg without the battery. Wheel to wheel width is 22cm (8”) and the distance between the front to rear wheel is 25cm (9.8”). Exactly these measurements were selected due to ensure optimal space and performance.

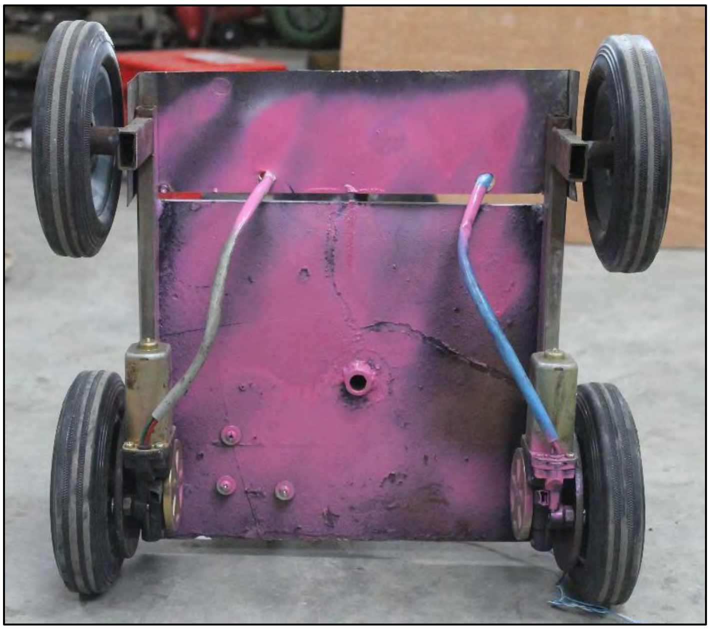


Figure 5.3-5 Chassis

Switches

There are total three mechanical switches in the system. These switches are used to determine the position of the actuators and steppers. Two of the switches are placed in the cylindrical case, one is at the top another one is at the bottom. The third one is at the top of the upper body actuator.

5.3.2 Circuit Design

Block Diagram of the Circuit

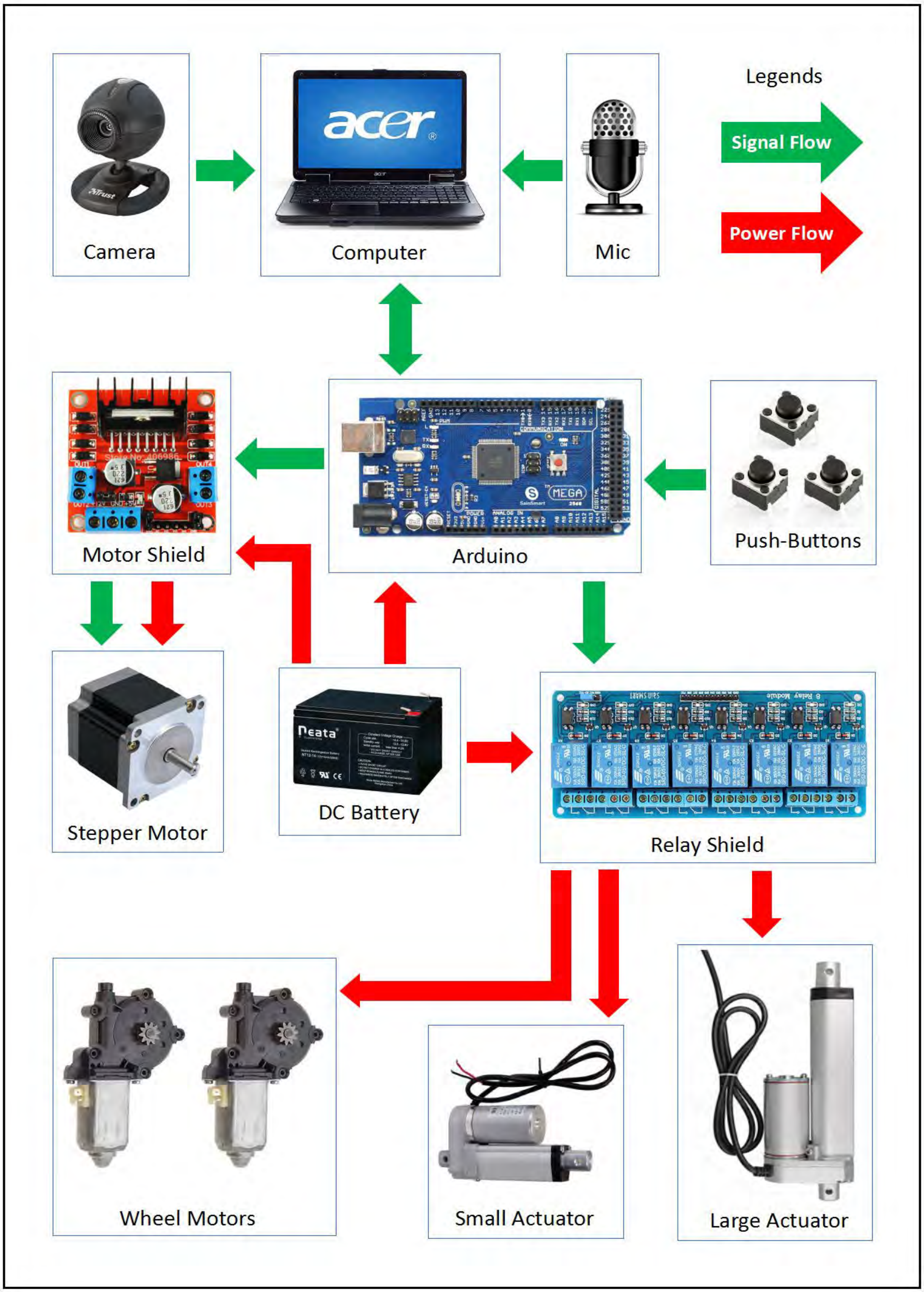


Figure 5.3-6 Block diagram of the circuit

Motor Connection

The DC motors that drives the rear wheels are connected to the battery through some electronic relays. Each motor drives through two relays. For two motors, we used 4 relays for the motor connection.

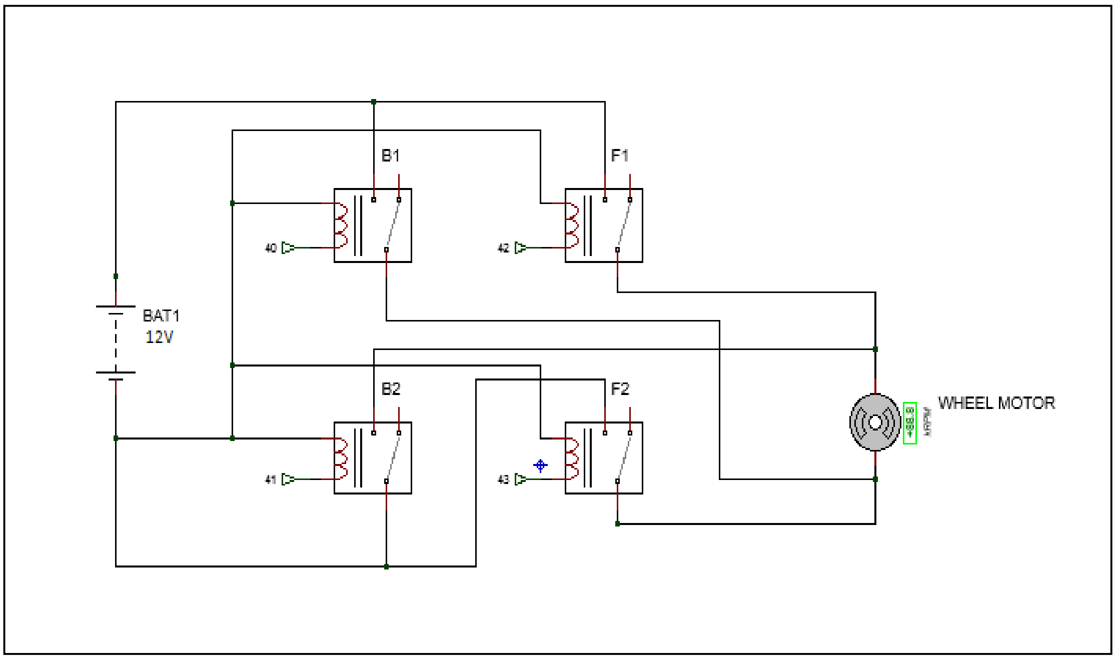


Figure 5.3-7 Circuit connection of DC motor

From the above figure, we can see that two forward relays F1 and F2 needs to be turned on in order to move forward and two backward relays B1 and B2 are to reverse the polarity for backward movement. The reason behind using two relays is to ensure no shortening of the circuit. When the motors are in forward motion, the backward relays stay opened and in backward motion, forward relays stay opened [12].

The next two figure will demonstrate how the current passes through the motors to move forward and backward. The green colored wires represent the current passing paths and the arrow signs are used to show the direction of the current. For right and left movement, the circuit uses the same logic to move the two motors in two different direction at the same time [13].

