CHAPTER 1

INTRODUCTION

1.1 Overview

In modern days disaster recovery mission has become one of the top priorities in any natural disaster management. Smart robots play a significant role in such missions, including search for life under earthquake hit buildings, searching for people in a building on fire and many other situations. We have selected Hexapod robot. We are focusing on how to navigate the robot and help the people in disasters. A hexapod robot is a mechanical vehicle that walks on six legs. Since a robot can be statically stable on three or more legs, a hexapod robot has a great deal of flexibility in how it can move. If legs become disabled, the robot may still be able to walk. Many hexapod robots are biologically inspired by Hexapoda locomotion. Hexapods may be used to test biological theories about insect locomotion, motor control, and neurobiology.

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 manoeuvrable legs allows hexapods to turn around on the spot. 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 centre 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. But in order to do that, wheeled based rescue robots will face difficulties moving in those irregular surface and obstacle-rich area . So a flexible six-legged robot will be more effective on these challenging situations.

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.

1.1.1 Hexapod designs

The first hexapods can be identified as robots based on a rigidly predetermined motion so that an adaptation to the ground was not possible. Early researches in the 1950s were focused on assigning the motion control completely by a human operator manually. One of the first successful hexapod robot was constructed at University of Rome in 1972 as a computer-controlled walking machine with electric drives [12]. In the middle 70s, at the Russian Academy of Sciences in Moscow, a six-legged walking machine was developed with a mathematical model of motion control. It was equipped with a laser scanning range finder and was connected with a two-computer control system [13]. In 1976, Masha hexapod walking robot was designed at Moscow State University. The robot had a tubular axial chassis, articulated legs with three DoFs .The hexapod was able to negotiate obstacles using contact on the feet and a proximity sensor. Ohio State University in 1977 developed a six-legged insect-like robot system called "OSU Hexapod" [15]. This hexapod was kept tethered and was made to walk short distances over obstacles. In 1983, Carnegie-Mellon University developed a "Six-Legged Hydraulic Walker" [16], a first man-carrying hexapod capable of navigating rough terrain using different types of gaits. The hexapod used a combination of hydraulic feedback, computer control and human control and was about 2.5 m long and the same width. It weighted about 800 kg and was powered by a 13 kW gasoline engine.

In 1984, Odetic Inc., California, USA, developed Odex I [17], a six-legged radially symmetric hexapod robot which used an onboard computer to play back pre-programmed motions. Its onboard computer could be operated remotely and the robot moved under its own power. Using remote human control or the prerecorded motions, the hexapod could climb obstacles such as stairs or a pickup truck. Odex I weighed 136 kg; each leg was able to lift 180 kg. In 1985, the "NMIIIA" Hexapod Manned Rover was developed in Russia [18]. This hexapod was designed for investigating the walking propulsive device and control system. NMIIA had a mass of 750 kg; its load-carrying capacity was 80 kg; travel speed was 0.7 km/h. In 1989, the Ohio State University started the

Adaptive Suspension Vehicle project [19]. The six-legged robot, shown in , used hydraulic actuation being powered by an internal combustion engine. A human was able to operate it through a joystick while the individual control of each leg was assured by a central computer. As main characteristics, its 250 kg payload capacity, and the possibility to surpass 1.8 m width ditches and climb vertical steps of maximum 1.65 m should be mentioned. A hexapod walking robot named Aquarobots was constructed in 1989 and used for underwater measurements of ground profiles for the construction of harbors [20]. A small hexapod robot named Genghis with 0.35 m length and 1 kg weight was developed in the same year [21]. The behavior of Genghis was not explicitly controlled, but was built by adding layers of control on top of existing simpler layer. This approach was different to the more traditional method of task decomposition.

Attila and Hannibal hexapod robots were built in the Mobot Lab in the early 1990s [22]; they were very sophisticated autonomous robots for their size, possessing over 19 degrees of freedom, more than 60 sensory inputs, eight microprocessors and real-time behavior. TUM Walking Machine was developed in 1991. The robot was designed and steered similar to a stick insect [23]; the control system was realized as a neural structure. AMBLER (Autonomous MoBiLe Exploration Robot) was a hexapod robot developed by the Jet Propulsion Laboratory during the mid-90s for operating under the particular constraints of planetary terrain [24]. The robot was about 5 m tall, up to 7 m wide, and weighed 2500 kg. While most robots bend their legs to step and walk, Ambler's legs remain vertical, while they swing horizontally, adopting a telescope like displacement to touch the ground.

1.1.2 Recent Developments

The two last decades have been characterized by a rapid development of control systems technology. Hexapod robots were equipped with various sensing systems. Artificial Intelligence systems were widely applied to the analysis of environment and motion of robots on a complex surface.

A series of bio inspired robots was developed at Case Western Reserve University (USA) at the end the 90s, such as, for example, Robot III that had a total of 24 DoFs. Robot III architecture was based on the structure of cockroach, trying to imitate their behaviour. In particular, each rear leg had three DoFs, each middle leg four DoFs and each front leg five DoFs. Similarly, Biobot was a biomimetic robot physically modeled as the American cockroach (Periplaneta Americana) and powered by pressurized air. This hexapod had a great speed and agility. Each leg of the robot had three segments, corresponding to the three main segments of insect legs: coxa, femur, and tibia.

Hamlet was a hexapod robot constructed at the University of Canterbury, New Zealand. Its legs were all identical and each had three revolute joints. Hamlet's application task was to study force and position control on uneven terrain.

In 2001, a project named RHex commenced RHex design comes from a multidisciplinary and multi-university DARPA funded effort that applies mathematical techniques from dynamical systems theory to problems of animal locomotion. Hexapod design consists of a rigid body with six compliant legs, each with one DoF. Thus, RHex has only six motors that rotate the legs such as a wheel.

Several prototypes of Rhex have been developed. At present the project is still active. Lauron V hexapod robot was the result of about 10 years of progressive improvement on the previous configurations Lauron I, II, III and IV. LAURON is biologically-inspired by the stick insect. Like this insect, the robot has six legs fixed to a central body. Each of the six legs is actuated by four joints. Each foot has a three-axis force sensor, and each motor has a current sensor that detects forces opposing to its movement. At present the project is still active.

Gregor I reproduces the cockroach's agility where the locomotion control is based on the theory of the Central Pattern Generator .Gregor I had a biological inspiration where each leg pair has a unique design. The front leg pair and the middle leg pair have three DoFs on each leg, and the rear leg pair has two DoFs. Another hexapod robot called Sprawlita was developed following the basic principles of locomotion of cockroaches: self-stabilizing posture, different functions for the legs, passive visco-elastic structure, open-loop control and integrated construction. In 2005, the hexapod robot named BILL-Ant-p was developed The robot was based on ants' behavior and it is composed of three DoFs on each leg with six force-sensing feet, a three-DoF neck and head, and actuated mandibles with force-sensing for a total of 28 DoFs.

A series of hexapod named LEMUR (Limbed Excursion Mechanical Utility Robots robot) was developed by Jet Propulsion Laboratory with the goals of using robots for repair and maintenance in near-zero gravity on the surface of spacecraft MARS (Multi Appendage Robotic System) was a hexapod mobile robotic research platform developed after the LEMUR project for similar applications by employing radial symmetry. MARS platforms were capable of walking in any direction without turning.

In 2004, a six-legged lunar robot called ATHLETE was developed by the Jet Propulsion Laboratory. This robot had the ability to roll rapidly on rotating wheels over flat smooth terrain and walk carefully on fixed wheels over irregular and steep terrain. ATHLETE had a payload capacity of 450 kg, a diameter of around 4 m and a reach of around 6 m.

