An Intelligent Hexapod Rescue Robot

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Bachelor of Computer Science and Engineering
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Declaration

We hereby assure that all the work done for this thesis project is compiled with the results attained from our own work. All of the algorithms, tools and materials that helped us developing this project have been properly acknowledged and referenced. This thesis either in whole or in part, has not been previously submitted for any degree anywhere.

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Abstract

This report proposes a survivor robot model inspired by the physique of a spider which can be used in the cases of search and rescue operations. Multiple walking algorithms have been tested on the robot and have been narrowed down to the most efficient walking algorithm among them. The control of the robot has been done by an embedded android controller. The navigation of the spider-bot has been implemented based on a six-leg system, which will be very convenient in rough terrains. Functional algorithms have been implemented to move the robot under duress and onto challenging fields. Moreover, these algorithms aids to the various speed parameters of the robot based on the structure of the legs. Each of the legs has been designed using three servo motors controlling the limbs from different joints. We have developed a unique algorithm to detect life and send the distance and direction of the life from the robot to respond team. Additionally, a prototype has been developed for experimental purpose and finally it has been upgraded to its final version.

CHAPTER 1

Introduction

1.1 Introduction

Important developments have been occurred in the history of science and technology. Among them, the concept and applications of robots with each passing year are a larger place. Speed and economic advantages in daily life and industrial applications have increased the use of robots day by day. The robot is an electromechanical system which is capable of autonomous or preprogrammed tasks [1]. Robots independently can also operate under the control of a computer program such as can be directly operated by operator. Six-legged robots can be used as search and rescue robots, space robots and discover robots. In these fields, hexapod robots present opportunities as having small size and practical mobility. When viewed from this perspective, six-legged walking robot can be easily scroll by produced algorithms in all types of terrain is an advantage. The acceptable number of legs and the ability to move provide more controlled balance to the robot when compared to the majority of multi-legged robots [2]. While wheeled robots are faster on level ground than legged robots, hexapods are the fastest of the legged robots, as they have the optimum number of legs for walking speed - studies have shown that a larger number of legs do not increase walking speed [21].

Hexapods are also superior to wheeled robots because wheeled robots need a continuous, even and most often a pre-constructed path. Hexapod robots however can traverse uneven ground, step over obstacles and choose footholds to maximize stability and traction. Having maneuverable legs allows hexapods to turn around on the spot [22]. In comparison to other multi-legged robots, hexapods have a higher degree of stability as there are can be up to 5 legs in contact with the ground during walking. Also, the robots center of mass stays consistently within the tripod created by the leg movements, which also gives great stability.

Hexapods also show robustness, because leg faults or loss can be managed by changing the walking mechanism. This redundancy of legs also makes it possible to use one or more legs as hands to perform dexterous tasks. Because of all of these benefits, hexapod robots are becoming more and more common, and it will be interesting to see what modifications robot cists come up with to further improve and develop their form and function.

Unpredictable occurrences like natural disasters, terrorist attacks may cause damage to the building structures and many lives may be trapped inside who may need assistance from outside. It will take a long time to send human assistance. So sending robots to the affected area might be a good solution [1]. But in order to do that, wheeled based rescue robots will face difficulties moving in those irregular surface and obstacle-rich area [5]. So a flexible six-legged robot will be more effective on these challenging situations [2].

1.2 Motivation

The knowledge we gathered from our university is the tool that we tried to use for the welfare of our society. People suffer a tragic loss in any sort of disaster or terrorism act. We wanted to minimize these sufferings by providing them a tool to fight back their loss. Moreover, we tried to keep the production cost as minimum as possible so that our government can easily mass-produce this robot without effecting the economy of our country much.

Robotics has created an impact all over the world in the field of modern technology. As a developing country, Bangladesh shows a promise in this arena. We tried to implement the feature of robotics for the betterment of not only our country, but also the whole world.

1.3 Problem Statement

It is really challenging to build a hexapod robot. We had to go through a lot of trouble to build the robot. Firstly, making the body of the robot was challenging as it is really hard to get access to a 3D printer and also it is expensive. Secondly, we wanted to build a system which is cost efficient, however servo motors that are required to make this project are expensive. Moreover, controlling 18 servo motors is really a tough task.

Weight management of the robot was another challenging task for us. As the robot demands a flexible movement, it needed to be light-weighted. Finally, developing the walking algorithm cost us a lot of time and efforts as it was required for the robot to be fast and efficient in action.

1.4 Solutions

We used PVC board to build the body of the robot with is highly cost efficient and light-weight. As the robot is now more light-weighted, we required servo motors with less torque which minimizes the overall cost. We used a 16-channel servo controller to ensure uninterrupted power to all the servos. Finally, we cut of all the unnecessary parts from the body to make it flexible.

1.5 Methodology

In the literature review, previous works regarding hexapod robots are mentioned. We are using the similar properties of hexapods and use them as rescue robot which is never done before. Also, we are making it smaller and more cost efficient. We are integrating microphones to the robots and use them to calculate approximate direction and distance of any survivor from the robot in a disaster terrain. In order to do that, we have designed a unique algorithm. Our prototype robot ran effectively and efficiently as we anticipated. So we are also creating outline for future working scopes. Ours is a semi-autonomous robot and there is a scope for making it autonomous.

1.6 Contribution Summary

The proposed robot model that we have represented here in this thesis can contribute in saving lives in any unpleasant occurrences like building collapses in natural disaster or terrorism attacks. Generally, a wheeled robot is not capable of moving through rough and irregular surfaces. So it will not be able to save lives in above mentioned scenarios. However, our proposed model shows a great promise in this certain scenarios

Moreover, this robot can be used as a defense robot for a country which will be able to spy and detect terrorist acts. Thus any unpleasant occurrences can be minimized.

1.7 Thesis Outline

- ❖ Chapter 2 elaborates the background study behind the motivation of this project.
- ❖ Chapter 3 covers the model of the hexapod rescue robot, walking algorithm, dimensions of the archetype.
- ❖ Chapter 4 shows the experimental results.
- ❖ Chapter 5 brings an end to this paper mentioning its challenges and limitations along with the future scope for this system.

CHAPTER 2

Literature Review and Research

2.1 Literature Review

In order to build such a robot that can walk smoothly and effortlessly through a rough terrain many works have been done. The most significant work of them is the MorpHex Hexapod Robot in 2011 [13]. It has a very flexible movement of the limbs. The whole robot was designed using a 3D printer. Another remarkable work was done in 2016 named Matrix and is a unique Hexapod Robot that is based on Arduino and SSC32. It is controlled using an FRSKY Taranis / X8R Receiver [14]. Similar work was done which is known as Walknet where they observed the movement behavior of the animals and formulated a structure for six-legged movement [16]. In order to observe and monitor crisis situations of an impacted area a work has been done in 2011 where they used satellite to identify condition of the affected area [17].

Lost lives in disasters and terrorism due to the lack of reinforcements is a matter of concern and is one of the motivation of this paper [7].However, the lifesaving robot of Korea had the most motivational impact on this proposed robot [8].

RHex developed by is a different robot compared to other hexapod robot because it is actuated by brushed DC motor [27]. The motors that are used at this robot are Maxon type motor with a 33:1 gearhead powered by a 24V NiMH battery. The design of the leg is one degree of freedom and half-circle. According to the author, the method is easy to build and maintain the robot and no sliding friction during spring displacement. This design is most suitable for stair climbing.

Another hexapod robot, Bill-Ant-P robot done by is made of aluminum and carbon fiber sheets [28]. It uses MPI MX-450HP hobby motors for its reliability, high torque and affordability movement. The motor have 8.37kg-cm of torque, can rotate about a 60 degree in 0.18sec, and has a small internal dc motor consumes 1125mW of power at stall torque.

Another robot called as Gregor has been developed. The Gregor robot development model has Autodesk Inverter 9.0 to define properties of parts such as mass. Rhinocerus 2.0 software is used to coordinate of the constraints and model the robot that can be easily exported into the dynamic simulation environment which is also used the same software [29].

MSR-H01 hexapod developed by Micromagic System is built from 26 precision laser-cut 5053 aluminum body and leg components. It is controlled by using a p.Brain-HexEngine and used eighteen servomotors from three different types of servomotors. The link for the robot is Bluetooth. Hexapod robot developed by used Devantech SD-21 board to control 18 servos by interfaced with the preferred microcontroller, which is Arduino Decimilla board. The software that is used to control the servo controller is Matlab. In other to control the robot leg, Jacobian inverse matrix method is used to define the angles and leg position [23].

The walking robot Ragno is 33 cm long and 30 cm wide and 2.15 kg weights [24]. It has four layers control architecture where the first is at off-board to compute the appropriate control signal for all leg's joint and send control commands to robots. The second layer is on-board control layer that interprets commands from first layer and sends to leg controllers. There are six leg controllers that work simultaneously and control the inputs send to them. The robot has a double axis accelerometer and a gyroscope to measure the trunk orientation in a 3D space. The on-board and off-board parts of the control system communicate by means of a Bluetooth connection.

Dash robot can move at 11 body-lengths per second or 1.5 meters per second [30]. The weights of entire system is 16.2 grams (10x5 cm body dimension) with include weight of battery, electronics, microcontroller, motor driver, and Bluetooth communication module. The alternating tripod gait is used with 10 cm wide and 5 cm tall of legs. When it moves, the center of mass follows a roughly sinusoidal trajectory, which is stable sinusoidal motion. Two statically stable gaits is programmed for Ragno robot that are exploits a simple crawl and a tripod-like gait [24]. The crawl is used for lower speed by transfer one leg per time while tripod gait is the fastest stable gait with three legs placed on the ground at a time.