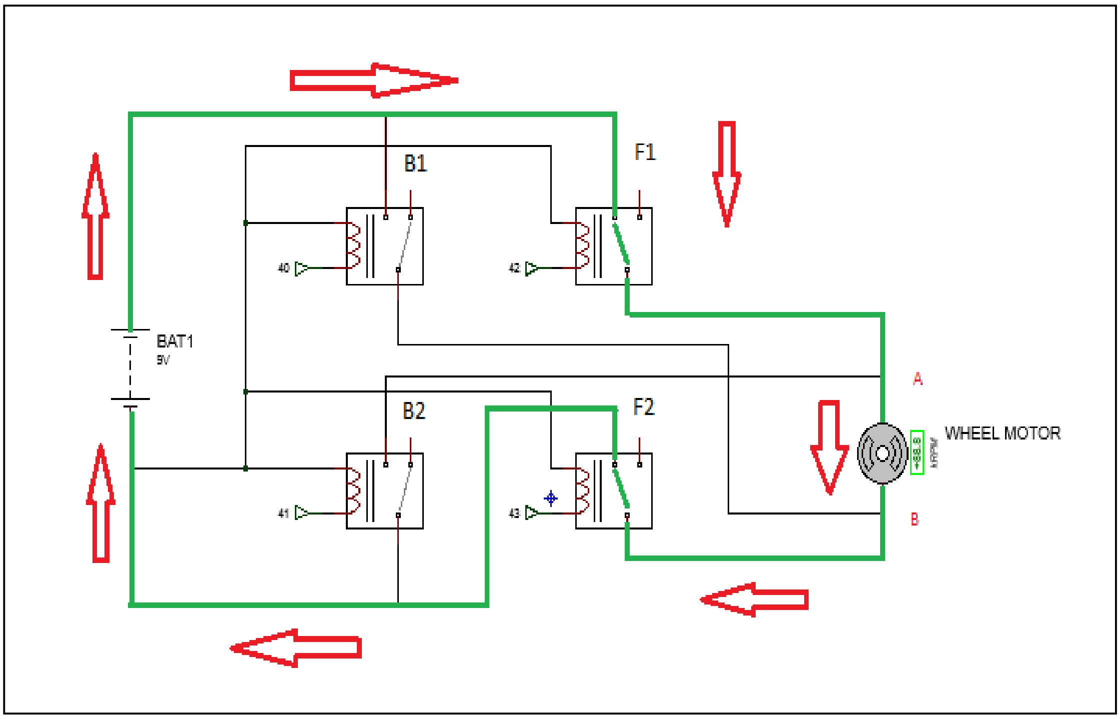


Figure 5.3-8 Relays: Current passing through A to B for the forward movement

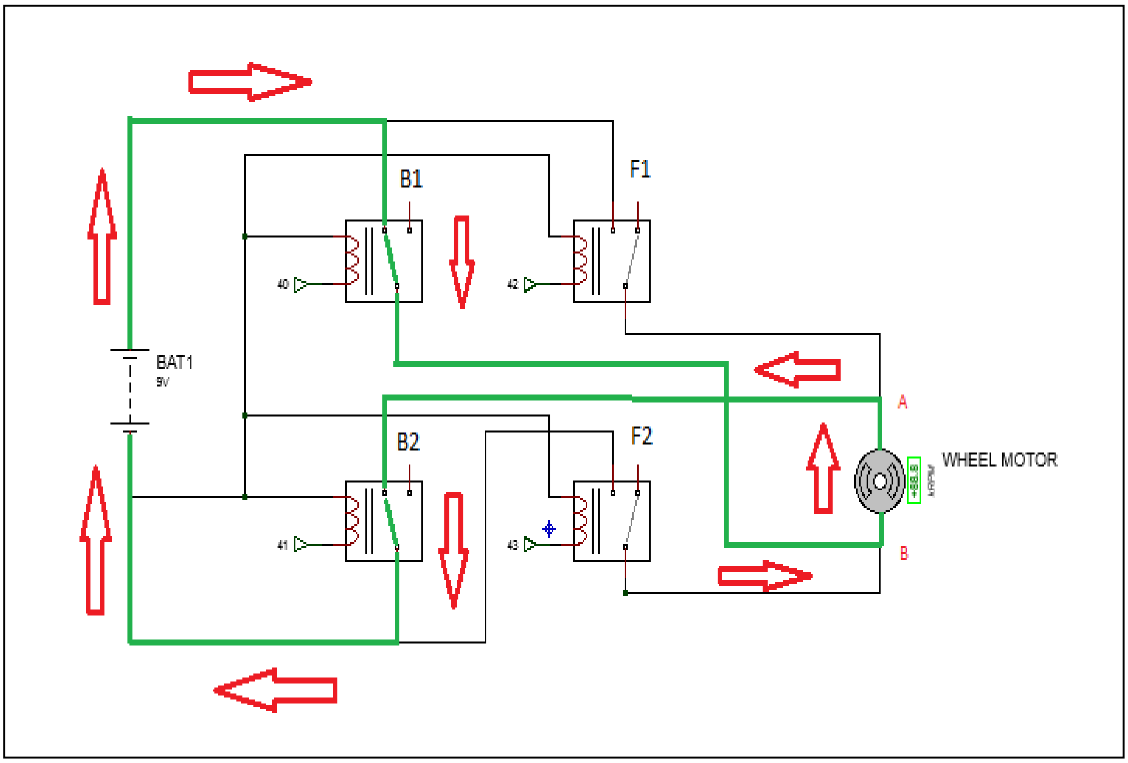


Figure 5.3-9 Relays: Current passing through B to A for backward movement

Stepper Motor

A 5V stepper motor is used for rotating the gear connected to the metallic axis rod. The motor is driven through a L298 motor driver. VCC is connected to 5V and the VS is connected to the 12V battery. The input pins are connected to the Arduino pins. Output pins out1 and out3 are connected to the pair A and out2 and out4 are connected to pair B of the stepper. The enable pins are connected to the 5V source. Stepper motor needs a high amount of current as to rotate faster. We need faster rotation to rotate the metallic rod which is too heavy. So, L298N driver is used as it can take a load of 4 Amp current [14].

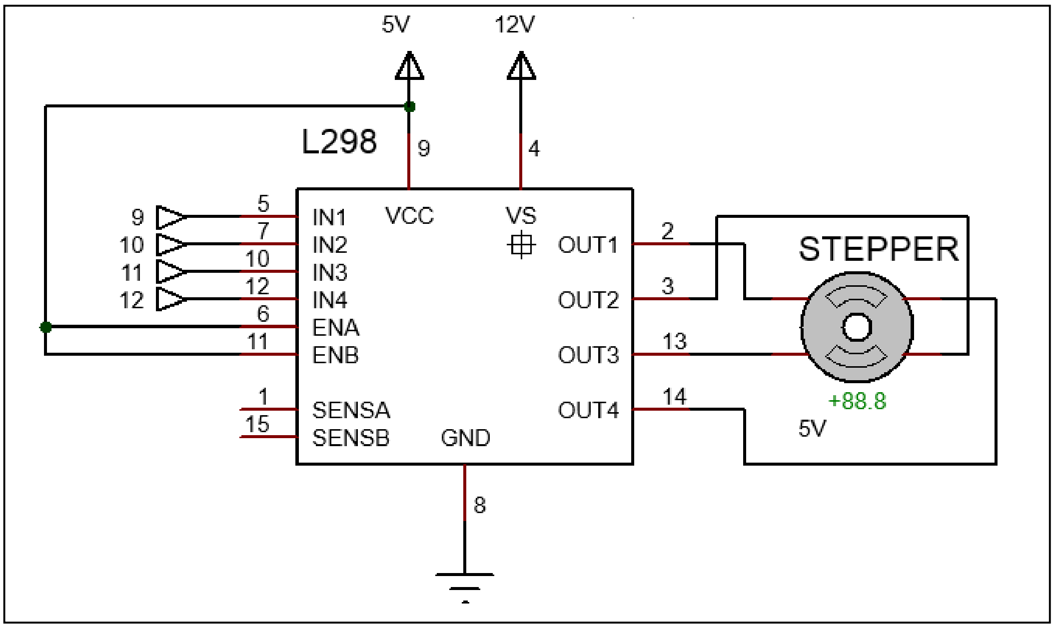


Figure 5.3-10 Stepper motor connection with L298 motor driver

Linear Actuators

The two 12V actuators used in the circuit are connected to the relay shield. Two relays are connected to the large actuator to move the cylindrical case up and down whenever UP and DOWN turns on. Same logic works on the small actuator which is used to pop out the medicine from the strip. Both the actuators are connected to the 12V battery through the relays. To move the actuators up, current passes through the up relay and the down relay stay opened. To move downward, current passes through the down relay whereas the up relay stay opened.

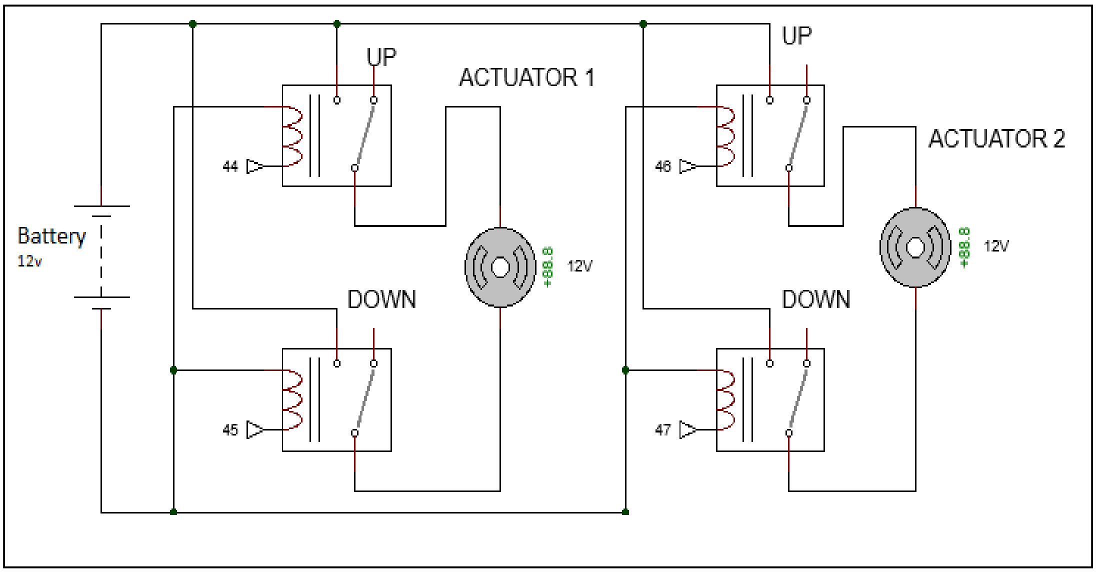


Figure 5.3-11 Circuit connection of the Linear Actuators

Voltage Regulator

A LM7805 voltage regulator is used along with a heat sink to drop the supply voltage to 5V as a 12V battery is used to run the whole circuit. The input is connected to the 12V battery and the output 5V is connected to the devices which need 5V to work. A heat sink is used with the regulator as it is being heated due to process high voltage [15].

