CHAPTER 1

INTRODUCTION

1.1 General:

A **humanoid robot** is a robot with its body shape built to resemble the **human body**. The design may be for functional purposes, such as interacting with human tools and environments, for experimental purposes, such as the study of bipedal locomotion (**Bipedalism** is a form of terrestrial locomotion where an organism moves by means of its two rear limbs or legs. An animal or machine that usually moves in a **bipedal** manner is known as a **biped**), or for other purposes. In general, humanoid robots have a torso, a head, two arms, and two legs, though some forms of humanoid robots may model only part of the body, for example, from the waist up. Some humanoid robots also have heads designed to replicate human facial features such as eyes and mouths. Androids (An **android** is a humanoid robot or synthetic organism designed to look and act like a human, especially one with a body having a flesh-like resemblance) are humanoid robots built to aesthetically resemble humans.

The development of a humanoid robot in the collaborative research Centre 588 has the objective of creating a machine that closely cooperates with humans. The collaborative research centre 588 (SFB588) "Humanoid Robots – learning and cooperating multi-modal robots" was established by the German Research Foundation (DFG) in Karlsruhe in May 2000. The SFB588 is a cooperation of the University of Karlsruhe, the Forschungs zentrum Karlsruhe (FZK), the Research Center for Information Technologies (FZI) and the Fraunhofer Institute for Information and Data Processing (IITB) in Karlsruhe.

In this project, scientists from different academic fields develop concepts, methods and concrete mechatronic components and integrate them into a humanoid robot that can share its working space with humans. The long-term target is the interactive cooperation of robots and humans in complex environments and situations. For communication with the robot, humans should be able to use natural communication channels like speech, touch or gestures. The demonstration scenario chosen in this project is a household robot for various tasks in the kitchen.

Humanoid robots are still a young technology with many research challenges. Only few humanoid robots are currently commercially available, often at high costs. Physical prototypes of robots are needed to investigate the complex interactions between robots and humans and to integrate and validate research results from the different research fields involved in humanoid robotics. The development of a humanoid robot platform according to a special target system at the beginning of a research project is often considered a time consuming hindrance. In this article a process for the efficient design of humanoid robot systems is presented. The goal of this process is to minimize the development time for new humanoid robot platforms by including the experience and knowledge gained in the development of humanoid robot components in the collaborative research centre 588.

Weight and stiffness of robot components have a significant influence on energy efficiency, operating time, safety for users and the dynamic behavior of the system in general. The finite element based method of topology optimization gives designers the possibility to develop structural components efficiently according to specified loads and boundary conditions without having to rely on coarse calculations, experience or intuition. The design of the central support structure of the upper body of the humanoid robot ARMAR III is an example for how topology optimization can be applied in humanoid robotics. Finally the design of the upper body of the humanoid ARMAR III is presented in detail.

1.2 Purpose:

Humanoid robots are now used as a research tool in several scientific areas.

Researchers need to understand the human body structure and behaviour (biomechanics) to build and study humanoid robots. On the other side, the attempt to the simulation of the human body leads to a better understanding of it. Human cognition is a field of study which is focused on how humans learn from sensory information in order to acquire perceptual and motor skills. This knowledge is used to develop computational models of human behaviour and it has been improving over time.

Although the initial aim of humanoid research was to build better orthotics and **prosthesis** for human beings, knowledge has been transferred between both disciplines. A few examples are: powered leg prosthesis for neuromuscular impaired, ankle-foot orthotics, biological realistic leg prosthesis and forearm prosthesis.

Besides the research, humanoid robots are being developed to perform human tasks like personal assistance, where they should be able to assist the sick and elderly, and dirty or dangerous jobs. Regular jobs like being a receptionist or a worker of an automotive manufacturing line are also suitable for humanoids. They are becoming increasingly popular for providing entertainment too. For example, Ursula, a female robot, sings, play music, dances, and speaks to her audiences at Universal Studios. Several Disney attractions employ the use of animations, robots that look, move, and speak much like human beings, in some of their theme park shows. These animations look so realistic that it can be hard to decipher from a distance whether or not they are actually human. Although they have a realistic look, they have no cognition or physical autonomy. Humanoid robots, especially with artificial intelligence algorithms, could be useful for future dangerous and/or distant space exploration missions, without having the need to turn back around again and return to Earth once the mission is completed.

1.3 Introduction of ALUMINA (ALUMINOID):

This robot is a professional small humanoid robot consist of full aluminum parts, smooth surface with smooth edges not hurting hands, the metal is unbleached, beautiful and durable.

The High Torque Standard Servo Motor with Dual Ball Bearing and Metal Gears. Provides 14kg/cm at 4.8V and 16kg/cm at 6V. Replacement for HS-645MG.

Arduino Uno R3 based USB 18 Servo Controller is ideal for making Autonomous and PC based systems which run over Hobby Servo motors. The software helps to develop the complex sequences in real time on the hardware like robotic arms, walkers, bipeds and any other servo controlled system. It also generates Arduino based code for the developed sequence which can be deployed on the controller on board thereby making the robot autonomous.

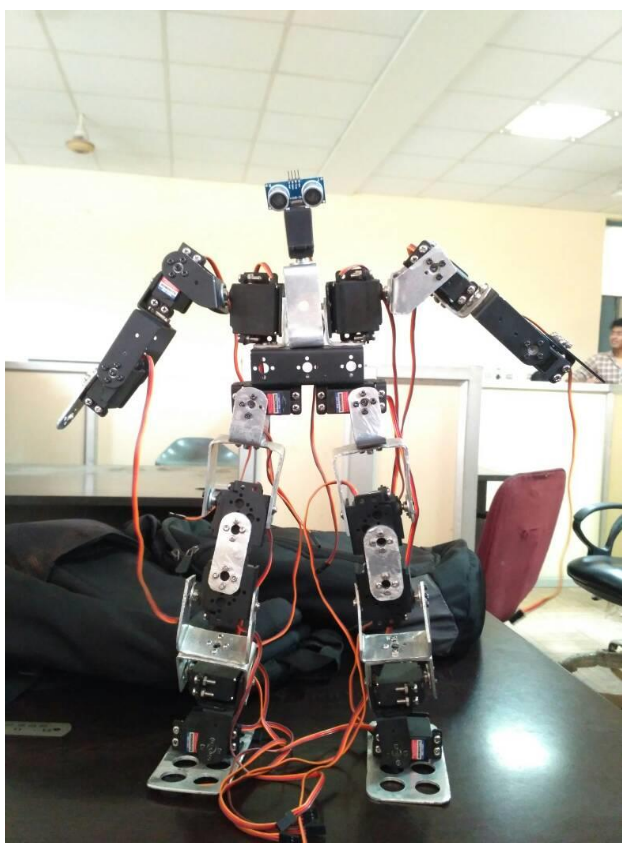

Fig: - 1.1 (ALUMINA)

1.4 Literature Overview:

- Lie Zi described about automation 250BC on which Robots works.
- Greek mathematician Hero of Alexandria described a machine to automatically pour wine for party guests in 50AD.
- Al-Jazari described a band made up of humanoid automata in 1206.
- Leonardo da Vinci designs a humanoid automaton that looks like an armoured knight, known as Leonardo's robot in 1495.
- Isaac Asimov formulates the Three Laws of Robotics, used in his robot science fiction storiess in 1941 – 42.
- Honda developed P1 (Prototype Model 1) through P3, an evolution from E series, with upper limbs in 1993.
- Honda creates its 11th bipedal humanoid robot, able to run ASIMO in 2000 and further amendments were done till now.
- iCub, a biped humanoid open source robot for cognition research 2006 (it is actually a spoiled baby having height 100cm & Weight 23kg).

1.5 Laws of Humanoid Robot:

- **Zeroth Law**: - "A Robot must not injure humanity although in action, allow humanity come to harm".
- **First Law**: - "A Robot must not harm a human body although in action, allow one to come to harm".
- **Second Law**: - "A Robot must always obey human being, unless it is in conflict with a higher order law".
- **Third Law**: - "A Robot must protect itself from harm unless that it is conflict with a higher order law".

1.6 Demand for efficient design of humanoid robots:

Industrial robots are being used in many manufacturing plants all over the world. This Product class has reached a high level of maturity and a broad variety of robots for special Applications is available from different manufacturers. Even though both kind of robots, industrial and humanoid, manipulate objects and the same types of components, e.g. harmonic drive gears, can be found in both types, the target systems differ significantly.

Industrial robots operate in secluded environments strictly separated from humans. They perform a limited number of clearly defined repetitive tasks. These machines and the tools they use are often designed for a special purpose. High accuracy, high payload, high velocities and stiffness are typical development goals.

Humanoid robots work together in a shared space with humans. They are designed as universal helpers and should be able to learn new skills and to apply them to new, previously unknown tasks. Humanlike kinematics allows the robot to act in an environment originally designed for humans and to use the same tools as humans in a similar way. Human appearance, behavior and motions which are familiar to the user from interaction with peers make humanoid robots more predictable and increase their acceptance. Safety for the user is a critical requirement. Besides energy efficient drive technology, a lightweight design is important not only for the mobility of the system but also for the safety of the user as a heavy robot arm will probably cause more harm in case of an accident than a light and more compliant one. Due to these significant differences, much of the development knowledge and product knowledge from industrial robots cannot be applied to humanoid robots.

The multi-modal interaction between a humanoid robot and its environment, the human users and eventually other humanoids cannot fully be simulated in its entire complexity. To investigate these coherences, actual humanoid robots and experiments are needed. Currently only toy robots and a few research platforms are commercially available, often at high cost. Most humanoid robots are designed and built according to the special focus or goals of a particular research project and many more will be built before mature and standardized robots will be available in larger numbers at lower prizes. Knowledge gained from the development of industrial robots that have been used in industrial production applications for decades cannot simply be reused in the design of humanoid robots due to significant differences in the target systems for both product classes. A few humanoid robots have been developed by companies, but not much is known about their design process and seldom is there any information available that can be used for increasing the time and cost efficiency in the development of new improved humanoid robots. Designing a humanoid robot is a long and iterative process as there are various interactions between e.g. mechanical parts and the control system. The goal of this article is to help shortening the development time and to reduce the number of iterations by presenting a process for efficient design, a method for optimizing light yet stiff support structures and presenting the design of the upper body of the humanoid robot ARMAR III.

1.7 Design process for humanoid robot modules:

The final goal of the development of humanoid robots is to reproduce the capabilities of a human being in a technical system. Even though several humanoid robots already exist and significant effort is put into this research field, we are still very far from reaching this goal.

Humanoid robots are complex systems which are characterized by high functional and spatial integration. The design of such systems is a challenge for designers which cannot yet be satisfactorily solved and which is often a long and iterative process. Mechatronic systems like humanoid robots feature multi-technological interactions, which are displayed by the existing development processes, e.g. in the VDI guideline 2206 "design methodology for mechatronics systems" (VDI 2004), in a rather general and therefore abstract way.

More specific development processes help to increase the efficiency of the system development. Humanoid robots are a good example for complex and highly integrated systems with spatial and functional interconnections between components and assembly groups. They are multi-body systems in which mechanical, electronic, and information-technological components are integrated into a small design space and designed to interact with each other.

1.8 Requirements:

The demands result from the actions that the humanoid robot is supposed to perform. The robot designed in the SFB 588 will interact with humans in their homes, especially in the kitchen. It will take over tasks from humans, for example loading a dish washer. For this task it is not necessary, that the robot can walk on two legs, but it has to feature kinematics, especially in the arms, that enable it to reach for objects in the human surrounding. In addition, the robot needs the ability to move and to hold objects in its hand (Schulz, 2003).