AQUA was an amphibious hexapod robot developed with six independently-controlled leg actuators. One of the most important features of this robot was the ability to switch from walking to swimming gaits as it is moving from a sand beach or surf-zone to deep water. The underwater walking robot CR200 was built as based on the concept of Crabster. The application field was inspection of shipwrecks or scour and survey of seafloor in high current and turbid environments. The hexapod robot called RiSE is able to climb on a variety of vertical surfaces as well as demonstrating horizontal mobility. A mechanism applied in RiSE uses compliant micro spines on its feet to reliably attach to textured vertical surfaces, in order to carry the payload while the robot climbs. COMET hexapods are a serious of robots designed to operate on extremely unstructured terrain. The latest prototype, COMET IV, is a hydraulically driven hexapod involving walking with the force/impedance control, fully autonomous navigation with laser mapping and teleoperation. Mantis is a hexapod robot hydraulic powered developed by Micromagic Systems. It stands nearly 3 m tall and weighs about 2 tons; at present, it is one of the biggest hexapod robots in the world.

In the recent study nearly 68000 lives are lost every year and millions are affected due to naturally disasters. Our purpose is to reduce the life lost in disaster and help the people stuck in disasters. We are building a hexapod robot which serves a purpose of identify hazard and aid to the victims. The robot will be able to navigate, sense the environment and communicate its findings to a remote locations.

1.2 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 [1]. 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 [2]. 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 [3]. 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 [4].

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 [5].However, the lifesaving robot of Korea had the most motivational impact on this proposed robot [6]. RHex developed by is a different robot compared to other hexapod robot because it is actuated by brushed DC motor [7]. 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 [8]. 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 [9].

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 [10].

The walking robot Ragno is 33 cm long and 30 cm wide and 2.15 kg weights [11]. 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 [12]. 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 [11]. 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 centre 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.

It also focuses 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 coax. 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 [10].

1.3 Aim

Since we are focusing on two scenarios the robot will first identify the hazard either earthquake or fire using different sensors. When the robot has identify the hazard it will detect number of people stuck or need help using camera or ultrasonic sensors. Robot will be able to communicate with the rescuers and provide major information about the disaster like number of people stuck, where are they located and how are the conditions.

Robot can be controlled manually this helps the rescuers as hexapod can go in places where humans are not able to and find a better way to reach the people stuck. This helps in coming up with a rescue plan and even executing it quickly. The faster we executing the plan more chances to saving lives.

CHAPTER 2

BLOCK DIAGRAM

2.1 Block Diagram of Hexapod

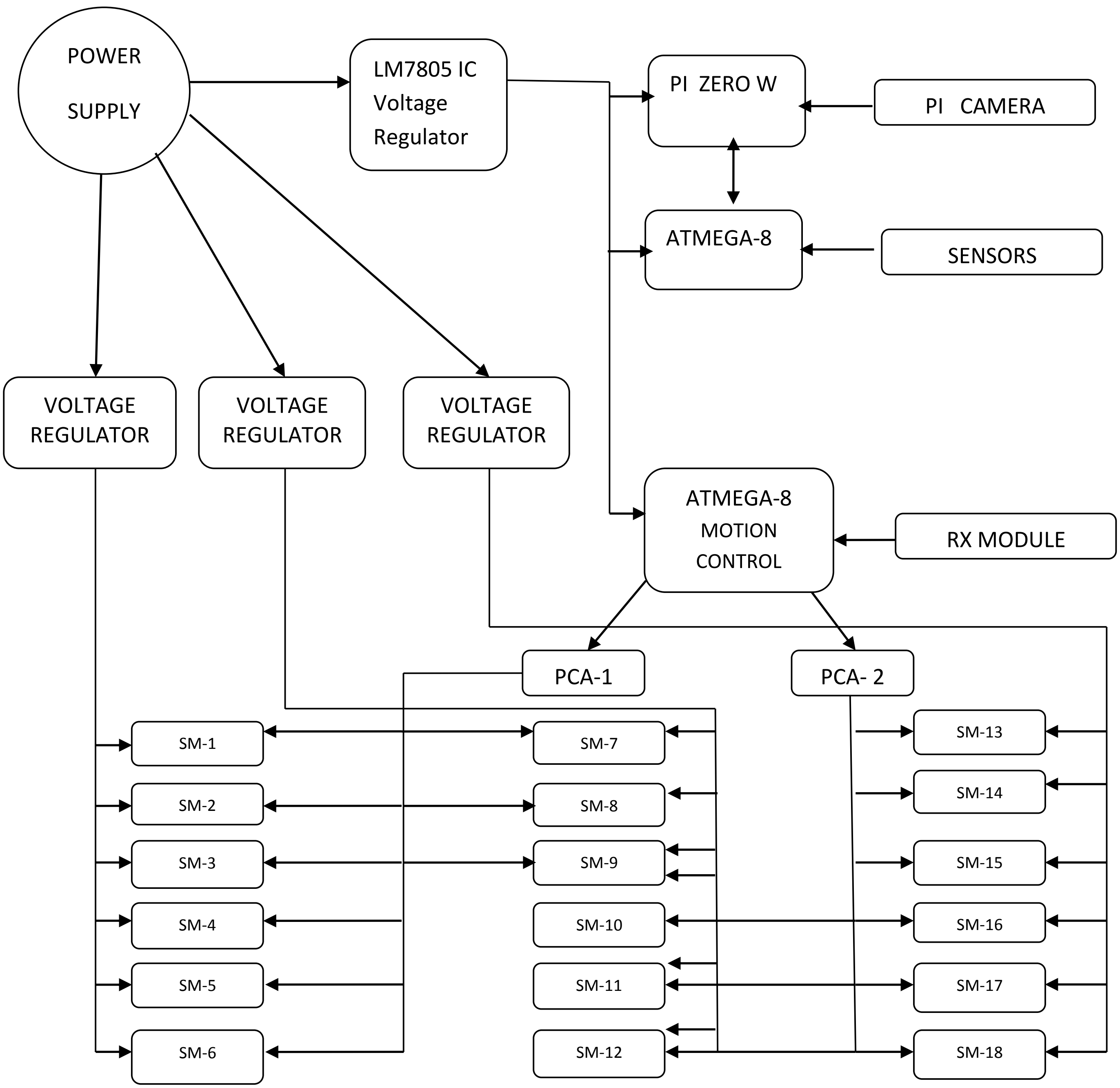

Fig2.1: Block diagram of hexapod

This block diagram represents the structure of the hexapod.

- Power supply- The voltage regulators are being supplied by this power supply.
- Voltage regulators – These voltage regulators regulate the voltage to 5v and a maximum current output of 3Amps. This regulated voltage is used to supply the microcontrollers, the raspberry pi zero w, the motor drivers and the servo motors.

There are 3 voltage regulators, each connected to give power supply to 6 servo motors.

- Raspberry pi zero w- Raspberry pi is used here for image processing and updating the sensor values on a html page.
- Atmega-8A – We are using two atmegas here. One atmega is used to update the sensor values to the pi.

The second atmega is used for motion control .It has a receiver module attached to it which is receiving data from the tx module connected to the wireless remote control. Also this atmega has two PCA boards attached to it which controls the servo motors on the hexapod.

