Next Generation Home Service Robot

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Declaration

We, hereby declare that this thesis is based on results we have found ourselves. Materials of work from researchers conducted by others are mentioned in References. This is to affirm that this thesis report is submitted by the authors listed for the degree of Bachelor of Science in Electrical and Electronic Engineering to the Department of Electrical and Electronic Engineering under the School of Engineering and Computer Science, BRAC University. We hereby declare that the research work is based on the results found by us and no other. Materials of work found by other researchers have been properly acknowledged. This thesis, neither in whole or in part, has been previously submitted elsewhere for assessment.

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Abstract

Home Automation robot is a type of robot that can work in home to make our household job easier. It enables robot to provide services for human in this modernized and changing world and assuredly it can work faster and better at every sector than human beings. In this modern era, by the help of technology, large numbers of automated robots are being created but most of the robot is very costly and not suitable enough for Home appliance over the world. The main reason behind this research is to make an artificial robot in very low cost with attractive and essential features. This work proposes an automated robot which is designed with low cost materials and also commonly available in our country. The main goal of the project was achieved to build a robot using low cost material and that could be used for home appliance purpose. Advanced tele operating, operated by an Android operating system, is the main feature of this research. This Robot can navigate through android devices to follow command and move inside the home according to the direction. It can travel to different places and can run comfortably on two motorized wheels and a third back wheel. The robot's coding platform is C++, which will provide the excellent private transport device. The onboard ArduinoMega control the features of the robot. The robot has four different features which can switch by serial command according to user need. It can be used for security of our house. As like, we can monitor our home from outside. The robot has such capability that with small changes, we can use it in many multi-dimensional purposes like coffee maker machine and vacuum cleaner controlled by android app.

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Chapter: 1: Introduction

1.1. Introduction:

Robotics has become a buzzword nowadays. With epoch-making advancements in information technology, there is hardly anyone who has never heard of this term though its practical implication in a third world country like ours still remains as a matter of regret. Now many of us may ask what a robotic system is. Basically a system which is electro mechanic and can perform autonomous and preprogrammed tasks is a robotic system [1]. The idea of robotics is not a modern notion rather it was first seeded in Greece, one of the very first civilizations. The idea remained confined within toys in Europe, China, Japan and elsewhere until 19th century when remotely controlled torpedoes were first demonstrated by Nicola Tesla. But the concept of autonomous robot was first envisaged by Isaac Asimov by formulating the three hypothetical laws of robotics. Then robotics improvised from the idea of mere toys to the concept of artificial intelligence. Compared to the developed countries, there have been very few research and utilization activities of robotics in Bangladesh where most of the notable works regarding robotics started from the beginning of 21st century. While the world is thriving to go to space, we are still lagging behind. In order to bridge the technological gap between the advanced countries and the third world countries, there is no way but to uplift ourselves from this ancient way of life to the machine-aided efficient way of modern life. If we dare to look at the most developed and powerful countries in terms of economics, politics and way of life, we would see that the more a country uses technology to solve their day to day to problems instead of muscle power, the more advanced and powerful the countries are. Here comes robotics which can be inarguably considered as one of the best criteria for evaluating technological advancement alias overall development of a country. Considering all these facts, in this advanced era of technology we have experienced the uses of modern gadgets in our daily life. In many cases these technologies are taking the place of conventional systems with flying colors. Nowadays the use of robotics in our surroundings is increasing day by day. With the help of this kind of system, people can do many tasks together within a short period of time. This kind of system also gives comfort to the workers or general

people in their daily work. To reduce the pressure of the daily household task the use of personal assistant robots are increasing day by day. People use them to do their household task easily and in a convenient way. So after studying all these facts we have decided to implement this kind of helping facility in a robot. With a vision of developing a system which can do certain task like coffee making, vacuum cleaning with some surveillance facility we have designed our home automation robot. We hope this effort is going to bring about a meaningful change in the daily activities of our lives.

Figure 1-1: Our Home Automation Robot

1.2. Motivation

Robotics is not a sheer theoretical knowledge rather a great scope for serving the mankind. With the intent of utilizing our acquired knowledge, we came up with this project. Nowadays people in the world want to have comfort in almost every sector of their life. Everyone wants to do tasks in an easier way to reduce stress. There are so many automated systems in the market available nowadays. This kind of system helps people in many tasks and gives comfort to them while doing their job. For example we can take the automated flush system in the toilet. After using the toilet we have to push the flush button and sometimes we do it frequently and waste water. Automated flush system works with sensor value. When users stand up after uses the toilet then the motion sensor can detect the human and automatically turn on the flush switch for once. That is how this system helps us and also save water as well. The uses of this kind of automation have been increased in our daily life. People want to have more automated system to reduce their workload. The demand of such system in the market also has increased. We have also seen that the developed countries like USA, UK, and Canada etc. developed their nation's quality of living by using automated systems in daily life. They make every work easier using those systems. Now after observing all these facts we get motivated to develop our country and quality of livings with the help of automated robotic system. We also got motivation to reduce the stress of the workers who have worked for hours and hours. Moreover, the people of our country are not native to the concept of automation. A lot needs to be done for changing the dilapidated plight of our countrymen. We believe that robotics can contribute a lot for easing the lives of millions as well as making remarkable advancement in science and technology and brighten the image of our country in the international arena. That's why we have chosen this topic and developed our system.

1.3. Methodology

In the literature review, we have mentioned previous works regarding automated coffee making, vacuum cleaning and security surveillance. We did the similar functions but with a different approach. We made an effort to align all the above mentioned functions in a single robot. We have integrated an android app to remotely control these functions within the robot. All the functional parts have been lucratively accommodated in the robot structure with proper synchronization. The robot can move in all directions according to the user's commands.

1.4. Literature Review

In the field of automated home appliances system there are many intelligent system that has amazed us by the unique quality of their own. Among all those systems the automated personal assistant robot is one of the best creations of modern technology. If we see at the developed countries the uses of robots are increasing day by day. After our brief study we have make a short list of robots which are highly used in household task and home automation. The list is consist of Kuri by Mayfield robotics, Sawyer – The coffee making robot, Roomba – The vacuum cleaning robot [2,3,4]. All these robots can help humans a lot to enjoy their daily life with less amount of stress. If we take sawyer robot as an example then we can know from its background that it works as a barista in the café in japan [3].

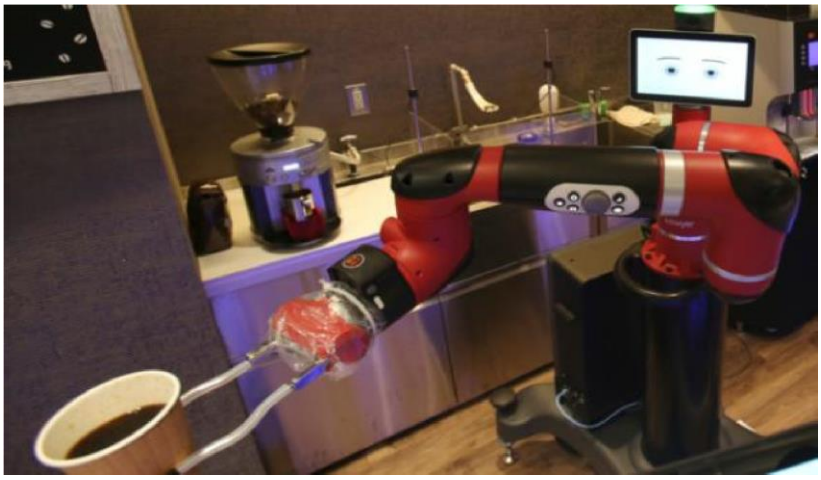


Figure 1-2: Sawyer Robot

Another useful robot for domestic help is Roomba [4]. This robot is basically a vacuum cleaning robot. It has self-charging mood and also can be connected with Wi-Fi.

Figure 1-3: Roomba

In our country recently one of the restaurants provides robots to serve foods to the customers [Figure: 1.3b]. The restaurant name is Robot Restaurant situated in the capital of Bangladesh Dhaka. By including robot they increase the number of customers. The manufacture of that robot is a china based company named HZX Electronic Technology Company [5]. Apart from these, numerous automated machines exists which can make coffee, clean floors or act as a vigilant for security purpose all over the world. The market of this kind of automated systems is emerging and there are more scope and opportunity for new products.

Multifunctional coffee makers have been made in USA, Japan, China and some other countries. Among them, a coffee maker invented by Kun-Lian Wei of Toptechnology Co Ltd is noteworthy [11]. The present invention provides a multi-function coffee maker, comprising at least two brewing accessories including an espresso coffee brewing accessory and a drip coffee brewing accessory, which are interchangeable and each can be loaded within said brewing room of said cover assembly to form an individual brewing chamber.