1.9 Subdivision of the total system:

The development of complex systems requires a subdivision of the total system into manageable partial systems and modules (Fig. 1). The segmentation of the total system of the humanoid robot is oriented on the interactions present in a system. The total system can be divided into several subsystems. The relations inside the subsystems are stronger compared to the interactions between these subsystems. One partial system of the humanoid robot is e.g. the upper body with the subsystem arm. The elements in the lowest level in the hierarchy of subsystems are here referred to as modules. In the humanoid robot's arm, these modules are hand-, elbow-, and shoulder joint. Under consideration of the remaining design, these modules can be exchanged with other modules that fulfil the same function. The modules again consist of function units, as e.g. the actuators for one of the module's joints. The function units themselves consist of components, here regarded as the smallest elements. In the entire drive, these components are the actuator providing the drive power and the components in the drive train connected in a serial arrangement, e.g. gears, drive belt, or worm gear transferring the drive power to the joint.

1.10 Selection and data base:

Many components used in such highly integrated systems are commonly known, commercially available and do not have to be newly invented. However, a humanoid robot consists of a large number of components, and for each of them there may be a variety of technical solutions. This leads to an overwhelming number of possible combinations, which cannot easily be overseen without help and which complicates an efficient target-oriented development. Therefore it is helpful to file the components of the joints, actuators and sensors as objects in an object-oriented classification. It enables a requirement-specific access to the objects and delivers information about possible combinations of components.

1.11 Development sequence:

The development sequence conforms to the order in which a component or information has to be provided for the further procedure. The development process can be roughly divided into two main sections. The first section determines the basic requirements for the total system, which have to be known before the design process. This phase includes primarily two iterations: In the first iteration, the kinematics of the robot is specified according to the motion space of the robot and the kinematics again has to be describable in order to be controllable. In the second iteration, the control concept for the robot and the general possibilities for operating the joints are adjusted to the requirements for the desired dynamics of the robots. The second sector is the actual design process.

The sequence in which the modules are developed is determined by their position in the serial kinematics of the robot. This means that e.g. in the arm, first the wrist, the elbow joint and then finally the shoulder joint are designed.

Since generally all modules have a similar design structure, they can be designed according to the same procedure. The sequence in this procedure model is determined by the interactions between the function units and between the components. The relation between the components and the behavior of their interaction in case of a change of the development order can be displayed graphically in a design structure matrix (Browning, 2001). Iterations, which always occur in the development of complex systems, can be limited by early considering the properties of the components that are integrated at the end of the development process. One example is the torque measurement in the drive train.

In the aforementioned data base, specifications of the components are given like the possibility for a component of the drive train to include some kind of torque measurement. It ensures that after the assembly of a drive train, a power measurement can be integrated.

1.12 Development of a shoulder joint:

The development of a robot shoulder joint according to this approach is exemplarily described in the following paragraphs. For the tasks that are required from the robot, it is sufficient if the robot is able to move the arm in front of its body. These movements can be performed by means of a ball joint in the shoulder without an additional pectoral girdle. In the available design space, a ball joint can be modelled with the required performance of the actuators and sensors as a serial connection of three single joints. The axes of rotation of these joints intersect at one point. A replacement joint is used which consists of a roll joint, a pitch joint, and then again of another roll joint. The description of the kinematics can only be clarified together with the entire arm, which requires limiting measures, especially if redundant degrees of freedom exist (Asfour, 2003).

Information about the mass of the arm and its distribution are requirements for the design of the shoulder joint module. In addition, information about the connection of elbow and shoulder has to be available. This includes the components that are led from the elbow to or through the shoulder, as e.g. cables or drive trains of lower joints. The entire mechatronic system can be described in an abstract way by the object-oriented means of SysML (System Modelling Language) (SysML, 2005) diagrams, with which it is possible to perform a system test with regard to compatibility and operational reliability. It enables the representation of complex systems at different abstraction levels. Components that are combined in this way can be accessed in the aforementioned classification, which facilitates a quick selection of the components that can be used for the system. In addition, it makes a function design model possible at every point of the development.

In the development of the shoulder module, at first the function units of the joints for the three rotating axes are selected according to the kinematics. Then, the function unit drive, including the actuators and the drive trains, are integrated. Hereafter, the sensors are selected and integrated. In order to prevent time consuming iterations in the development, 6 Humanoid Robots, New Developments the components of the total system, integrated at a later stage, are already considered from the start with regard to their general requirements for being integrated. Examples for this are the sensors, which can then be assembled without problems since it is made sure that the already designed system offers the possibility to integrate them. During the next step the neighboring module is designed. Information about the required interface of the shoulder and the mass of the arm and its distribution are given to the torso module.

CHAPTER 2

PARTS OF HUMANOID ROBOT (ALUMINA)

- Arduino Uno R3 based Bluetooth + USB 18 Servo Controller
- Lithium Polymer (Li-Po) Rechargeable Battery 7.4V 1500mAH 20C
- Metal Gear Standard Servo Economy
- Multipurpose Aluminum Standard Servo Bracket
- Short U Shape Aluminum Servo Bracket
- Long U Aluminum Servo Bracket
- Oblique U Shape Aluminum Servo Bracket
- Interconnect Aluminum Servo Bracket
- L Shaped Interconnect Servo Bracket
- Large U Beam Aluminum Servo Bracket
- Robot feet Aluminum Servo Bracket
- Miniature Ball Radial Bearing
- Metal Horn for Servo 25T
- Screw and screw cap set
- Ultrasonic sensor

2.1 Arduino Uno R3 based Bluetooth + USB 18 Servo Controller:

Arduino Uno R3 based Bluetooth + USB 18 Servo Controller is variant of our USB servo controller for wireless applications. This device can be operated wirelessly on Bluetooth or through USB connection. This also means that it can receive signals from any devices like PCs, Laptops, Mobile phones with Bluetooth and Java, Android and windows smartphones etc. Arduino Uno R3 based Bluetooth + USB 18 Servo Controller is ideal for making Autonomous and PC based systems which run over Hobby Servo motors. The software helps to develop the complex sequences in real time on the hardware like robotic arms, walkers, bipeds and any other servo controlled system. It also generates Arduino based code for the developed sequence which can be deployed on the controller on board thereby making the robot autonomous.

The compact module measures just 80 mm X 47 mm, and it offers both USB and asynchronous serial (UART) connectivity. No features are compromised for the small size, as our USB controller supports independent speed and range settings for each servo while delivering 0.5-microsecond resolution for smooth output across its broad output pulse range of 500 through 2500 microseconds.

Servo motor configurations like Centre, Offsets, Maximum, Minimum, servo directions and speed can be individually set. The servo configurations set can be saved to the on board controller. Additionally servo sequence functions can be created through software itself. Moreover Groups of servos can be rotated simultaneously for creating accurate and easy angular movements.

The board holds two chips configured as Master and Slave. Major servo motor positioning and servo related calculations are done by the salve chip. The Master chip i.e. Atmega 328 which is preloaded with Arduino Uno boot loader communicates with the software serially and send commands to the slave chip through I2C making the Master CPU available for other tasks. Various sensor and wireless devices like TSOP-1738 etc can be interfaced with the master making the robot wirelessly controlled.

When installed, the USB servo controller appears as a serial port to the host computer. Programming is therefore as easy as sending commands to a serial port, and as an added benefit, the servo controller is compatible with many existing programs. The servo controller is compatible with USB 1.1 and USB 2.0 standards, and driver support will initially be available for Windows 98 through Windows 8.

With its Bluetooth, USB and UART interface, the servo controller can at first be used with a PC to quickly develop motion sequences with the advantage of graphical interfaces and quick program changes.

This Robokits Arduino Uno R3 based USB 18 Servo Controller provides one of the most simple, small, and economical alternatives to standard serial servo controllers.

Fig:- 2.1 (ARDUNIO CIRCUIT BOARD)

2.2 Specifications of Arduino circuit:

- Bluetooth interface for wireless control of robots
- Controls 18 hobby servos from PC and Microcontroller
- USB interface
- Comes Pre-loaded Arduino Uno boot loader
- Software exports servo sequences to Arduino Uno for running servo sequences
- Independent range setting for each servo
- Independent offset, Maximum, Minimum and Direction setting for each servo
- 0.5-microsecond resolution
- 50 Hz update rate

- Small size of 80 X 47 mm
- Plug and Play, Auto detection of hardware
- Easy to use software
- Servo sequencer with speed, delay, go to and many other features
- Home and neutral position setting
- Easy to install USB driver and Application software

2.3 Elements of Arduino Circuits:

- USB Connector for connecting USB Cable to PC
- Power Connector 5 - 7.5 V DC
- Switch for Switching Between Bluetooth and USB Mode.
- Bluetooth Module (Only with RKI - 1252)
- Bluetooth Status LED
- LED on Pin 13 of Circuit Board as in Arduino
- Reset Switch

2.3.1 Power (USB / Barrel Jack):

Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from your computer or a wall power supply (like this) that is terminated in a barrel jack. The USB connection is also how you will load code onto your Arduino board.

NOTE: Do NOT use a power supply greater than 20 Volts as you will overpower (and thereby destroy) you're Arduino. The recommended voltage for most Arduino models is between 6 and 12 Volts

2.3.2 Pins (5V, 3.3V, GND, Analog, Digital, PWM, and AREF):

The pins on your Arduino are the places where you connect wires to construct a circuit probably in conjunction with a breadboard and some wire. They usually have black plastic 'headers' that allow you to just plug a wire right into the board. The Arduino has several different kinds of pins, each of which is labeled on the board and used for different functions.

- **GND**: Short for ‘Ground’. There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- **5V (4) & 3.3V**: As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run happily off of 5 or 3.3 volts.
- **Analog**: The area of pins under the ‘Analog In’ label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor (like a temperature sensor) and convert it into a digital value that we can read.
- **Digital**: Across from the analog pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED).
- **PWM**: You may have noticed the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM).
- **AREF**: Stands for Analog Reference. Most of the time you can leave this pin alone. It is sometimes used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

2.3.3 Reset Button:

Just like the original Nintendo, the Arduino has a reset button. Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. This can be very useful if your code doesn’t repeat, but you want to test it multiple times. Unlike the original Nintendo however, blowing on the Arduino doesn’t usually fix any problems.

2.3.4 Power LED Indicator:

Just beneath and to the right of the word “UNO” on your circuit board, there’s a tiny LED next to the word ‘ON’. This LED should light up whenever you plug your Arduino into a power source. If this light doesn’t turn on, there’s a good chance something is wrong. Time to re-check your circuit.

2.3.5 TX RX LEDs:

TX is short for transmit, RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication. In our case, there are two places on the Arduino UNO where TX and RX appear – once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs. These LEDs will give us some nice visual indications whenever our Arduino is receiving or transmitting data (like when we're loading a new program onto the board).

2.3.6 Main IC:

The black thing with all the metal legs is an IC, or Integrated Circuit. Think of it as the brains of our Arduino. The main IC on the Arduino is slightly different from board type to board type, but is usually from the ATmega line of IC's from the ATMEL Company. This can be important, as you may need to know the IC type (along with your board type) before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC. If you want to know more about the difference between various IC's, reading the datasheets is often a good idea.

2.3.7 Voltage Regulator:

The voltage regulator is not actually something you can (or should) interact with on the Arduino. But it is potentially useful to know that it is there and what it's for. The voltage regulator does exactly what it says – it controls the amount of voltage that is let into the Arduino board. Think of it as a kind of gatekeeper; it will turn away an extra voltage that might harm the circuit. Of course, it has its limits, so don't hook up your Arduino to anything greater than 20 volts.

2.4 Specifications of Microcontrollers Basically used in Arduino Circuit:

- ATmega328 (used on most recent boards)

Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6 (DIP) or 8 (SMD)
DC Current per I/O Pin	40 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1KB

- ATmega168 (used on most Arduino Diecimila and early Duemilanove)

Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6 (DIP) or 8 (SMD)
DC Current per I/O Pin	40 mA
Flash Memory	16 KB
SRAM	1 KB
EEPROM	512 bytes

- ATmega8 (used on some older board)

Digital I/O Pins	14 (of which 3 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
Flash Memory	8 KB
SRAM	1 KB
EEPROM	512 bytes

2.5 Properties & Specifications of Pins Uses in Arduino Circuit:

2.5.1 Digital Pins:

The digital pins on an Arduino board can be used for general purpose input and output via the Pin Mode, Digital Read, and Digital Write commands. Each pin has an internal pull-up resistor which can be turned on and off using Digital Write (a value of HIGH or LOW, respectively) when the pin is configured as an input. The maximum current per pin is 40 mA.