Method of movement for Gregor 1 hexapod robot is the locomotion control inspired from the biological paradigm of the Central Pattern Generators (CPG). CPGs are neural networks that produce rhythmic patterned outputs without sensory feedback. There are three types of robots motion. Those are walking mode, lifting mode and shifting mode which can be selected by the user. However, only the walking mode is selected in this subchapter to be explained further. The author used tripod gait is used because it is stable compared to other gaits for hexapod robot. The first step in gait control, the initial posture of all legs is decided, and the position of the leg tip is defined as the "reference position". Then, six cylinders of the legs movement are generated so as to be included in the work space with the center of the robotics base is set as the reference position. Thus, the center of rotation of the motion is obtained. Then, the diameter of each cylinder is reduced so that it may be proportional to the distance between the centre of robot (COR) and each reference position. The desired path of each leg is generated along the circumference of the cross section of the cylinder which is perpendicular to the line from the COR to the reference position and passes through the reference position. Finally, the angles of all joints are generated at every control period so that each leg tip might track the desired path and the center of body might have the provided velocity, and transmitted to the robot. The hexapod robot in the research, the hexapod robot also use tripod gaits, the body of the robot and ground in parallel mechanism and supported by three legs. This journal is focused on the kinetics movement of robot and the locomotion system. It is about the

Calculation on how the hexapod robot moves. The important aspects taken into consideration are the inertial frame, locomotive referenced coordinate system of chassis and coordinate system on the coxa.

In the disaster recovery, the robot used two types of gait which help it move at all kind of terrain. On even terrain, tripod gait is used while on uneven terrain, wave gait is used. The most rear leg is start moved forward in succession to all the legs. This gait is highly stable since a leg is lifted at a time. The reason for choosing the gait is the greatest stability edge for uneven terrain navigation. Wave gait locomotion adopting the control algorithm with an angular position input and torque command output. Each foot is moved at same length as analysis from the main body at each integration time interval [23].

CHAPTER 3

Proposed Model

3.1 Proposed working principle

The hexapod robot acts as a rescue robot in a targeted arena. We will place the robot at a place where human are not able to go further. We will have the full control of the robot. We will control the robots movements and send it inside the disaster area. We will get a live camera feed from the robot over WIFI. As we control the movements of the robot, the robot itself will also adapt its movements by detecting obstacles in front of it by an ultrasonic sensor.

The proposed model of the Hexapod robot should have an industrial grade lightweight material to build the body. For the model one-piece that constituting the main body is lightweight composite materials. It is comfortable and cost material in terms of process ability Fig. 1 shows the block diagram of the robot.

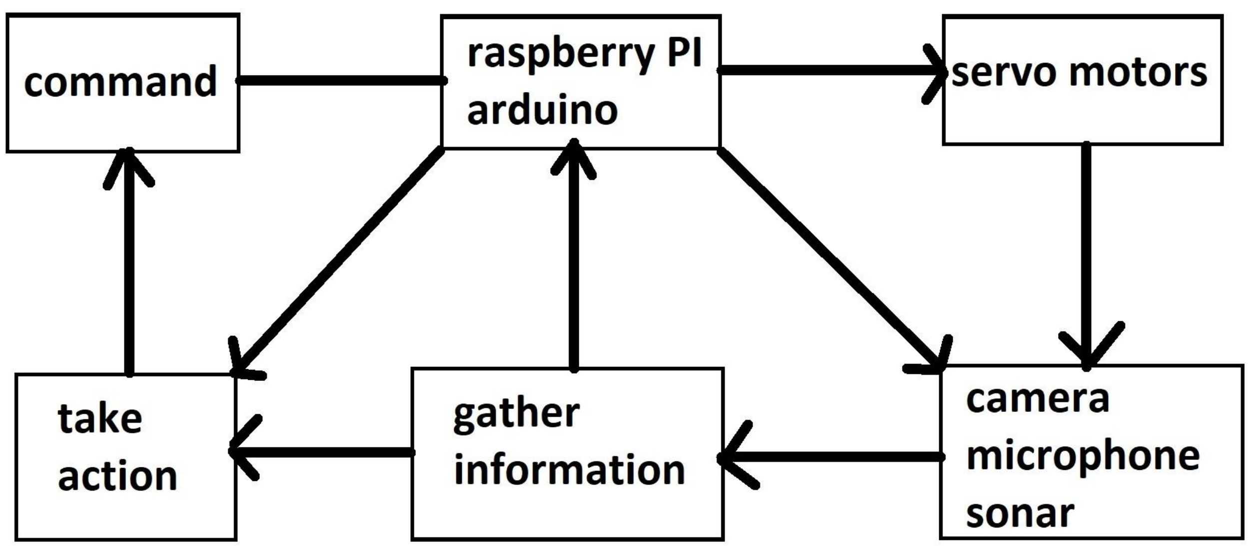


Fig. 1. Block Diagram of the Robot

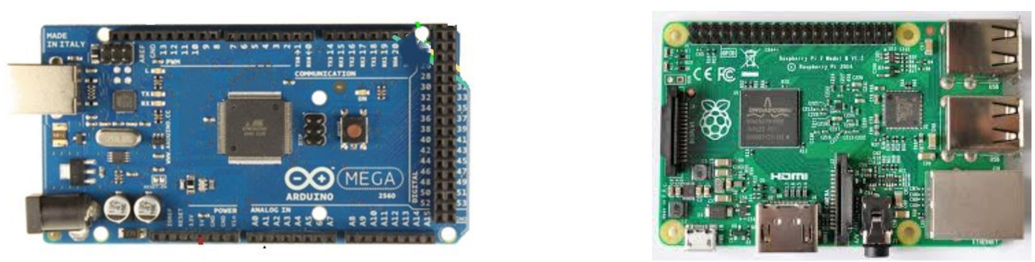
3.2 Components

Building the model hexapod robot includes Arduino-MEGA as the processing unit and manipulation of inputs and outputs. One HC-06 Bluetooth Module is used to create an interface between Android device and the Arduino.

Moreover, one Ultrasonic Sensor is used to detect any obstacles in the surroundings. Then eighteen SG90 Micro Servo Motors have been used which work as the movement joint of the robot.

3.2.1 Arduino Mega

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. 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. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC to-DC adapter or battery to get started. Fig. 2 shows the Arduino Mega and Raspberry PI.



(a) (b)

Fig. 2. (a) Arduino Mega, (b) Raspberry PI

3.2.2 Raspberry PI

The Raspberry Pi is open hardware, with the exception of the primary chip on the Raspberry Pi, the Broadcomm SoC (System on a Chip), which runs many of the main components of the board–CPU, graphics, memory, the USB controller, etc. There are a two Raspberry Pi models, the A and the B, named after the aforementioned BBC Micro, which was also released in a Model A and a Model B. The A comes with 256MB of RAM and one USB port. It is cheaper and uses less power than the B. The current model B comes with a second USB port, an ethernet port for connection to a network, and 512MB of RAM.

A temperature sensor is added to measure the temperature of the targeted area. A camera has been integrated in the robot which will provide live feed of the environment. Lastly, a PVC board is used to make the entire body of the robot.

The following Fig. 3 shows the flowchart of the Detective Mode.

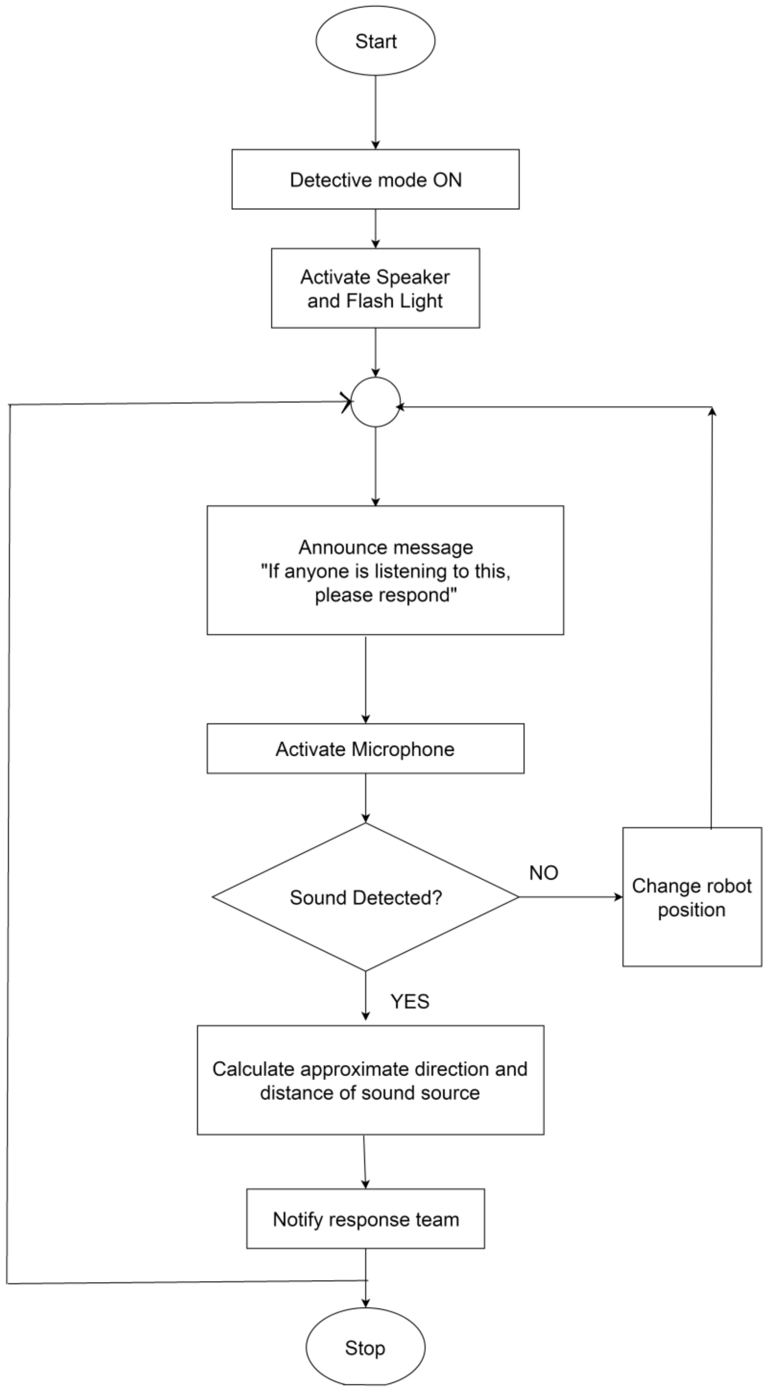


Fig. 3. Flowchart of Detective Mode

Fig. 4 shows the Micro-servo-sg90 and Microphone Module.

(a) (b)

Fig. 4. (a) Micro-servo-sg90, (**b**) Microphone Module

The robot will have 2 Modes; General Mode & Detective Mode. We are including 3 Microphone Module to the robot. General mode is for simple movements of the robot. All the sensors are turned off in this state. Only the Bluetooth module and the servos remain turned on.