If we are to mention a vacuum cleaner, a robot invented by Shai Abramson, Shalom Levin and Ran Zaslavsky of F Robotics Acquisition, USA is a good example [10]. It autonomous robot, that is for example, suitable for operations such as vacuuming and surface cleaning includes a payload configured for vacuum cleaning, a drive system including a steering system, a navigation system, and a control system for integrating operations of the aforementioned systems.

Figure 1-4: Robot restaurant in Dhaka

"The coffee maker for brewing powder coffee contained in a cartridge" invented by Gianni Remo and Arthur Schmed in 2004 comprises a brewing chamber adapted to receive the cartridge, at least one punching member for punching the cartridge and a pump for feeding brewing water into the brewing chamber. [12]

Figure1-5: Room cleaning robot

"Automatic coffee maker with sensor for detecting the quantity of coffee in the machine" invented by Stephano Pozzari and Cire Adelmo Pirone in 2009 is mentionable. The sensor is connected to the electronic control unit, which is programmed to supply to a user by means of the interface at least a piece of information regarding the quantity of coffee in said container. [13]

Figure1-6: Brewbot

“Brewing device with control of the amount of grounds” invented by Michel Leforgeais, Thomas Leterrier, Frederic Hiron, Patrick Deliens and Ronan Le Goueff is also a good innovation. Provided is a brewing device for an espresso maker having a brewing chamber for receiving grounds, a pressing ram mounted movably on a path of travel extending between a top position and a bottom compaction position in which it penetrates into said brewing chamber to form a cake of compacted grounds, a hydraulic drive mechanism for the pressing ram having a hydraulic pump and means for measuring the volume of hydraulic fluid injected into the drive mechanism. [14]

We focused on combining all these functions and inventing a single machine that can do them autonomously. This hybridization would lessen the amount of resources required to build individual robots performing a single function. We have effectively combined these functions and brought them inside a single box. It can act as a coffee maker, a vacuum cleaner and a security guard.

Figure1-7: Ampbot

“Vacuum cleaner agitator cleaner with power control**”** is invented by Henrik Eriksson in 2008 is mentionable. A vacuum cleaner agitator system having an agitator, an electric motor to rotate the

agitator, a power source, and an agitator cleaner. The cleaner moves between a first position in which it is spaced from the agitator and a second position in which it engages the agitator to remove debris while the agitator rotates.[15]

Figure1-8: Sanbot

Chapter 2: System Design

2.1. System Architecture Review

In our system we have used different types of components. We have divided the total system design in two major parts. They are Mechanical structure and Electronics & power system. The mechanical structure consist of many sub part like chassis, drive motors, wheels, pump for suction, mixer motors and suction motor for cleaning. We have chosen such materials so that we can make the structure light weight with maximum rigidity. In the electronics and power system there are many parts which are interconnected and dependent on each other. In this sub system we have our Microcontroller unit, driver circuit for driving the motors, PIR sensor, Sharp Sensor, portable camera module, relay module. The system is also consisting of lead acid sealed battery packs for powering up each and every component. Software is another sub system of electronics part. In this system we have implemented mobile application for control and autonomous mode.

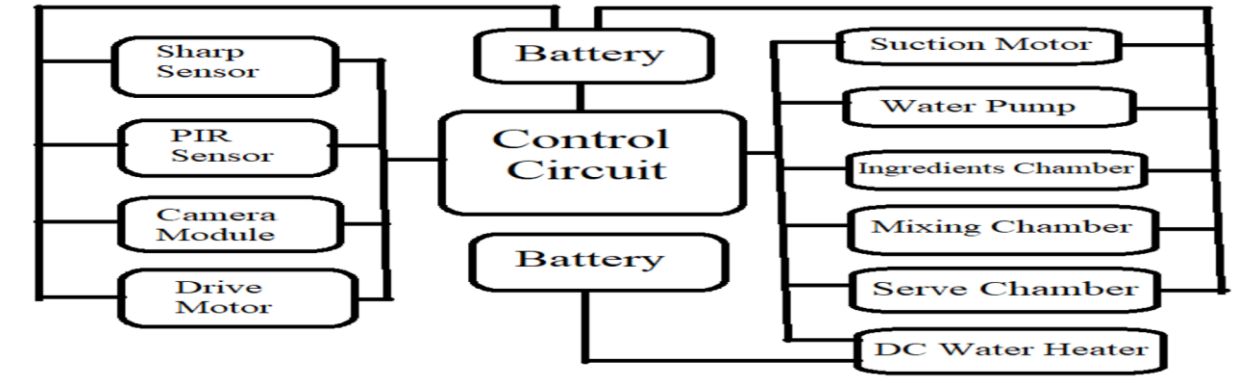


Figure 2-1: System Block Diagram

For the coffee maker to function, we need some raw materials e.g. coffee beans, milk, sugar and water. The machine follows genuine coffee making procedure. It is shortly described in the flow chart in the following page.

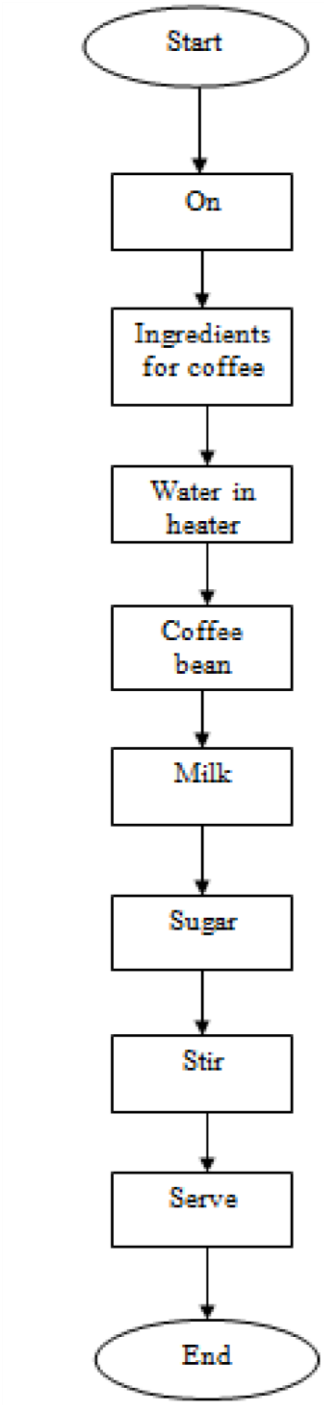


Figure2-2: Flowchart of coffee maker

The robot can move in all directions according to the demand of the user. A pre-installed android app is synchronized with the machine which is used to control the wheel mediated movement of the robot in any direction. Its mode of action is mentioned in the following flow chart:

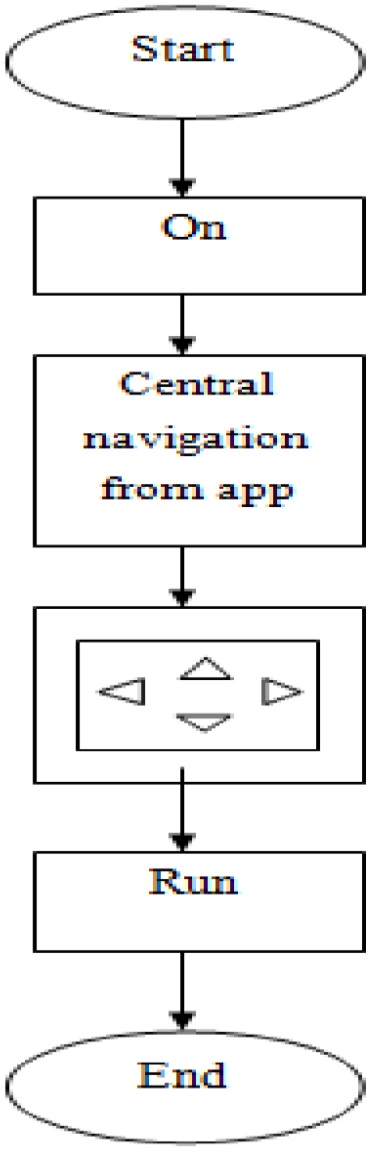


Figure 2-3: Flow chart of vacuum cleaner

We can also use this robot for the security purpose. It can detect sharp object and decide whether to stop or move forward. This process can be used for surveillance of a house. The relevant flow chart is mentioned below:

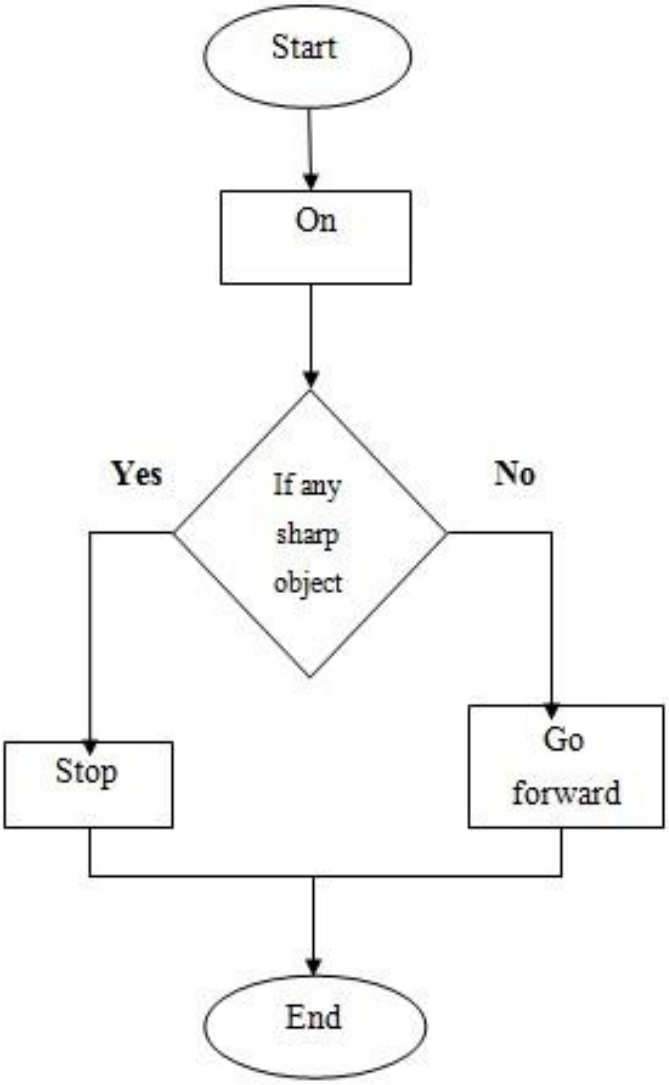


Figure 2-4: Flow chart of security surveillance

2.2. Mechanical Design:

The mechanical design consists of the following parts:

1. Chassis
2. Wheel
3. Motor

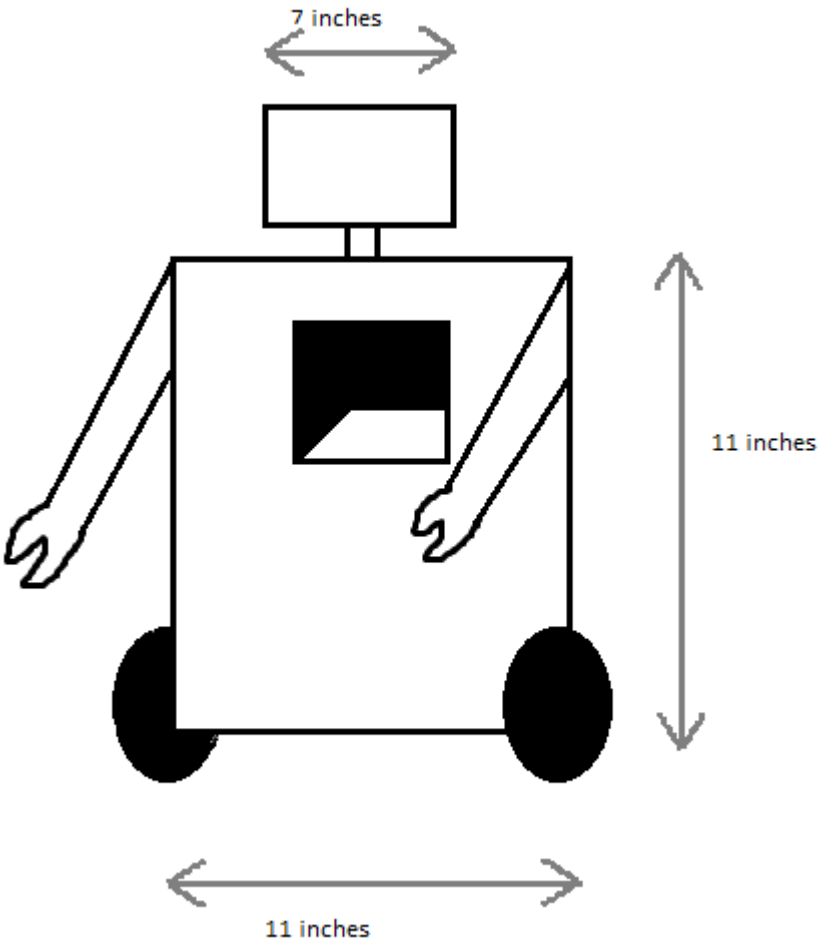


Figure 2-5: Chassis Frame (front)

Chassis:

The chassis of a robot is one of the most important parts as visibility and mobility of the system is highly dependent on this portion. If a systems chassis is not rigid enough then it may not survive for a long period. Again if a system chassis has extra weight then it cannot achieve efficient amount of mobility. Now considering light weight and rigid structure we have tried different type of materials for chassis. Firstly we have tried PVC board. This material is light weight but not rigid enough to hold all the parts of our robot. Then we went for light weight partex board. We have found better rigidity with light weight feature in this material. The shape of the chassis is a square box having 11 x 11 x 11 inch cubic shape [Figure: 2.6]. We have choose this structure because we need sufficient amount of space for all the other parts like vacuum cleaning system, coffee making system and sensor.

Figure 2-6: Chassis (side view)

Wheel:

As our robot is a home assistance robot it will spend maximum amount of time inside the house. We know that inside floor of a house is generally consist of a flat surface. So for this reason we have chosen two wheels with a diameter of 2 inch [Figure: 2.7]. As the robot needs not to run through a rough surface and also need not to cover a large run space that's why wheels with 2 inch

diameter is perfect for this operation. Now the third point of contact of our robot is a free wheel. We have selected a free wheel because of many reasons. Inside of a house the robot may have to take sharp turns for avoid obstacles. Now if we use four wheels then we have to use steering for turns which is a complicated mechanism. That's why we choose free wheel to reduce complexity from drive system.

Figure 2-7: Wheel

Motor:

Inside of a house we need a minimum amount of speed to drive the robot. Also need sufficient amount of torque for our robot as it will carry heavy things. After trying many motors we found a DC gear motor with an rpm of 30 and a horse power of 5w. It provides minimum speed with load that's why while running between obstacles it gives better performance.

Figure 2-8: DC Gear

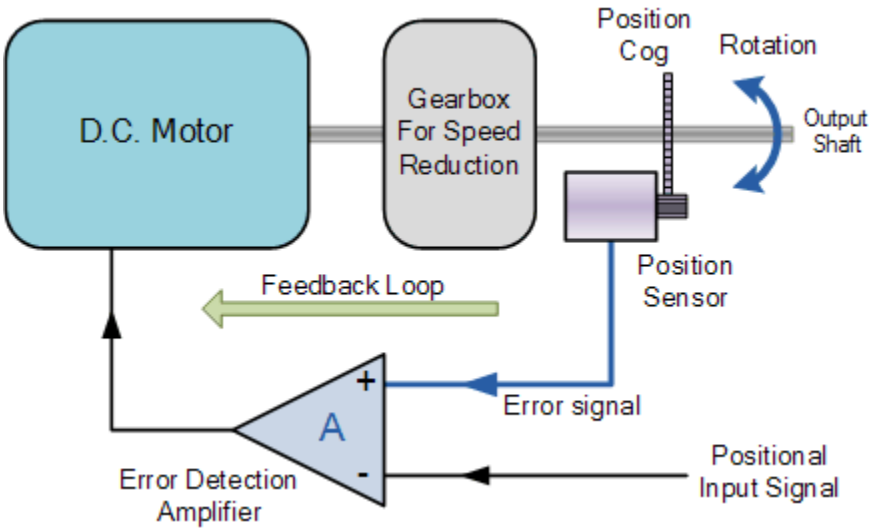


Figure 2-9: DC Gear diagram

2.3: Electrical Design

Circuit:

From the electronic system of a robot the circuit is the main portion. If the circuit does not have strong connection between components then there will be problem with the system every time. In our circuit system we have implemented a compact design within a short space. Our main microcontroller unit is Arduino mega. This micro controller unit has several digital and analog pin out for connecting several modules. Now the arduino board consist of Atmega 328 microcontroller which has 16 MHz processing power, this power is good enough for our system. In our system there are couple of motors which are controlled through motor driver module. For drive motor control we have used two L298 motor controller module. For using those modules we can control the speed of the drive motors which helps us to control the robot smoothly. There are two DC water pumps and also a DC vacuum cleaning motor inside our system. To control those motors we have used relay module. Our system is also consisting of a DC water heater which draws high amount of ampere. That's why we have used 10A relay module to control the heater. There is also a servo motor in the coffee ingredients box. That motor is controlled through analog pin of the Arduino. Two major sensor PIR and Sharp sensor has been incorporated in our system. Using those sensors we have detected obstacle and human being. To control our robot through Mobile application we have include a Bluetooth module inside our circuit system.