- PCA Board- There are 2 PCA boards connected to the atmega . Each PCA board gives logic to 9 servo motors. Therefore we use 2 PCA boards for 18 servomotors.
- Servo motors – There are 18 servo motors , 3 for each leg which gives each leg 3 degrees of freedom(DOF).These 18 servo motors are labeled SM1 ,SM2 ……….
- Raspberry Pi Camera v2- A pi camera module is connected to the raspberry pi for image processing for human detection.
- Sensors- There are 3 sensors whose values are being continuously communicated to the pi from where these are being pushed to the html page. These 4 sensors are

1. Temperature sensor- It is used to detect sudden temperature increment in the environment, to detect disaster like fire.
2. Ultrasonic sensor- Ultrasonic sensor is being used to detect the obstacles in the path of the hexapod robot.
3. Gas sensor- Gas sensors are being used to detect the presence of flammable gas and products of an active flame.

2.1.2 Wireless Remote Control

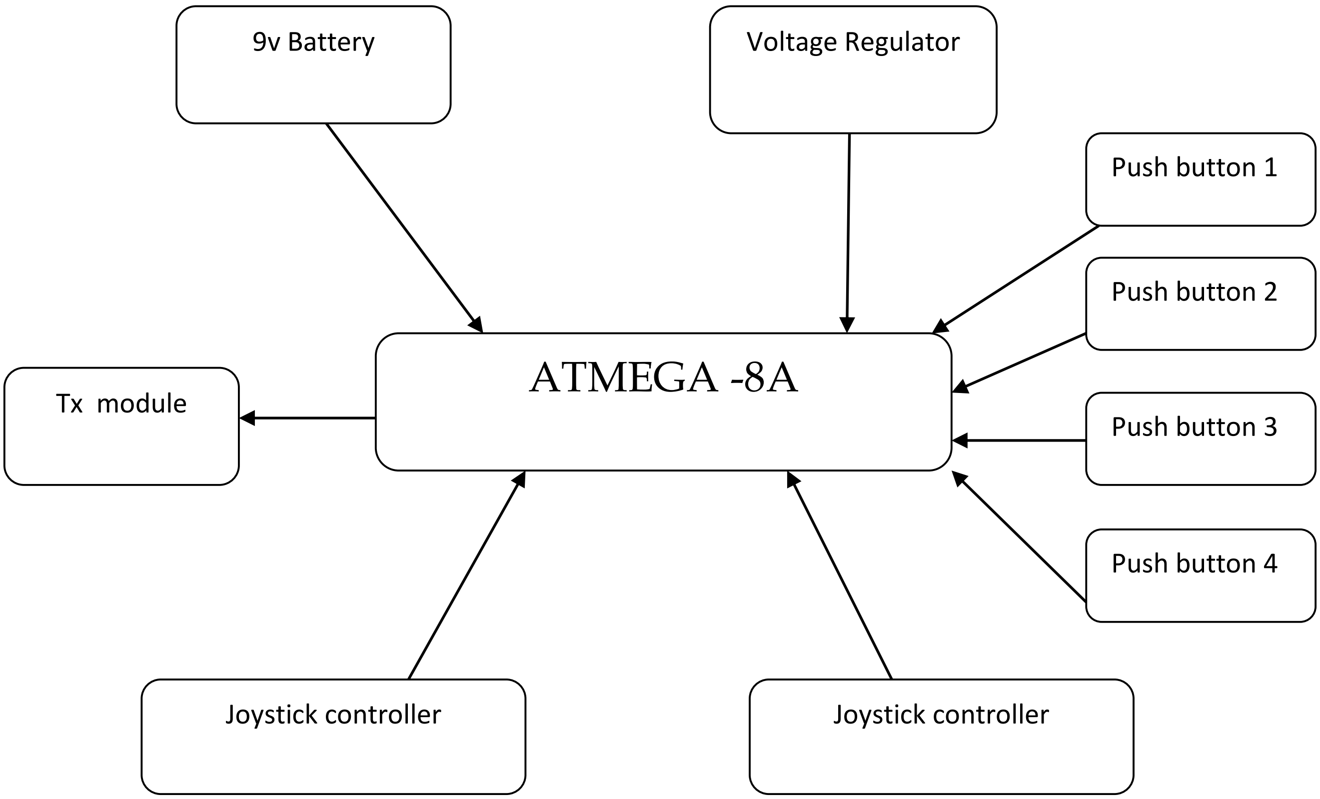

Fig 2.2: Block diagram of a remote controller

This block diagram gives the structure of the wireless remote control used to control the movement of the hexapod.

The main processing unit of the wireless remote control is the atmega 8A. A transmitter module is connected to one of its pins which sends data to the receiver module connected on the atmega8A on the hexapod .This receiver and transmitter module helps the hexapod's movements when controlled manually.

The atmega is powered by a 9v battery and the voltage is being regulated by a voltage regulator. The atmega is also connected to 4 push buttons and 2 joystick controllers for the movement control.

CHAPTER 3

HARDWARE/SOFTWARE TOOLS/DESCRIPTION/ INTERFACING

3.1 HARDWARE:

The hardware used in the project work is as listed below:

3.1.1 3-D Printer

Fig 3.1: 3D printer

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic with for instance a milling machine.3D printing enables you to produce complex (functional) shapes using less material than traditional manufacturing methods.

The 3-D printer is being used in this project to print the parts of the hexapod. The design models are being saved on the sd card which can be mounted on the 3-D printer.

3.1.2 PLA (3-D Printer Material)

PLA (Polylactic Acid) is one of the most commonly used filaments in 3D Printing. The ease of use is one of the main reasons it is sought after by beginners to professionals. It is a biodegradable thermoplastic material that is made from fragments of corn starch and sugarcanes which are often renewable.

3.1.3 Raspberry Pi 3B

Fig3.2: Raspberry pi 3B

Raspberry Pi is an ARM based credit card sized SBC(Single Board Computer) created by Raspberry Pi Foundation. Raspberry Pi runs Debian based GNU/Linux operating system Raspbian and ports of many other OSes exist for this SBC.The Raspberry Pi Foundation provides Raspbian, a Debian-based Linux distribution for download, as well as third-party Ubuntu, Windows 10 IoT Core, RISC OS, and specialized media centre distributions. It promotes Python and Scratch as the main programming languages, with support for many other languages. The default firmware is closed source, while an unofficial open source is available.

3.1.4 Atmega microcontroller

Fig3.3: Atmega 328

The high-performance, low-power Microchip 8-bit AVR RISC-based microcontroller combines 8KB ISP flash memory with read-while-write capabilities, 512B EEPROM, 1KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte oriented two-wire serial interface, 6-channel 10-bit A/D converter (8-channel in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, SPI serial port, and five software selectable power saving modes. The device operates between 2.7-5.5 volts.

3.1.5 PCA Board (Motor Driver)

Fig3.4: Pca Board

The PCA9685 is an I²C-bus controlled 16-channel LED controller optimized for Red/Green/Blue/Amber (RGBA) color backlighting applications. Each LED output has its own 12-bit resolution (4096 steps) fixed frequency individual PWM controller that operates at a programmable frequency from a typical of 24 Hz to 1526 Hz with a duty cycle that is adjustable from 0 % to 100 % to allow the LED to be set to a specific brightness value. All outputs are set to the same

PWM frequency. Each LED output can be off or on (no PWM control) or set at its individual PWM controller value.

Voltage Regulators: Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 IC, a member of 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC). The xx in 78xx indicates the output voltage it provides. 7805 IC provides +5 volts regulated power supply with provisions to add a heat sink

3.1.6 Raspberry Pi Camera v2:

Fig3.5: Raspberry pi camera v2

The Raspberry Pi NoIR Camera V2 is the "night vision" version of the official camera board released by the Raspberry Pi Foundation. The Raspberry Pi NoIR Camera Board V2 has no Infrared filter, which makes it perfect for taking Infrared photographs or photographing objects in low light (twilight) conditions! Custom designed and manufactured by the Raspberry Pi Foundation in the UK, the Raspberry Pi NoIR Camera Board V2 features an ultra-high quality 8 megapixel Sony IMX219 image sensor (up from 5MP on the V1 camera board), and a fixed focus camera lens. The V2 camera module is capable of 3280 x 2464 pixel static images, and also supports 1080p30, 720p60 and 640x480p90 video.