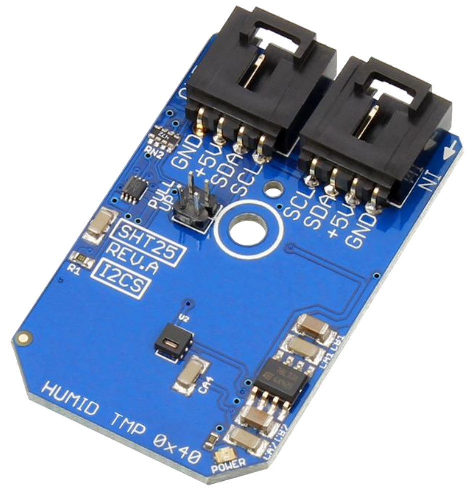
When the robot enters in detective mode, it activates the Speaker and flash light included in the robot. A message is announced through the speaker which is “If anyone is listening to this, please respond.” Then it activates the microphones and wait for response. If it detects any sound, it calculates the approximate direction and distance of the sound source and notifies the response team by an SMS. Otherwise it changes its position and go through the same process multiple times.

The robot will be developed using an Arduino Mega and a Raspberry PI 2. It will be build using 18 servo motors, 6 legs having 3 servos for each one. The movements will be controlled by the Arduino Mega which will control the servos using a 16-channel servo controller. We will control rest of the 2 servo motors with separate battery unit. Moreover, 3 Microphone Modules and a Camera Module will be connected to the Raspberry PI. This Raspberry PI will process all the input data.

The unique feature of our robot is it has an adaptive movement algorithm. Although we are controlling the robot manually and remotely, the robot can detect any obstacle in front of it and it can avoid them while moving forward. Moreover, although the robot is a manual robot, if it loses connectivity with the device that is used to control the robot, it initiate the Autonomous Mode which includes detecting sound and sign of life and send the information to rescue team.

Fig. 5 shows the Ultrasonic Sensor and humidity and temperature Module

(a)



(b)

Fig. 5. (a) Ultrasonic Sensor, (**b**) humidity and temperature Module

3.3 Current Working Principal

3.3.1 Flow Chart of the model

Once the power switch is turned on, the robot will be ready for its task. Firstly, an android device is needed to be paired with the robot. Once the pairing is done, the robot will be ready for controlling through the specially designed robot-controlling app [9].Then the robot will wait for instructions from the app. All the 6 legs of the robot can be controlled separately. Moreover, the robot can be navigated to forward, backward, left and right directions. The speed of this movements can also be controlled. There is a dedicated command which triggers the robot into detective mode. In this mode, the robot takes input from the temperature sensor. The readings will be sent to Arduino for processing. The camera will capture images or video and provide live feed to the android app. Using the camera feed, user will be able to locate if there is anyone stuck inside the destroyed building structure [8]. Moreover, there is a Semi-autonomous mode that will turn on the sonar sensor. If the sonar detects any obstacle in its way, the robot will automatically avoid the obstacle by moving beside it. Fig. 6 shows the flowchart of the entire system.

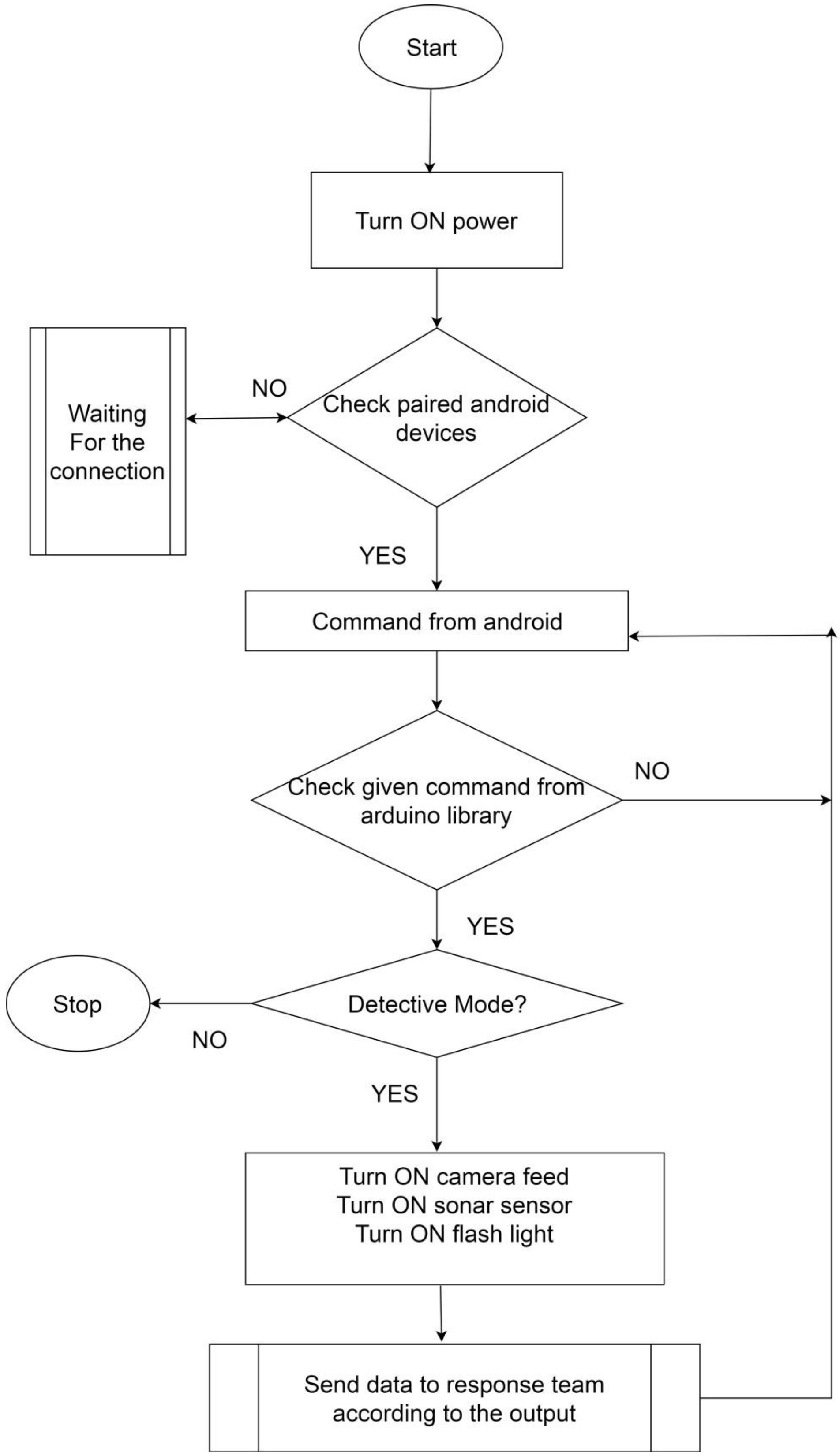


Fig.6. Flowchart of the robot system

3.3.2 Unique Walking Algorithm

```
readMovement()
    If move == forward,
          moveForward();
    Else If move == backward,
          moveBackward();
    Else If move == left,
          moveLeft();
    Else If move == right,
          moveRight();
End

For moveForward()
        Move three alternate legs 30 degree clockwise
        Move other three alternate legs 30 degree anti-clockwise
For moveBackward()
        Move three alternate legs 30 degree clockwise
        Move other three alternate legs 30 degree anti-clockwise
For moveLeft()
        Move all legs 30 degree anti-clockwise
For moveRight()
        Move all legs 30 degree clockwise
End
```

3.3.3 Hexapod Robot Gait

This walking mechanism of the hexapod follows a six legged insect. This mechanism involves the robot having three legs standing on the ground supporting the body while the other three swing forward. In the below figure shown, the dotted line are for stance phase and the straight line indicated as legs are for forward swing phase.

If the legs of the hexapod are labeled in an anticlockwise manner legs 1, 3 and 5 in Fig. 7.

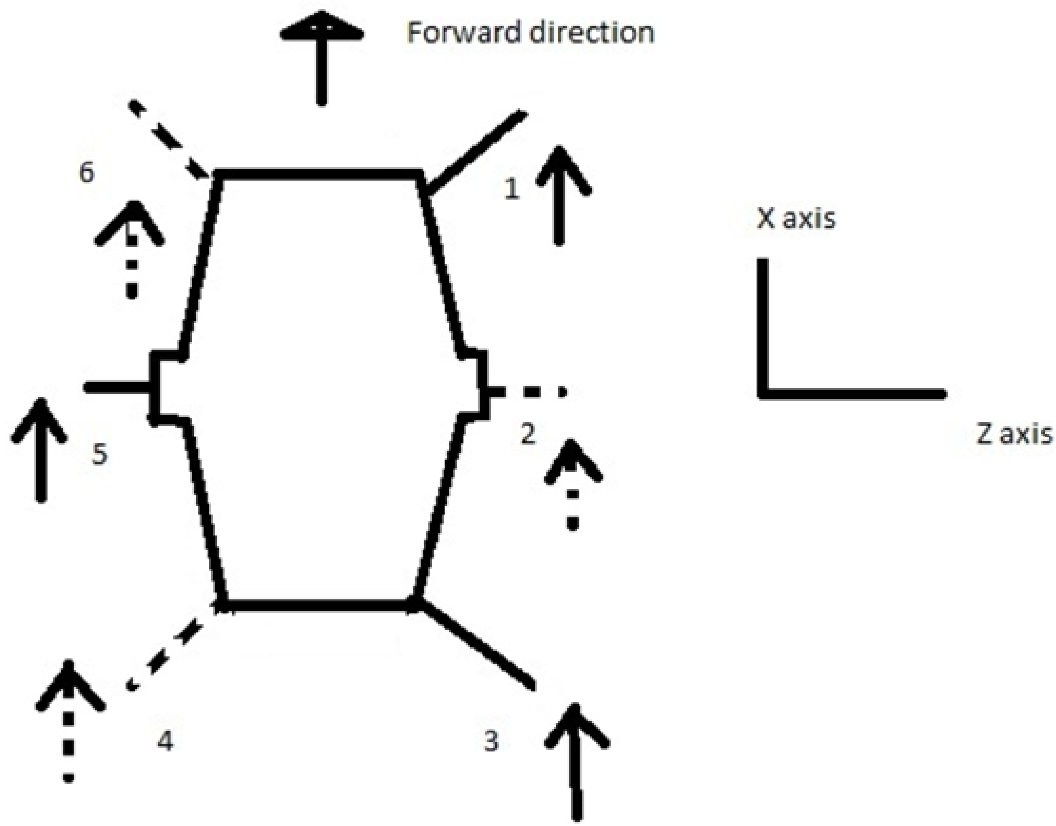


Fig.7. Top view of the robot showing the movement direction

Start in swing forward, and support and body and push it forward as legs 2, 4 and 6 s in stance phase. Then, legs 2, 4 and 6 are in 'swing forward phase' while legs 1, 3 and 5 in stance phase. This gait therefore includes 2 steps, with the robot moving twice.