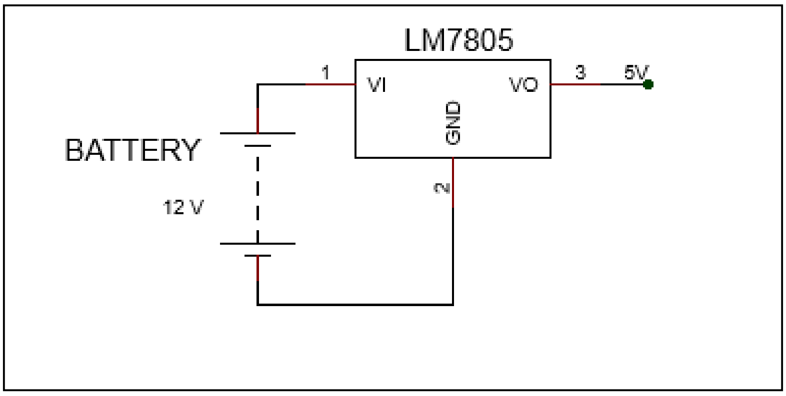


Figure 5.3-12 Circuit connection of LM7805

Push Switches

Three push switches are used to measure and control the strip size. The switches are connected to the 5V through 10K resistors.

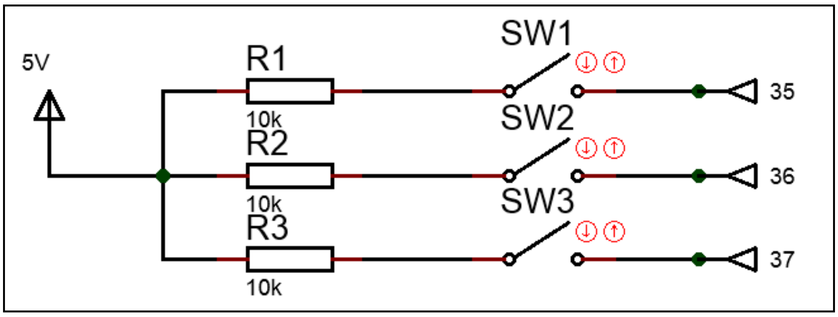


Figure 5.3-13 Connection of push switches

Arduino

This is the main processor of the system. It integrates all the components together. The Arduino board is powered by a 9V battery. The backward relays are connected in the digital pins 40 and 41 and the forward relays are connected to pin 42 and 43. The small linear actuator is connected to pin 44 and 45 and the large actuator is in 46 and 47. L298 motor driver is connected to the digital pin 9, 10, 11 and 12. The switches are connected to the pin 35,36 and 37 respectively.

Circuit Diagram

Proteus Professional 8.2 is used to design the main circuit of the system. Fig 11.2 represents the whole circuit of the system. The numbers in the inputs of the relays represent the connection in Arduino pin no.

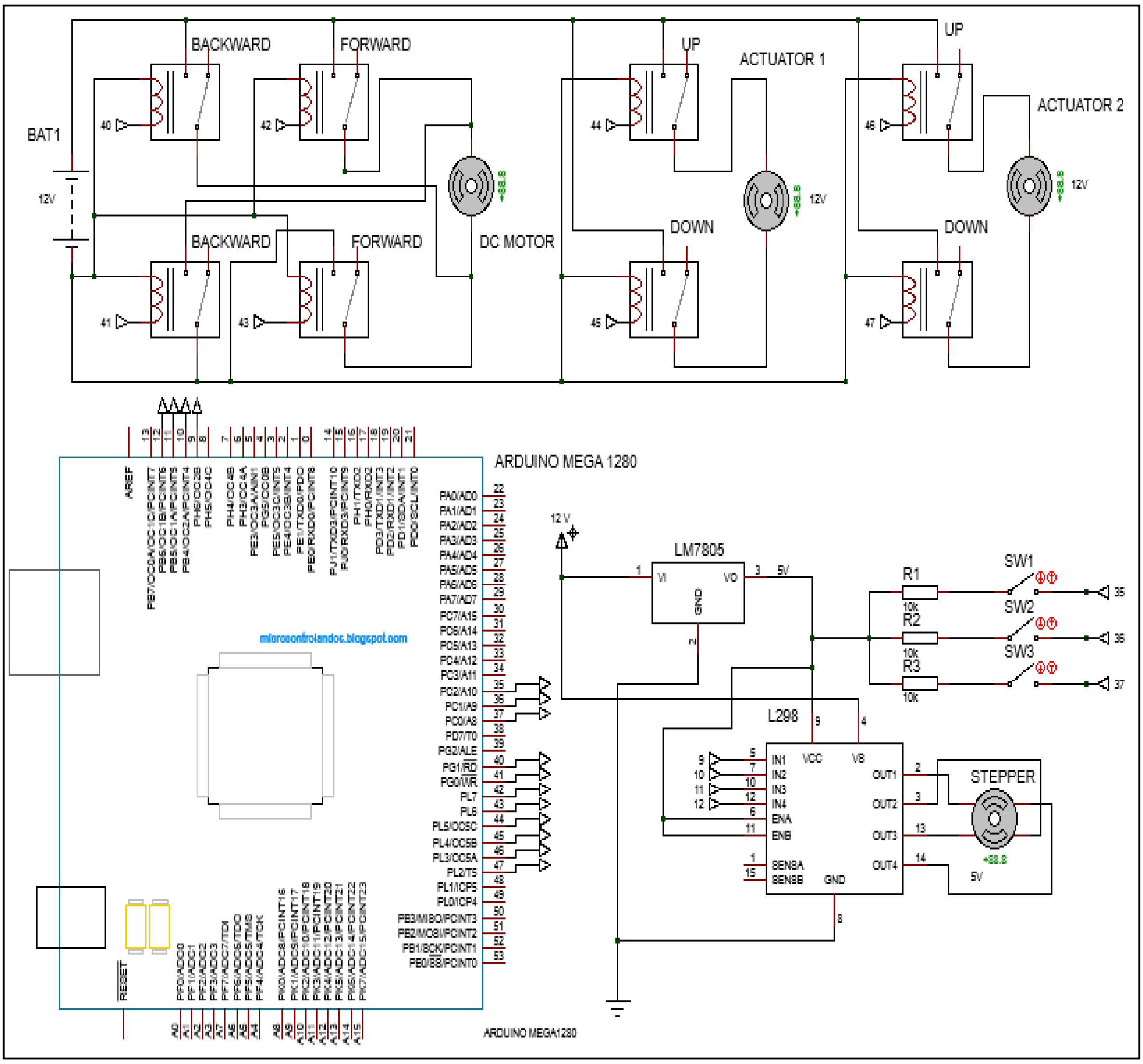


Figure 5.3-14 Circuit diagram of the system (using Proteus 8.2)

Final Circuit

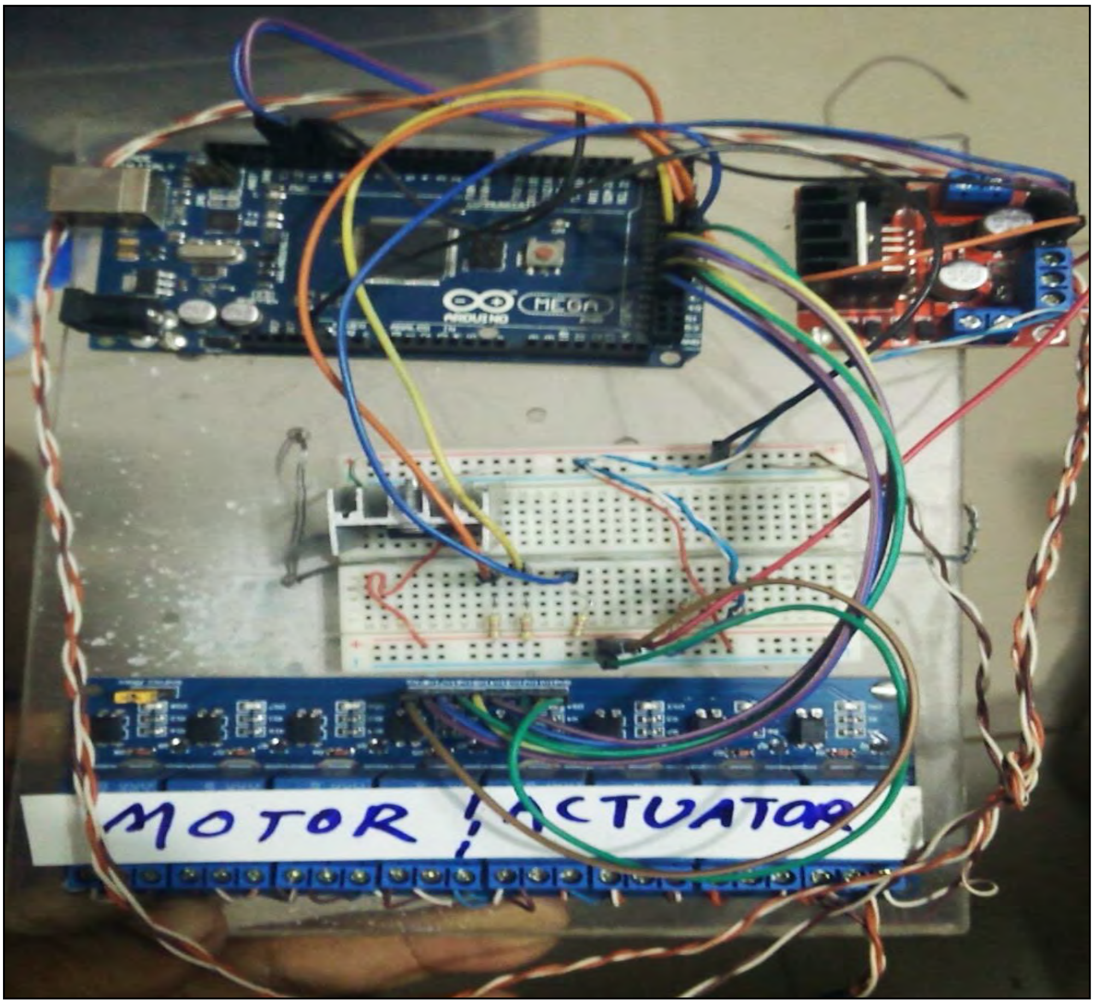


Figure 5.3-15 Final implemented circuit of the system

The circuit needed a strong, light and solid base in order to overcome the vibration of the device when it is in motion. So a solid and transparent plastic sheet is used as the base. The Arduino board, Relay motor shield and L298 Motor shield were fixed with screws to the circuit board. The whole board is covered with a box, made of hard partex board along with the gear, base plate and stepper motor. The size of the box is square shaped, approximately 15 inch of height, 8 inch of length at each side. The box cover is used because the circuit should not be exposed to dirt and to keep safe from any kind of damage.