The module attaches to Raspberry Pi by way of a 15 Pin Ribbon Cable, to the dedicated 15-pin MIPI Camera Serial Interface (CSI), which was designed especially for interfacing to cameras. The CSI bus is capable of extremely high data rates, and it exclusively carries pixel data to the BCM2835 processor. The board itself is tiny, at around 25mm x 23mm x 9mm, and weighs just over 3g, making it perfect for mobile or other applications where size and weight are important.

Spec:

Improved resolution – 8-Megapixel native resolution sensor-capable of

3280 x 2464 pixel static images

Supports 1080p30, 720p60 and 640x480p90 video

Size 25mm x 23mm x 9mm

Weight just over 3g

3.1.7 Sensors

3.1.7.1 Servo motors:

Fig3.6: Servo motor

It is light weight and a good choice for most planes with 9g servos. The resin gear train is very reliable and the case is one of the slimmest available. The servo features a universal connector which works with nearly all receivers.

Spec:

Model: SG90

Weight: 9 gm

Operating voltage: 3.0V~ 7.2V

Stall torque 4.8V : 1.2kg-cm

Stall torque 6.6V : 1.6kg-cm

3.1.7.2 RF Tx-Rx modules:

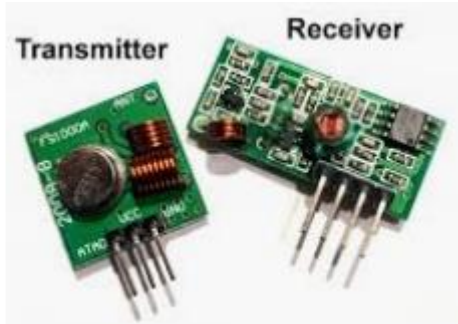

Fig3.7: RF module of 433 MHz

RF modules are widely used for wireless data transfers and remote control applications. These days, cost of RF modules are very low and are compact in size. Most of these RF modules are operating around 433MHz. Amplitude Shift Keying (ASK) or Frequency Shift Keying (FSK) are mainly used for wireless data transfers

3.1.7.3 Joystick:

Fig3.8: MH Joystick

PS2 game joystick module suits for Arduino connects to two analog inputs, the robot is at your commands with X, Y control. It also has a switch that is connected to a digital pin, convenient to use.

3.1.7.4 DHT11:

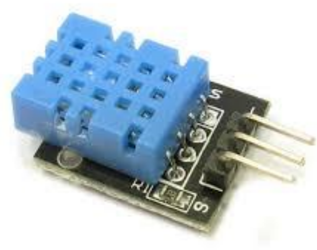

Fig3.9: DHT11

The DHT11 is a commonly used Temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor is also factory calibrated and hence easy to interface with other microcontrollers. The DHT11 is a composite sensor that contains a calibrated digital signal output of temperature and humidity. The technology of a dedicated digital modules collection and the temperature and humidity sensing technology are applied to ensure that the product has high reliability and excellent long-term stability. The sensor includes a resistive sense of wet component and an NTC temperature measurement device, and is connected with a high-performance 8-bit microcontroller. The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%.

3.1.8 Voltage Regulator (7805)

Fig3.10: Voltage regulator 7805

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

3.1.9 Battery

Zippy Compact, the latest addition to our Zippy battery series offers excellent performance and high quality in a "Compact" size. These packs provide the same capacity and discharge rate as our Flight max line, but give you alternative sizes for applications that require a specific shape.
Great for models with limited battery compartment space!
Zippy batteries deliver full capacity & discharge as well as being the best value batteries in the hobby market today!

Spec.

Capacity: 850mAh

Voltage: 2S1P / 2 Cell / 7.4V

Discharge: 25C Constant / 35C Burst

Weight: 51g (including wire, plug & case)

Dimensions: 54x18x30mm

Fig 3.11: Compact battery

3.1.10 3D Printed Materials

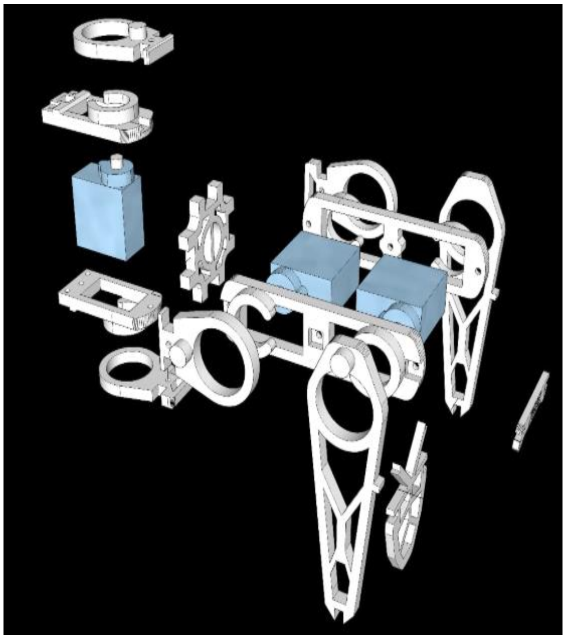

Fig 3.12 (a)

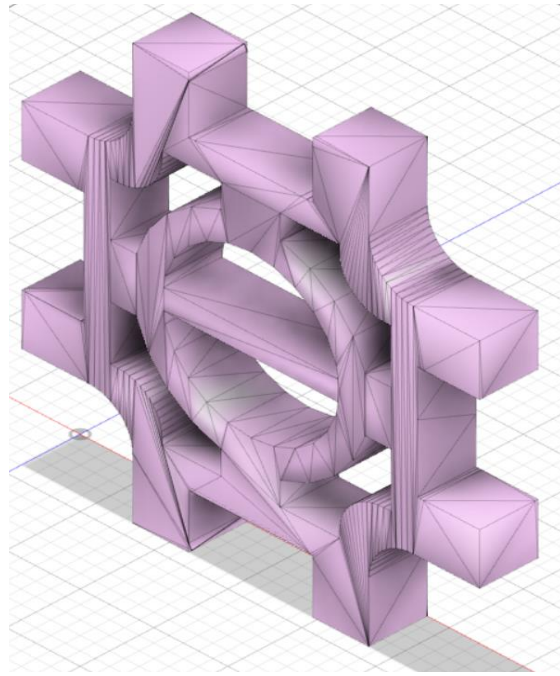

Fig 3.12 (b)

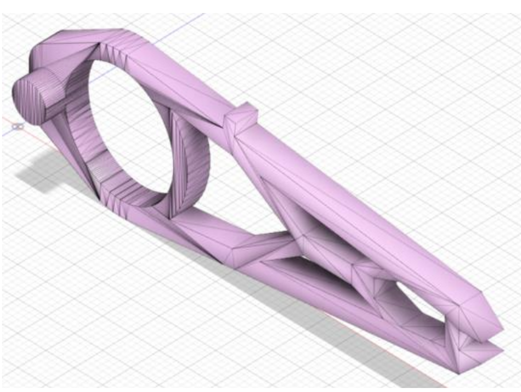

Fig 3.12 (c)