2.5.2 Serial: 0 (RX) and 1 (TX): Used to receive (RX) and transmit (TX) TTL serial data. On the Arduino Diecimila, these pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip. On the Arduino BT, they are connected to the corresponding pins of the WT11 Bluetooth module. On the Arduino Mini and LilyPad Arduino, they are intended for use with an external TTL serial module (e.g. the Mini-USB Adapter).

2.5.3 External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the Attach Interrupt function for details.

2.5.4 PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the Analog Write function. On boards with an ATmega8, PWM output is available only on pins 9, 10, and 11.

2.5.5 BT Reset: 7. (Arduino BT-only) Connected to the reset line of the Bluetooth module.

2.5.6 SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

2.5.7 LED: 13. On the Diecimila and LilyPad, there is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

2.5.8 Analog Pins:

The analog input pins support 10-bit analog-to-digital conversion (ADC) using the Analog Read function. Most of the analog inputs can also be used as digital pins: analog input 0 as digital pin 14 through analog input 5 as digital pin 19. Analog inputs 6 and 7 (present on the Mini and BT) cannot be used as digital pins.

2.5.9 Power Pins:

- **VIN (sometimes labelled "9V"):** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin. Note that different boards accept different input voltages ranges, please see the documentation for your board. Also note that the LilyPad has no VIN pin and accepts only a regulated input.
- **5V**: The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3**: (Diecimila-only) A 3.3 volt supply generated by the on-board FTDI chip.
  GND. Ground pins.

2.6 Connecting servos to Controller through Arduino:

Table 2.1:- General wire colour description for servo

All standard servo motors have 3 wire connector for connecting to any device. 2 Wires are for Power that is VDD and GND, VDD is +4.8V to 6V (Max 7V) GND is for Ground. General wire colours are as follow:

Signal	VDD (+4.8 V DC to 7 V DC)	GND
White	Red	Black
Orange	Red	Brown
Yellow	Red/Orange	Black/Brown
Orange	Red	Black
Blue	Red	Black

2.6.1 Arduino UNO: The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

2.7 Lithium Polymer (Li-Po) Rechargeable Battery 7.4V 1500mAH 20C:

Lithium-Polymer (Li-Po) Battery for robotic applications. It can give great instantaneous discharge current up to 30A. Very light weight and small size compared to Ni-Cd, Ni-MH and Lead acid batteries. Very long life without losing charging capacity. Weighs just 94 gm.

2.7.1 Precautions: Li-Ion batteries are very sensitive and can get damaged easily and permanently if not used properly. Charging batteries with non-standard chargers will ensure reduction in battery life and efficiency. We strongly recommend to charge battery with our chargers or only standard chargers designed to charge Li-Ion batteries. If the batteries are drained beyond their discharge capacity they will get heated and will get damaged permanently. Each battery is rated for discharge current. If the battery is rated at 2000mAH, 2C it means that it can discharge 4 Ampere (2000ma x 2) current at max. If the load is above

4A the battery will heat up and loose its efficiency to store charge over a period. Over discharging of battery may also create problem. If the voltage of battery reduces to 3.5V per cell (i.e. 10.5V or below for 12.4V battery) the battery is considered discharged. If still battery is connected the battery may get damaged.

Fig: - 2.2 (Lithium Polymer Battery)

2.7.2 Specifications:

- Very Small in size and weight compared to Ni-Cd, Ni-MH and Lead Acid Batteries
- Full Charge in 180 minutes with special charger
- Long life with full capacity for up to 1000 charge cycles
- 2X Li-Po 3.7V 1500mAh cells (2S1P)
- Low maintenance
- 94Grams Weight
- Volume: 7.2cm*3.4cm*1.7cm
- Discharge Current: 20*1500maH = 30Amp
- Max Charging Current: 1A

2.7.3 Compatible chargers:

- IMAX B6AC 5A Multipurpose Battery Charger
- IMAX B6 5A Multipurpose Battery Charger
- Li-Ion / Li-Po Intelligent Fast Charger for 2-3 Cell Battery

2.8 Metal Gear Standard Servo Economy of ALUMINA: High Torque Standard Servo Motor with Metal Gears. Provides 11kg/cm at 4.8V, 13.5kgcm at 6V and 16kg/cm at 7.2V.

2.8.1 Servomotor:

A **servo motor** is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through **servo mechanism**. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight packages. Doe to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor; the motor always rotates at full speed (or is stopped). This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models.

More sophisticated servomotors use optical rotary encoders to measure the speed of the output shaft and a variable-speed drive to control the motor speed. Both of these enhancements, usually in combination with a PID control algorithm, allow the servomotor to be brought to its commanded position more quickly and more precisely, with less overshooting.

2.8.2 Servo Mechanism:

It consists of three parts:

- Controlled device
- Output sensor
- Feedback system

It is a closed loop system where it uses positive feedback system to control motion and final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to reference output signal and the third signal is produces by feedback system. And this third signal acts as input signal to control device. This signal is present as long as feedback signal is generated or there is difference between reference input signal and reference output signal. So the main task of servomechanism is to maintain output of a system at desired value at presence of noises.

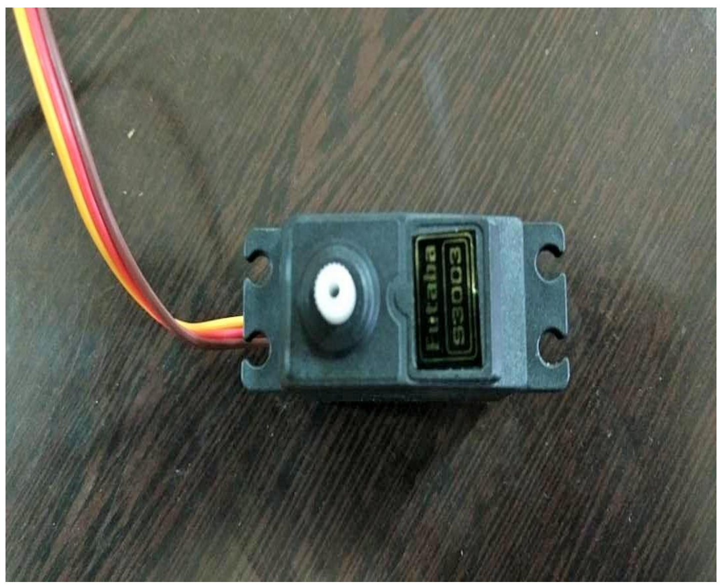

Fig: - 2.3 (Servomotor)

2.8.3 Working principle of Servo Motors:

A servo consists of a Motor (DC or AC), a potentiometer, gear assembly and a controlling circuit. First of all we use gear assembly to reduce RPM and to increase torque of motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now difference between these two signals, one comes from potentiometer and another comes from other source, will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Now motor shaft is connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating

2.8.4 Controlling Servo Motor:

All motors have three wires coming out of them. Out of which two will be used for Supply (positive and negative) and one will be used for the signal that is to be sent from the MCU.

Servo motor is controlled by PWM (Pulse with Modulation) which is provided by the control wires. There is a minimum pulse, a maximum pulse and a repetition rate. Servo motor can turn 90 degree from either direction form its neutral position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position, such as if pulse is shorter than 1.5ms shaft moves to 0° and if it is longer than 1.5ms than it will turn the servo to 180°.

Servo motor works on PWM (Pulse width modulation) principle, means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. Basically servo motor is made up of DC motor which is controlled by a variable resistor (potentiometer) and some gears. High speed force of DC motor is converted into torque by Gears. We know that WORK= FORCE X DISTANCE, in DC motor Force is less and distance (speed) is high and in Servo, force is High and distance is less. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle.

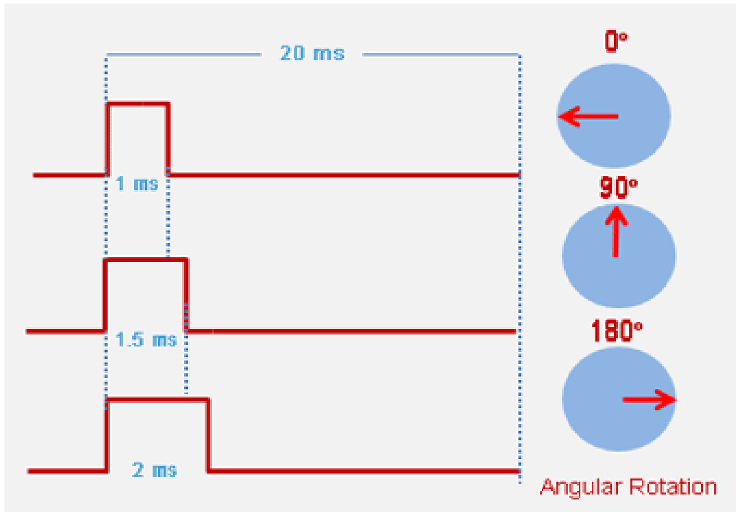

Fig: - 2.4 (Servomotor pulse)

Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree, depending on the manufacturing. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. Servo checks the pulse in every 20 milliseconds. Pulse of 1 ms (1 millisecond) width can rotate servo to 0 degree, 1.5ms can rotate to 90 degree (neutral position) and 2 ms pulse can rotate it to 180 degree.

All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume, if you are planning to use more than two servo motors a proper servo shield should be designed.

2.8.5 Servo Specifications of ALUMINA:-

- Required Pulse: 3-5 Volt Peak to Peak Square Wave
- Operating Voltage: 4.8-7.2 Volts
- Operating Temperature Range: -10 to +60 Degree C
- Operating Speed (4.8V): 0.18sec/60 degrees at no load
- Operating Speed (6V): 0.16sec/60 degrees at no load
- Operating Speed (7.2V): 0.14sec/60 degrees at no load
- Stall Torque (4.8V): 11kg/cm
- Stall Torque (6V): 13.5kg/cm
- Stall Torque (7.2V): 16kg/cm
- 360 Modifiable: Yes

- Potentiometer Drive: Indirect Drive
- Bearing Type: Double Ball Bearing
- Gear Type: All Metal Gears
- Connector Wire Length: 12"
- Dimensions: 1.6" x 0.8"x 1.4" (41 x 20 x 36mm)
- Weight: 56gm

2.8.6 Servo Controlling of Features of ALUMINA:-

- Bluetooth interface for wireless control of robots
- Controls 18 hobby servos from PC and Microcontroller
- USB interface
- Comes Pre-loaded Arduino Uno boot loader
- Software exports servo sequences to Arduino Uno for running servo sequences
- Independent range setting for each servo
- Independent offset, Maximum, Minimum and Direction setting for each servo
- 0.5-microsecond resolution
- 50 Hz update rate
- Small size of 80 X 47 mm
- Plug and Play, Auto detection of hardware
- Easy to use software
- Servo sequencer with speed, delay, go to and many other features
- Home and neutral position setting

2.9 Multipurpose Aluminum Standard Servo Bracket: -

Aluminum Pan and Tilt for horizontal surface, unassembled, Pan and Tilt Mount Servo Stand for Robot Clamp Claw, Servo bracket used in the shoulders and knees or other joint of humanoid robots, biped robots etc.

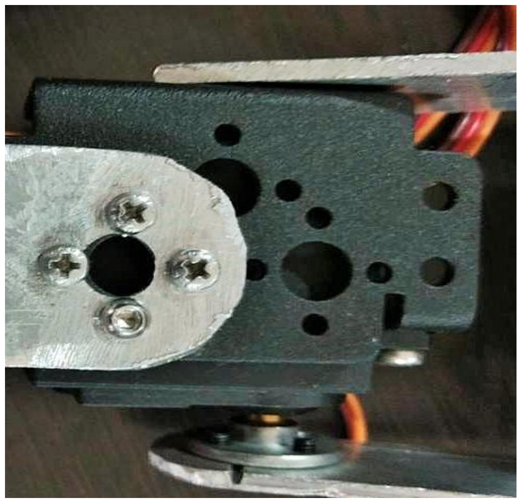

Fig: - 2.5 (Servo Bracket)

2.10 Short U Shape Aluminum Servo Bracket: -

This Short 'U' shaped brackets is designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns.