5.4 Software Implementation

The software components of the system play driving role on how the system work and perform each of its tasks. These software components are subdivided into two major criteria, the software part and the firmware part. The software part basically refers to the complex software systems used to help generate the inputs and instructions from complex sensor data. These inputs and instructions, later on, used in the firmware part to direct and control the hardware.

5.4.1 Software

As mentioned earlier, complex sensor data was processed and used to generate inputs and instructions for the system. Image data from camera and audio data from microphone are the most complex form of data that our system uses. To be specific, image of the medicine strip is used to determine the locations of available medicines that can be served. Similarly, human voice commands are recognized and converted into instructions by audio processing utility.

Table 5.4-1 Software technologies used to process data

Job	Criteria	Used technology	Alternatives explored
Determine medicine location	Image Processing	MATLAB Image Processing Toolbox	OpenCV, Mathematica Image Processing
Determine medication schedule	Image Processing (OCR)	Tesseract Open Source OCR	MATLAB OCR
Recognize user instructions	Speech Recognition	MS Visual Studio Voice Recognition	Google Speech API

Image processing

Main task of image processing in our system is to provide with the locations of available medicines in a strip. A medicine strip may be entirely empty, or some of the tablets slots may be empty while others contain tablets. Image processing provides real time detection of medicines at a particular time. So, there is no need to store or maintain a database of the medicines stored, nor any counter is required to find next available medicine.

Most of the medicines are round tablets. They appear as circles on an image of the strip. This circles can be easily detected. Then after filtering and post processing, empty or filled slots of tablets can be differentiated. This lead to main idea of medicine detection using the concept of circle detection.

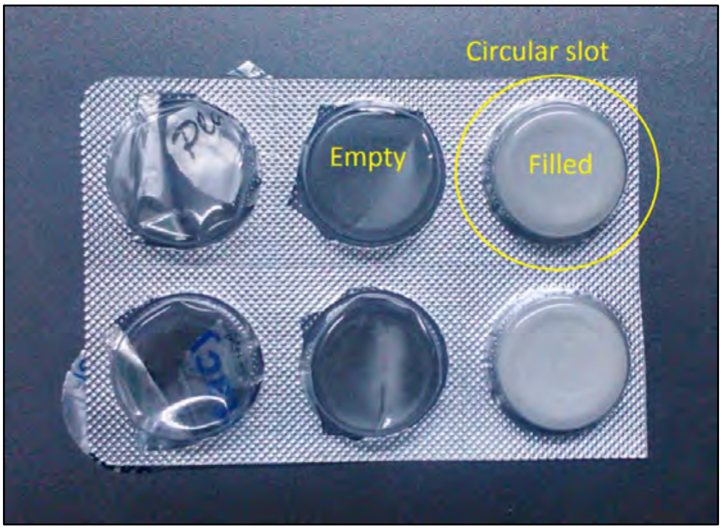


Figure 5.4-1 Medicine detection concept

To prototype medicine detection mechanism, circular objects are detected from an image. After detection of circles, further processing, filtering and segmentations are done to sort out empty slots from filled ones. The target of the prototype is to attain locations of the filled or intact slots.

While developing the prototype, primarily, OpenCV Image Processing Library was used. Later on, due to some limitations and difficulties, MATLAB Image Processing Toolbox is used to detect medicine.

OpenCV Image Processing Library: OpenCV is widely used in the area of computer vision. Circular slots were easily detected using the Hough-Transform method [16], provided that the lighting condition was good enough and the image quality is sufficiently good. However, in the actual lighting condition of the medicine container is not that good as it is very congested and the camera focus is not always appropriate. Therefore, results generated using OpenCV were not that satisfactory and there were discrepancy in the results for variable conditions [17]. Besides, OpenCV is a vast area of research and implementation, so, it appeared with some difficulties while post processing the image after circle detection. Segmentation based on object polarity and distortion, deformation requires profound knowledge and understanding on the methods and procedures of image processing which could not be conducted within the time schedule. Therefore, alternative ways were explored to get efficient result quickly.

MATLAB Image Processing Toolbox: MATLAB is a very popular platform for numerical and engineering data processing. It is vastly used for image, video and other data processing. While exploring the alternatives to OpenCV, MATLAB provided with efficient and satisfactory results. Besides, MATLAB has extremely good documentation [18], which helps developers to utilize the potential of the software. Therefore, MATLAB was chosen to perform the image processing task.

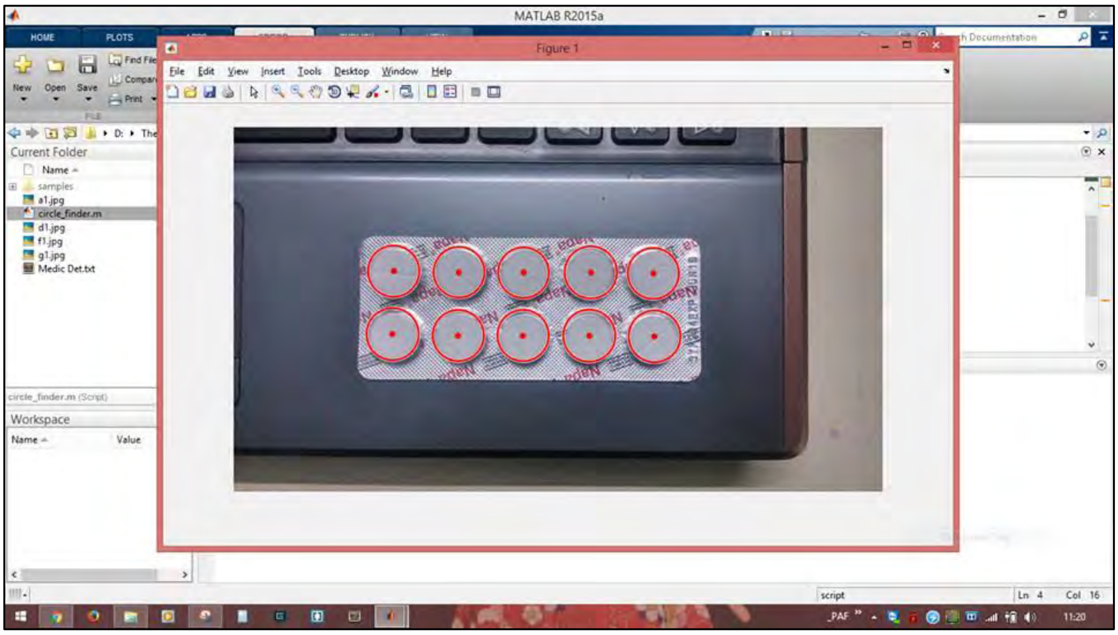


Figure 5.4-2 Image processing using MATLAB

MATLAB version 2015a is used to develop the prototype. MATLAB has dedicated library and tool set for image processing. MATLAB Image Acquisition Toolbox is used to retrieve image from image sources, hassle free. MATLAB Image Processing Toolbox has number of efficient methods, processes and algorithms to perform image processing [19]. Using MATLAB, circular object detection and post processing was performed efficiently.

One of the major challenges of detecting the medicine slots is to perform the detection while the radius, color tone and luminosity of each tablet slot are variable for different tablets. Even, color tone and luminosity can vary for different slots of same tablet strip due to lighting condition. Hence, adjustable radius range and sensitivity is used in the detection algorithm.

Outline of the Algorithm: Earlier, the medicine detection algorithm was implemented within a script. One sequential script of MATLAB language was written, but later on, the process was modularized and divided into several functions. In brief, the process is as following,

a. Get instruction over communication port.
b. Capture an image of the target medicine strip.
c. Set default parameters for detection.
d. Call detection algorithm.
    i. Apply image filters.
    ii. Start with larger radius range.
    iii. Check for round objects.
    iv. Adjust sensitivity if required.
    v. If tablets directed, sort the locations.
    vi. Identify next available tablet.
e. Identify row, column number of next tablet.
f. Send instruction to control unit with row and column data.

Pseudo-codes: Pseudo-codes of the different functions written in MATLAB programming language are listed in the following section. Several built in functions were called within these functions, which are not particularly mentioned to maintain pseudo-code standard [20].