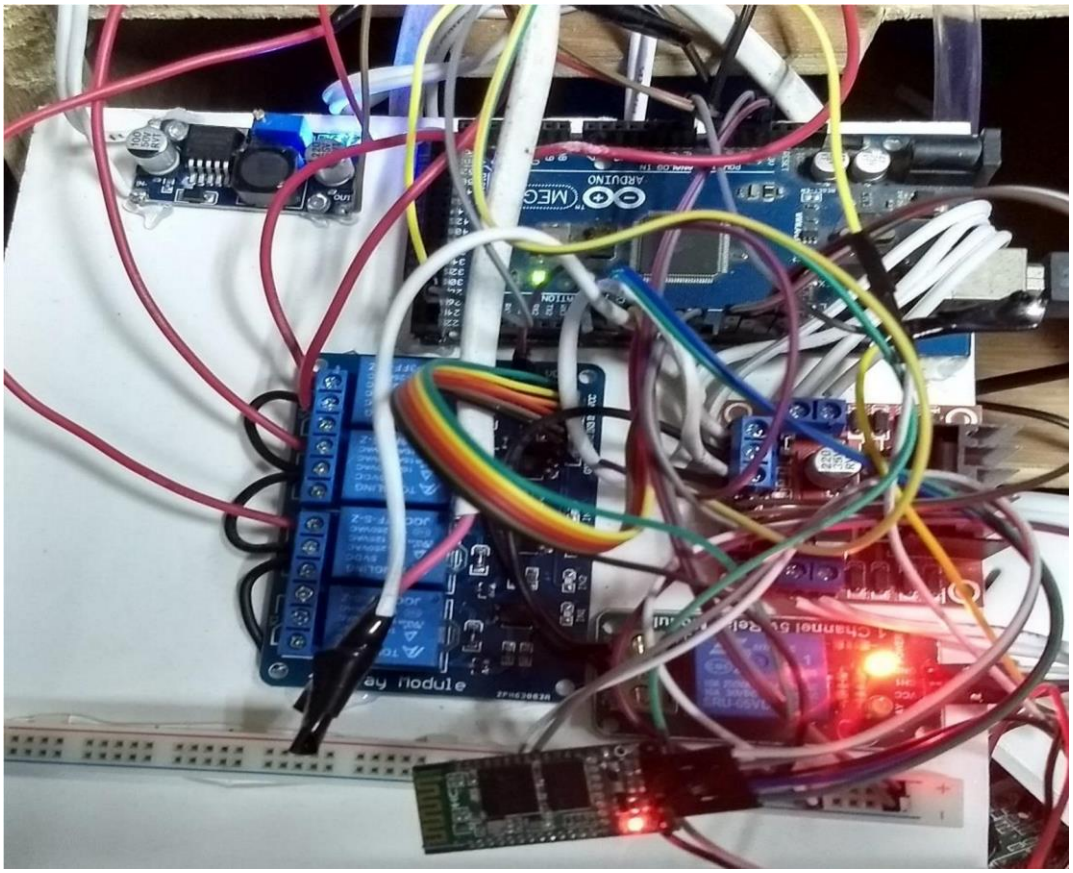


Figure 2-10: Control Circuit

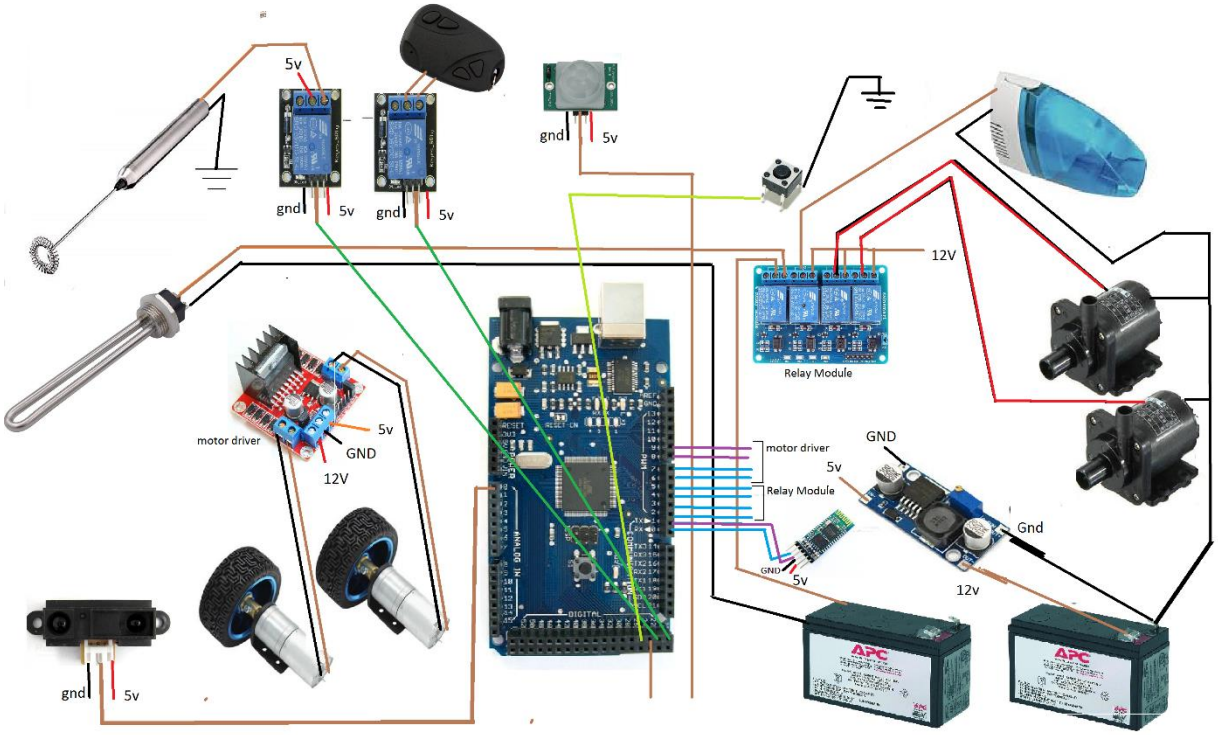


Figure 2-11: Control circuit diagram

2.4: Power Distribution:

For distributing the power sources to all the components we have used two different kind of battery. We have measured the ampere draws by each and every component in our system. The drive motors draws 1A individually. The water pump draws 0.7A with load. The mixer motor and the vacuum motor draw 0.8A separately. The maximum amount of ampere is consumed by the DC water heater module. It draws continues 2.5A. So having all the measurement in mind we have decided to include two separate 12V sealed lead acid batteries with 7500 mAh. From our calculation we have found that the battery packs are sufficient enough for this system.

Chapter 3: Vacuum cleaning and Coffee Machine Mechanisms

Two of the major features or our robots are vacuum cleaning and onboard coffee making. As our robot is a home automation robot so have tried to implement these two features successfully. In every house coffee is a common drink that everyone wants to have. Now if a robot make the drink and serve you at your favorite corner of the house then it will be an appreciable work. It reduces the coffee making work load from the user and gives a unique option to enjoy the drink to the user. Cleaning the home is a work that we cannot skip. As we live inside the house we have to keep every corner clean. Now cleaning is a hectic work for every person. To reduce the pressure of cleaning from us we have implement a vacuum cleaning mechanism inside our robot. By using that mechanism robot can easily clean every corner of a house.