These brackets are light and strong and the numerous mounting holes enable you to easily make custom mechanisms using standard servo motors. Works great for making multi-axis joints for use in robot arms and legs.

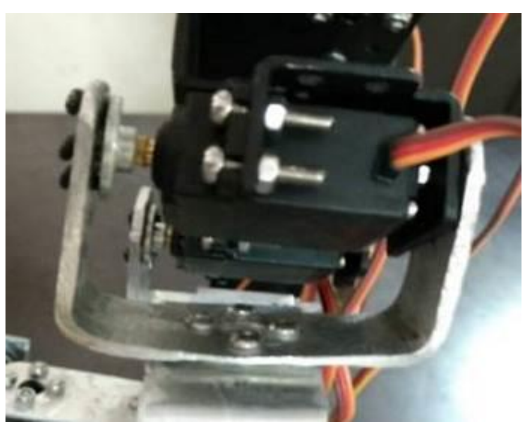

Fig: - 2.6 (Short U Clamp)

2.11 Long U Aluminum Servo Bracket: -

This Long 'U' shaped brackets is designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns.

These brackets are light and strong and the numerous mounting holes enable you to easily make custom mechanisms using standard servo motors. Works great for making multi-axis joints for use in robot arms and legs.

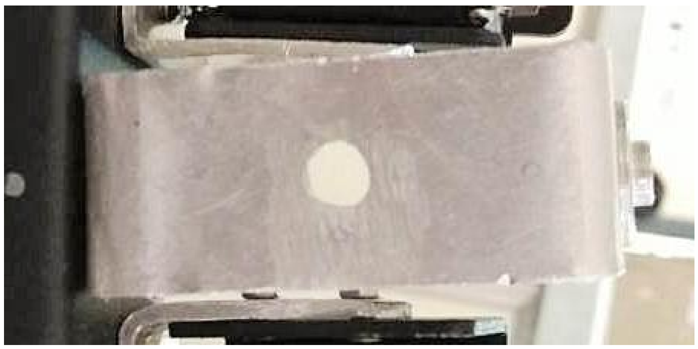

Fig: - 2.7 (Long U Clamp)

2.12 Oblique U Shape Aluminum Servo Bracket: -

This Oblique 'U' shaped brackets is designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns.

These brackets are light and strong and the numerous mounting holes enable you to easily make custom mechanisms using standard servo motors. Works great for making multi-axis joints for use in robot arms and legs.

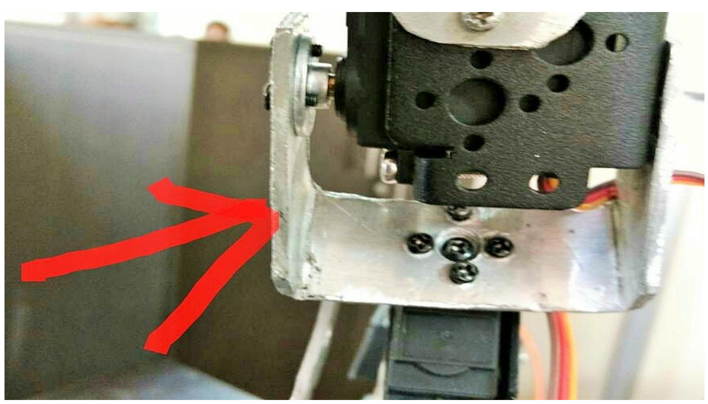

Fig: - 2.8 (Oblique Clamp for servo)

2.13 Interconnect Aluminum Servo Bracket: -

This Slotted Servo bracket straight board Mount designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns.

Fig: - 2.9 (Interconnected Aluminum Servo Bracket)

2.14 L Shaped Interconnect Servo Bracket: -

This 'L' shaped brackets is designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns. These brackets are light and strong and the numerous mounting holes enable you to easily make custom mechanisms using standard servo motors.

Fig: - 2.10 (L Shaped Interconnected Servo Bracket)

2.15 Large U Beam Aluminum Servo Bracket: -

This large 'U' shaped brackets is designed to fit most standard sized servos. This bracket is both lightweight and strong. Various holes are located on the bracket that fit most servo horns.

These brackets are light and strong and the numerous mounting holes enable you to easily make custom mechanisms using standard servo motors.

Fig: - 2.11 (Large U Beam Aluminum Servo Bracket)

2.16 Robot feet Aluminum Servo Bracket: -

This Robot foot base mount bracket is designed to fit most standard sized servos. This bracket is both lightweight and strong.

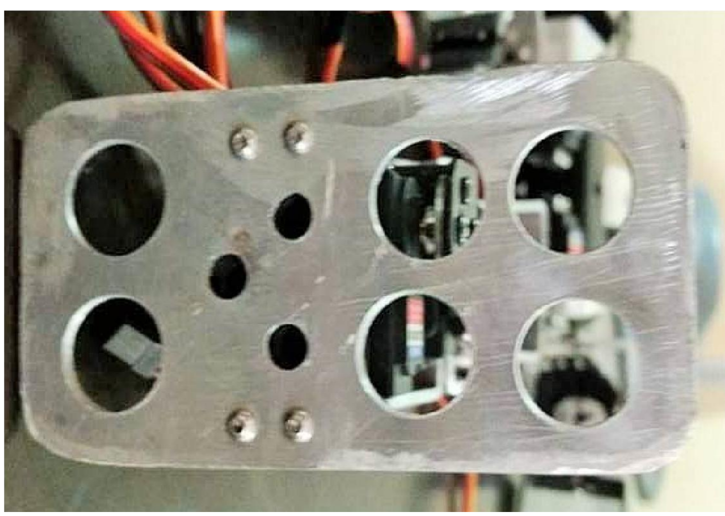

Fig: - 2.12 (Robot Feet Aluminum Servo Bracket)

2.17 Metal Horn for Servo 25T:-

Servo metal disc board 25T for servos. Compatible with RKI-1200, RKI-1206, RKI-1204, RKI-1210, RKI-1211 and HS-311 servos.

Fig: - 2.13 (Metallic Horn)

Specifications for part made up of aluminum:-

- Material: 2.5mm Hard aluminium
- Surfacing: Grinding & Filing
- Cutting: Glinder
- Drilling: Drill Machine
- Colour: Silver

2.18 Ultrasonic Sensor:-

Ultrasonic sensors "are based on the measurement of the properties of acoustic waves with frequencies above the human audible range," often at roughly 40 kHz [1)]. They typically operate by generating a high-frequency pulse of sound, and then receiving and evaluating the properties of the echo pulse.

Three different properties of the received echo pulse may be evaluated, for different sensing purposes. They are:

- Time of flight (for sensing distance)
- Doppler shift (for sensing velocity)
- Amplitude attenuation (for sensing distance, directionality, or attenuation coefficient)

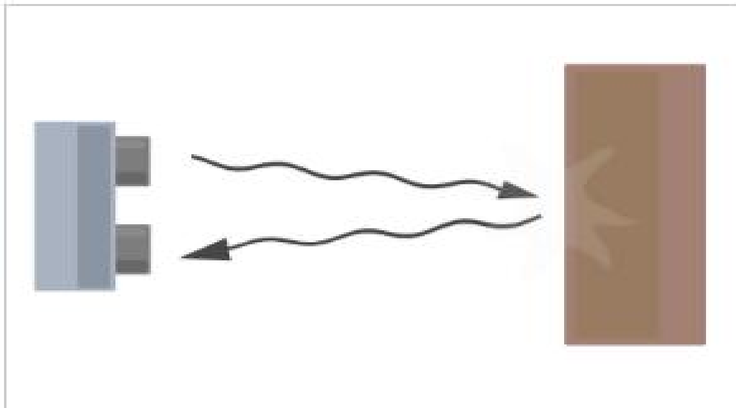

Fig:- 2.14 (Working of Ultrasonic Sensor)

This performance of the ultrasonic sensor distance measuring module is stable, measure the distance accurately. The module is with High precision, blind spots (3cm) super close. This module provides a full set of ranging process.

$$distance = \frac{speed\ of\ sound\ \times time\ taken}{2}$$

Fig: - 2.15 (Ultrasonic Sensor)

2.18.1 Difference between Infrared sensor & Ultrasonic sensor:

Table: - 2.18

INFRARED SENSOR	ULTRASONIC SENSOR
• IR sensor is an electronic instrument which is used to sense certain characteristics of its surroundings by either emitting and/or detecting infrared radiation. • IR sensor are also capable of measuring the heat being emitted by an object and detecting motion.	• Ultrasonic sensors are almost completely insensitive to interfering factors (such as extraneous light, dust, smoke, mist, vapor, lint, oily air, etc.). • They are best suited for the detection of transparent and dark objects, reflective surfaces, and shiny objects and of bulk materials and liquids. • Ultrasonic sensors allow for the reliable detection and measurement of objects, independent of their material, color, transparency and texture.

Note: The fundamental difference between the sensors is that IR sensors are detecting electromagnetic radiation while ultra sound sensors are detecting mechanical or acoustical energy.

Features:

- Working voltage: 5V (DC)
- Static current: Less than 2mA.
- Output signal: Electric frequency signal, high level 5V, low level 0V.
- Sensor angle: Not more than 15 degrees.
- Detection distance: 2cm~450cm.
- High precision: Up to 3mm
- Mode of connection: VCC / trig(T) / echo(R) / GND

CHAPTER 3

MATERIALS & TOOLS USED IN FORMATION OF ALUMINA

3.1 Material Used:

3.1.1 Aluminum Sheet (2.5mm thickness): Aluminium or aluminum (in North American English) is a chemical element in the boron group with symbol Al and atomic number 13. It is a silvery-white, soft, nonmagnetic, ductile metal. By mass, aluminium makes up about 8% of the Earth's crust, it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite. Aluminium is remarkable for the metal's low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and structures, such as building facades and window frames. The oxides and sulfates are the most useful compounds of aluminium.

Despite its prevalence in the environment, no known form of life uses aluminium salts metabolically, but aluminium is well tolerated by plants and animals. Because of these salts' abundance, the potential for a biological role for them is of continuing interest, and studies continue.

3.1.2 Characteristics:

Physical: Aluminum is a relatively soft, durable, lightweight, ductile, and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A fresh film of aluminium serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa.

Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded.

Aluminium atoms are arranged in a face-centered cubic (fcc) structure. Aluminium has a stacking-fault energy of approximately 200 mJ/m2.

Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of superconductivity, with a superconducting critical temperature of 1.2 kelvin and a critical magnetic field of about 100 gauss (10 milliteslas). Aluminium is the most common material for the fabrication of superconducting cubits.

Chemical: Corrosion resistance can be excellent because a thin surface layer of aluminium oxide forms when the bare metal is exposed to air, effectively preventing further oxidation, in a process termed passivation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

In highly acidic solutions, aluminium reacts with water to form hydrogen, and in highly alkaline ones to form aluminates— protective passivation under these conditions is negligible. Primarily because it is corroded by dissolved chlorides, such as common sodium chloride, household plumbing is never made from aluminium.

However, because of its general resistance to corrosion, aluminium is one of the few metals by tin and silver and in the 700–3000 nm (near IR) by silver, gold, and copper.

Aluminium is oxidized by water at temperatures below 280 °C to produce hydrogen, aluminium hydroxide and heat:

$$2\ Al + 6\ H_2O \rightarrow 2\ Al\ (OH)_3 + 3\ H_2$$

This conversion is of interest for the production of hydrogen. However, commercial application of this fact has challenges in circumventing the passivation oxide layer, which inhibits the reaction, and in storing the energy required to regenerate the aluminium metal.