Following is the pseudo-code of the main algorithm [18, 19]. Here, several other functions are called which are separated for the sake of modularity, which are also described afterwards.

```
START
    instruction <== CALL function receive( port_number );
    IF instruction is to serve medicine THEN
        captured_image <== CALL function snap();
        SET sensitivity TO default value;
        [centers, next] <== CALL function detector(captured_image,
                                                   sensitivity);
        post process centers and next;
        GET strip_no from processed data;
        GET column_no from processed data;
        GET row_no from processed data;
        INITIALIZE payload with strip_no, column_no and row_no;
        CALL function transmit( port_number, payload );
    END IF
END
```

Following snap function captures image from imaging device and apply basic filtering [18, 19].

```
FUNCTION snap ( width, height ) {
    IF width and height are not provided THEN
        SET width TO default value;
        SET height TO default value;
    END IF
    GET default image source;
    capture image;
    resize image;
    rotate image to proper orientation;
    apply noise filter and primary segmentation;
    SET image_data TO filtered image;
    RETURN image_data;
}
```

The detector function is the core function of the algorithm [19].

```
FUNCTION detector ( image_data , sensitivity ) {
    IMPORT matlab image processing toolbox;
    IF sensitivity is not provided THEN
        SET sensitivity TO default value;
    END IF
    INITIALIZE radius_range TO maximum default value;
    INITIALIZE is_empty_strip TO false;
    WHILE true DO
        CALL circle detection function with image_data, sensitivity;
     find circles in image_data;
        GET centers of found circles in image_data;
        GET radius of found circles in image_data;
        IF no circles found within radius_range THEN
            IF radius_range can be decreased THEN
                DECREASE radius_range;
            ELSE IF radius_range equals to minimum default THEN
                IF sensitivity meets within threshold THEN
                    REPEAT for adjusted sensitivity;
                ELSE IF sensitivity exceeds threshold THEN
                    SET is_empty_strip TO true;
                    BREAK WHILE;
                END IF
            END IF
        ELSE IF circles found within radius_range THEN
            BREAK WHILE;
        END IF
    END WHILE

    IF circles found AND is_empty_strip is equal to false THEN
        sort center locations;
        INITIALIZE center_array with sorted data;
        INITIALIZE next_tablet_location with first location;

        RETURN [ center_array , next_tablet_location ];
    ELSE IF no circles found THEN
        RETURN false;
    END IF
}
```

Two functions receive and transmit are used to receive and send data over communication port [18, 19].

```
FUNCTION receive ( port_number ) {
    INITIALIZE serial port using port_number;
    apply standard parity parameter for serial port;
    apply standard baud rate for serial port;

    TRY TO {
        open connection to serial port;
        SCAN from serial port;
        SET received_data TO scanned data;
        validate received_data;
        close connection to serial port;
    } CATCH IF error {
        THROW exception;
    }

    RETURN received_data;
}
```

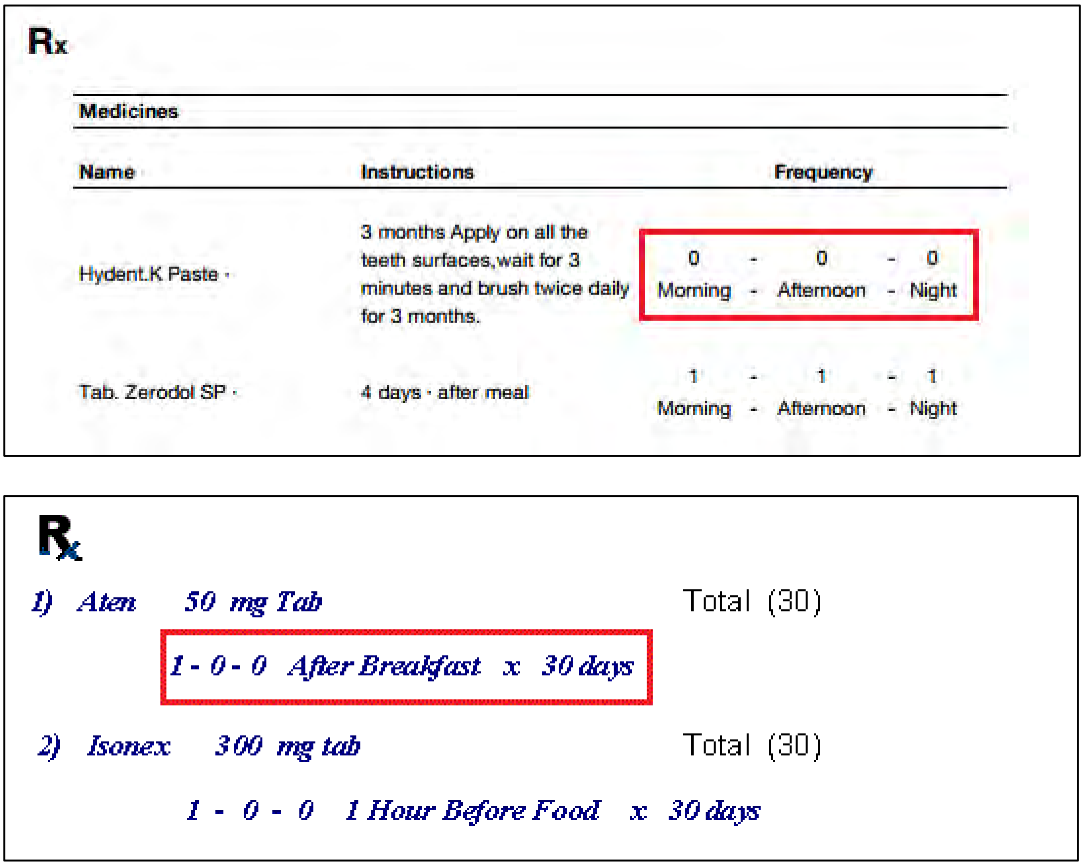
```
FUNCTION transmit ( port_number , payload ) {
    validate payload;
    INITIALIZE serial port using port_number;
    apply standard parity parameter for serial port;
    apply standard baud rate for serial port;

    TRY TO {
        open connection to serial port;
        PRINT payload string to serial port;
        close connection to serial port;
    } CATCH IF error {
        THROW exception;
    }
}
```

OCR

The medicine serving system monitors commands from user inputs or instructions. However, to implement medication reminder system and to develop automatic selection of proper medicines for medication, medication schedule is very important for the system. It, it fact, is an input of the system. Primary source of medication schedule is the prescription of a patient. A prescription includes which medicine to take, when and how much to take. So, to automate the medicine service, these information needs to be decoded from the prescription. OCR recognition from the image of the prescription is performed to decode medicine names and corresponding schedule from the picture of the prescription.

OCR has been made easy by the recent developments of Tesseract Open Source OCR Engine [21]. It has good efficiency and performance. Tesseract is used to decode medication schedule from prescription image. Traditional prescription contains medicine name followed by a sequence of numbers which represents how many medicines to take before or after breakfast, lunch and dinner.


Rx

Medicines

Name	Instructions	Frequency
Hydent.K Paste -	3 months Apply on all the teeth surfaces,wait for 3 minutes and brush twice daily for 3 months.	0 - 0 - 0 Morning - Afternoon - Night
Tab. Zerodol SP -	4 days - after meal	1 - 1 - 1 Morning - Afternoon - Night

Rx

1) Aten 50 mg Tab Total (30)

1 - 0 - 0 After Breakfast x 30 days

2) Isonex 300 mg tab Total (30)

1 - 0 - 0 1 Hour Before Food x 30 days

Figure 5.4-3 Sample printed prescriptions

The main target of prescription decoding is to find out how many medicines to serve at each meal, breakfast, lunch and dinner. So, data from a prescription analogically is showed below,

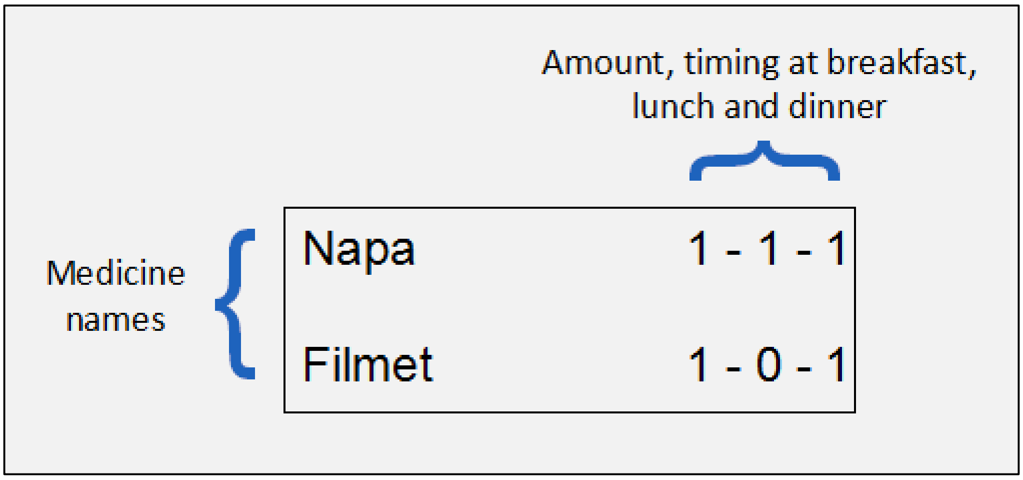


Figure 5.4-4 Data from a prescription

Here Tesseract comes in action. Tesseract reads text from an image and saves text data in a text file [21, 22]. This text file is later on processed with string processor to retrieve medication schedule. For example, from above figure, Tesseract extracts the following text an saves in a text file [22].

```
Napa 1-1-1
Filmet 1-0-1
```

Using simple string operation afterwards, amount of medicine to be served for breakfast, lunch and dinner is retrieved from this text. This amount is combined with the predefined schedule for breakfast, lunch and dinner respectively and generate instruction for medicine serving system.

Notably, hand written prescription cannot be processed for ambiguity. Also, some simple simple searching inside the text is performed to find out if the medicine is before or after the meal.

Voice Processing

Microsoft Visual Studio 12.0:

Microsoft VS is an IDE from Microsoft which is used to develop computer programs as well as web applications and web services. This software uses Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silverlight. It can produce both native and managed code.

Visual Studio is used to build a windows program for the voice based control. The program recognizes certain voice command and process according to the command.