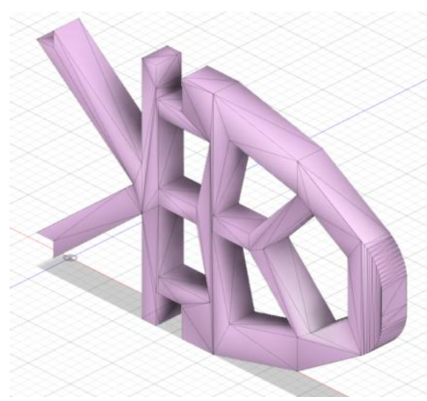

Fig 3.12 (d)

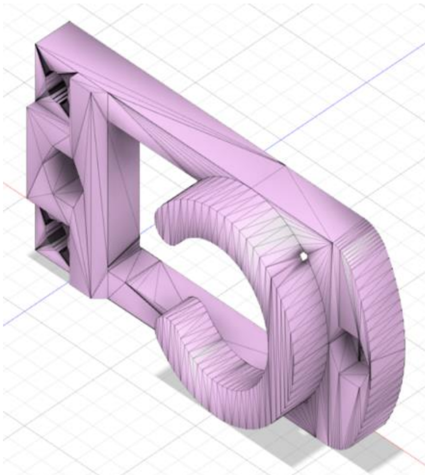

Fig 3.12 (e)

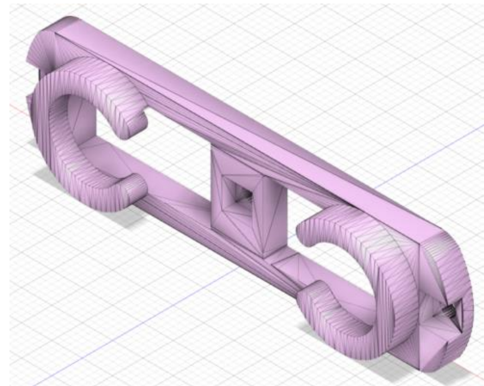

Fig 3.12 (f)

Fig 3.12(a) shows the different sub parts to form one leg. From 15(b) to 15(f) shows the figure in the software Cura where those parts are individually presented and these source files are stored in memory card. This memory card is inserted in 3D printer and then the bed heat and the speed of printing is set. These figures were obtained by surfing so it could reduce our work of designing legs which helped us to focus on the application part of our project.

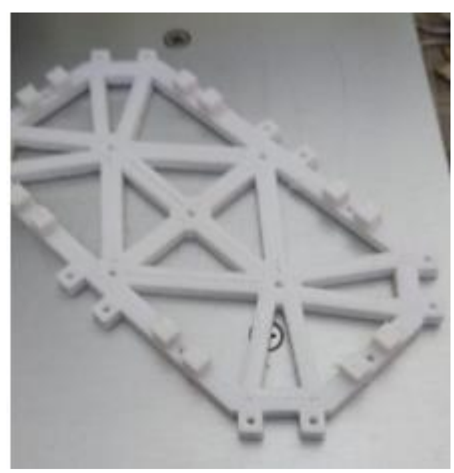

Fig 3.13(a) Fig3.13(b)

Fig 3.13(c)

Fig 3.13(d)

Fig 3.12 &3.13 : Structure Printed on 3D printer of leg that contains coxa ,femur and tibia

The Fig 3.12(a) shows the required pieces to make one leg . We require 13 pieces to make one leg and such 6 legs were done. Care had to be taken while screwing or assembling the parts as too tight would restrict the movements of hexapod infact servos, loosening it would disturb its gait plus certain screwing positions could not be obtained on the material through 3D printing. These were done manually.each leg had 3DOF. Those can be seen in Fig 16 a,b,c and d.

3.1.11 Ultrasonic Sensor

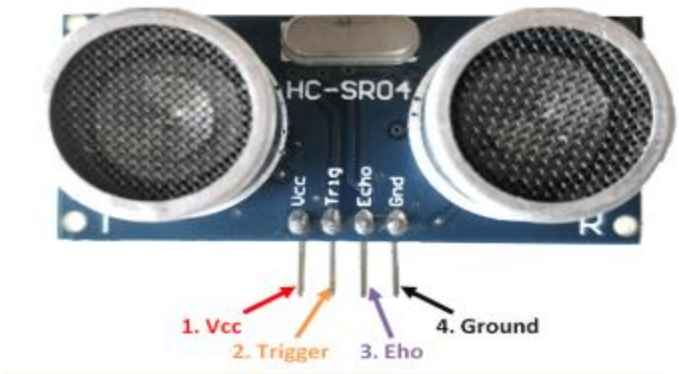

Fig 3.14 :HC-SR04

HC-SR04 distance sensor is commonly used with both microcontroller and microprocessor platforms like Arduino, ARM, PIC, Raspberry Pie etc. The following guide is universally since it has to be followed irrespective of the type of computational device used.

Power the Sensor using a regulated +5V through the Vcc ad Ground pins of the sensor. The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins (If available). The Trigger and the Echo pins are both I/O pins and hence they can be connected to I/O pins of the microcontroller. To start the measurement, the trigger pin has to be made high for 10uS and then turned off. This action will trigger an ultrasonic wave at frequency of 40Hz from the transmitter and the receiver will wait for the wave to return. Once the wave is returned after it getting reflected by any object the Echo pin goes high for a particular amount of time which will be equal to the time taken for the wave to return back to the sensor.

3.2 SOFTWARE:

The software used in the project work is as listed below:

3.2.1 Fusion-360:

Fusion 360 is the first 3D CAD, CAM tool of its kind that connects your entire product development process in a single cloud based platform that works on PC. In this project it was used to show different gaits of hexapod.

3.2.2 Cura ultimate: **Cura** is an open source 3D printer slicing application. It was created by David Braam who was later employed by Ultimaker, a 3D printer manufacturing company, to maintain the software. Cura is available under LGPLv3 license. Cura was initially released under the open source Affero General Public License version 3, but on 28 September 2017 the license was changed to LGPLv3. This change allowed for more integration with third-party CAD applications. Development is hosted on GitHub. Ultimaker Cura is used by over one million users worldwide and it is the preferred 3D printing software for Ultimaker 3D printers, but it can be used with other printers as well. Ultimaker Cura works by slicing the user's model file into layers and generating a printer-specific g-code. Once finished, the g-code can be sent to the printer for the manufacturing the physical object. The open source software is compatible with most desktop 3D printers can work with files in the most common 3D formats such as STL, OBJ, X3D, 3MF as well as image file formats such as BMP, GIF, JPG, and PNG. With the help of this hexapod's legs and body were printed which later on were screwed and assembled together.

3.2.3 Vnc viewer: Vnc (virtual network computing) is a graphical desktop-sharing system that uses the Remote Frame Buffer protocol (RFB) to remotely control another computer. It transmits the keyboard and mouse events from one computer to another, relaying the graphical-screen updates back in the other direction, over a network. Vnc allows one to view and operate the console of another computer remotely across the network. It is also known generally as Remote frame buffer. The speed gain is probably noticed over a low speed dial-up modem connection. It is installed on the local computer and connects to the server component, which must be installed on the remote computer. The server transmits a duplicate of the remote computer's display screen to the viewer. It also interprets commands coming from the viewer and carries them out on the remote computer.

VNC is platform independent and is compatible with any operating system. Computers must be networked with TCP/IP and have open ports allowing traffic from the IP addresses of devices that may need to connect. VNC was developed at AT&T Laboratories. The original VNC source code is open source under the GNU General Public License, and other variations are also available commercially. With the help of which IP address of Raspberry Zero is found and also shows devices that are connected to the router and their corresponding IP address.