Figure 3-1: Vacuum cleaner

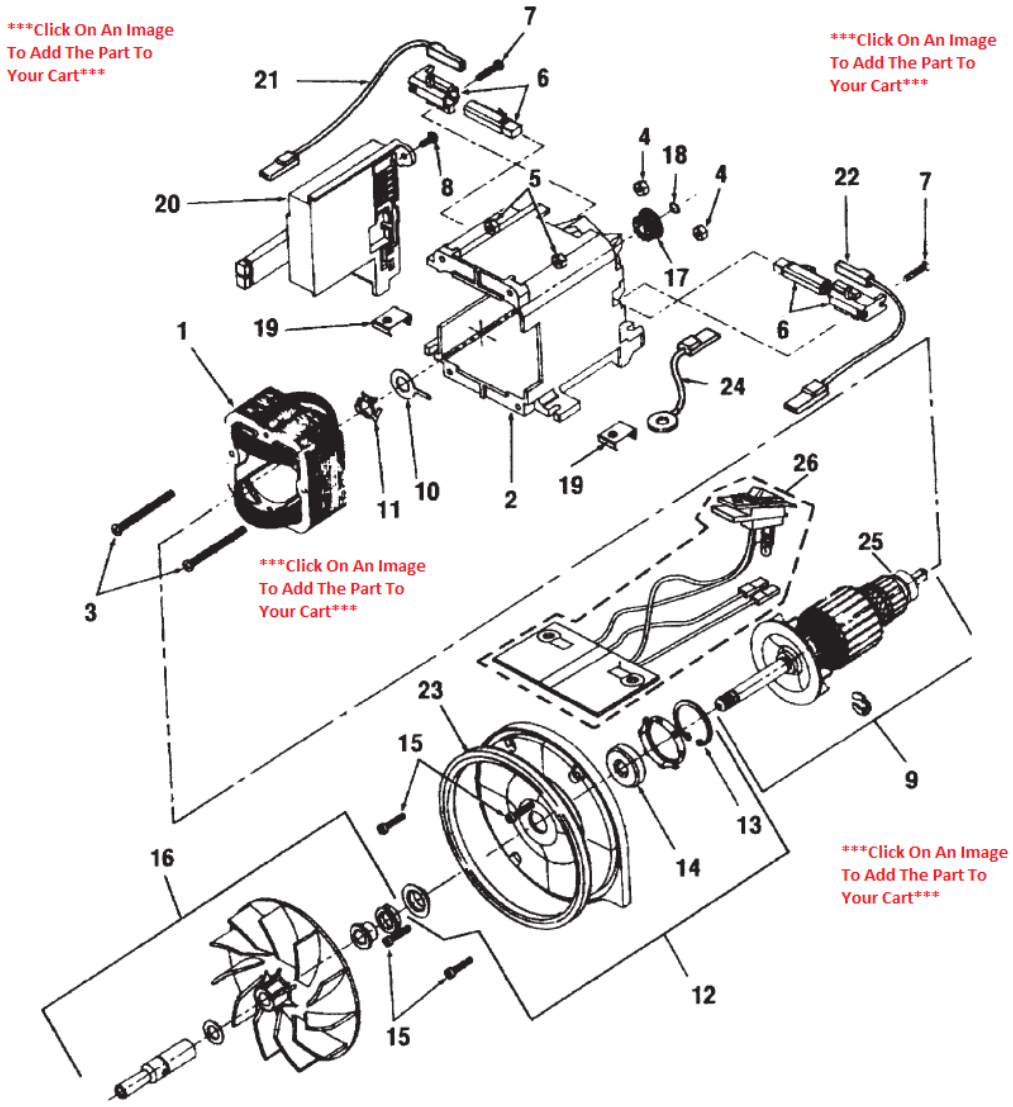


Figure 3-2: Vacuum cleaner internal parts

3.1: Suction Method:

For vacuum cleaning we have to use a suction mechanism to suck all the dust from the surface. For our system we have to select a light weight mechanism as it will affect the total pay load of the robot. For designing the technique we have used a DC motor and a propeller [Figure: 3.3]. When the motor rotate then the propeller rotate in a manner that it can take the air force from downwards to upward. While the air is going to upward then it creates suction upwards. Using that suction we have make our vacuum cleaning mechanism. There is a chamber inside of the module to store all the dust inside it. The total system is light weight. As we have used DC motor to generate suction so the power consumption is also less.

Figure 3-3: Vacuum cleaning motor

3.2. Cleaning Mechanism:

After developing the vacuum mechanism we have to design the cleaning mechanism also. For cleaning the home and every corner of the house the robot needs to go through every corner of the

house. Now we have decided to set up the vacuum cleaner under the base of the robot. Because when the robot will travel to all the corner of the house then it will clean all the corners as because the vacuum cleaner is set underneath it.

3.3. Water heating with DC voltage:

As we have included onboard coffee making a feature in our robot so we need warm water onboard, because warm water is one of the primary elements of coffee. When we study about the water heating mechanism, we have found almost all the mechanism in AC voltage. But our system is DC as we have to move the system frequently. Now solving the problem we have designed a new kind of DC water heating mechanism [Figure: 3.4]. In this mechanism we have a coil which is connected with a stainless steel round pipe. The coil is get excited when we put DC voltage into it. When coil get excited then it also passes the heat to the stainless steel pipe. The pipe will directly get contact with the water and passes the temperature to the water. This is how we can heat the water using DC voltage. As we are using coil mechanism in DC voltage that's why it consumes little bit of extra power. It draws 2.5A for heating the water.

Figure 3-4: DC water Heater

3.4. Ingredient Distribution:

After warm water the important ingredient for making coffee is milk, sugar and coffee itself. Now for making a cup of coffee we need specific amount of these ingredients. Like we need one tea spoon milk and sugar and half tea spoon coffee for one cup. Now for that we need to distribute all the ingredients equally. Now in our system we have a custom made ingredient holder. We have developed a mechanism using servo motor and our custom made ingredient box to release specific amount of materials. In our ingredients pot there are three different sections that contains sugar, milk and coffee [Figure: 3.5]. Now when the system received any command from user then a servo motor which is connected with the pot and holds the mouth of that pot, just rerate 90 degree and open the mouth of the pot for a certain time. Under that part we have drill three different hole in the three chamber of the ingredients. These three hole are make in a way that it only release that specific amount of ingredients for one cup of coffee. After releasing the ingredients to the mixing jar the servo again rotate 90 degree and cover the pot so that it cannot release extra ingredients. This is how we make the mechanism to have fixed amount of materials.

Figure 3-5: Ingredient Distribution Chamber

3.5. Mixing Method & Serving:

After having the raw materials inside of a custom made mixer jar the system imports warm water into jar that has been heated using DC voltage heating mechanism. The custom made jar is consisting of a DC motor [Figure: 3.6]. At the tip of that motor shaft we have implemented a propeller made of steel for mixing everything properly. The warm water from the water jar is collected by a DC water pump and submitted to the mixer jar. After putting all the raw materials inside of the mixing jar the DC motor with a propeller on at the tip just rotate with a good speed to mix all the ingredients properly. After a certain run time the mixing motor turn itself automatically off. Now time to server. We have used a DC water pump to serve the coffee to the designated cup. The serving portion is fixed at the middle of the body of our robot. As a cup of coffee has an extra weight, so for maintaining the balance we have placed the serving counter at the center. There will be a cup at the serving counter and the pump will fill the cup with coffee from the mixing jar. This is how the serving process has been conduct.

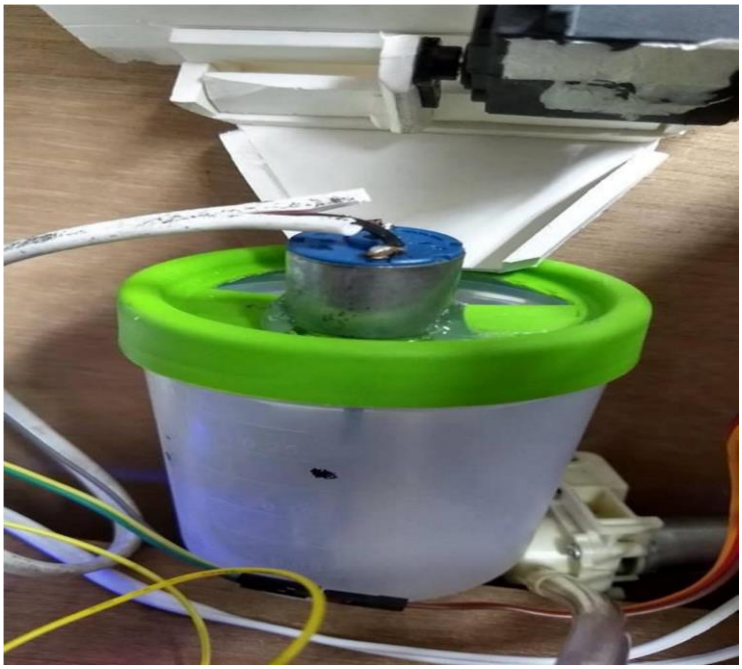


Figure 3-6: Mixing Chamber

Chapter: 4: Autonomous Features

The world is now relying on technology for many things. One of the key features of this technological era is autonomy. If we look at the products of every giant company then we can relate that everyone wants to introduce products with an amount of autonomy. For example the automobiles industries are now doing research with driver less car. They are trying to introduce autonomy at the vehicle control. We can see some tooth brush companies are introducing electric toothbrush to the customers. Each and every one is trying to produce some products to following the trend. In our system we have also tried to develop some sort of autonomy. Our autonomous features are as follows:

4.1: Obstacle detection & Sharp Sensor Implementation:

As our robot will be inside of a house so there will be many obstacle that needs to be detected by itself for a safe drive. We have studied a lot of sensors for obstacle detection. For detecting an obstacle efficiently we have to first measure the distance accurately then we can easily avoid the obstacle using that distance value. Now after a brief observation we have found sharp distance sensor as an efficient one. Between all other IR sensors this sharp sensor is most economical and also accurate [Figure: 4.1]. The sensor provides a single analog value as output which make the control system easier for this sensor. The operating voltage of this sensor is 4.5V to 5.5V. The average amount of current consumption for this sensor is 30mA which is much lesser than any other sensor. This sensor can measure 10cm to up to 80cm of distance at a time. The size of this sensor is very much compact with a size of 44.5 mm x 18.9 mm x 13.5 mm. The weight is also a little which is 3.5 g. The efficiency rate of the sensor is much higher than the sonar sensors. Now for avoiding obstacle we can easily measure the exact distance using the analog output from the sharp sensor and avoid obstacle within an efficient manner [6].