3.2 Tools used in the Manufacturing & Design of ALUMINA:

- Scriber
- Glinder
- Drill Bit
- Circular File
- Half Round File
- Screw Driver
- Allen Key
- Plier Plass
- Mallet
- Bench Vise
- Center Punch

3.2.1 Scriber:

A scriber is a hand tool used in metalworking to mark lines on work pieces, prior to machining. The process of using a scriber is called scribing and is just part of the process of marking out. It is used instead of pencils or ink lines, because the marks are hard to see, easily erased, and inaccurate due to their wide mark, scribe lines are thin and semi-permanent. They are a rod with a tip made of cast steel that has been hardened and tempered. The point is sharpened to an angle of 30 or 40 degrees. Some scribers have a point at both ends. It is used by drawing the point over the surface of the work piece to leave a shallow scratch on its surface.

Fig: - 3.1 (Scribers)

3.2.2 Center Punch:

Center punch is used to mark the center of a point. It is usually used to mark the center of a hole when drilling holes. A drill has the tendency to "wander" if it does not start in a recess. A center punch forms a large enough dimple to "guide" the tip of the drill. The tip of a center punch has an angle between 60 and 90 degrees. When drilling larger holes, and the web of the drill is wider than the indentation produced by a center punch, the drilling of a pilot hole is usually needed.

An automatic center punch operates without the need for a hammer.

Fig: - 3.2 (Center Punch)

3.2.3 Drill Bit:

Drill bits are cutting tools used to remove material to create holes, almost always of circular cross-section. Drill bits come in many sizes and shape and can create different kinds of holes in many different materials. In order to create holes drill bits are attached to a drill, which powers them to cut through the work piece, typically by rotation. The drill will grasp the upper end of a bit called the shank in the chuck.

Drill bits come in standard sizes, described in the drill bit sizes article. A comprehensive drill bit and tap size chart lists metric and imperial sized drill bits alongside the required screw tap sizes.

Fig: - 3.3 (Drill Bit)

3.2.4 Circular & Half Round File:

A file is a tool used to remove fine amounts of material from a work piece. It is common in woodworking, metalworking, and other similar trade and hobby tasks. Most are hand tools, made of a case hardened steel bar of rectangular, square, triangular, or round cross-section, with one or more surfaces cut with sharp, generally parallel teeth. A narrow, pointed tang is common at one end, to which a handle may be fitted.

Files have also been developed with abrasive surfaces, such as natural or synthetic diamond grains or silicon carbide, allowing removal of material that would dull or resist metal, such as ceramic.

Fig: - 3.4 (Circular file)

Fig: - 3.5 (Half Round File)

3.2.5 Screw Driver:

A screwdriver is a tool, manual or powered, for turning (driving or removing) screws. A typical simple screwdriver has a handle and a shaft, and a tip that the user inserts into the screw head to turn it. The shaft is usually made of tough steel to resist bending or twisting. The tip may be hardened to resist wear, treated with a dark tip coating for improved visual contrast between tip and screw or ridged or treated for additional 'grip'. Handles are typically wood, metal, or plastic and usually hexagonal, square, or oval in cross-section to improve grip and prevent the tool from rolling when set down.

Fig: - 3.6 (Screw Driver)

3.2.6 Allen Key:

A hex key, Allen key or Allen wrench is a tool used to drive bolts and screws with hexagonal sockets in their heads.

The Allen name is a registered trademark, originated by the Allen Manufacturing Company of Hartford, Connecticut circa 1910, and currently owned by Apex Tool Group, LLC. Its generalized use is discouraged by this company. The standard generic name used in catalogues and published books and journals is "hex key".

Fig: - 3.7 (Allen Key)

Features:-

- The tool is simple, small and light
- The contact surfaces of the screw or bolt are protected from external damage
- There are six contact surfaces between bolt and driver
- The tool can be used with a headless screw
- The screw can be inserted into its hole using the key
- Torque is constrained by the length and thickness of the key
- Very small bolt heads can be accommodated
- The tool can be manufactured very cheaply, so one is often included with products requiring end-user assembly
- Either end of the tool can be used to take advantage of reach or torque
- The tool is L-shaped
- The tool can be reconditioned using an electric grinder by removing the worn-out part, and then it works like new

- The hexagon is typically a smaller diameter than would be used with an external cap, and is more likely to round off its contact surfaces.
- It is much more difficult to turn a damaged (rounded or otherwise) internal fastener than an external one.

3.2.7 Plier Plass:

Pliers plass are a hand tool used to hold objects firmly, possibly developed from tongs used to handle hot metal in Bronze Age Europe. They are also useful for bending and compressing a wide range of materials. Generally, pliers consist of a pair of metal first-class levers joined at a fulcrum positioned closer to one end of the levers, creating short jaws on one side of the fulcrum, and longer handles on the other side. This arrangement creates a mechanical advantage, allowing the force of the hand's grip to be amplified and focused on an object with precision. The jaws can also be used to manipulate objects too small or unwieldy to be manipulated with the fingers.

Fig: - 3.8 (Plier Plass)

3.2.8 Mallet:

A mallet is a kind of hammer, often made of rubber or sometimes wood, that is smaller than a maul or beetle, and usually has a relatively large head. The term is descriptive of the overall size and proportions of the tool, and not the materials it may be made of, though most mallets have striking [illegible] are softer than steel.

Fig: - 3.9 (Mallet)

3.2.9 Bench Vise:

Woodworking vises are attached to a workbench, typically flush with its work surface. Their jaws are made of wood or metal, the latter usually faced with wood, called cheeks, to avoid marring the work.[1] The movable jaw may include a retractable dog to hold work against a bench dog.

"Quick-release" vises employ a split nut that allows the screw to engage or disengage with a half-turn of the handle. When disengaged the movable jaw may be moved in or out throughout its entire range of motion, vastly speeding up the process of adjustment. Common thread types are Acme and buttress.

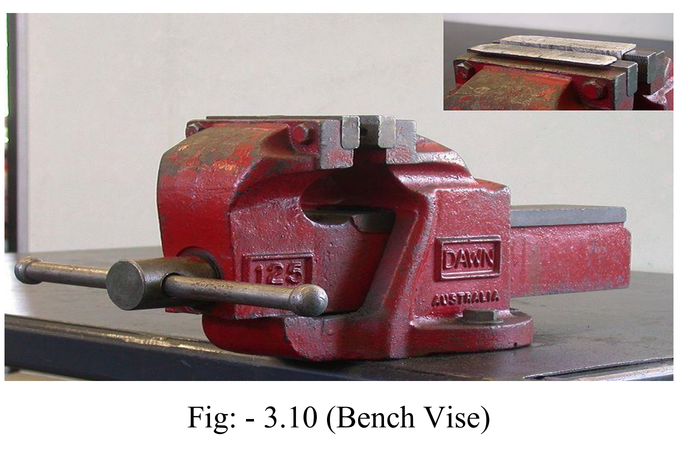

Fig: - 3.10 (Bench Vise)

Chapter 4

MANUFACRING PROCESS USED IN THE FORMATION OF ALUMINA

- Cutting
- Grinding
- Drilling
- Filing
- Marking
- Punching
- Holding
- Hammering
- Assembling

4.1 Cutting:

Cutting is the basic start for this project which is being done with the help of glinder, Glinder contains a blade which is rotated at a fixed speed through which a required force is generated for the cutting. In our project cutting is done on the aluminum sheet after the markings.

“Cutting is the separation of a physical object, into two or more portions, through the application of an acutely directed force. Implements commonly used for cutting are the knife and saw, or in medicine and science the scalpel and microtome”.

Cutting is a compressive and shearing phenomenon, and occurs only when the total stress generated by the cutting implement exceeds the ultimate strength of the material of the object being cut.

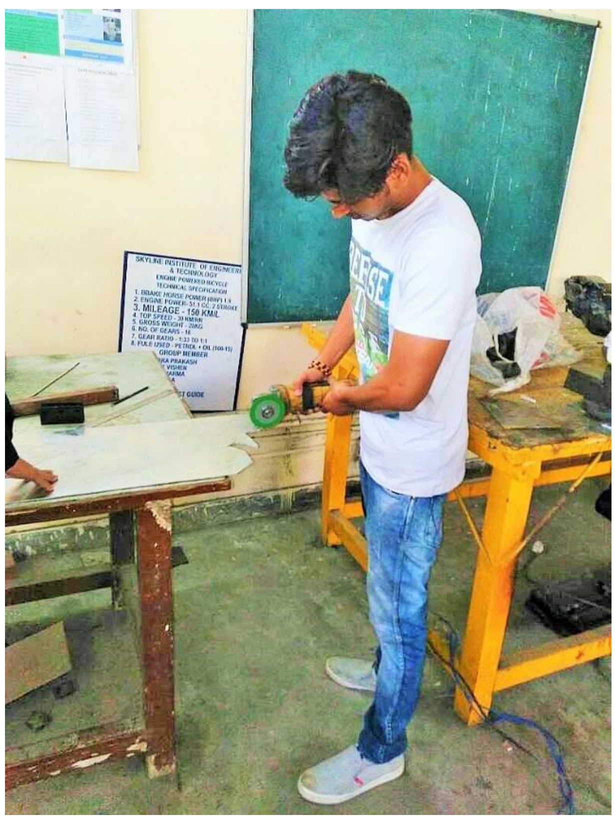

Fig: - 4.1 (Cutting operation performed by Glinder)

4.2 Grinding:

The Grinding Process was carried out and it was a major activity because the surface properties & surface condition of the aluminum sheet has its importance.

So in this process after the cutting of sheet Grinding is done to ensure the smoothness of the surface of the parts. Grinding process can be executed in a different ways, the method which we adopted in this project is the conventional grinding process with the help of Grinding Machine available in our Manufacturing workshop. This method requires some safety measures such as gloves & glasses to protect our hands & eyes. This machine comprises of a rotating roller of composites alloy which helps in shaping & smoothing of the surface when it comes in contact with it while rotating.

Fig: - 4.2 (Performing Grinding Operation)

4.3 Drilling:

In our Project Drilling is done by the Geared head dill machine in which the X & Y axis is defined by the bed or Z axis is defines the dill axis up & down.

A geared head drill press is a drill press in which power transmission from the motor to the spindle is achieved solely through spur gearing inside the machine's head. No friction elements (e.g., belts) of any kind are used, which assures a positive drive at all times and minimizes maintenance requirements.

Gear head drills are intended for metalworking applications where the drilling forces are higher and the desired speed (RPM) is lower than that used for woodworking. Geared head drill presses are commonly found in tool rooms and other commercial environments where a heavy duty machine capable of production drilling and quick setup changes is required. In most cases, the spindle is machined to accept Morse taper tooling for greater flexibility.

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the work piece and rotated at rates from hundreds to thousands of revolutions per minute.

Fig: - 4.3 (Geared Head Drill Machine)

4.4 Filing:

After grinding process, then we proceeded to the filing of the aluminum parts formed by the sheets. The main objective of filing was to provide perfect finishing to the edges of the aluminum parts. It was used to remove the slight unevenness on the edges which escaped the grinding machine, also it was more precise in the smoothening of the edges.

Basically, in this process we took the use of center file & half round file, where center file was used to cleaning and reaming of the drilled holes & half round file was utilized in shaping & finishing the edges of the parts.

Filing is a material removal process in manufacturing. Similar, depending on use, to both sawing and grinding in effect, it is functionally versatile, but used mostly for finishing operations, namely in deburring operations. Filing operations can be used on a wide range of materials as a finishing operation. Filing helps achieve work piece function by removing some excess material and deburring the surface. Sandpaper may be used as a filing tool for other materials, such as glass.

Fig: - 4.4 (Performing Filing operations on the parts of Robot)

4.5 Marking:

In this project, marking is done by the scriber on the aluminum sheet. Marking is basically defined as the process of transferring a design or pattern to a work piece by the help of sketched lines according to the requirements. It is the basic step perform while we do designing or manufacturing of any object with its proper dimensions. In different materials different types of tools required to perform the marking function such as in woods pencil is used. Marking is done with some calculations according to requirement or measure of the design.

4.6 Punching:

Punching is basically done to form an impression by shear force, if the force we applied is large then it is able to make a hole depends on some conditions such as material property.

In our project, punching is performed with the help of center punch or a ball peen hammer to form an impression of center before performing the drilling operation in the aluminum sheet parts such as in oblique brackets, Short U brackets, Long U brackets, Interconnect brackets, L shaped brackets, etc.

