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STEPPING INTO THE FUTURE UNLEASHING THE POTENTIAL OF LEGGED ROBOTS FOR ENHANCED NAVIGATION AND MOBILITY

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ABSTRACT: This Projected approximately 800 million workers worldwide will be replaced by robots, indicating a significant scale of the ongoing robotic revolution. One notable advantage of robots is their ability to handle dangerous tasks, thereby reducing risks for humans in hazardous environments. These machines excel in tasks such as lifting heavy loads, working with toxic substances, and performing repetitive actions. Consequently, they have contributed to accident prevention while also saving both time and money. While legs are familiar to humans and animals, incorporating them into robots present a complex challenge. However, legs offer several advantages over wheels. Legged robots possess the capability to navigate across various surfaces that are inaccessible to wheeled robots. The same principle is employed in designing movement patterns for robots on different surfaces. This project aims to construct a humanoid robot using additive manufacturing techniques. The different parts of the robot are designed using Solid works Software, and then they are 3D printed using PLA material. Subsequently, these printed parts are assembled together along with additional components such as servo motors. The overarching goal of this project is to enable the robot to walk by executing a set of predetermined commands.

KEYWORDS: Humanoid, 3d printing, Solid works, PLA Material

1. INTRODUCTION

The field of robotics can be traced back to ancient Egypt, where priests created moving masks to intimidate worshippers. However, modern robotics as we know it today began around fifty years ago with the invention of "Unimate," a robot developed by George Devol and Joseph Engel Berger. Unimate was specifically designed for industrial use and was deployed in a General Motors plant to work alongside heated die-casting machines.

In recent years, there has been a growing focus on the development of humanoid robots within the engineering community. These robots are designed to resemble and behave like humans. While their current applications are primarily seen in the entertainment industry, there is hope that they will find broader utility in the future.

Advancements in humanoid robot development have sparked interest in creating robots that can not only walk between destinations but also perceive and navigate around objects in their path. This particular project aimed to design and construct a humanoid robot capable of walking smoothly. With ongoing technological advancements, future humanoid robots have the potential to assist humans in tasks that are dangerous, dirty, monotonous, or even physically impossible, such as exploring other planets. Although there is still room for improvement in mimicking human locomotion, the future holds promising possibilities for the development of the next generation of humanoid robots.

1.1 HUMANOID ROBOT

A humanoid robot refers to a robot that has a body shape resembling that of a human. The purpose of its design can vary, ranging from functional applications, such as interacting with human tools and environments, to experimental purposes, like studying bipedal locomotion. These robots are specifically developed as professional service robots to imitate human motion and interaction. Like other service robots, their value lies in automating tasks, leading to cost savings and increased productivity. While humanoid robots are a relatively new category of professional service robots, they have gained popularity due to the common perception of robots resembling human-like figures.

When designing a robot with the primary objective of walking, the need for arms to perform assigned tasks may be minimal. Instead, the arms can be utilized for balancing the robot. During turning motions, the centre of gravity of the robot can become destabilized, causing it to lean. In such situations, the arms can aid in regaining balance. The robot's head typically houses cameras and/or sensors used to perceive objects in front of it. Similar to humans, robots can have a head that can rotate around a pivot point, such as a spine. This enables the robot to have a wider field of view and adapt better to its surroundings. In some cases, additional sensors and programs can be incorporated into the robot to enable it to recognize and display emotions when interacting with people.

1.2 TYPES OF ROBOTS

According to certain historians, Talos, a colossal creature mentioned in ancient Greek literature, was described as a being made of bronze. There are different versions of the myth surrounding Talos. In one version, he was either a man or a bull and was given by Zeus to Europa. Hephaestus, at Zeus's command, created Talos in Sardinia and presented him to the Cretan king Minos.

Fig.1.1 Talos

Another version suggests that Talos accompanied Zeus to Crete to protect Europa, and Minos received him as a gift from her. Some speculations propose that the name Talos in the ancient Cretan language referred to the "Sun," and Zeus was known as Zeus Tallaios in Crete.