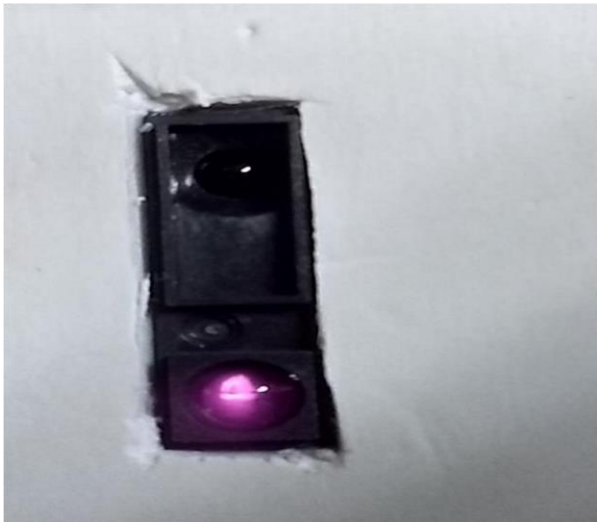


Figure 4-1: Sharp Sensor

4.2: Autonomous Vacuum Cleaning:

As we have mentioned earlier that we have tried some autonomous into our system. One of the features of the system is vacuum cleaning. In our system we have developed a mechanism; by using that our robot can move through the surface of the house and also can do vacuum cleaning. Our robot is controlled through a mobile application. In the app there is a button named autonomous mood. If anyone presses that button then the robot will go to the self-driving mood. Means it will drive by itself and no need any assistance or command. After going to the autonomous mood the robot start collecting extra amount of data from the sharp sensor and also collect data from the motion sensor. Distributed controlled application within sensors network. [20]. by using those data the robot has detect the entire obstacle and avoid them cleverly. While moving autonomously the robot turn on the suction motor and clean the surface while traveling to each corner of the house.

Chapter: 5: Surveillance System

5.1. Onboard Portable Camera:

In our robot we have implemented an onboard camera module. The camera module is very much light weight and also has a compact design [Figure: 5.1]. That's why it can get fit in any tiny place. This module is a digital camera module with a 2 MP camera on it. It can record images in jpeg format. It has a built in memory card slot in it. By using that slot it can save all the data inside of a memory card. "Scanning a document with a small camera" invented by T. Nakao is mentionable. When a user wants to input an image of the obstacle it automatically takes pictures. [16]. "Automatic fog detection and estimation of visibility and distance through use of an onboard camera" invented by Nicholas Hautiere, Didier Aubert. This image preprocessing also serves to identify the level of compatibility of the processed image. [18].

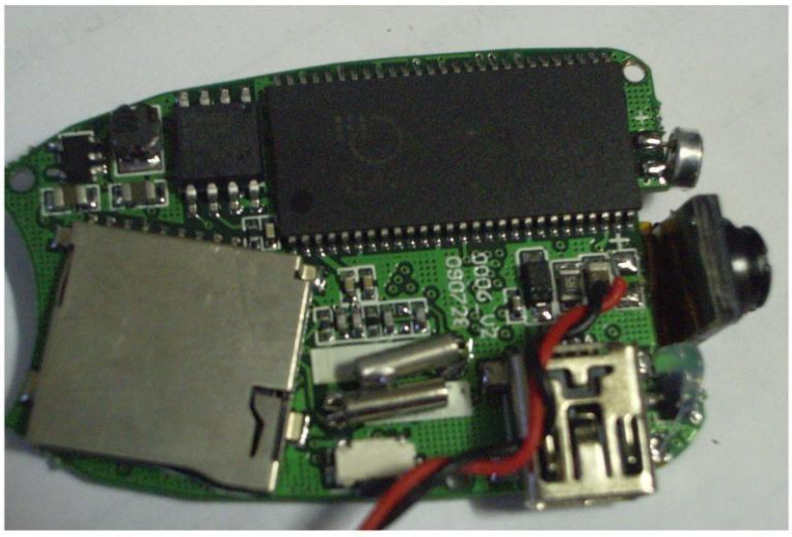


Figure 5-1: Onboard Camera

5.2. Motion detection:

While moving autonomously in an empty house the robot can detect unwanted human being. There is a PIR motion sensor inside of the system. PIR is also known as passive infrared sensors. This sensor is generally made using the pyro-electric sensor. Using this sensor we can detect the level of infrared radiation. Suppose you leave the home automation robot in autonomous mood inside the house. For security we can detect multiple human tracking system based on binary pyroelectric infrared (PIR) sensors. [19]. If any unwanted person comes inside the house then the robot can detect the person using motion sensor and can easily take a picture of that person. Later on it can save the picture inside the inboard memory card of the camera module [7]. "Motion detector sensor for positioning vehicle" invented by John Giangardella is mentionable. A tubular shroud defines the field of view of a passive infrared sensor placed above the desired stopping point for a vehicle in a garage. [17]

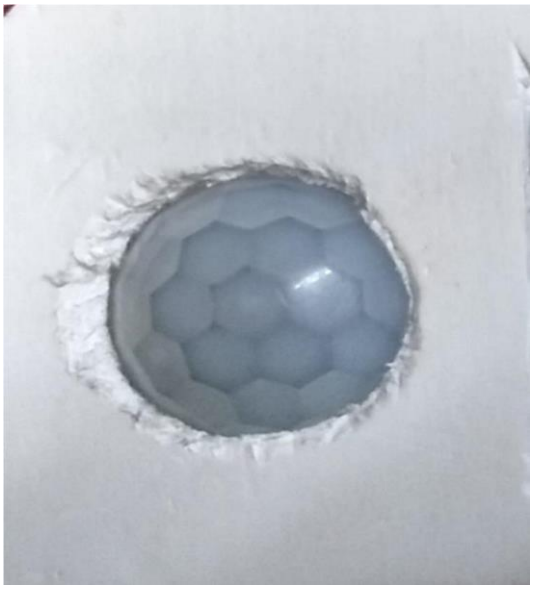


Figure 5-2: PIR Sensor

Chapter 6: Control through mobile Application

6.1. App development:

For controlling the robot manually we have developed a mobile application using App Inventor. The app is an android application and has various functionality. App inventor is an open source mobile app development platform which is owned by Google. Nowadays this platform is maintained by Massachusetts Institute of Technology (MIT). That is why everyone now know this platform as MIT app Inventor. In this platform app development is way easier and faster than any other platform like android studio or others. In this platform user can drag and drop virtual objects to develop the application [8].

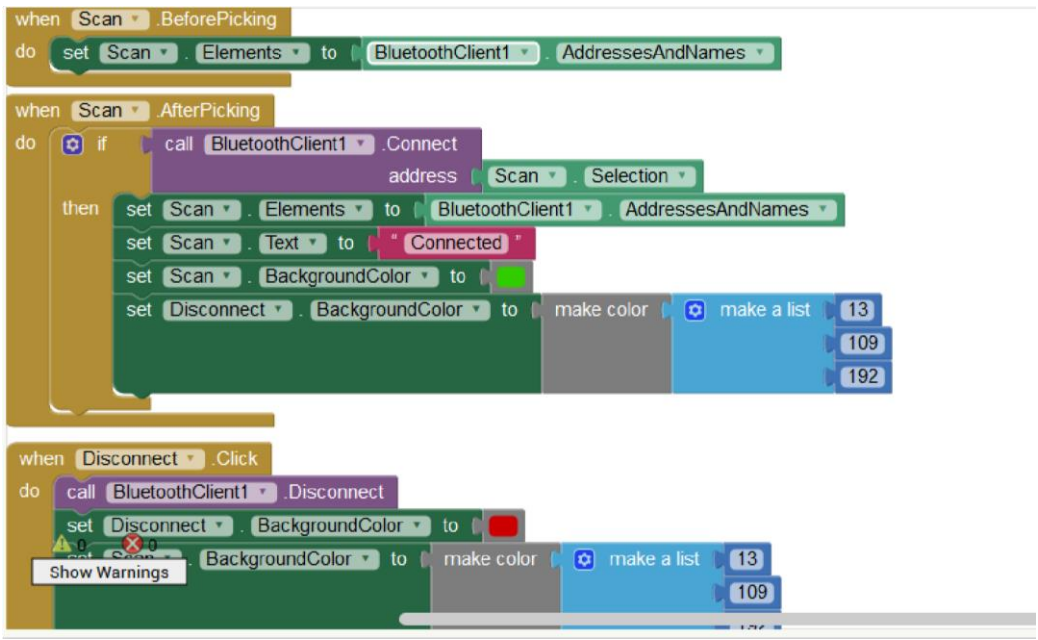


Figure 6-1: App development Phase

In our custom mobile application we have used many buttons for different type of tasks [Figure: 6.1b].There are four buttons are dedicated to move the robot forward, backward, left and right. If we press the coffee button on the apps then the system will start the coffee making procedure, if we press auto vacuum button the system will travel through the house using its sensor and do vacuum cleaning by itself. If we press security then it will turn on its camera and detect motion through PIR or Sharp sensor to click photos of unwanted persons and saves them in the memory card. This app will communicate with the robot through Bluetooth.