3.3.4 Terrain adaptation

The regular tripod gait algorithm only works if the surface is flat. If the surface is an uneven terrain, which has different height, there is a possibility that the end of leg would not touch the ground although it had reached position 4 according to the program. That condition could make the robot unstable and also harm the servo because the weight's distribution among its legs is not equal. A new algorithm is introduced to deal with this condition. Fig. 8 shows the Scheme of proposed gait.

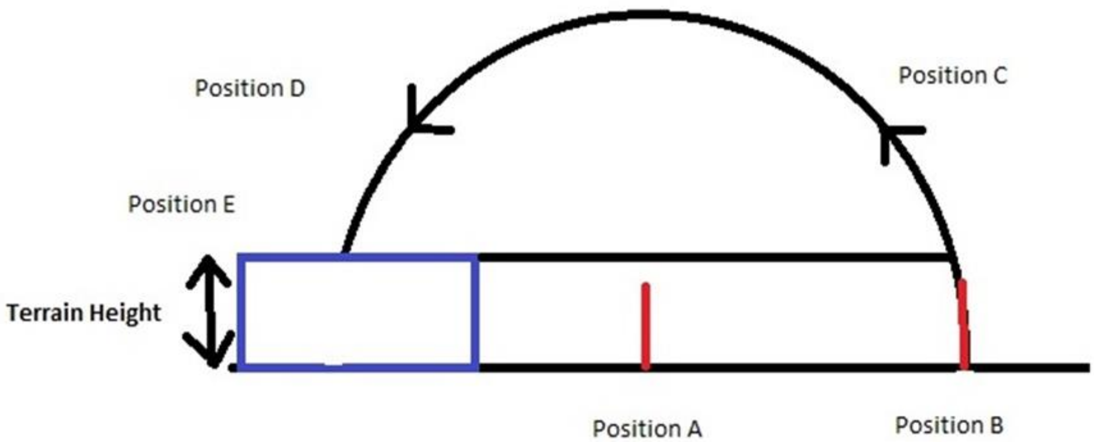


Fig. 8. Scheme of proposed gait.

Fig 8 shows this gait scheme. There are four points the end-effector should achieve [1]. The leg trajectory proposed still using the Bezier curve [1]. In this algorithm, when the hexapod is switched on and ready to walk around, the microcontroller initiates on the legs to position ‘A’. Then, the first step is taken moving the odd numbered legs. leg in a swing phase or while moving from point 3 to point 4 the tactile sensor’s reading is about to begin. When the leg contacts to the ground or another obstacle, the movement of robot’s leg is stopped. After that the leg’s trajectory will maintain its height value while reaching the position B. The leg will maintain its height position when move to position 0 and position 1 based, this make the robot’s body still flat with Z axis. Then after completion of the first step or moving the odd numbered legs, it starts moving the even numbered legs from position ‘A’. Then for uneven terrain, legs have to lift up from position C to position D and continue the before mentioned algorithm.

Fig. 9 shows the flowchart of terrain adaptation gait algorithm.

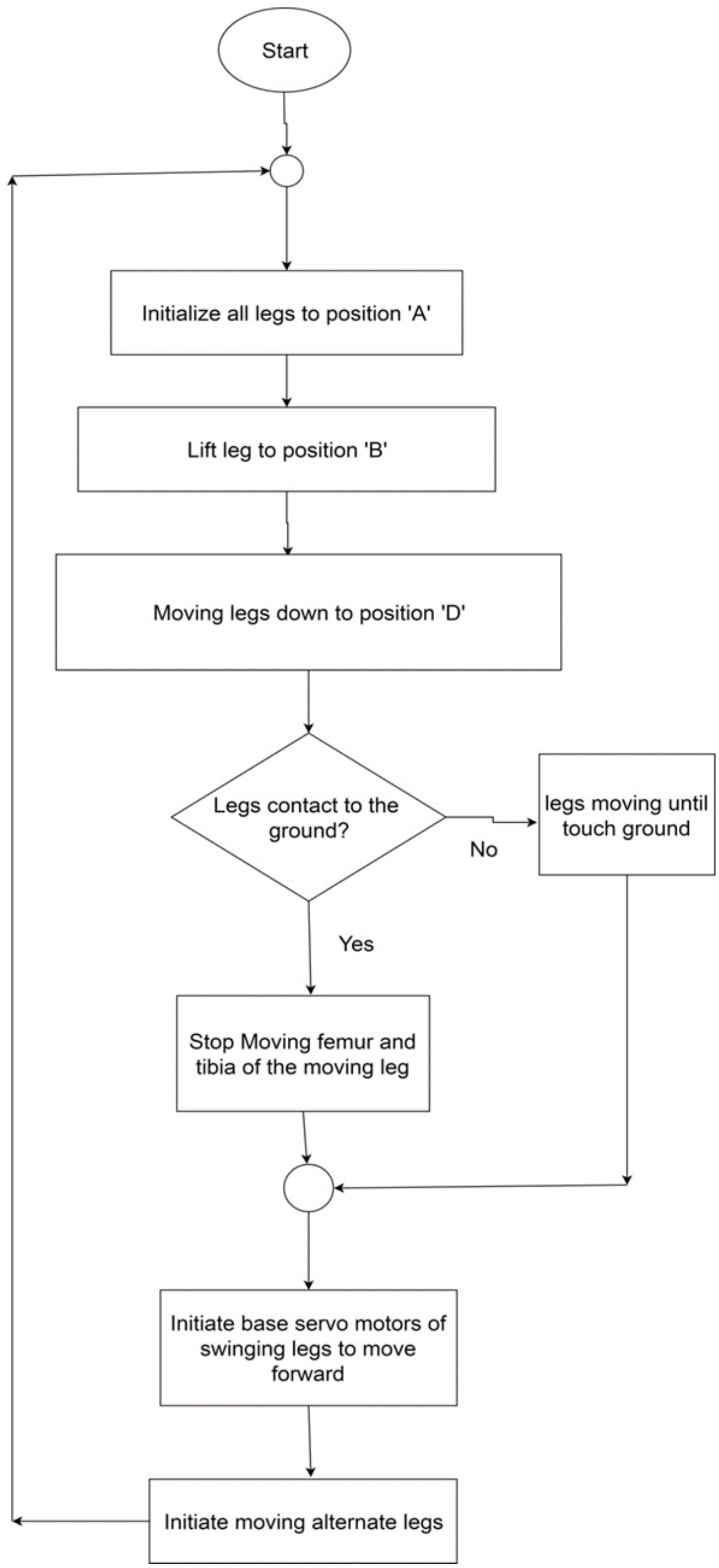


Fig. 9. The flowchart of terrain adaptation gait algorithm.

3.3.5 Life Detection Algorithm

We have developed an algorithm to detect the sign of life using the microphone where we detect and process sound to predict the approximate direction and distance of sound source, in this case, life.

Firstly, the robot will use the speaker to announce the message “If anyone is listening to this, please respond.” Shortly after the announcement, the three microphones will be turned on and they will detect sound for 30 seconds. Then it will compare the Analog Input readings of the microphones and calculate the approximate direction and distance of the sound source using the following algorithm that we developed. Fig. 10 shows the microphone orientation in the hexapod.

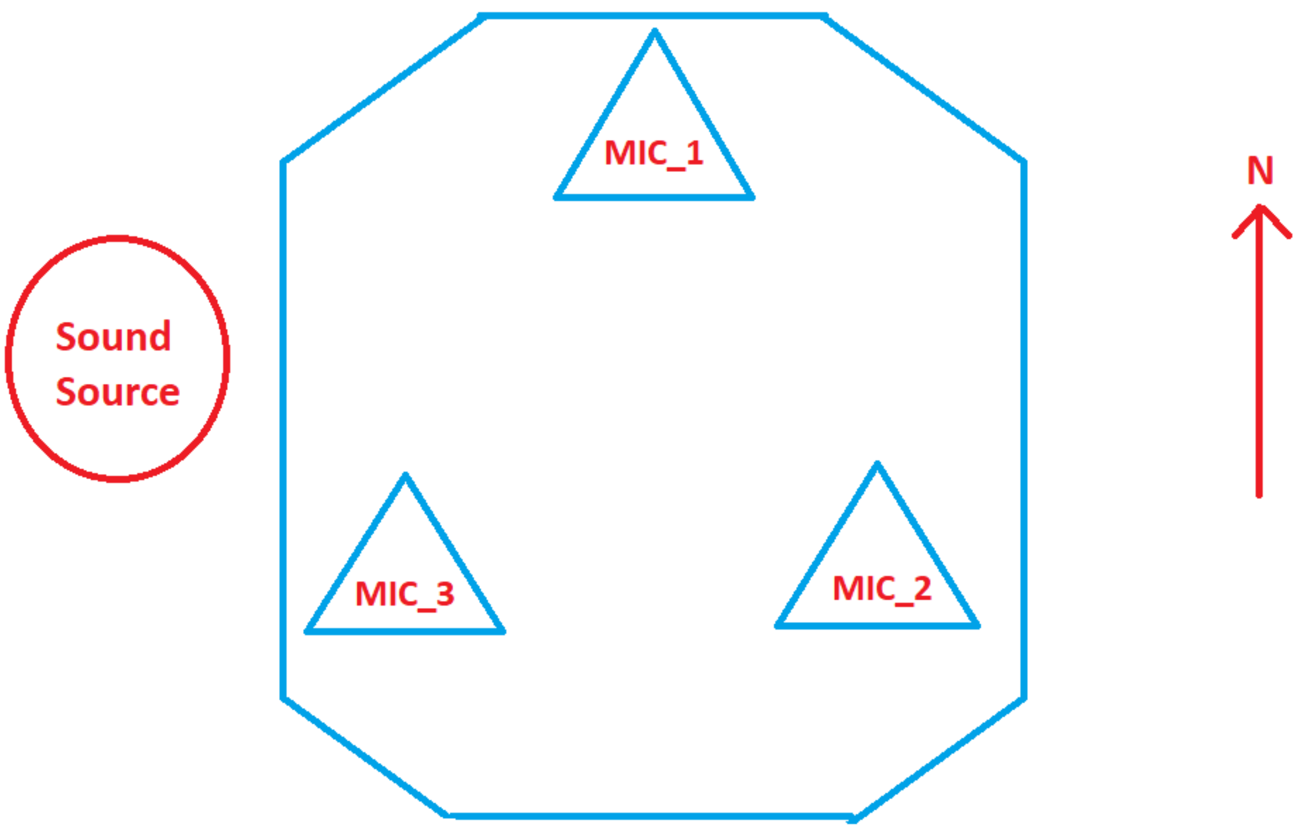


Fig. 10. The microphone orientation in the hexapod.