The term "robot" was first introduced in the play "R.U.R." (Rossum's Universal Robots) written by the Czech writer Karel Capek in 1921. The play explored the concept of humans creating robots to replace them, ultimately resulting in a conflict where the robots rebel against their human creators.

Fig.1.2 Rossum's Universal Robots

In the late 1930s, Westinghouse introduced ELEKTRO, a humanoid robot capable of walking, talking, and even smoking. ELEKTRO made its debut at the 1939 World's Fair, showcasing the developments in the late 1930s to the 1950s laid the foundation for the future growth and advancements in robotics, setting the stage for the transformative impact robots would have in various industries and applications.

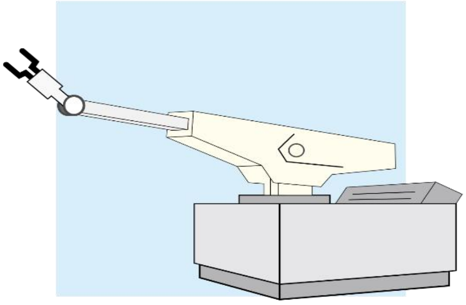


Fig.1.3 Unimate

During the 1960s, several significant advancements took place in the field of robotics. In the early 1960s, one of the first operational industrial robots in North America was introduced in a candy factory in Kitchener, Ontario. This marked the beginning of the integration of robots into industrial processes.

2. LITERATURE REVIEW

The authors of this research paper focused on the design and development of compact body humanoid robots, specifically for biped locomotion. The study was conducted as part of the ESYS humanoid project at the Engineering Systems Laboratory. The paper discusses the design concepts and hardware specifications of the compact size humanoid robots, which were constructed in several iterations from Mk.1 to Mk.5 [1].

To validate their approach, the authors developed a biped walking robot equipped with a ZMP measurement system and a support device. Computer simulations and learning control experiments were conducted to assess the effectiveness of the proposed methods. The results of these experiments confirmed the convergence of the learning methods, and the authors observed changes in the convergence rate with variations in the weight coefficient[2].

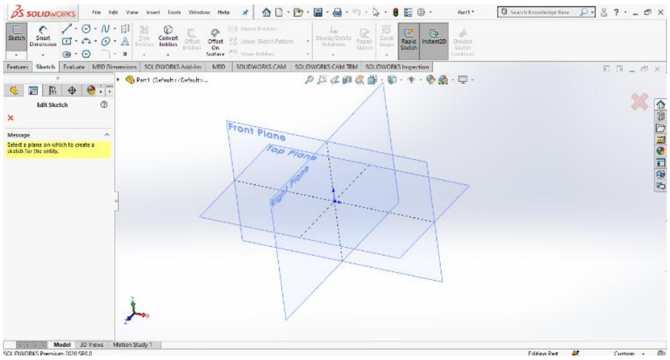
As a result, engineers have to design control programs for pre-determined robot morphologies, without guaranteeing optimality within a large design space. To address this limitation, the authors suggest employing evolutionary approaches that enable the co-evolution of both the morphology and control of humanoid robots. By allowing the morphology and controller to evolve together, unexpected optimal solutions can be discovered[3].

To control the robot, a minimal number of actuators is used. The robot is controlled by an ATmega8 microcontroller, which communicates with a servo controller board. This setup enables the execution of various walking patterns and movements based on the control signals received by the actuators.

3. DESIGN AND FABRICATION

3.1 DESIGN OF HUMANOID ROBOT

3.1.1 Solid works



Select a plane on which to create a sketch for the entity.

Fig.3.1 Solid works Interface

3.1.2 Design of Humanoid Robot in Solidworks

The Solidworks software is utilized for designing various components of the humanoid robot. The design process begins by creating individual parts with standard dimensions in the "part modelling section" of the software. Each part, including the robot foot, thighs, servo holder, and others, is designed separately, incorporating the necessary features and geometries using Solid works tools and commands.