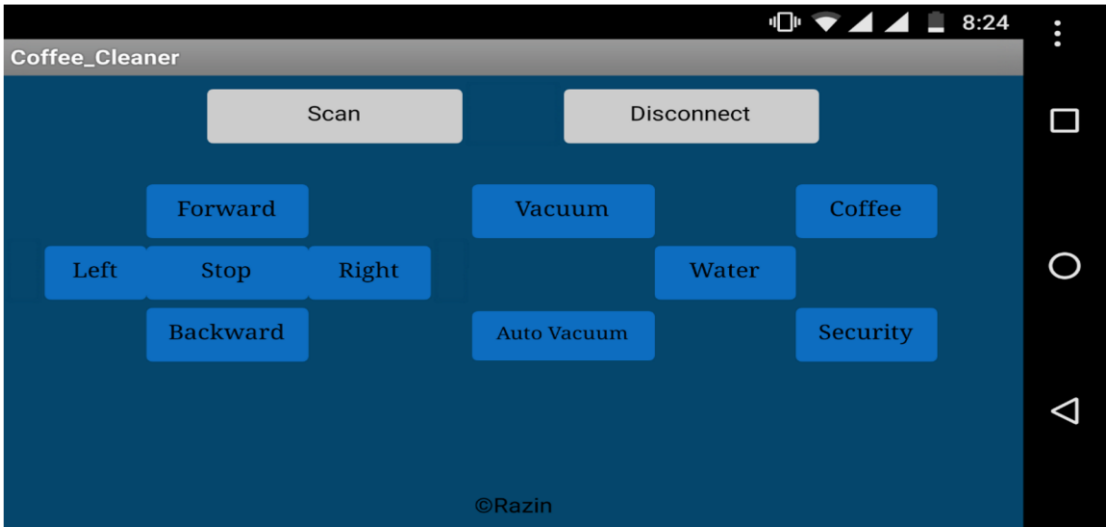


Figure 6-2: App GUI

6.2. Problem with Bluetooth module:

Bluetooth module has a low amount of signal coverage area. In a conventional Bluetooth system we have seen that there is a Bluetooth module connected with the circuit and it get paired with the mobile app. Following this procedure we have found a less amount of coverage area. For solving this problem we have used the master and slave formation of Bluetooth module in our system. In this formation there will be a master Bluetooth module connected with the app. Then the master will pair up with the slave module which is connected with the circuit. In this procedure app will send command to the master module then master will forward it to the slave module and then slave module will execute the command. This system is more secure and has a long range of signal coverage than the conventional system [9].

Chapter 7: Results and Implementation Challenges

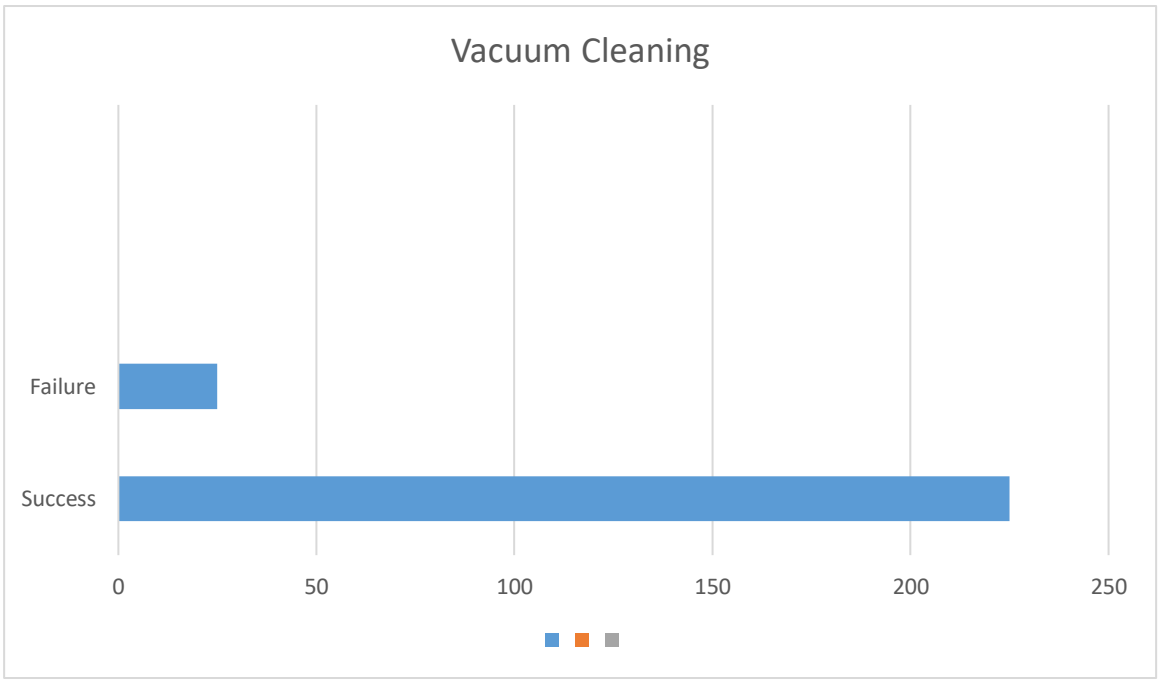
7.1: Result Analysis:

We have tested the vacuum cleaning mechanism in a dusty mattress and the cleaner collect almost 70% of the dust from the mattress as the mattress was full of dust. Then for testing the coffee making mechanism we have given command through manually and also through the app. Both of the command was executed properly by the system. To check the obstacle detection we have set a track inside the house full of obstacles and also at the end of the track we have placed a dummy human. The robot cannot fully avoid the obstacles, it avoids 80 percent obstacles perfectly. For fluctuation of the sensor values it may not avoid all the obstacles. But in the end it detects the dummy human being and took several pictures from different angle and saved it. However, to our best imagination there are a lot of improvements that can be done. We have got our primary objective fulfilled nonetheless.

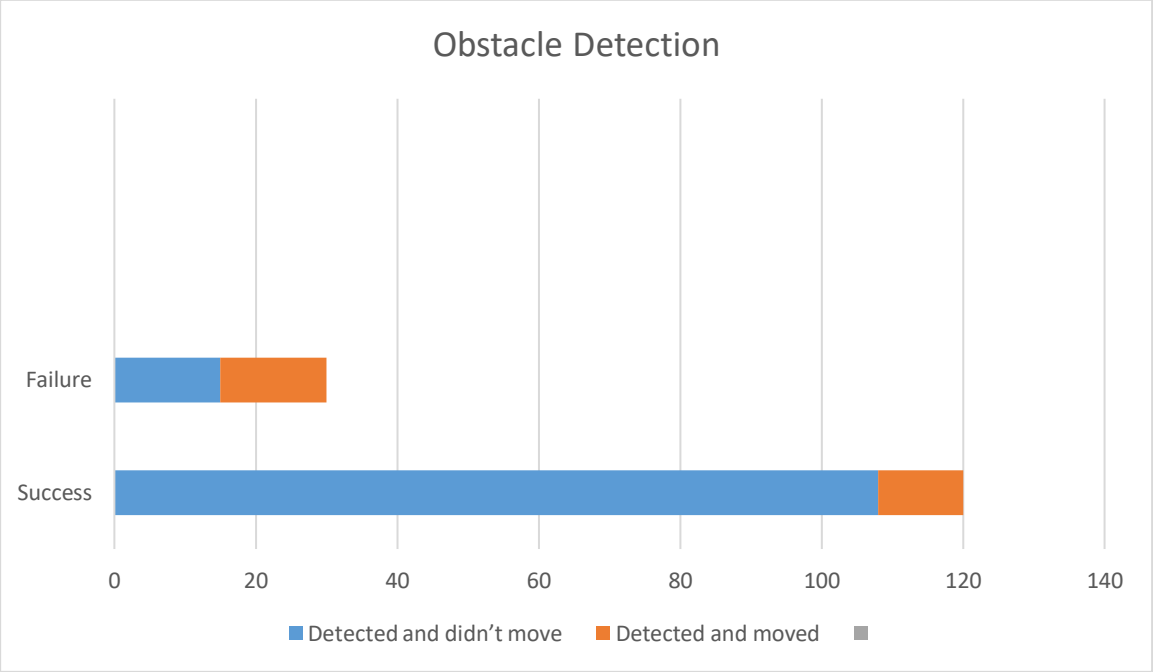
Vacuum cleaning: We spread around 50 gram of dust over an area of 100 square feet. Then we controlled the robot to clean the floor. We found that around 35gm of dust was removed. We did this experiment 5 times and found its cleaning efficiency around 80%, 65%, 68%%, 72% and 65% consecutively. So, on average it has a cleaning capacity of 70% which is pretty high for a prototype.