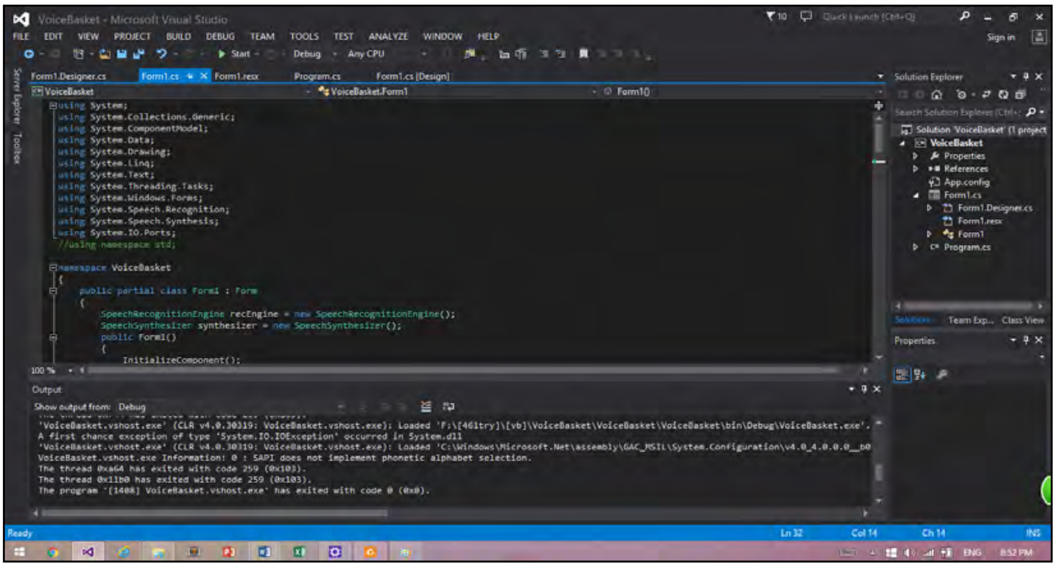


Figure 5.4-5 Microsoft Visual Studio interface

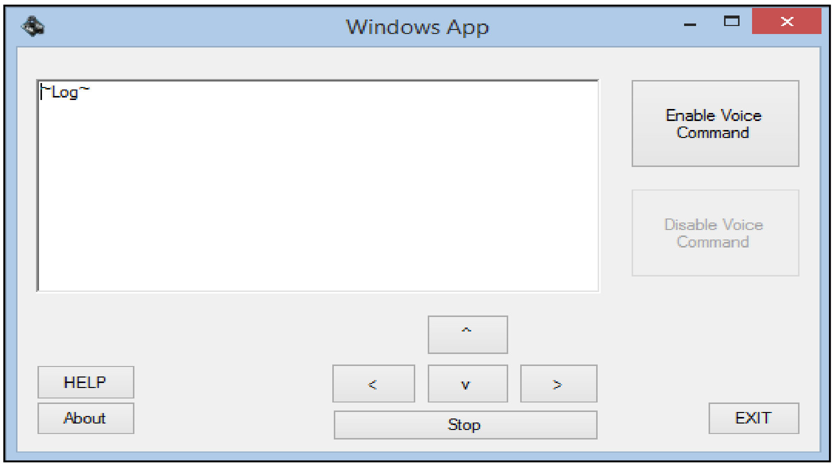


Figure 5.4-6 The GUI application for voice command recognition

A GUI application is created for the voice command process and to send the command through the serial port [23]. The application has an ENABLE button to start process the command and a DISABLE button to stop the process. There are another four buttons to send the coded command for four different directions and a STOP button to stop the movement. The HELP button describes the application, ABOUT shows the credit and EXIT button closes the application.

```
START
   Initialize port name
   Initialize Baud rate
   Main{
       IF the port is not open
           THEN open serial port
       END IF
       Go to buttonOnClick()
       Go to CommandProcess()

   }

END
```

```
CommandProcess(){
    Add command strings to command
    Start recognizing voice and save it to command
    IF command is forward
        THEN write FORWARD in serial
    IF command is backward
        THEN write BACKWARD in serial
    IF command is right
        THEN write RIGHT in serial

    IF command is left
        THEN write LEFT in serial
    IF command is stop
        THEN write STOP in serial
}
```

```
buttonOnClick(){
    IF button1 is clicked
        THEN go to CommandProcess()
    IF button2 is clicked
        THEN exit from CommandProcess()
    IF button3 is clicked
        THEN write FORWARD in serial
    IF button4 is clicked
        THEN write BACKWARD in serial
    IF button5 is clicked
        THEN write RIGHT in serial
    IF button6 is clicked
        THEN write LEFT in serial
    IF button7 is clicked
        THEN write STOP in serial
    IF button8 is clicked
        THEN show HELP message
    IF button9 is clicked
        THEN show ABOUT message
    IF button10 is clicked
        THEN exit the program
 }
```

5.4.2 Firmware of the system

Arduino IDE

This is an open source software. The environment is written in Java and based on processing and other open source software. The software can be used with any Arduino based boards. The programs must be written in C language and uploading the program is very easy. It can be run in any OS such as Windows, Linux, MAC OS X.

Arduino Mega board and Arduino version-1.6.4 software is used for the project. The main process for the device is being controlled by the program written in the software.

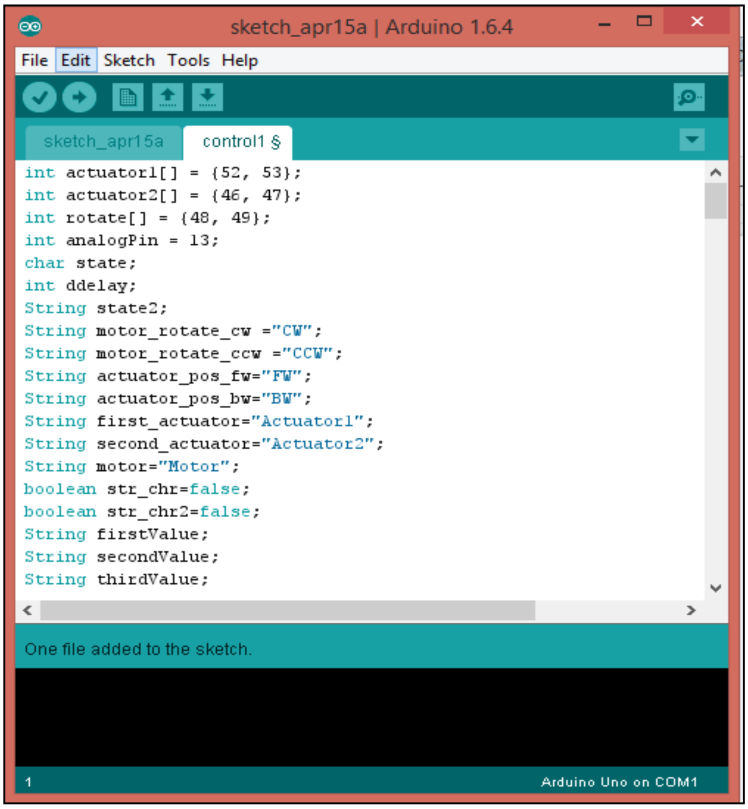


Figure 5.4-7 Arduino IDE interface

The firmware for the circuit logic is written using Arduino software in C code [24]. The main program has approximately 464 lines. The whole logic is described here as pseudo code.

```
START
include the header files
initialize the pins for dc motor,actuator,reset switches and stepper motor
initialize the steps for the strip location
setup(){
       BEGIN serial
       FOR i equals to 0 to 2
       Run the stepper motor
                     Run the actuators
              END FOR
              SET initial speed for the stepper
              WHILE
                     Check for command through serial
              END WHILE
       }
       Loop {
           IF Serial is available
               Read the movement command from the serial
               IF the command is forward
                   Go forward
               ELSE IF the command is backward
                   Go backward
               ELSE IF command is right
                   Go right
               ELSE IF command is left
                   Go left
               ELSE
                   Stop
           END IF
           Read strip number or name and the medicine number
           IF the command is strip 1
                THEN  run the switches for the strip measurement
                WHILE loop runs until stepper is in the strip location
                    RUN the stepper to go to the strip location
                    RUN the actuator to go to the medicine location
                END WHILE
            ELSE IF the command is strip 2
                THEN  run the switches for the strip measurement
                WHILE loop runs until stepper is in the strip location
                    RUN the stepper to go to the strip location
                    RUN the actuator to go to the medicine location
                END WHILE
            ELSE IF the command is strip 3
                THEN  run the switches for the strip measurement
                WHILE loop runs until stepper is in the strip location
                    RUN the stepper to go to the strip location
                    RUN the actuator to go to the medicine location
                END WHILE
            END IF
        END IF
    }
    END
```

6 Experimental Results

There are three major parts of our robotic system. The Image processing part, the voice command module and the medicine serving mechanism. Each has their own testing field and each part were tested separately. These testing field gave us an idea which part is working properly and which part needs improvement.

6.1 Image Processing

We finished the image processing part first for medicine detection. In order to do that we had to test image detection for detecting different kinds of medicines. First we had to choose what kinds of medicines are suitable for our project. So, we completed a survey on what kind of medicines are available in the market and what type of medicines are used most. Then we categorized them into tablets and capsules. Since the amount of capsule is lower than tablet's amount in the market, we mostly used tablet for our test cases. Here are some test cases we used to measure. We used more than 100 medicines, below, a chart is given for 10 test case.

So, for most cases we had to use polarity as bright. Only for colored medicines we need to use polarity as dark. But, in this case bright polarity also gives 60-70% accuracy. So, we used polarity as bright. Sensitivity is also a big factor for image processing mostly for shape recognizing.

Table 6.1-1 Sample medicine strip measurement

Name	Type	Pack Type	Pack Matrix	Pack Dimension	Horizontal Distance	Vertical Distance
Ace	Tablet	Plastic Case	2 x 5	8.8 x 4.8	1.7	2.4
Napa	Tablet	Plastic Case	2 x 5	9.5 x 4	0.5	0.5
Napa Extra	Tablet	Plastic Case	2 x 5	12 x 4.5	2.5	2.5
Ace+	Tablet	Plastic Case	2 x 5	13.6 x 5.4	2.7	2.65
Deflacort	Tablet	Plastic Case	2 x 5	10 x 4	7	2
Oxicam	Tablet	Plastic Case	2 x 5	8.5 x 3.5	1.6	1.7
Bufen SR	Capsule	Aluminium Foil	1 x 5	9.2 x 3.6	0.7	1.6
Etorix 90	Tablet	Plastic Case	2 x 5	8.0 x 4.4	2	1.6
Povital	Tablet	Plastic Case	2 x 5	9.0 c 3.5	1.7	1.5

From the table we can see most of the medicines are in plastic case and they are table. We also got the distance of the center and the average radius of the centers. It helps us with image processing.

Now, for image processing we had to test for some different cases. The test result varies for different polarities. We can use two kinds of polarities 1. Bright and 2. Dark. Since most of the medicines are white in color, if we use polarity dark then it cannot detect the circle properly.

The average sensitivity we used is 0.94 since it gives the optimum result for the camera we used. Here is the table shown the result for different sensitivity.