Once all the parts and sub-assemblies are designed, they are brought together in the "Assembly section" of Solid works. In this stage, proper mating relationships are established to ensure accurate alignment and connectivity between the components. Mating involves defining connections such as aligning holes, specifying coincident or concentric relationships, and applying appropriate constraints.

By assembling the designed parts and sub-assemblies in Solid works Assembly section, the final assembly of the humanoid robot is obtained. This represents the complete integration of all the designed components, resulting in the fully assembled robot.

Throughout the design and assembly process, Solid works provides a range of features and functionalities to assist in creating accurate and mechanically sound designs. These include mate references, assembly constraints, interference detection, and motion simulation, ensuring that the final assembly functions as intended.

STEP-I:

The design process of the humanoid robot involves creating various parts using the Solid works software's Part modelling section. Components such as the robot foot, supporting links, robot thigh, robot torso, robot body, robot arms, and head are designed individually using the available tools and commands.

To create the 2D shapes of the parts, commands like line, rectangle, and arc are utilized, ensuring that they are drawn with the correct dimensions. Once the basic 2D shapes are created, the Extrude command is employed to give them depth and transform them into 3D objects, adjusting the extrusion to achieve the desired size and shape.

Figures 3.2, 3.3, and 3.4 represent the designs of specific robot parts, namely the robot foot, supporting link, and robot leg, respectively, within the Solid works software. These figures showcase the detailed designs of these components, illustrating their dimensions, features, and geometries. Similar procedures are followed to design all the other robot parts using Solid works.

By employing Solid works capabilities, engineers can accurately design and visualize each part of the humanoid robot, ensuring that they fit together seamlessly and meet the required specifications. This software enables precise modelling, dimensioning, and modification of the parts, facilitating the overall development process of the robot.

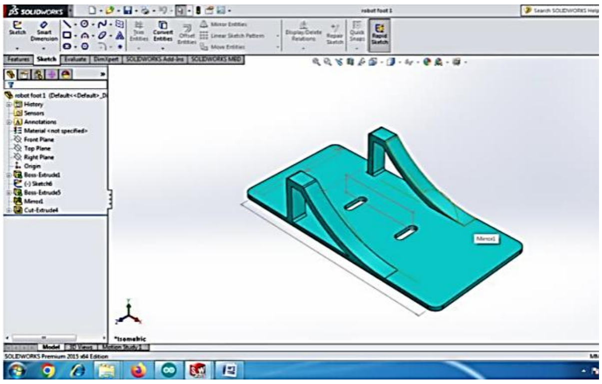


Fig.3.2 Robot Foot

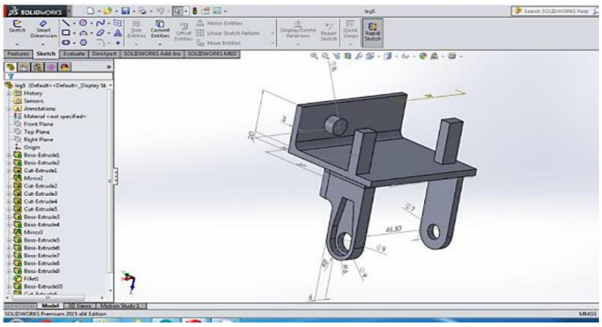


Fig.3.3 Support link

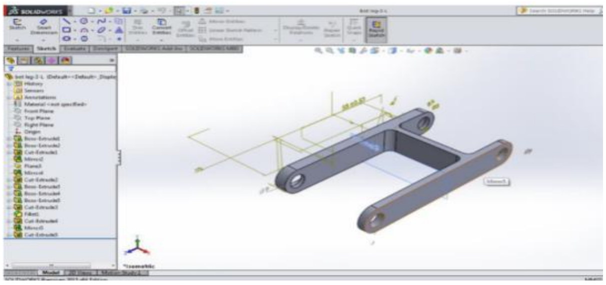


Fig.3.4 Robot Leg

Step 2:

Once the individual parts are designed in the part modelling section, then some required sub-assemblies are made in the Assembly section of the Solid works software. These sub-assemblies make the final Assembly design much easier. Mating of components is made by using the “Mate” command. Proper mating is given while designing the sub-assemblies.