3.2.4 Opencv tool : OpenCV was started at Intel in 1999 by Gary Bradsky, and the first release came out in 2000. Vadim Pisarevsky joined Gary Bradsky to manage Intel's Russian software OpenCV team. In 2005, OpenCV was used on Stanley, the vehicle that won the 2005 DARPA Grand Challenge. Later, its active development continued under the support of Willow Garage with Gary Bradsky and Vadim Pisarevsky leading the project. OpenCV now supports a multitude of algorithms related to Computer Vision and Machine Learning and is expanding day by day. OpenCV supports a wide variety of programming languages such as C++, Python, Java, etc., and is available on different platforms including Windows, Linux, OS X, Android, and iOS. Interfaces for high-speed GPU operations based on CUDA and OpenCL are also under active development.

OpenCV-Python is a library of Python bindings designed to solve computer vision problems. Python is a general purpose programming language started by Guido van Rossum that became very popular very quickly, mainly because of its simplicity and code readability. It enables the programmer to express ideas in fewer lines of code without reducing readability. Compared to languages like C/C++, Python is slower. That said, Python can be easily extended with C/C++, which allows us to write computationally intensive code in C/C++ and create Python wrappers that can be used as Python modules. This gives us two advantages: first, the code is as fast as the original C/C++ code (since it is the actual C++ code working in background) and second, it easier to code in Python than C/C++. OpenCV-Python is a Python wrapper for the original OpenCV C++ implementation. OpenCV-Python makes use of Numpy, which is a highly optimized library for numerical operations with a MATLAB-style syntax. All the OpenCV array structures are converted to and from Numpy arrays. This also makes it easier to integrate with other libraries that use Numpy such as SciPy and Matplotlib. OpenCV-Python is the Python API for OpenCV, combining the best qualities of the OpenCV C++ API and the Python language.

3.2.5 Python: Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales.[26] Van Rossum led the language community until July 2018.

Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Python features a comprehensive standard library, and is referred to as "batteries included". Python interpreters are available for many operating systems. CPython, the reference implementation of Python, is open-source software and has a community-based development model. Python and CPython are managed by the non-profit Python Software Foundation.

3.2.6 Raspbian OS : The Rapsberry Pi hardware wouldn't be of much worth if there were no supported operating systems. Luckily, the Raspberry Pi supports many operating systems, most of them Linux-based. Because the Raspberry Pi has an **ARM-based CPU**, not all operating systems can be run on the device. For example, you can't install a **Windows OS** on your Raspberry Pi (although some newer versions of Raspberry will be able to run **Windows 10 IoT**, a version of Windows for embedded devices).

The recommended way of installing an operating system on your Raspberry Pi is by using a program called **NOOBS**. NOOBS (stands for **New Out of Box Software**) enables you to install the operating system of your choice, even if you don't have any experience with Linux-based operating systems. With NOOBS, you can install the following operating systems: Raspbian ,Arch Linux ARM , OpenELEC , Pidora, Puppy Linux , Raspbmc , RISC OS. Rasbian is the operating system of choice for beginners. It is based on a popular Linux distribution called **Debian** and was specially designed for the Raspberry Pi.

3.2.7Cprogramming: is general-purpose, imperative computer programming language, supporting structured programming, lexical variable scope and recursion, while a static type system prevents many unintended operations. By design, C provides constructs that map efficiently to typical machine instructions, and it has therefore found lasting use in applications that were previously coded in assembly language. Such applications include operating systems, as well as various application software for computers ranging from supercomputers to embedded systems. C was originally developed at Bell Labs by Dennis Ritchie, between 1972 and 1973. It was created to make utilities running on Unix. Later, it was applied to re-implementing the kernel of the Unix operating system. During the 1980s, C gradually gained popularity. Nowadays, it is one of the most widely used programming languages, with C compilers from various vendors available for the majority of existing computer architectures and operating systems. C has been standardized by the American National Standards Institute (ANSI) since 1989 (see ANSI C) and subsequently by the International Organization for Standardization (ISO).

C is an imperative procedural language. It was designed to be compiled using a relatively straightforward compiler, to provide low-level access to memory, to provide language constructs that map efficiently to machine instructions, and to require minimal runtime support. Despite its low-level capabilities, the language was designed to encourage cross-platform programming. A standards-compliant C program that is written with portability in mind can be compiled for a wide variety of computer platforms and operating systems.

CHAPTER 4

FLOWCHART

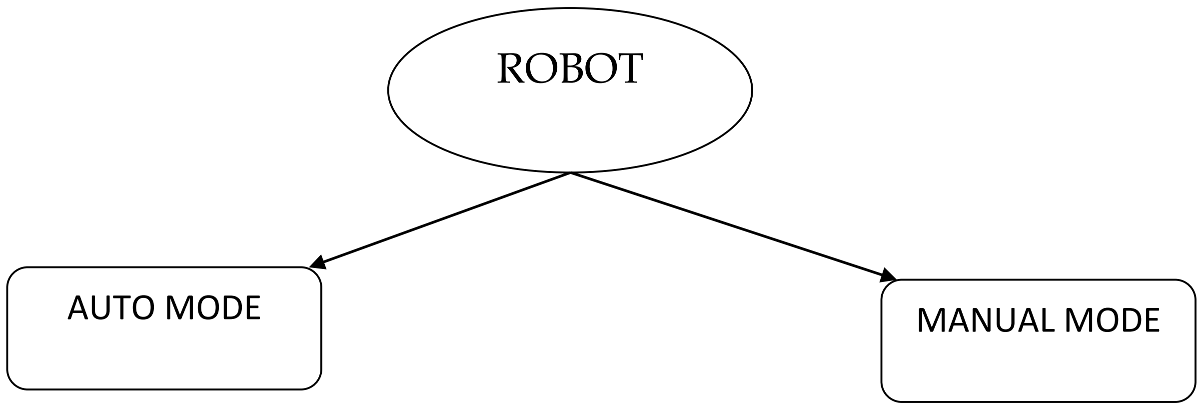

Fig4.1: Flowchart of hexapod

MANUAL MODE:

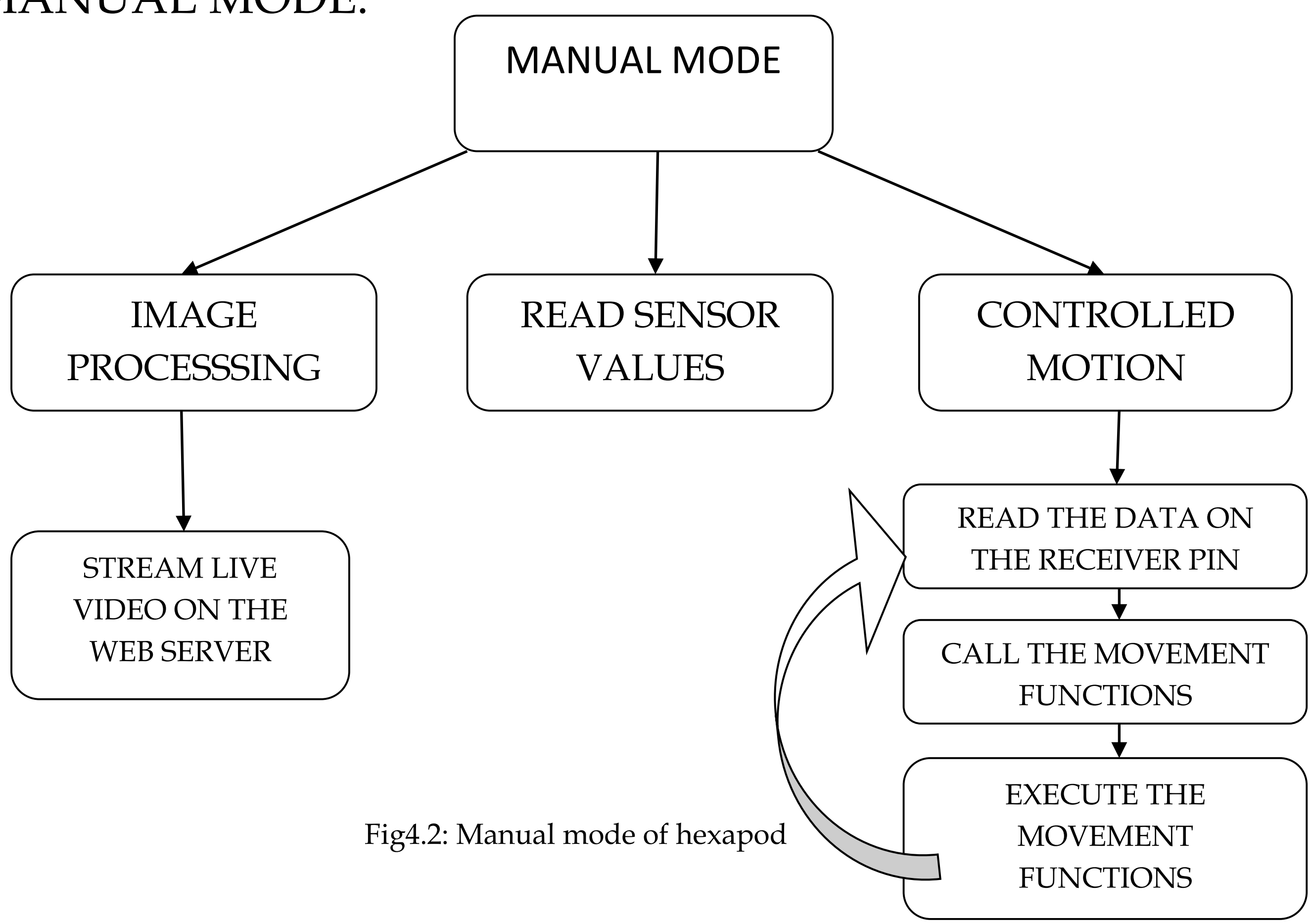

Fig4.2: Manual mode of hexapod

AUTO MODE:

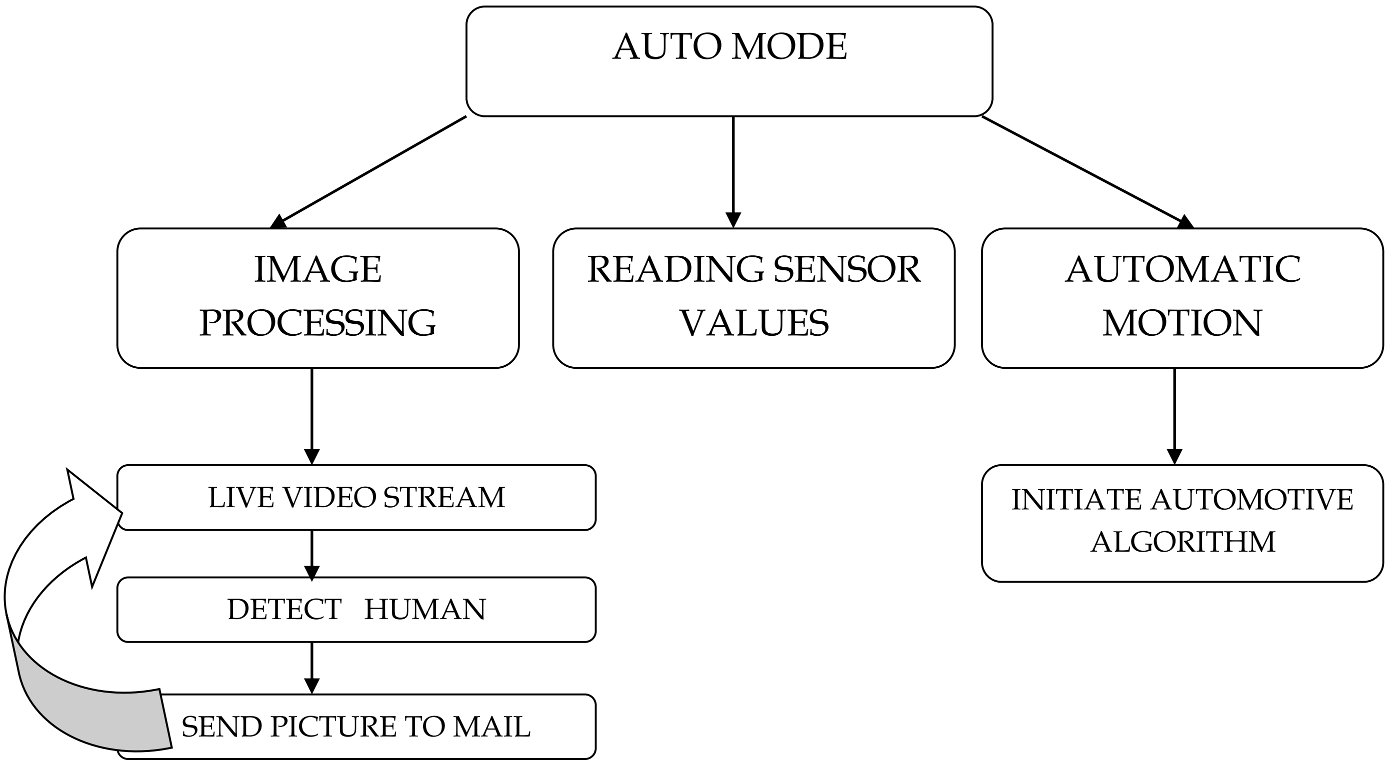

Fig4.3: Auto mode of hexapod

The robot has two modes of motion:

1. Manual mode- In manual mode we can move the robot using a joystick and the live video would be streamed on an html page. The sensor values will be updated on the server. The controlled motion will work through wireless remote control.
2. Auto mode- In auto mode we, the image processing is being done where a live video is being is being streamed on a web page and if a human is detected it captures a picture and mails it.

In manual mode the robot is controlled by RF tx-rx module that is the transmitter is connected to the MH joystick module and this module has 8 functions that is to move front, back, left, right , turn right ,turn left, body movement up and down. Once this is transmitted the Rx module is connected to an atmega32p which consists of the code of movements and that gets executed. On the Hexapod sensors such as gas and temperature sensors are connected. They read the temperature and content of CO in the atmosphere it is in and sends those value to pi's terminal.

This is done by first calibrating the sensors individually and noting down the maximum value it can detect and then these sensors which is lm35 (temperature sensor) and mq2 (Gas sensor) are connected to atmega 328 these values are sent to pi through i2c connection. This helps the Rescuers by giving them an idea about the environment which they will be going and gives them a heads up in preparing for the consequence. On pi's terminal the sensors value and even the image of that place it is in can be viewed that is the camera used is pi camera which works on opencv tool and it detects the number of people sends a mail to a pre referred email. This is done by narrowing down the detecting objects to only humans. Once it finds humans it makes a pink box around them and displays the amount of matching with its pre fed data.

In auto mode the sensors does the same work and follows the sample template as in manual mode. The camera also does a similar function but the change is in auto mode the hexapod first moves a step front until it detects an obstacle which is achieved by an ultrasonic sensor. If there is any obstacle it is programed to go write, if again happens to find obstacle then left else to continue in that direction. This Hexapod uses 18 SG90 1.2kg/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 1.2 kg/cm torque with the operating speed of 0.3/60 degrees. Servo controller is used to control 18 servos.