Table 6.1-2 Experimental Results for Different Parameters

Sensitivity	Test case	Success	Success rate
0.99	10	0	0%
0.98	10	0	0%
0.97	10	0	0%
0.96	20	6	30%
0.95	30	12	40%
0.94	30	13	43%
0.93	30	16	53%
0.92	30	24	80%
0.91	20	15	75%
0.90	20	13	65%
			Overall – 59 %

Now, the one of the most important part for this image processing part is lighting. If the lighting condition is not good enough then medicine detection get very tough. Even high sensitivity cannot detect the medicine. But in proper lighting condition medicine can be detected very easily and accurately. So, proper lighting is very important.

The following graph represents the relation between sensitivity and success rate. The graph indicates that with a sensitivity of 0.9 to 0.92 gives maximum success on detection.

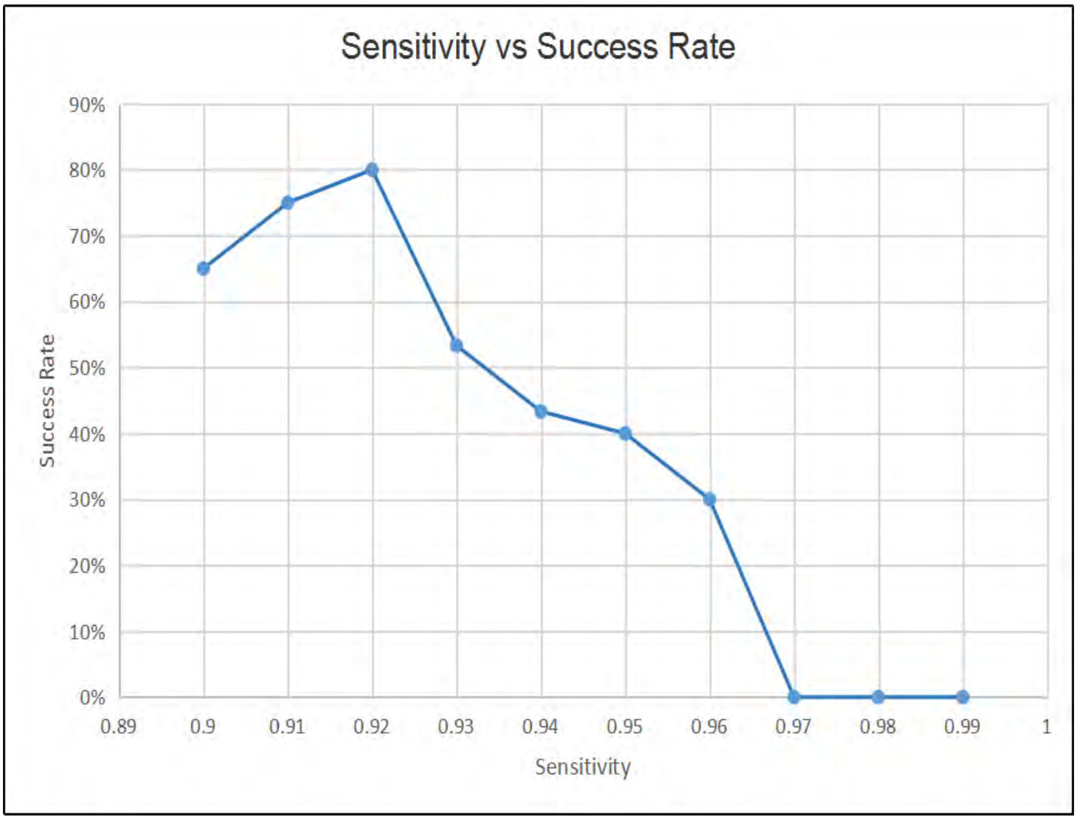


Figure 6.1-1 Relation between sensitivity and success rate

Test Examples for Different Parameters and Conditions:

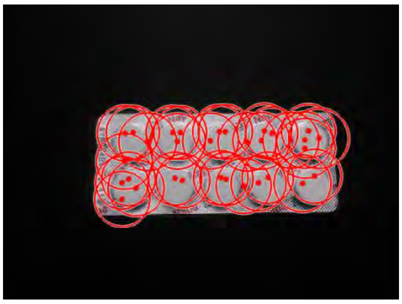
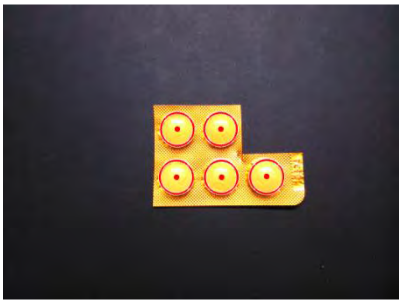
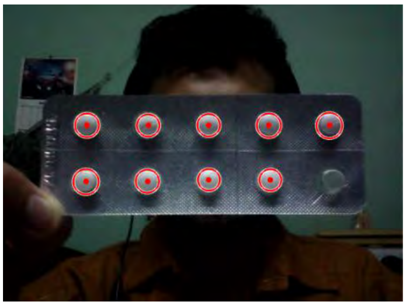
 Sensitivity 93% Object Polarity: Bright Accurate detection.	 Sensitivity 94% Object Polarity: Dark Improper polarity leads to failure.	 Sensitivity 90% Object Polarity: Bright Sensitivity is too low.
 Sensitivity 98% Object Polarity: Bright High sensitivity leads to failure.	 Sensitivity 99% Object Polarity: Bright High sensitivity leads to excessive unwanted detection.	 Sensitivity 93% Object Polarity: Bright Subject too close to camera leads to failure.
 Sensitivity 93% Object Polarity: Bright Proper detection for used strip.	 Sensitivity 93% Object Polarity: Bright Detection for different colored strip.	 Sensitivity 93% Object Polarity: Bright Detection in improper background , in a smaller tablet strip.

Figure 6.1-2 Demonatration of results under various conditions

6.2 Voice Module

Voice module controls the communication between the user and robotic system. User gives multiple commands and the robotic system reacts accordingly. This voice module's success rate hugely depends on the hardware components such as: Microphone, Arduino board etc. Noise suppression and cancellation also plays a vital role in this case. For some given basic voice commands, we have collected some data to figure out the success rate and failure rate of the module. The table is given below:

Table 6.2-1 Experimental results for voice module

Commands	Success rate (In Percentage %)		Failure cause	
	With noise suppression	Without noise suppression	Arduino serial	Microphone
Go	75	35	Yes	Yes
Back	78	44	No	Yes
Left	81	50	No	Yes
Right	81	50	No	Yes
Strip 1	85	49	Yes	No
Strip 2	83	46	Yes	No
Strip 3	83	44	Yes	No

According to the table, we can see with proper noise suppression success rate is average of 80 percent, whereas without noise suppression success is below 50 percent on average. For the commands (Go, Back, Left and Right), main failure cause is microphone. When the microphone receives the command accurately, most of the data are sent via Arduino serial properly. The Arduino serial is not the main cause of failure for these commands. The case is complete different for commands Strip 1, Strip 2 and Strip 3.

To sum up, we can conclude with a better quality microphone we can have more success rate. Whereas, the issue of Arduino serial is pretty much non-solvable.

6.3 Medicine Serving

The medicine serving mechanism's success rate depends on how successfully the robotic system can take the medicine out from the strip. For our basic testing and experiments we used three different medicine strips. Ten strips of each medicine strips were used during experiment. The results are given below in the table:

Table 6.3-1 Experimental result for medicine serving

Name of the medicine	Successfully retained medicine (In Percentage %)	More than one medicine retained (In Percentage %)	Failed to obtain medicine (In Percentage %)
Filmet	60	10.10	29.9
Napa	65	11	24
Theovent-SR	59.8	9.899	30.30
Alatrol	55.6	8.75	35.65
Antacid	51	12	37
Betaloc 50	48.9	7.83	43.27

Below, given some picture of successfully obtaining medicine, half successfully obtained medicine and failed to obtain medicines:

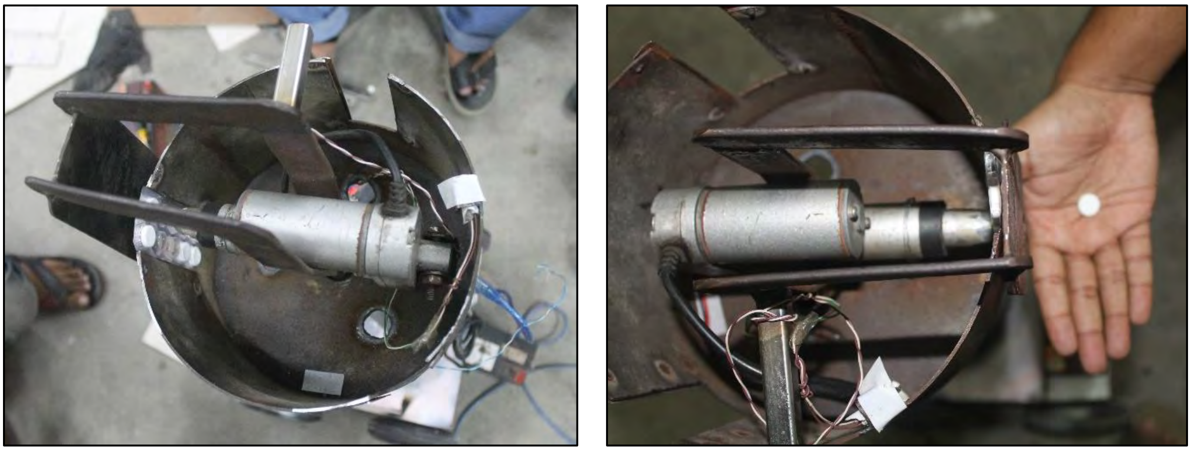


Figure 6.3-1 Successfully obtained medicine

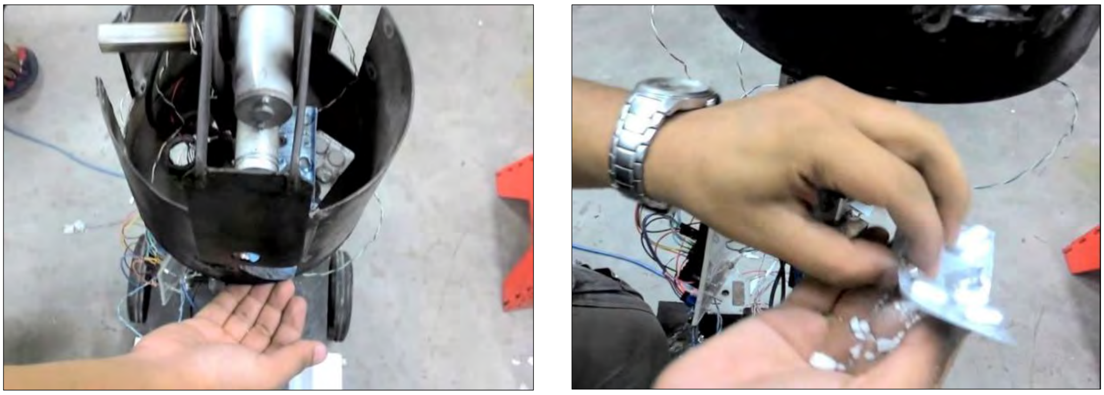


Figure 6.3-2 Half successful on obtaining medicine

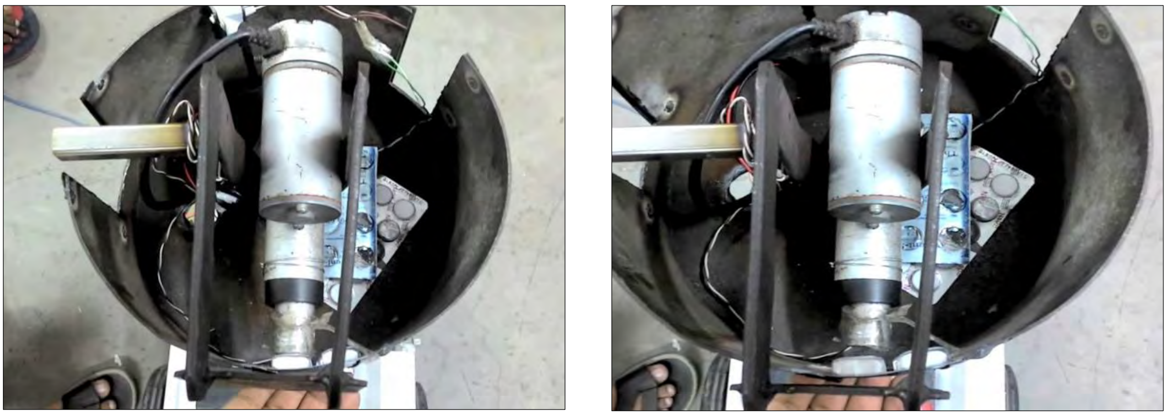


Figure 6.3-3 Failed to obtain medicine (broken and undetached)

7 Limitations and Flaws

Although the project reached its initial goals, there were some unavoidable limitations which caused to change and modify its initial design and implementation method. Firstly, limitation of proper equipment was the main limitation of the project. The project would be much more easy and efficient if proper equipments could be available. For example, to strip out medicine a big actuator was used but, what it needed was a smaller one which was not available in our country and was very costly in international market. Same goes to the strip holder and the base of the robot. Since the medicine pushing actuator was bigger in size, so the strip holder had to be made bigger so that it can hold the actuator inside and enough medicine can be stored. And because of the bigger and heavier medicine holder the base of the structure had to be strong enough to hold the weight of the body. So, the base was built with thick iron plate which made the whole structure heavier and bigger. Since, most of the materials was taken from local market, it was hard to match it properly with each other. If all the parts of the structure could be built, it would be more efficient and compact.

Secondly, time was a big limitation too. This kind of project takes normally a lot of time to be finished. But, for this project there was approximately eleven months. From this eleven months a good amount of time was spent on research purpose. So, the working hour was less.

Thirdly, to build this kind of project money have a big role to play. Since, for this project there was no financial help from any organization so, the group members had to spend their own money on the project. Though there was some help from BRAC University's workshop which provides with technical support and the actuators. Because of the limitations there was some flow of the robotic system.

Some of the limitations of the current system are:

- The robot cannot detect the name of the medicine yet. So, the medicine is needed to installed by a human on the medicine holder and tell the machine what pocket is used for which medicine.

- The medicine opening system is still mechanical. Switches and sensors had been used to detect the position of the medicine and a variable was used to count how many medicine is still on the strip. Since, it is totally mechanically controlled, there might have some mechanical error in long term use.

- There might have some overheating issue if the device is turned on for long time since, two actuators and tow motors drives good amount of current. The transistor used to step down voltage for stepper also overheats sometimes.

- During prototyping the medicine detection, image processing is used for circle detection. Hence, circular or round shaped medicine tablets can be detected currently. There are some other types of medicine which are of different shapes. Detection for those medicines are not incorporated for the prototype.

- The cylindrical medicine container being too much congested, a camera could not be fixed inside the container. Pictures are taken from the outside. A miniature camera or a larger container could have solved the issue, but computer interfacable miniature camera could not be managed nor a metal pipe having more than 9 inch diameter is sold in portion or piece in the local market.

- The smallest actuator used for pushing the medicine out of the strip is relatively large for standard medicine. It had to be contracted manually. A smaller actuator would have increase the efficiency of the system.

- During developing the OCR extraction, printed prescription was used. Handwritten prescription could not be processed as handwriting is quite ambiguous. So the system cannot use traditional handwritten prescriptions as input.

8 Future Aspects

Like all other robotic systems the scope of working on the project in future is limitless. From the extensive research it is found that this project can be improved and extra facilities can be added. Firstly, it can be made totally automated from semi-automated. If two camera can be set inside and outside of the medicine holder cylinder, by image processing and with the help of OCR the device will be automatically detect which medicine is need to be pushed from the strip and which strip contain what medicine respectively. The inside camera will make its medicine striping system from mechanical to automated since live reading of medicines position will be found by image processing and a signal of this reading can be sent through the serial port of Arduino microcontroller to control the rotation. It will reduce the error rate almost near to zero. And with the back camera installed there will be no need for a person go give manual input for the medicine name which will eliminate any chance of human error regarding medicine recognition of the machine. Since, a simple misplacement of medicine can cause the death of a life.

Secondly, some medical checkup equipment like blood pressure sensor, heart rate, body temperature, blood sugar etc. can be added to the device for regular health checkup of the targeted patient. A database system can be implemented so that the all the checkup results can be stored in the database so that it can be found easily.

Thirdly, if an GSM module can be added with the device, it will be able to maintain an online health database with the information of the health checkup so that the doctor of that patient can see through the health checkup report easily and decide if there will be any change in his future medication. There was some work done on this kind of thing. Chandan [25] in his paper mentioned about their research on some closed loop medication system for which they made an online database system. In their paper they also mentioned about connecting doctor, nurse, dispensary, patients and their family in a closed loop system so that error in medication get reduced and to ensure proper treatment. By implementing it will also be able to send some emergency information to the relative of the patient like, if the medicine is about to finish it will be able to send a message or E-mail to them to refill the medicine. Also if it detect some kind of trouble to its patient like, if the patient doesn’t respond to it for long time and no movement detected then it will be able to give some alarming message to their relatives.

Fourthly, for future implementation the body of the current system can be replaced with humanoid robotics body and with some artificial intelligence so that the robot can communicate with the patient for their time passing since over 51 percent of people aged 75 and above live alone [26] and around 10 percent of them need help from other people for their personal care [27]. So, a humanoid robot with communication skill can be able to solve this problem.

There is a lot of scope on this project which can be implemented in future, like make a subsystem which will help elderly people with their walk and will provide some basic work from the main system. It will communicate with the base device and alarm the patient about their medication, food taking and sleeping timer. It also be able to track the patient.

9 Conclusion

The growing need of nurses and doctors are alarming as the needs aren't fulfilled due to the lack of good doctors and nurses. To contribute in this cause, we came up with this idea of an ideal health care companion, which can serve as a nurse and maybe a possible replacement of human assistant. Also we tried to provide a robotic system that not only can help to take one's medication but also within his or her budget range Of course, our robotic systems has flaws, it doesn't always work efficiently. However, if what we discussed in the future aspect is met and with better resources we might get even better results. . We hope, that this system can reach to everywhere, from hospitals to households, from old people to infants and be as much help as possible.

Overall, the device was a sixty percent successful, our aim was to make it more precise. We asked the help of experts, discussed solutions to make the device more successful. They suggested to use different hardware or improve the existing ones. We emphasized on the feedbacks and tried many different ways to solve the issue and the most successful one is elaborated in our paper. However, there is yet more work to be done in both hardware and software.

According to our observation, the concept and idea of automated medicine serving is not very common. Research and development on this topic is still very few. The opportunities and advantages of this system is yet to be determined, but hopefully it would be an achievement to medical field. Also, it can contribute in other sectors such as restaurants and offices and can be developed accordingly. In conclusion, this robotic system can open new possibilities and opportunities and probable solutions to elderly and disabled people.

Acronyms

1. OS – Operating System
2. IDE – Integrated Development Environment
3. GUI – Graphical User Interface
4. API – Application Programming Interface
5. OCR – Optical Character Recognition
6. CAD – Computer Aided Design

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Appendix A

For Arduino commands used in serial:

FW - Instruction for Actuator 1 to go up

BW - Instruction for Actuator 1 to go down

PUSH- Instruction for Actuator 2 to go up

PULL - Instruction for Actuator 2 to go down

ROTATE - Rotate stepper motor continuously

Strip1 - Go to medicine strip number one

Strip2 - Go to medicine strip number two

Strip3 - Go to medicine strip number three

fwd - Robot to move forward

bwd - Robot to move backward

left - Robot to move left

right - Robot to move right

Appendix B

For voice commands used as microphone input:

GO - Move forward

BACK - Move backward

LEFT - Move left

RIGHT - Move right

STRIP ONE - Go to medicine strip one

STRIP TWO - Go to medicine strip two

STRIP THREE- Go to medicine strip three