We hold the center punch on the center position and apply the force by the ball peen hammer, due to shear force there is an impression formed on the sheet which easily show the exact center for the drilling operation.

Punching Characteristics:

- Punching is the most cost effective process of making holes in strip or sheet metal for average to high fabrication
- It is able to create multiple shaped holes
- Punches and dies are usually fabricated from conventional tool steel or carbides
- Creates a burnished region roll-over, and die break on sidewall of the resulting hole[1]
- It's quick

4.7 Holding:

Holding is basically done by the jigs & fixture where jigs is used to hold & guide the tool & fixtures only hold or support the tool or work piece for the operations. It is done by bench vises in our project, there are different types of vises used in different manufacturing shops for different types of processes. In our project we hold the aluminum sheet parts on the bench vise for the filing & surface finishing process as our requirement, we also used pipe vise for the bending operation in the formation of aluminum clamps for the servo motor with desired specifications according to our need.

The different types of vises used in the manufacturing process for holding the work pieces are as follows:-

- Bench Vise (It is used to hold metal while filing or cutting)
- Vacuum Vise (It is used to hold circuit boards, model airplanes and other works)
- Pipe Vise (It is used to hold the pipes, basically used in plumbing operations)
- Machine Vise (Mounted on dill machine, grinding machine, milling machine to hold the work piece).

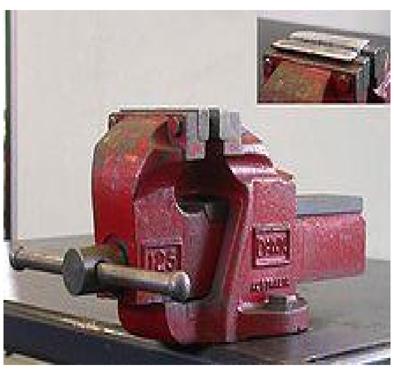

Fig: - 4.5 (Bench Vise)

Fig: - 4.6 (Vacuum vise)

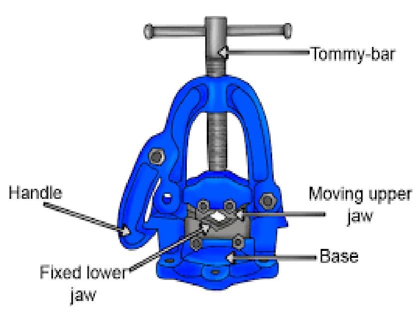

Fig: - 4.7 (Pipe Vise)

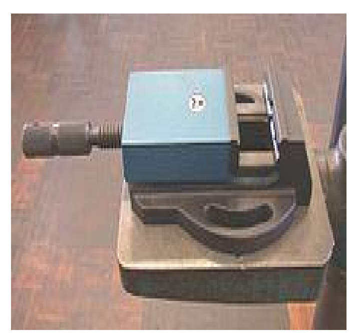

Fig: - 4.8 (Machine Vise)

4.8 Hammering:

Now to transform the parts according to the desired shape & design hammering was done, this hammering process was carried out by mallet not a regular hammer to avoid unnecessary impressions on the surface of the parts which could have deteriorate its properties.

In this process the bending of the clamps was done by striking it with a mallet until it gained the desired shape.

Hammering is defined as the deformation in structure by heavy force applied by the device named as hammer, this operation apply impact force on the work piece to form into a specified structure according to the requirement or the need. In our Project, it used to form the servo clamps or brackets for the bending operation with the help of mallet which is also a type of hammer & made up of wooden material.

Fig: - 4.9 (Bending the parts by Mallet)

4.9 Assembling:

<u>Step 1</u>:- After the successful execution of all the activities then it was time to assemble all the designed & finished parts to form the desired Structure.

First we installed a servo on Right Robot feet aluminum servo bracket after that the same process was carried to the left Robot feet aluminum servo & similarly all the other parts of the robot were attached along with the servo joined to them. In the assembling of ALUMINA we used Allen nut & bolt to tightened the parts with the help of help of Allen key theses nut & bolt assembly are so perfect to perform the function of joining, there is no chance of loosening the nut from the bolt in that type of assembly of nut & bolts.

In our project first we join the servo motors with their feet by the help of servo brackets, clamps & robot feet aluminum servo brackets.

Fig: - 4.10 (Assembling of feet)

<u>Step 2</u>: - In this step we done the formation of legs with the help of U shaped Servo Clamps, Oblique shaped servo brackets, Servo motor & nut & bolt assembly.

We provide the maximum angle moments to thighs are 45 degree in each of the direction as per the consideration we select the servo motors & joining. In our project, formation of thighs or legs takes a lot of time due to lack of knowledge about the tightening the screws & don't know how to use the Allen key after that we all know the proper use of Allen key effectively with Allen nut.

The servo motors were also connected to the thigh parts of the Alumina when it was joint to the rest of the robot, the thighs were placed while keeping in mind the alignment of the feet of the robot, it alignment was one of the most difficult to execute as the proper shape of the robot was very much depended on it. The servo motors were placed in the Multipurpose Aluminum servo bracket for holding & supporting the motor safely and for connecting them to the U Clamp.

Fig: - 4.11 (Assembling of thighs of ALUMINA)

<u>Step 3</u>: - In this step the formation of belly is done by the Large U beam Aluminum Servo Brackets is connected with 2 multipurpose brackets, 2 L shaped brackets &1 Large U brackets. It is joined by the Big Buttons Screw with lock nuts.

In our project, we placed the battery & Arduino inside the Large U beam Aluminum Servo brackets for the safety of battery & Arduino. After we complete the belly then we go for the preparation of the hands by aluminum brackets & servo. Which is to be connected with the belly with the help of metallic horn & servo motor.

Metals horns were placed in the Long U shaped servo brackets & oblique servo brackets which is going to connect with the servo motors for the proper movement of the servo.

In the formation of the belly we used the designed L shaped Aluminum servo brackets & other brackets which we design for the formation of belly, in our project it is the most important part where we have to place the main circuit of the robot (Arduino Circuit) & Battery (Lithium polymer) so we have to make sure that this portion of the robot be highly secure & safe, a single damage should destroy the functions of ALUMINA.

Fig:- 4.12 (Belly connected with aluminum brackets)

<u>Step 4:</u> -

Then it came to assemble the arms with the help of Oblique U shape, interconnected shape, L shape Interconnected Aluminum Servo bracket by using Allen bolt & Lock nut which was tightened with the help of Allen key. The main motive behind using the Allen nut & bolt because of its high efficiency which is due to the presence of plastic fixing constituent material in the bolt which helps in avoiding bond breaking of nut & bolt as it is impossible to reverse it without the help of Allen key. The mechanical hands were connected to the shoulders by joining with the shoulder servo which was moved with the help of Metallic horn.

There should be a major considerations in the formation of hands, basically about the direction of movements of the hands & their servo motor action & their step angle of rotation for the hands. In our project, we make sure that that the movements of hand should be rotate at maximum step angle for the flexibility of the robot. In this project, hands contains two servo motor which provide two motions at different places & one motion is also provide on the shoulder, so we can that the movements of hands or the motion of hands of ALUMIA is 3.

Fig: - 4.13 (Formation of Hands)

Step 4: -

After the complete assembly of all the parts with a lot of difficulties finally the robot came in play for the mechanical action & now we have to the programming parts with the help of Arduino Circuit & Arduino Codes. The mechanical portion is assembled now such as legs are connected with the belly servo, hands are connected with the shoulder servos. The mechanical portion or the part of our robot is done.

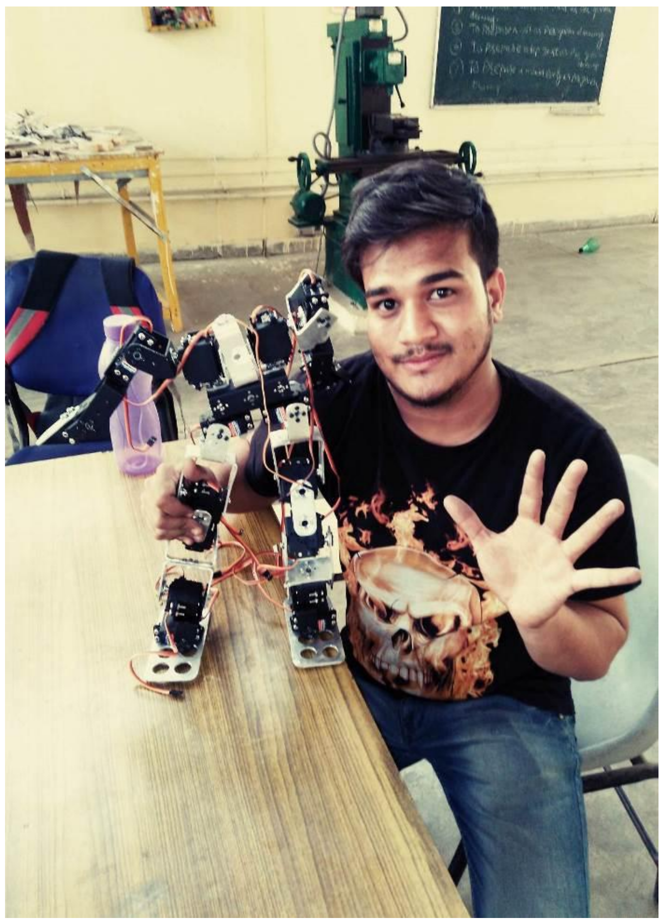

Fig: - 4.14 (Complete formation of Mechanical parts of ALUMINA)

CHAPTER 5

SELECTION OF SERVO TORQUE & DESIGNING CRITERIAS

5.1 Torque:

Torque is a measure of how much a force acting on an object causes that object to rotate. The object rotates about an axis, which we will call the pivot point, and will label 'O'. We will call the force 'F'. The distance from the pivot point to the point where the force acts is called the moment arm, and is denoted by 'r'. Note that this distance, 'r', is also a vector, and points from the axis of rotation to the point where the force acts.

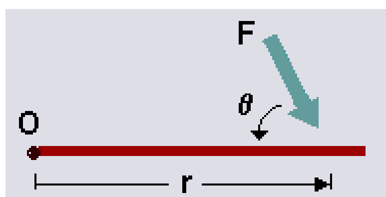

Fig: - 5.1 (Defining Torque)

Torque is defined as,

$$\tau = \mathbf{r} \times \mathbf{F}$$

Where, τ = Torque
r = Radial distance
F = force

The SI units of torque is a **Newton-meter**, which is also a way of expressing a Joule but it is not an energy.

Rotational Equilibrium is analogous to translational equilibrium, where the sum of the forces are equal to zero. In rotational equilibrium, the sum of the torques is equal to zero. In other words, there is no net torque on the object.

$$\sum \tau = 0$$

Another way of expressing the above equation is that torque is the product of the magnitude of the force and the perpendicular distance from the force to the axis of rotation.

Let the force acting on an object be broken up into its tangential ($F_{tangential}$) and radial (F_{radial}) components (Note that the tangential component is perpendicular to the moment arm, while the radial component is parallel to the moment arm.) The radial component of the force has no contribution to the torque because it passes through the pivot point. So, it is only the tangential component of the force which affects torque (since it is perpendicular to the line between the point of action of the force and the pivot point).

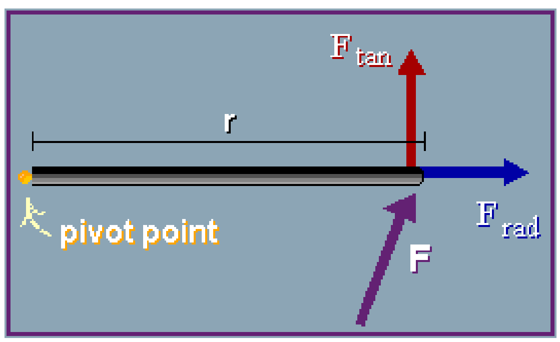

Fig: - 5.2 (Radial & Tangential Components of Force)

5.2 Weight:

The weight of an object is usually taken to be the force on the object due to gravity. Weight is a vector whose magnitude (a scalar quantity), is the product of the mass (m) of the object and the magnitude of the local gravitational acceleration (g)

$$W = mg.$$

Its SI Unit is Newton.