3.3.5.1 Direction Algorithm

```
signalValue_1 = analogRead(MIC_1)*50;
signalValue_2 = analogRead(MIC_2)*50;
signalValue_3 = analogRead(MIC_3)*50;

if signalValue_1 > 0
      MIC_1 detected sound

if signalValue_2 > 0
      MIC_2 detected sound

if signalValue_3 > 0
      MIC_3 detected sound

direction = maxValue(signalValue_1, signalValue_2, signalValue_3);

if direction == (signalValue_1 && signalValue_3)
      sound source is in North-West

else if direction == (signalValue_1 && signalValue_2)
      sound source is in North-East

else if direction == (signalValue_2 && signalValue_3)
      sound source is in South

else if direction == signalValue_1
      sound source is in North

else if direction == signalValue_2
      sound source is in East

else if direction == signalValue_3
      sound source is in West
```

Using this algorithm, the robot will be able to predict the direction of a life or the sound source.

3.3.5.2 Distance Algorithm

```
signalValue_1 = analogRead(MIC_1)*50;
signalValue_2 = analogRead(MIC_2)*50;
signalValue_3 = analogRead(MIC_3)*50;

pointer = maxValue(signalValue_1, signalValue_2, signalValue_3);

if pointer > 1200
      sound source is within 3 meters

else if pointer > 900
      sound source is within 2 meters

else if pointer > 600
      sound source is within 1 meters

else if pointer > 300
      sound source is within 0.5 meters
```

Using this algorithm, the robot will be able to predict the distance of a life or the sound source.

3.4 Building prototype model

Initially, we created a prototype of our proposed system. It was a simple hexapod robot with only 18 servo motors and no other sensors. We build this prototype to test our hypothesis.

3.4.1 Circuit details of the prototype model

Firstly, all the electrical instruments were connected in a simulated circuit model for testing purpose. Overall voltage and current requirements were calculated and the feasibility of the circuits were tested. Fig. 11 shows the circuit diagram of the robot.

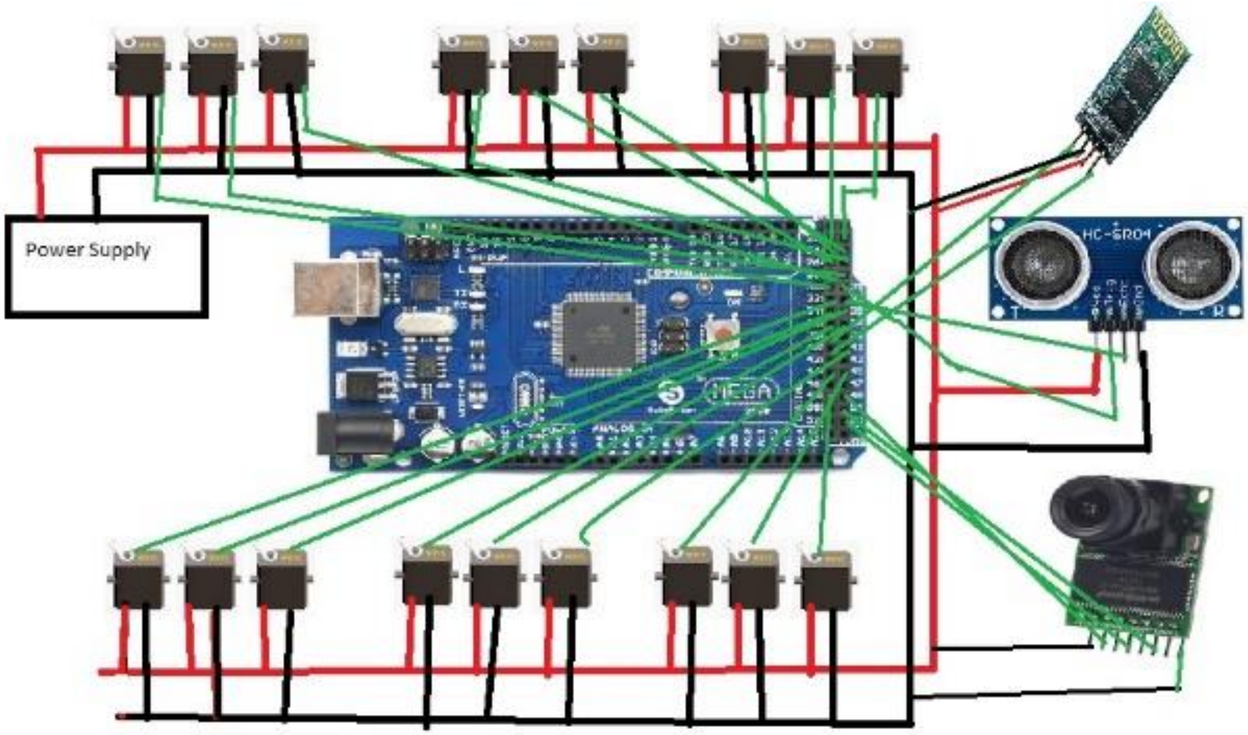


Fig. 11. Circuit Diagram of the prototype

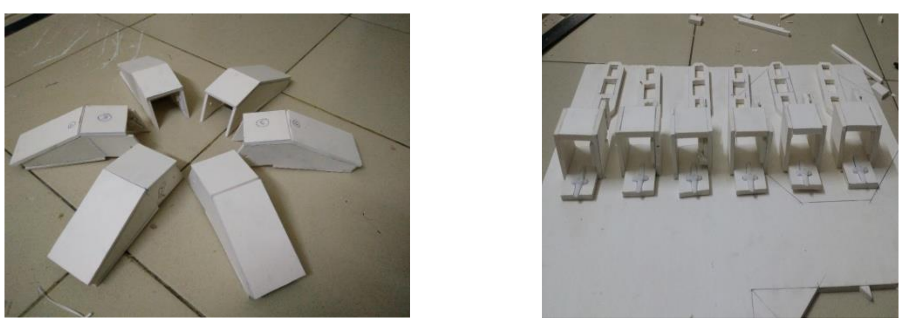
3.4.2 Hardware implementation

Following the circuit diagram, all the electronic components were connected using Male-Male and Male-Female Jumper wires. A 10000MAH power bank was used to supply 5V to the Arduino and to power up the servos. Two switch controls the whole system one for turning on-off the whole system and another for the Arduino only. Is this hardware implementation, we did not use any servo controller. So there were certain power issues that were causing the servo motors malfunctioning. Here, Fig. 12 shows the prototype model of the hexapod robot.

Fig.12. Model of the robot

3.4.3 Dimension of Coxa Femur and Tibia

Each of the six legs has been built using 3 segments; Coxa, Tibia and Femur. The Tibia has a dimension of 14cm X 5cm X 5cm, the Femur has a dimension of 8.5cm X 5.5cm X 5.5cm and the Coxa has a dimension of 9cm X 3cm X 3cm [10]. Fig. 13(a) shows the Tibia of the hexapod robot and Fig. 13(b) represents the femur of the hexapod of the robot.



(a) (b)

Fig. 13. (a) Tibia of the hexapod robot, (**b**) Femur of the hexapod robot

For the coxa we have used two servos each. Fig. 14 shows the Coxa of the hexapod robot.

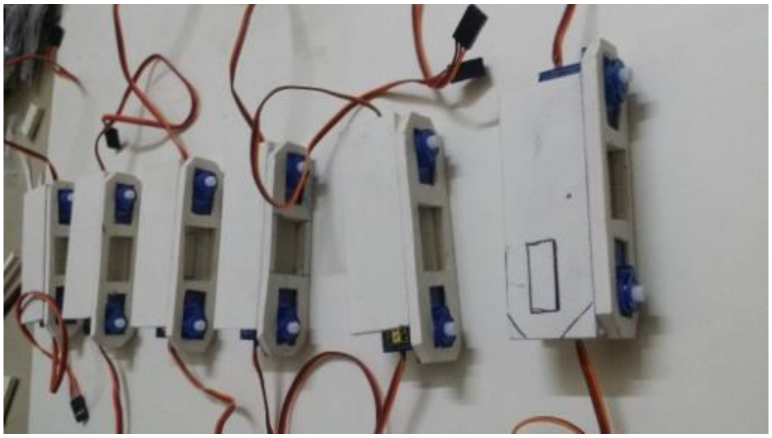


Fig. 14. Coxa of the hexapod robot

3.5 Building final model

The prototype that we built had certain limitations. It was carrying too much weight and its movements were not that much precise. So we needed to upgrade our robot and make it more light-weight and smaller. Thus we developed the second version of the robot. This robot has more sensors attached to it. Fig. 15 shows the Coxa of the hexapod robot.