Experiment	Amount of dust on the floor (gram)	Amount of dust removed by the robot (gram)	Efficiency
1.	**50**	**40**	**80%**
2.	**100**	**65**	**65%**
3.	**150**	**102**	**68%**
4.	**200**	**144**	**72%**
5.	**250**	**162.5**	**65%**

Before performing the experiment, we set up a target efficiency value of 70% but during the first 5 experiments we had 2 success out of 5 trials (40% success). Then we made some modifications in its design and placement. We reduced the distance of the cleaner from the floor by lowering the chassis and found 90% success which was a breakthrough.



Surveillance: We set a maximum target distance of 30cm within 2 seconds for detection of sharp objects. We performed several trials to test our efforts. We achieved 80% success in 150 trials. Among the successful attempts, in 90% cases it detected obstacle within 2 seconds and did not move and among the failed attempts, it could detect the obstacle within 5 seconds and moved after the appearance of object in 50% cases.



Result Analysis Criterion	Number of attempts	Number of success	Number of failures	Results
Vacuum cleaning	250	225	25	90%
Obstacle avoiding	150	120	30	80%
Surveillance (Security Breach)	200	190	10	95%

Result Analysis Criterion	Number of attempts	Number of success	Number of failures	Results
Movement range (360 degree)	150	150	0	100%

Time duration:

Coffee making:

The time requirement for the whole process of coffee making is as follows:

1. Water Heating: If we consider heating 200g of water from room temperature to boiling point, we get the following result:

   $W=mS\Delta\theta$ _____ (i)

   $P=VI$ _____(ii)

   $P=W/t$ _____(iii)

   Hence, we get

$$t = \frac{mS\Delta\theta}{VI}$$

$$= \frac{0.2\times4200\times75}{12\times7.5} \text{ sec}$$

$$=11.67 \text{ sec}$$

2. Coffee mixing: The time duration depends on the user's discretion.

3. Pouring coffee: The amount of coffee poured on the glass also depends on the user and so is the time.

Vacuum cleaning: The cleaning duration is reasonably fast and its duration depends on the owner's discretion and the surface area of the floor.

Surveillance: The robot can continue its survey as long as the battery supports.

Efficiency: Here, we are going to calculate the efficiency of our robot by calculating the energy requirement in a single day for a family of 4 members living in a flat of 360square meter. Let us consider that every member of the family takes 2 cups of coffee daily. We have also considered that the robot moves an average distance of $8x9.5\sqrt{2}$ for the purpose of coffee making.

$P=VI$..... (i)

$W_1=VIt$..... (ii)

$F= ma$

$=) a = \frac{F}{M}$

$=) a = \frac{F_1 - F^1}{m}$ ..... (iii)

$p=VI$

$=) F_1v=VI$

$=F_1 = \frac{VI}{v}$

(iii) $=) a = \frac{\frac{VI}{v} - F'}{m}$

$=) a = \frac{VI}{m} - \frac{F^1v}{m}$..... (iv)

$V = 12V$

$I = 7.5A$

$S = 9.5$ m

$n = 34$

$F^1 = mw$

$= 0.42 \times 9.8 \times 8N$

$= 32.93N$

$F_1 = ?$

$v^2=a^2+2as$

=) v = $\sqrt{2as} = 13.5\sqrt{a}$ ..... (v)

(v) =) a x $13.5\sqrt{a} = \frac{12\times7.5}{8} - \frac{32.93\times3.5\sqrt{a}}{8}$

=) $13.5a^{3/2} = 11.25 - 5.57\sqrt{a}$

=) $a = 0.71\ m5^2$

$\therefore W_1 = maS$

= 8 x 0.71 x 9.5J

= 53.96J

$W_2 = ma's'$

$= m\frac{V^2}{2s'}s'$

$= 1/2\ mv^2$

= 45.5J

$v'^2 = u'^2 - 2a'5'$

=) $a' = \frac{u^2}{2s'}$

& v=u'

$\therefore w = w^1+w^2$

= (53.96 + 45.5) J

= 99.46J

<u>Energy for movement duoing vacuum cleaning</u> :

$W_t = n(w_1 + w_2)$ x $(w_1 + w_2)$ x 4

=) W_t = 3481.1J x 4

=) W_t = 13.926 KJ

<u>Energy doing movement of the motor</u> :

$W = P't = 5 \text{ x } \frac{Wt}{VI} = 5\times\frac{13924}{12\times7.5}J = 770J$

<u>Energy for movements</u>:

W = mas

= 8 x 0.71 x 8 x $\sqrt{2}$ x 9.5J

= 610.49J

<u>Coffee making:</u>

W = MS $\Delta\theta\times8$[Per day 2 times only for 4 people]

= 0.2 x4200x75x8J

= 504kJ t_3 = 5600 sec

Total = 513264.67 J + 770J

= 514034.67J

W^1=VIt

= 12 x 7.5 x 3600

= 324000J

$$n = \frac{W}{W'} = \frac{514034.67}{324000}$$

= 1.6

So it is possible perform a day's function with 2 charges which prove the robot to be highly efficient.

7.2. Limitations during Implementation and Solutions:

During the development phase we had to face some difficulties with some modules. The following problems came up and were solved accordingly:

1. When we implemented the DC water heater then the battery power was consumed very quickly by the system. It was a huge setback as the efficiency of this robot was called into question.

   Solution: Firstly we didn't find the solution. Then after our findings we measured the current consumption of the heater which is 2.5 Ah. So for solving this problem we have changed our low ampere battery's and include 7.5Ah lead acid battery's into the system.

2. Often we faced the problem where we could not detect the signal, or send the signal to desired motors.

   Solution: We solved those problems by trial and error method.

3. The range of signal transmission was very short which was exposed as a drawback. If this problem was not solved, then the robot would not be able to function around the entire house arena.

   Solution: We used master and slave method for Bluetooth signal transmission which greatly enhanced the range of our robot. It can hover around the entire house/flat.

4. In the beginning, the materials we used for building the robot was quite heavy reducing its efficiency.

   Solution: We replaced them with lightweight but durable materials. It reduced its power consumption and increased its efficiency.

5. The camera we used at first had to use manually. As a result, it could not be controlled using an android device.

   Solution: In order to solve this problem, we reverse engineered the camera and introduced a relay which helped us to connect it with Arduino. Then it was ready for being remotely controlled using an android device.

6. The multi-functionality of the robot required it to be quite large in size. Consequently, the robot could not be easily accommodated.

   Solution: We solved this problem by careful designing and utilization of the space inside the body of the robot.

Chapter 8: Conclusion and Future Development Scopes

Robotics is not a stagnant subject rather a vibrant and thriving aspect of science and technology. Development of a functional robot requires continuous efforts involving almost every dimension of engineering. As a manmade object, every robot has its own flaws which provide scope for improvement and calls for further research and development. In the field of home automation, the uses of robots are increased in a significant amount in the world. People want comfort in every work or situation. So for ensuring comfort in the daily household task we need more amount of new home automated robotic systems.

In our system we have developed the vacuum cleaning facility, automated coffee making feature, autonomous mode with surveillance feature. In the near future we want to develop the system. We want to add two working robotic arm in the system so that the robot can pick and place some objects from one place to another place. We also want to increase the level of autonomy inside the system. The system can be upgraded by integrating voice command, time specific automatic command execution, supplying first aid toolkit, adding ESP controlled central database system and many other normal functions that helps normal household chores. We can make the system fully autonomous if we can get financial and technical support. In developing country like ours if government and private investors both invest in this sector then this sector can open new opportunities for our country. Automation is a trend now days. If we want to do better in the race of technology then we have to follow this trend and work properly to achieve the goal.

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