5.3 Selection Criteria's:

✓ Why we choose Aluminum for the designing?

We choose Aluminum sheet for the designing of ALUMINA because it is light in weight easy to operation the operation on that, the major considerations for selecting the

aluminum sheet is the force which is responsible the servo torque, if our structure is heavy (i.e. the force generated due to acceleration due to gravity is high) so we have to generate that much torque on the servo for the functioning and the operation of the servo action.
So we should have to reduce the weight of the structure as much as necessary for the proper stand of the ALUMINA & to perform the functions as per our requirement & usage. The designing of the ALUMINA needs a major consideration of the torque produced by the servo motor. So we measure the torque & according to which we consider some factor of safety (FOS) for the servo motor for the better performance.

✓ Defining the selection of servo torque in the different parts of ALUMIA:

The overall weight of the ALUMIA is 3 kg, then according to parts it is divided.
The value of g is 10 m/s^2.
We consider factor of safety (FOS) as 1.5

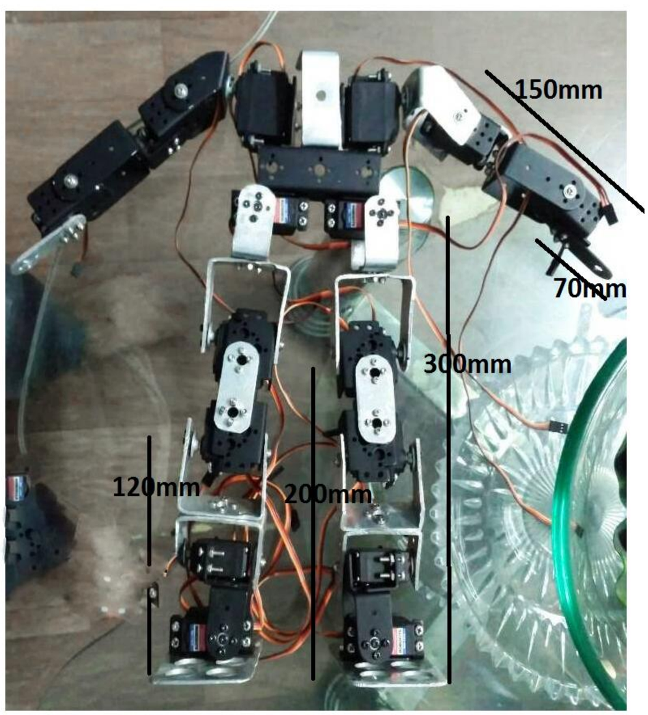

Fig: - 5.3 (Humanoid Dimensions)

1. Deciding parameters for the motor of THIGH on torque characteristics:

The total force applied on the thighs is 10N (i.e. due to weight of robot (mg), where m = 1kg).

The perpendicular distance from this to the end point is 300mm.

As we know that, the load is UDL but it is not perfectly UDL (Uniformly distributed load) approximately, so we do all the calculations on UDL & take some FOS for the safety of servo motor.

If the load is 10N, & distance is 300mm, the maximum angle fluctuation is 45 degree.

Then, torque = (10*300sin (45))/2

= 106 N-cm.

Then on applying FOS torque = 1.5*106

= 159 N-cm = 15.9 kg-cm

NOTE: - So we selected 16 kg-cm torque servo motor.

2. Deciding parameters for the motor of KNEE on torque characteristics:

The total force applied on the thighs is 6 N (i.e. due to weight of robot (mg), where m = 0.6 kg).

The perpendicular distance from this to the end point is 200 mm.

If the load is 6 N, & distance is 200mm, the maximum angle fluctuation is 45 degree.

Then, torque = (6*200sin (45))/2

= 42.42 N-cm.

Then on applying FOS torque = 1.5*42.4

= 63.6 N-cm = 6.36 kg-cm

NOTE: - So we selected 8 kg-cm torque servo motor because the servo doesn’t came in 7 kg-cm torque.

3. **Deciding parameters for the motor of KNEE joint on torque characteristics:**

   The total force applied on the thighs is 4 N (i.e. due to weight of robot (mg), where m = 0.4 kg).

   The perpendicular distance from this to the end point is 120 mm.

   If the load is 4 N, & distance is 120mm, the maximum angle fluctuation is 45 degree.

   Then, torque = (4*120sin (45))/2

   = 17 N-cm.

   Then on applying FOS torque = 1.5*17

   = 26 N-cm = 2.6 kg-cm

NOTE: - So we selected 4 kg-cm torque servo motor because the servo doesn't came in 3 kg-cm torque.

4. **Deciding parameters for the motor of SHOULDER on torque characteristics:**

   The total force applied on the thighs is 5 N (i.e. due to weight of robot (mg), where m = 0.5 kg).

   The perpendicular distance from this to the end point is 150 mm.

   If the load is 5 N, & distance is 150mm, the maximum angle fluctuation is 90 degree.

   We design the arm for point load, because in arm the weight of servo is low, so we take that the load is applied on the end of the arm.

   Then, torque = 5*150

   = 75 N-cm.

   Then on applying FOS torque = 1.5*75

   = 112.5 N-cm = 11.25 kg-cm

NOTE: - So we selected 14 kg-cm torque servo motor to improve the performance of the hands of ALUMINA.

5. Deciding parameters for the motor of HAND (END EFFECTOR) on torque characteristics:

The total force applied on the thighs is 5 N (i.e. due to weight of robot (mg), where m = 0.5 kg).

The perpendicular distance from this to the end point is 70 mm.

If the load is 5 N, & distance is 70mm, the maximum angle fluctuation is 90 degree.

We design the arm for point load, because in arm the weight of servo is low, so we take that the load is applied on the end of the arm.

Then, torque = 5*70

= 35 N-cm.

Then on applying FOS torque = 1.5*35

= 52.5 N-cm = 5.25 kg-cm

NOTE: - So we selected 8 kg-cm torque servo motor to improve the performance of the hands of ALUMINA, so in this project our hands (end effector) is designed in such a way that it can carry a load up to ½ kg.

CHAPTER 6

FUTURE SCOPE OF ALUMINA & ITS MODIFICATION

Robotics has a very crucial & wide scope in the future as the technology is kissing advancement every single moment to make our life better & more comfortable. Robotics is the present & future of science, a humanoid robot have their own importance because they are design to perform all the task of a human being but in a more precise manner they can perform the task which are nearly impossible for human hands or their strength & speed enables them to perform the task of 10 to 12 humans single handedly & that's why their bodies are design on the basis of a shape of a human body.

6.1 Generations of Robot:

- First Generation (1960): First generation robot are designed to perform factory work such as performed simple tasks that were dangerous or unpleasant for people. Robots were used to weld, spray paint, move heavy objects, handle hot materials, etc.
- Second Generation (1980): Second generation robot perform more complex task and stimulate many human functions such as sense surroundings and respond to their change in environment.
- Third Generation (1992): On-line computation & controlling, artificial vision, active force/torque interaction with environment.
- Fourth Generation (2000): True android or an artificial biological robot or a super humanoid capable of its own clone.
- Fifth Generation: This generation of robots doesn't came in play till now, in this type of robot they have artificial intelligence to perform their actions.

New perspectives as compared to the wheeled robots Such as, the humanoid robots are capable of maneuvering in various terrains, in hazards environments and in climbing objects. However, there are few flaws where the humanoid robot faces, that are, they generally suffer from backlashes and frictions in joints, have walking instability and have very limited payloads during motion execution. But such motion execution usually results in terrible noises, and motion sensors may provide unreliable, unrealistic and inaccurate results. Therefore, the problem faced in humanoid robots is accurate localization.

Nowadays, various research approaches have been presented for humanoid localization; the most popular research approaches were usually carried in 2D spaces. In one such research, the 2D representation information was stored in quantized cells but they were not reliable in navigation of obstacles. So to navigate the humanoid to make its way through obstacles and to determine the heights of different objects, the 2.5D representation was utilized. However, various other approaches such as 3D representation is used for arbitrary environments having several levels , a 6D representation is used for multi-levelled and non-planar movements. In contrast to all the approaches, research has been made for determining the 6D poses of humanoid robots by using a 3D representation integrating only on-board sensors.

Another latest research carried out on humanoid robots is the means analyzing the human grasping behavior and utilize this principle on robots hand. The humanoid robot is designed and developed to interact with the real-time world. The increase degree of freedom of the robot's hand in addition to flexibility results in complexity in control.

To receive response of humanoid hand control to perform various manipulative tasks and complex grasping intentions has become very cumbersome. Reason being, humans have biologically muscular system of hand to arm to wrist configuration for controlling high degree of freedom. Choices regarding parts of the hand have already been made just before acquiring a grasp, so as to allow the human hand to engage in certain tasks such as turning a knob or dial, opening and closing a lid, etc. stable grasps are determined with the guidelines of grasp intentions and they also determine the grasp functions, postures, motions, forces and torques when handling an object

As of now up to fourth generation robot have been introduced which performs all the functions as per commands usually they are instructed to do day to day tasks in highly advance laboratories & big industries to accelerate the work process & to boost productivity.

6.2 Artificial Intelligence in Upcoming Humanoid Robots:

Artificial intelligence (AI) is intelligence exhibited by machines. In computer science, the field of AI research defines itself as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of success at some goal.

Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving" (known as machine learning).

As machines become increasingly capable, mental facilities once thought to require intelligence are removed from the definition. For instance, optical character recognition is no longer perceived as an example of "artificial intelligence", having become a routine technology.

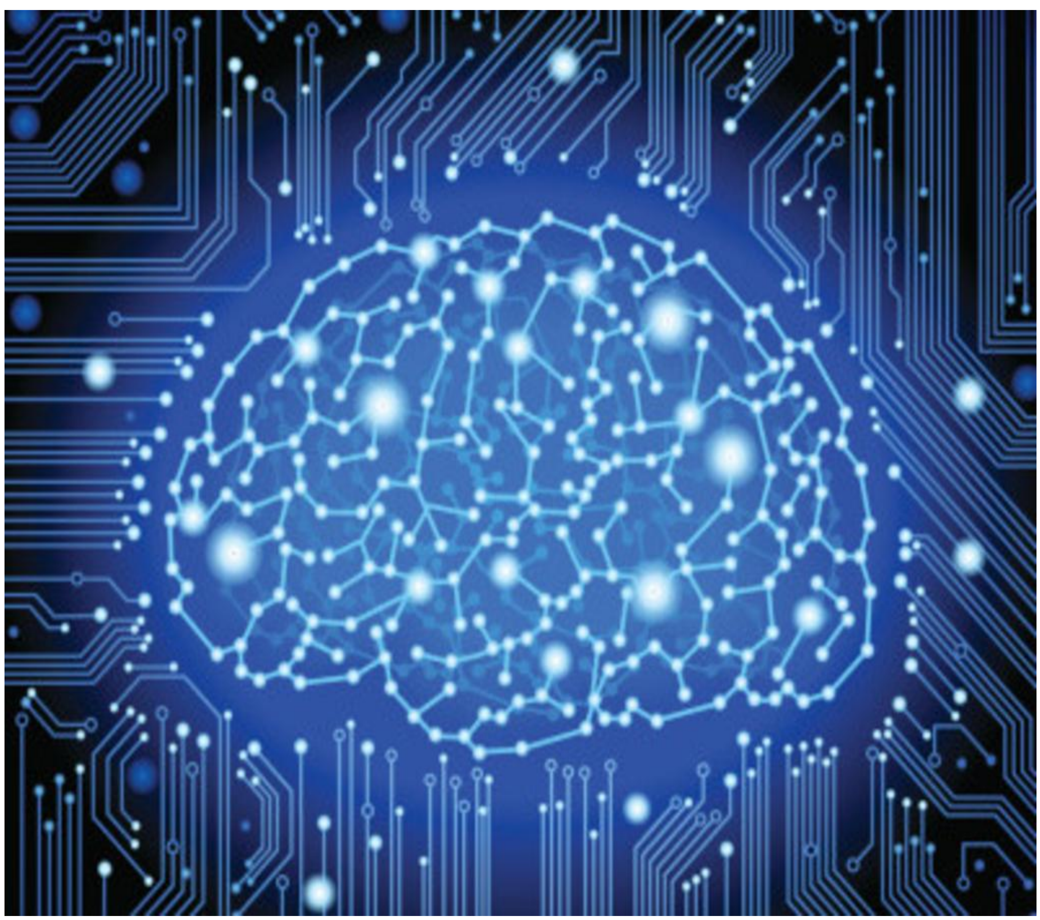

Fig: - 6.1 (Imaginable artificial circuitry)

Capabilities currently classified as AI include successfully understanding human speech, competing at a high level in strategic game systems (such as chess and Go), self-driving cars, intelligent routing in content delivery networks, and interpreting complex data.