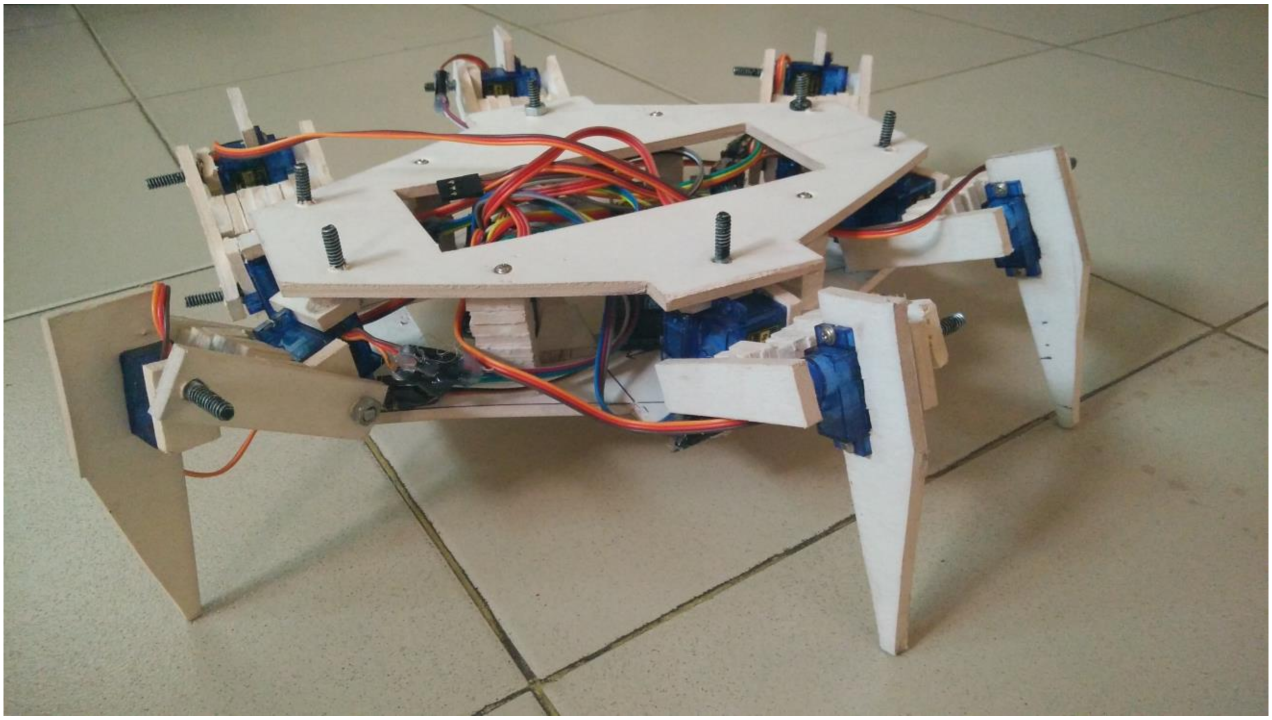


Fig. 15. Final version of the hexapod robot

3.5.1 Servo Control Unit

Previously we were using a powerbank to power up 18 servos, but some of the servos were facing jitter problem due to lack of power. To overcome this, we used a 16 channel servo controller to ensure 5V to the servos. Fig. 16 shows the circuit diagram of the servo control unit.

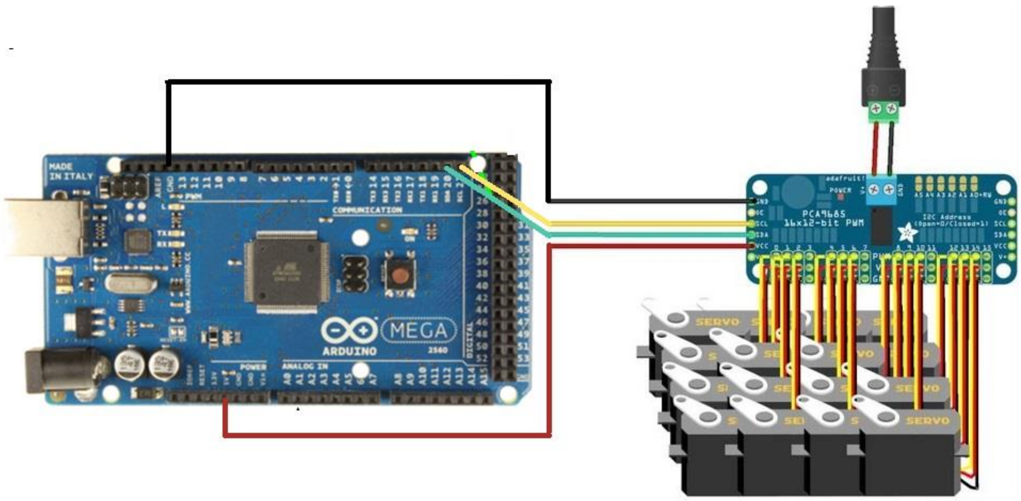


Fig. 16. Circuit diagram of the servo control unit

3.5.2 Circuit diagram for version 2

Fig. 17 shows the Circuit diagram of the robot version 2.

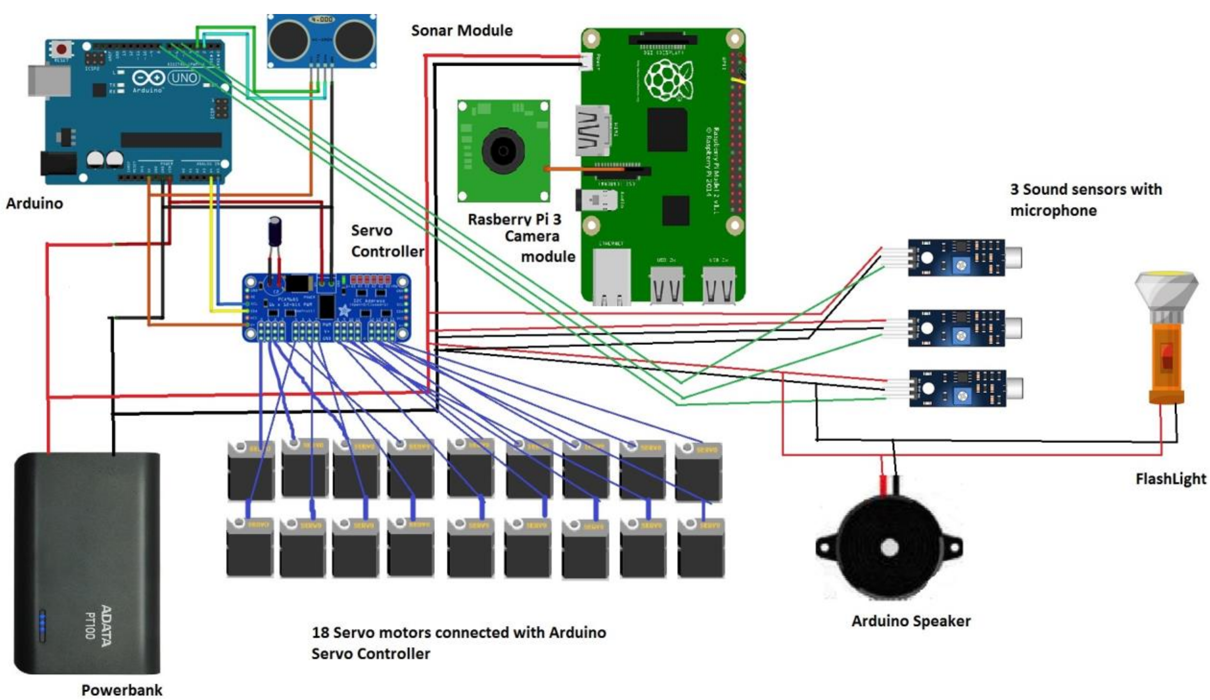


Fig. 17. Circuit diagram of the robot version 2

3.5.3 Circuit diagram for Microphone Unit

3 microphone module has been connected to the arduino Mega using Analog Pins and Digital Pins for Analog input and Digital input respectively. These module's Vcc pins are connected to the Vcc pin of the arduino and the ground pins are shorted with the arduino ground. Fig. 18 shows the Circuit diagram of the Microphone Unit.

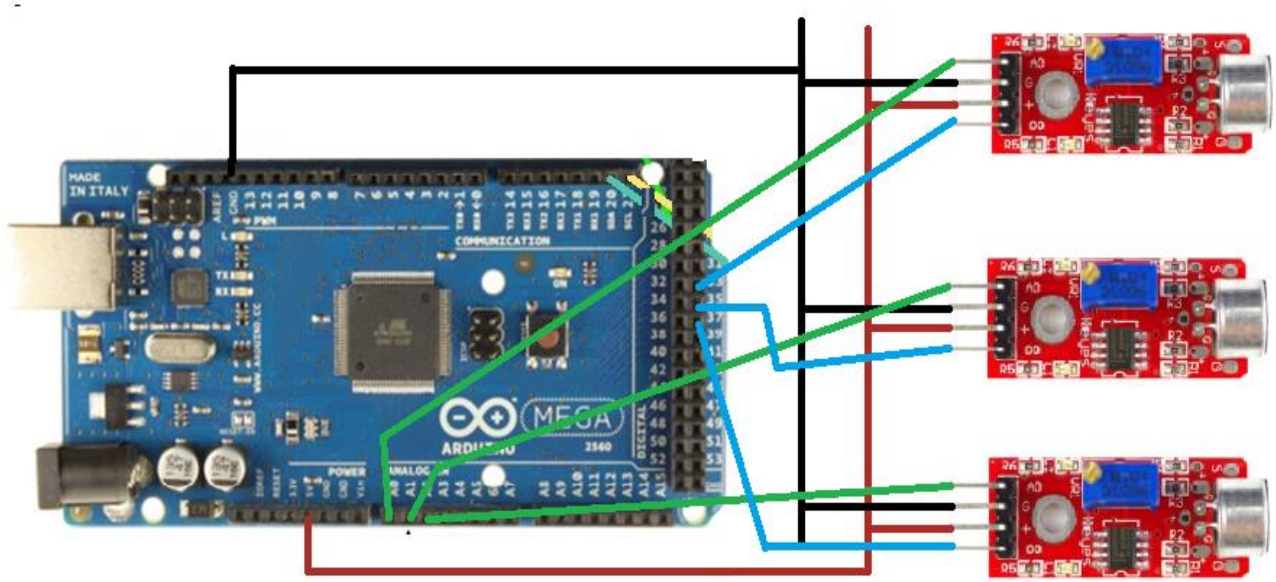


Fig. 18. Circuit diagram of the for Microphone Unit

3.5.4 Mechanic design of hexapod

3.5.4.1 Body

The hexapod robot is constructed from PVC (polymerizing vinyl chloride) board and weighs about 2.5 kilograms without battery, and the heights is about from the ground. The figure below shows the physical figure of Hexapod robot. Robot body shape and leg dimensions influence not only the kinematics and dynamics of robot locomotion but also stability. Stability is a requirement for all robots. Basic definition of stability is that at least three legs must support the whole weight of the robot all the time. In other words, there must be a support polygon (at least

Triangle) and the robot's center of mass must be inside of this polygon. The bigger the polygon, the better the stability [8]. The length, width and height main body base are respectively 22.5 cm, 16.5 cm and 4.5cm. Fig. 19 shows the main body of hexapod.