CHAPTER 5

RESULTS AND DISCUSSIONS

The outcome of this project are:

- Hexapod - a six legged robot is built with the help of 3d printer through which the body and the leg parts were printed. 13 pieces were assembled to form one leg of the hexapod. Such 6 legs were built. For assembling Screws of 2mm diameter and 6mm, 8mm, 12mm long were used. This was then attached to the body which is also called chassis, its shape is in a form of box so the controller and Batteries can be placed.

Fig5.1: Structure of Hexapod

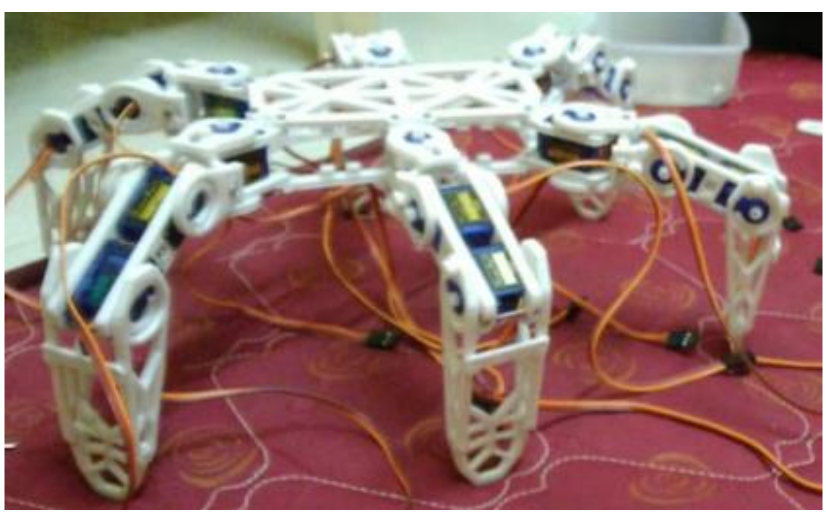

Fig5.2: Final model of hexapod

- Temperature sensor value is read from arduino and this data is sent to raspberry pi's terminal through i2c connection. This` sensors could have been directly connected to pi but they draw more current and camera which is connected to pi wouldn't get enough current. Connection could be done through serial and through usb. As zero w pi's usb port is too small that was ruled out and in serial communication before dumping the code rx-tx connection has to be taken out and that requires relay which makes the bot heavy. So the best option is i2c to which more sensors if required can be added and multiple master and slaves can be detected too.

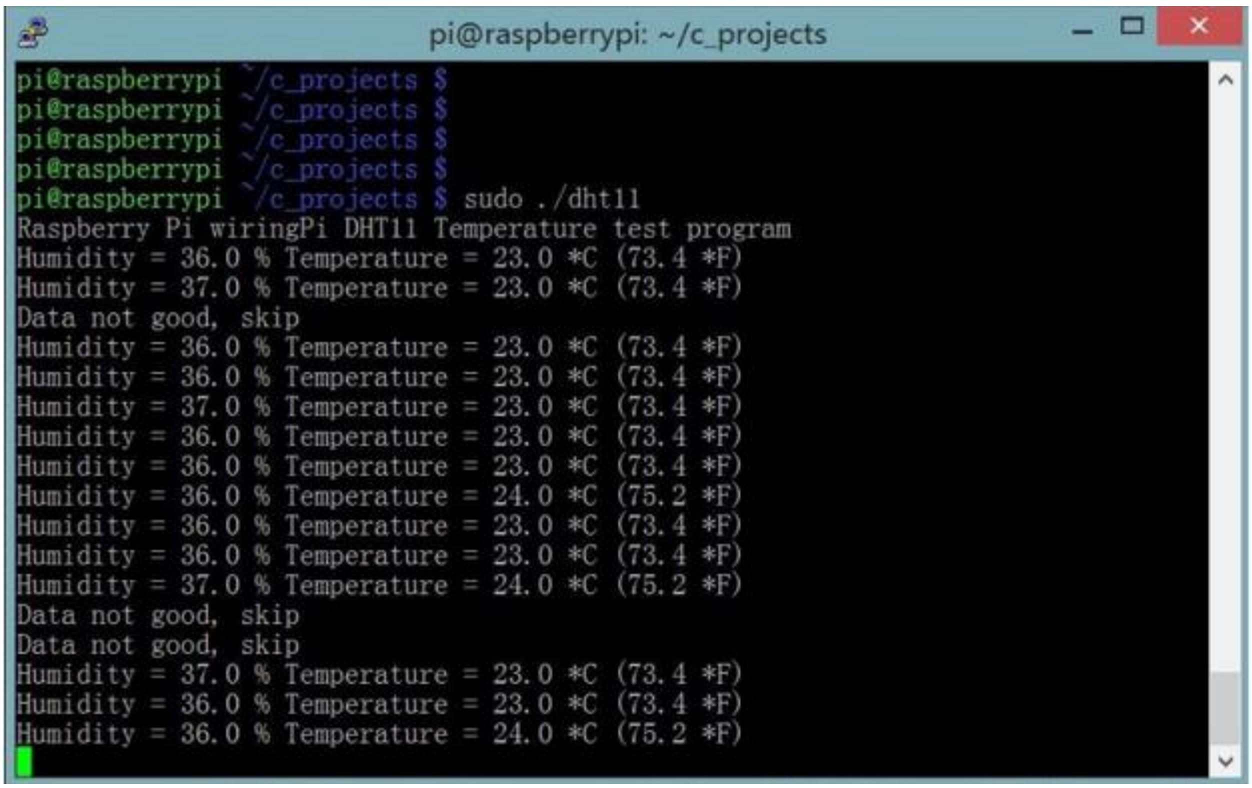

Fig5.3: Temperature sensor values from arduino to Raspberry pi

Fig5.4: Manual controller

- Hexapod works on two modes one on manual and auto mode. The auto mode detects for the obstacle if it finds any in front it takes left if again it finds any obstacles then it turns right when it won't find any obstacle it takes a step forward in that direction. In manual mode there are two controllers which sends instructions to the hexapod to move front, back, right and left which is sent by an rf module of 433mhz.

Fig5.5: Camera detecting humans

- Initially camera could take pics so this was taken forward to live streaming during auto mode and taking pics during manual mode. It detects the number of people and even sends a mail of the live streamed video. It sends frame 1ms so it’s a bit late which can be improved by webcam but due to cost issue pi cam v2 is used

CHAPTER 6

APPLICATIONS, ADVANTAGES AND LIMITATIONS

Hexapod robots have a large number of real life applications, from crossing potentially dangerous terrain to carrying out search and rescue operations in hazardous and unpredictable disaster zones. They have a number of advantages over wheeled, quadruped or bipedal robots:

- 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 does not increase walking speed.
- 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.
- 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.
- If any leg fails it can still walk with the rest of the leg if properly oriented. Considering this project it's a future scope but hexapod opens a door to this type of orientation which cannot be replicated by wheeled robots.

The only disadvantage of Hexapod is during its movement the noise from servo makes it difficult to be used as spy robots and even on sand terrain it leaves its trace and consumes more power to walk on such area.

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 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 average rate of efficiency when compared to other such robots in related fields. To control the spider-bot we have successfully made use of ps2 controller and have implemented this through radio frequency module and is also automated with the help of ultrasonic sensor. 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 and can display gas and temperature value in ppm and degree Celsius and can also send a mail of live streaming video. 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.

7.2 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. A better version of camera would give a better quality of image and a voice module of higher range would help in detecting the affected people when camera would go off or dies. A bulb or IR module can be used to detect people in dark condition but all of this should be done keeping the weight and power consumption of the hexapod in consideration.

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