AI research is divided into subfields that focus on specific problems, approaches, the use of a particular tool, or towards satisfying particular applications.

This raises philosophical arguments about the nature of the mind and the ethics of creating artificial beings endowed with human-like intelligence, issues which have been explored by myth, fiction and philosophy since antiquity. Some people also consider AI a danger to humanity if it progresses unabatedly. Attempts to create artificial intelligence have experienced many setbacks, including the ALPAC report of 1966, the abandonment of perceptron's in 1970, the Light-hill Report of 1973, the second AI winter 1987–1993 and the collapse of the Lisp machine market in 1987.

In the twenty-first century, AI techniques, both hard (using a symbolic approach) and soft (sub-symbolic), have experienced a resurgence following concurrent advances in computer power, sizes of training sets, and theoretical understanding, and AI techniques have become an essential part of the technology industry, helping to solve many challenging problems in computer science. Recent advancements in AI, and specifically in machine learning, have contributed to the growth of Autonomous Things such as drones and self-driving cars, becoming the main driver of innovation in the automotive industry.

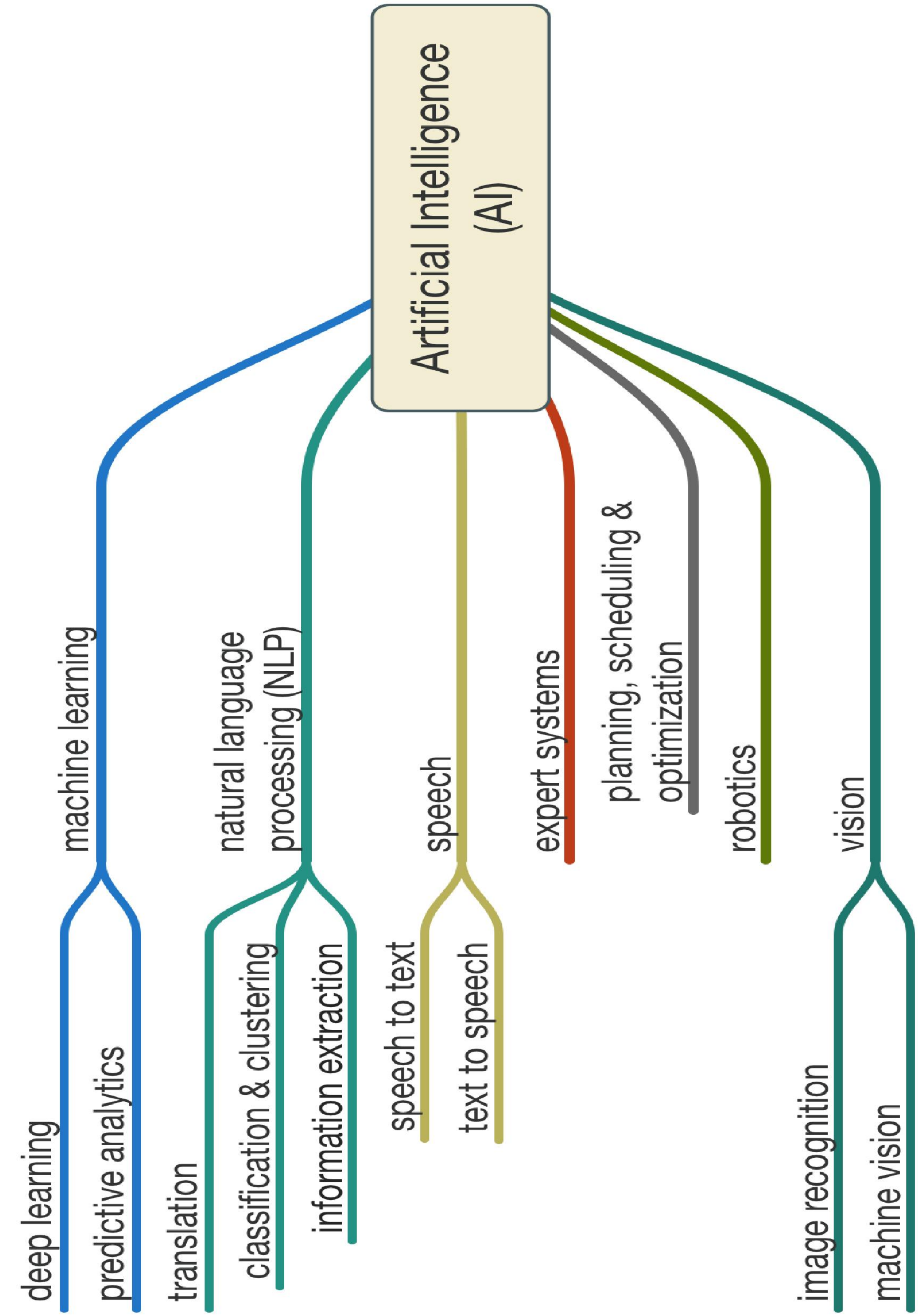

Fig: - 6.2 (Artificial Intelligence Characterstics)

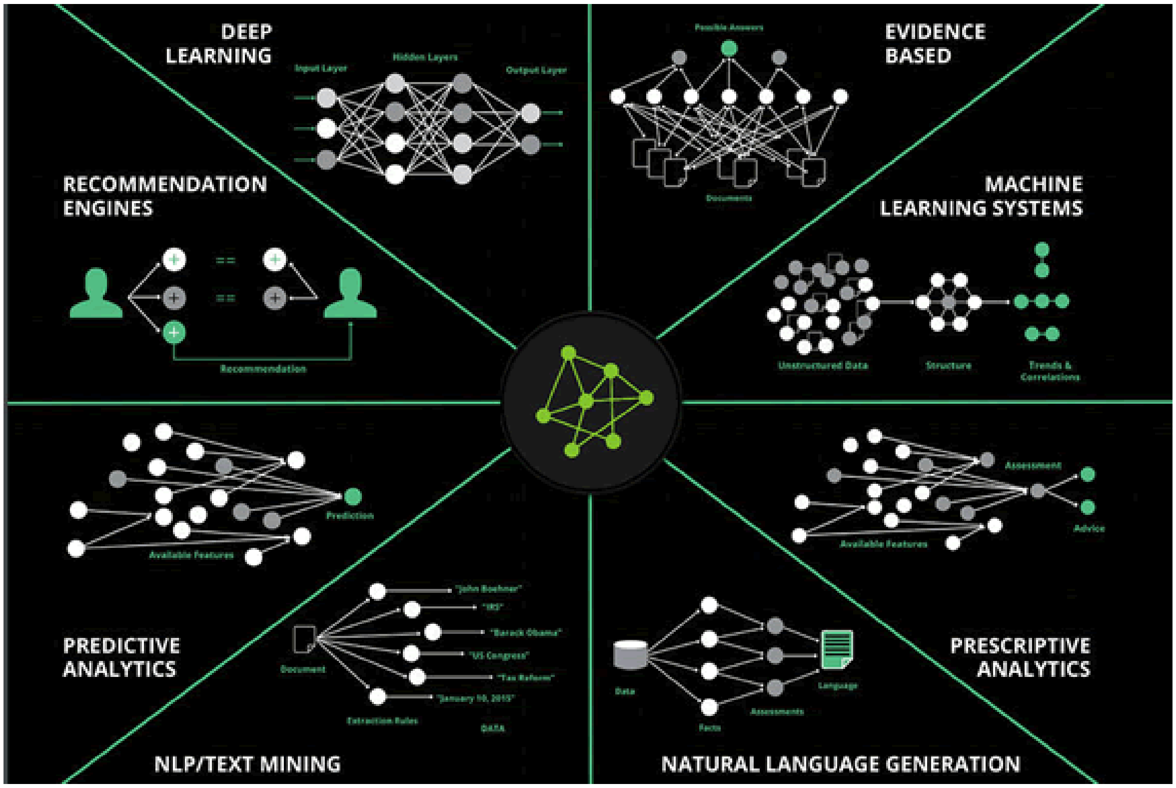

Fig: - 6.3 (Deep Phase of Artificial Intelligence)

In future the scientist are planning to introduce fifth generation humanoid robots which will have their own artificial intelligence enabling them to perform the various task & functions without taking any commands & instructions, it can sense the situations & to carryout response according to it. Though it will be amazing but some people are a bit apprehensive of its evolution, according to them what if it went rouge of if its intelligence can be hacked by some anti-social groups etc. to cause destructions, it can be a danger but if proper security protocols are installed then this threat can be eliminated because the robots are design to follow four basic LAWS OF ROBOTS as described in the introduction parts **Chapter 1 section no. 1.5**. In the end all we can speculate that this is an amazing discovery & the future holds great many formidable & exquisite things for robots as they can execute various endeavors which are not beyond conceiving for human force & intelligence, their strength & speed makes them more reliable & efficient to perform all the functions in a perfect manner.

CHAPTER 8

CONCLUSION

In this project we have designed a humanoid robot by servo motor as its main motion provider & lithium polymer battery as its main source of power. Aluminum sheets have been used as a building block or body of the robot.

The designed robot is purposed for the assistance & to follow orders as per the instructions given to it. The Instruction of walking, turning has been programmed by the help of arduino programming language which is to be saved in the arduino circuits to perform the action of the robots as ordered.

It follows order on commands, Ultrasonic sensor are connected & installed in it for sensing obstructions in the path while walking & then diverting its path to avoid that obstructions.

This project shows the spectacular functions of a robot its credibility & efficiency. Robotics is everything in the coming future, a robot can perform all the functions effectively and efficiently as per command given to them, their speed & strength makes them more reliable & efficient then the human hands. It has no mind of its own so the robot only follows order by this way it can be considered as human most faithful friend.

In this project our humanoid robot (ALUMINA) has been designed to follow commands, when we command it to walk, it starts walking & only stops when it command to do so. We have installed some sensors in it to sense various obstructions & threats. These robots can be used as assistance for performing various hard & tough labors which are a bit unenviable for humans they are currently being used in various big industries & factories to perform various task which are a bit tough for the human force, they can perform all the heavy task without taking much time & without doing any mistakes & causing any delay, & we can have all our work under precision by their assistance all we have to do is to command it & it will perform all the functions.

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APPENDIX I

BOM (Bill of Materials)

- The main cost on this robot is metallic servo motor 16kgcm torque is of **Rs – 19600/-**
- The Lithium Polymer Battery costs **Rs -1000/-**
- The metallic horn for servo costs **Rs- 2677/-**
- The multipurpose servo bracket cost **Rs – 2142/-**
- The Arduino Circuit costs **Rs- 2600/-**
- The Aluminum sheet cost **Rs – 1550/-** with conveyance
- Jumper wires costs **Rs- 215/-**
- The overall cost of the robot is **Rs- 29784/-**

In the arrangement of products some are purchased online such as servo motor, arduino circuit, multipurpose aluminum brackets, metallic horn & battery which is impossible to design or construct. But so many parts are made up of aluminum sheet of thickness 2.5mm which we purchased from Delhi by which we made so many parts such as oblique shaped aluminum servo brackets, Long U shaped aluminum servo brackets, Short U shaped aluminum servo brackets, interconnected servo brackets & L Shaped aluminum servo brackets. The designing of these brackets takes a lot of time & finishing to make it precise for the robot.