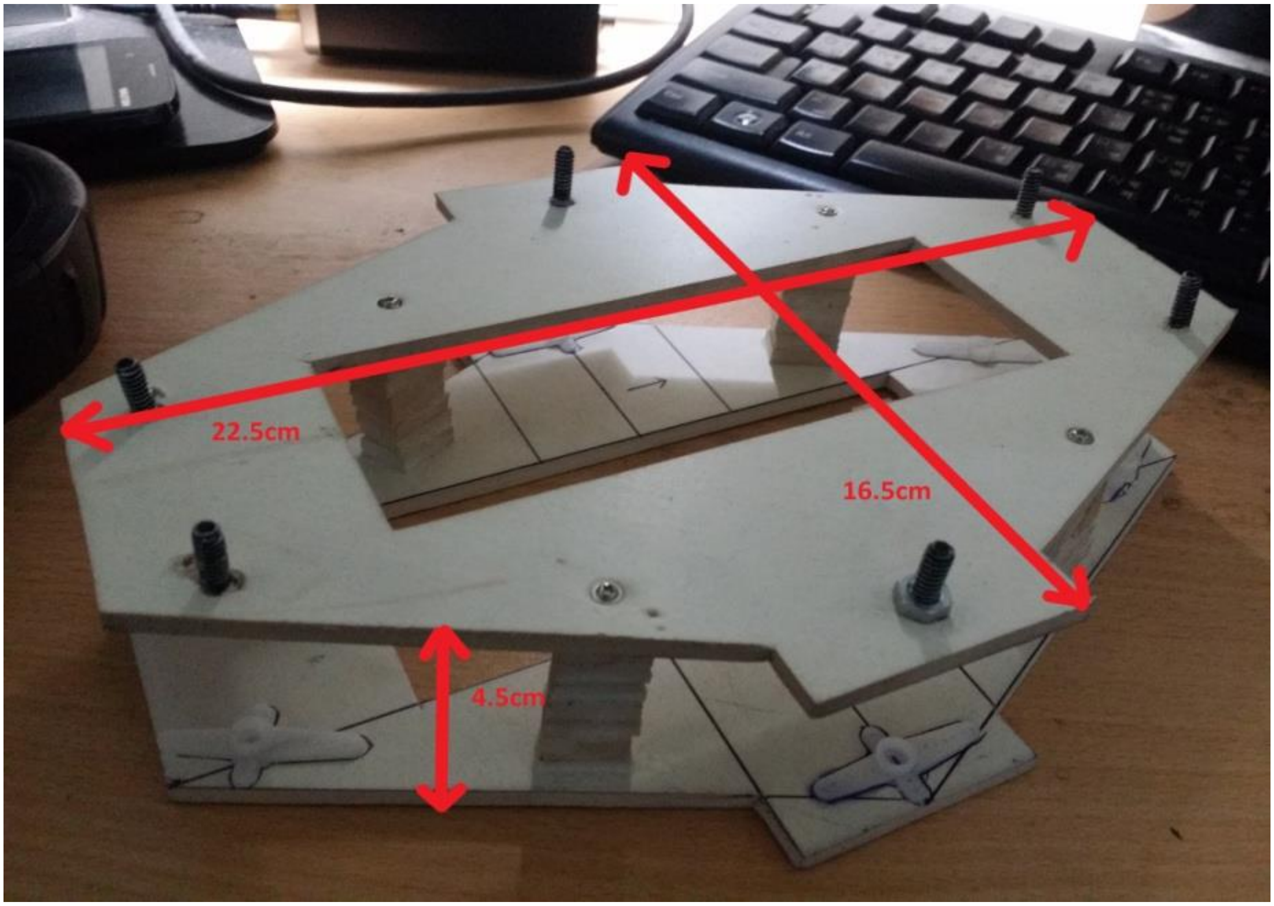


Fig. 19. Main Body of hexapod

3.5.4.2 Structured legs

This Hexapod uses 18 SG90 1.5kg/0.3 sec 9g Micro servo motors to actuate its 18 joints. The design of all legs is identical and consist of coxa, femur, and tibia link and joint. The servos are capable of delivering up to 1.5 kg/cm torque with the operating speed of 0.3/60 degrees. Servo controller is used to control 18 servos. Fig. 20 shows the hexapod leg measurement.

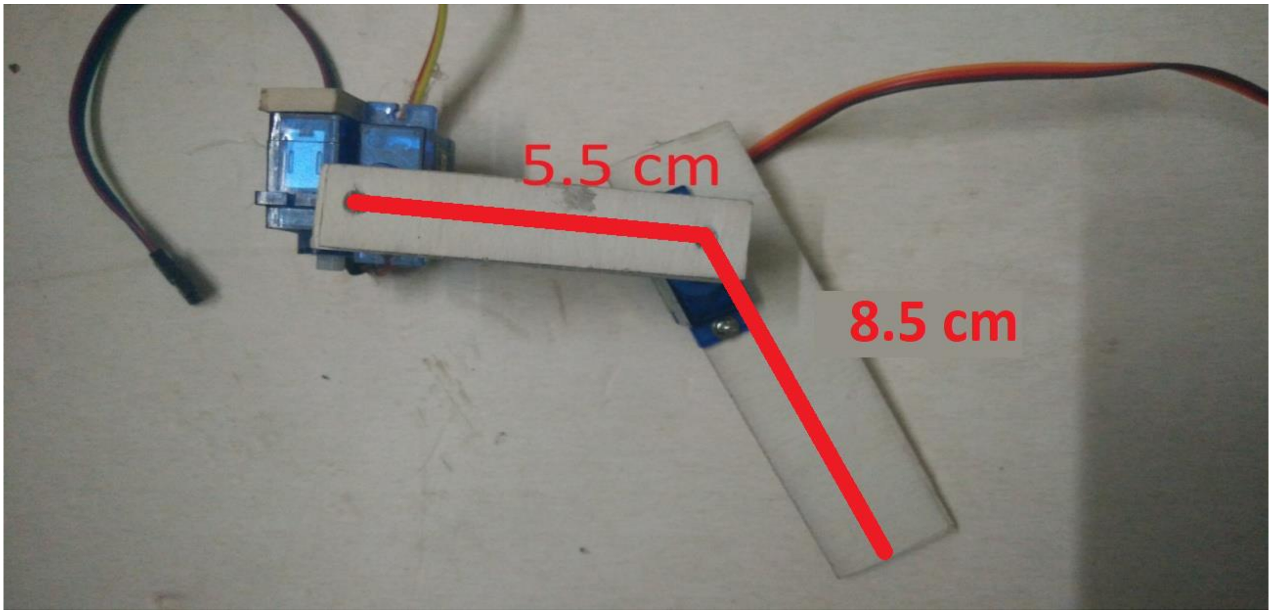


Fig. 20. Hexapod leg measurement

The length of each coxa, femur, and tibia links are 2cm, 5.5cm, and 8.5 cm. The range movement of each link and joint (coxa, femur and tibia) is limited by the physical constraint. Coxa joint has movement range from 60 to 120 Degree, femur has movement range from 75 degree to 90 degree, and tibia has movement range from 60o to 90o.

3.5.4.3 Coordinate System

There are three coordinate system used in this robot. Firstly, the coordinate system with respect to coxa joint. This coordinate system is used to deal with the movement of each leg. Second, the coordinate system with respect to center of robot's body and used to deal with the static movement of robot such as body shifting, rotation, pitch, and roll. The third coordinate system is respect to the ground and used to deal with the dynamic movement of robot such as forward, backward, left, and right movement [1]. Fig. 21 shows the Coordinate System of structured leg of hexapod.

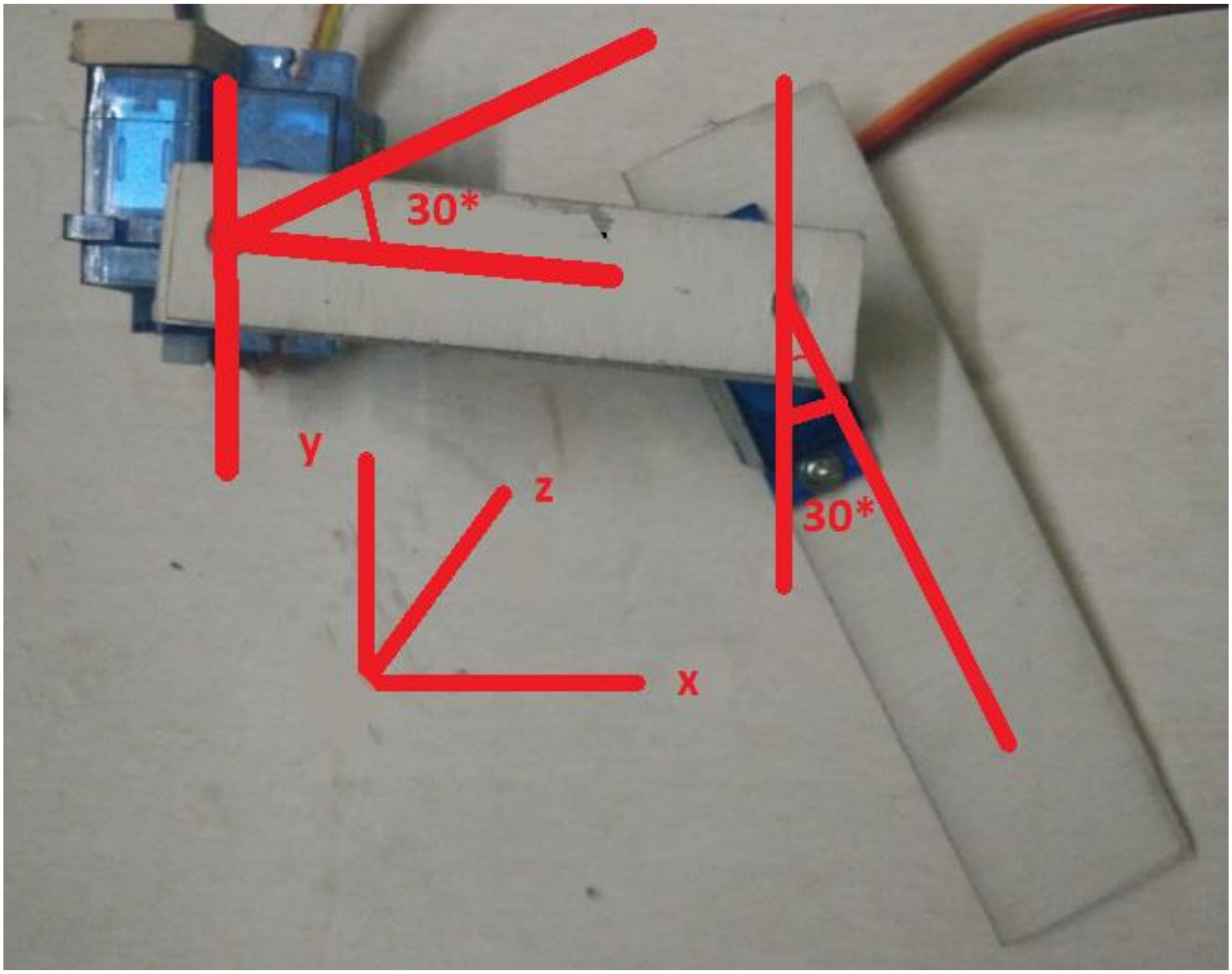


Fig. 21. Coordinate System of structured leg of hexapod

CHAPTER 4

Experimental Results

4.1 Experimental Setup

We have completed several experiments on our hexapod robot. These experiments can be categorized into two major sectors. Firstly, we focused on the walking of the robot. Finally. We experimented on the life detection algorithm using the microphones.

4.1.1 Experiments on Walking

After the completion of our prototype hexapod, while we tried to run the robot we faced power failure as we did not powered up the servo motors properly. Moreover, the robot was carrying a lot of weights. As a result, it was not able to stand in its feet. Besides, the ration of each parts of legs were not balanced, so the leg movements were not smooth.

All these drawbacks led us to develop the second version of the hexapod. In this updated version, we made all the parts smaller. We also used a servo-controller to make sure the power issue has been taken care of. Moreover, we replaced the powerbank with cellphone-batteries to reduce the overall weight of the robot.

After these modifications, the robot is currently able to stand in its feet and move forward, backward, left and right. We have tested this movements both in plain surface and irregular surface. The robot performs a perfect movement in the plain surface. However, it faces some challenges moving in any surface with a slope. We increased the grip of each leg and it shows slightly better performance. We tried to move the robot in stairs but it is still not capable of doing so.

4.1.2 Experiments on Life Detection

Table I shows the ideal values of sound levels L (loudness of noise) with corresponding sound source.

TABLE I: Sound levels

Sound sources (noise) Examples with distance	Sound Level
aircraft, 50 m away	140 dB
Threshold of pain	130 dB
Threshold of discomfort	120 dB
Machinery, 1 m distance	110 dB
Music, 1 m from speaker	100 dB
Truck, 10 m away	90 dB
Busy road, 5 m	80 dB
Vacuum cleaner, 1 m	70 dB
Conversational speech, 1 m	60 dB
Average home	50 dB
Quiet library	40 dB
Quiet night	30 dB
Background TV	20 dB
Hearing threshold	0 dB

Using this table, we can see that, a conversation sound creates a sound level of 50dB – 70dB. So while we execute detective mode, from the microphones value, we can detect conversations from the sound level calculated from the microphone input.

4.2 Experimental Result and Analysis

We made a sound in the North of the robot having a distance of 1 meter. Fig. 22 shows the results for sound source in North, distance 1m.

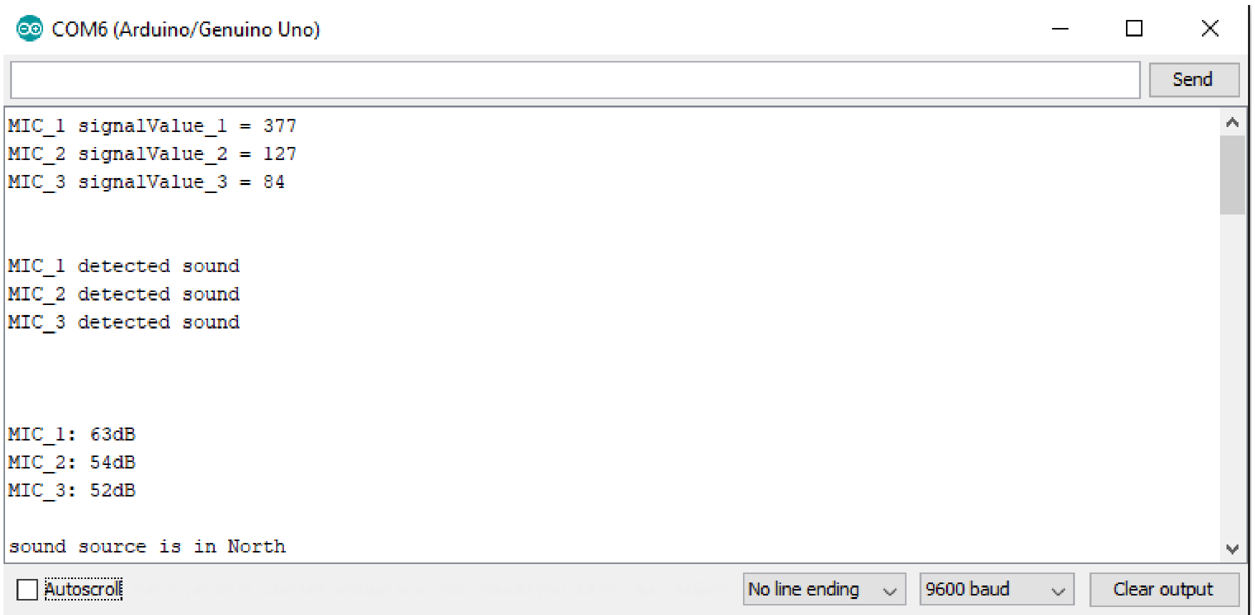


Fig. 22. Results for sound source in North, distance 1m

Fig. 23 shows the results for sound source in North-West, distance 0.7m.

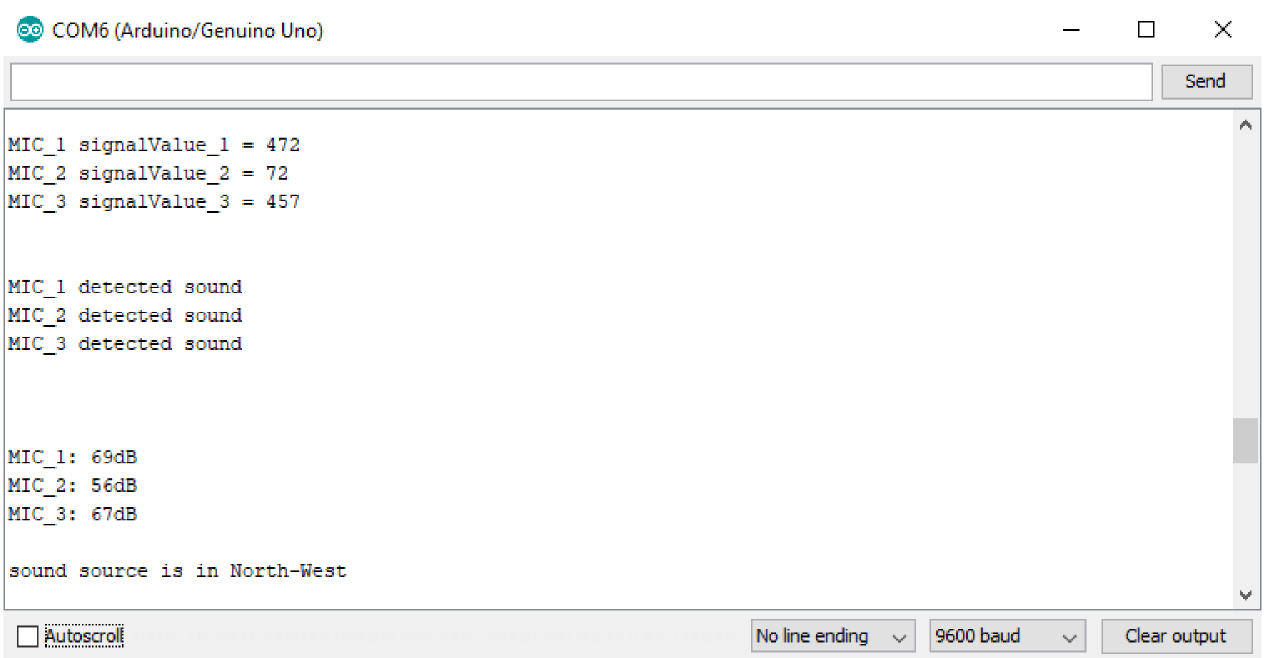


Fig. 23. Results for sound source in North-West, distance 0.7m

Here we can see that, all the 3 microphones detected sound a calculated approximate directions. We made another sound in the North-West of the robot having a distance of 0.7 meter.

CHAPTER 5

Conclusion and Future Work

5.1 Conclusion

In the proposed system we have proposed a search and rescue robot that would be efficient in crawling through narrow holes and spaces over rough and unfriendly terrains. The walking algorithms used in the robot have been field tested properly and has an above average rate of efficiency when compared to other such robots in related fields. To control the spider-bot we have successfully made use of android UI and have implemented a navigation panel onto the user interface. In many accidents that need inspection of the ground, and in cases where it is impossible for a human being to properly look for any evidence that might help to save lives, the spider-bot can come in handy, and the functional algorithms implemented would be quite efficient in helping the robot move under extreme conditions. The robot has worked tremendously well in different speed scenarios and responded well to each of the cases, which was entirely possible for the six leg based design of the model, which has 3 servo motors each. It is hoped that small amount of modification to our proposed system will transform it into a fully functional and ready-to-use robot in real life scenario.

5.2 Future Work

Our robot is able to walk through rough and irregular surface which open up several window of opportunities. In the future, robot can be functioned in such a way that it will have the ability to climbing walls or gliding down to destination so that, it can be deployed to the disaster area from air support as helicopters or planes. Moreover, if the size can be minimized, it can be used as a spy robot which will help to stop terrorism acts.

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