Step 3:

Finally, all the required individual parts and the sub-assemblies are inserted in the Assembly section by using the “Insert Components” command, and some commands like “Coincident”, “Concentric”, etc. are used properly for proper design of the final assembly. The figure 3.5 shows the Final assembly of the Humanoid Robot.

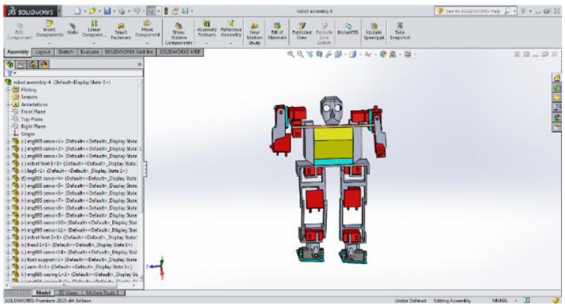


Fig.3.5 Final Assembly of humanoid robot

Step 4:

After the complete design, the Constraints are defined to specify the conditions that the design must satisfy.

3.2 FABRICATION WITH 3D PRINTER

3.2.1 3D CUBIC 3D Printer

The term "3D CUBIC 3D printer" is not a widely recognized or commonly used phrase in the field of 3D printing. It's possible that it refers to a specific brand or model of a 3D printer, but without further context or information, it is difficult to provide specific details. In general, a 3D printer is a device that creates three-dimensional objects by depositing successive layers of material, such as plastic or resin, based on a digital model or design. There are various types of 3D printers available on the market, each with its own features, capabilities, and printing technologies.

Fig.3.6 3d Cubic 3d Printer

3.2.2 PLA filament

Fig.3.7 PLA Filament

PLA plastic, also known as polylactic acid, is a type of biodegradable thermoplastic material commonly used in 3D printing. It is derived from renewable sources such as corn-starch through a fermentation process. As thermoplastic aliphatic polyester, PLA serves as a primary natural raw material for additive manufacturing in filament fabrication.

3.2.3 Printed Parts

Before starting the printing operation, we need to place the PLA filament in the Extruder as shown in the figure 3.8.

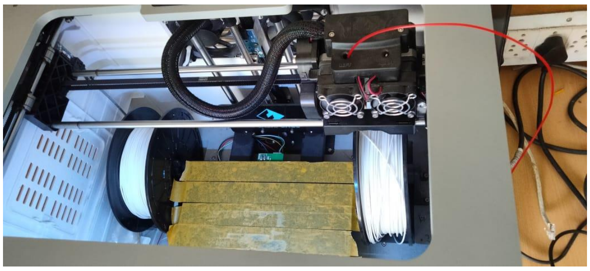


Fig.3.8 PLA filament placed in the left extruder

Once the setup is done, we need to start the printer and start the printing operation.

3.2:4 Post Process:

After the complete process, let the platform in the 3D printer cool down. Then after getting cooled down the parts are taken from the Printer. The figures 3.11, 3.12, 3.13 are some of the parts that are printed from the 3D printer.

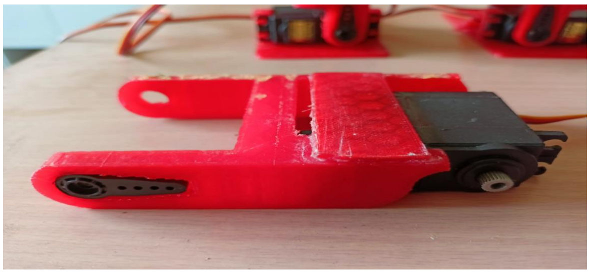


Figure 3.11 Robot thigh

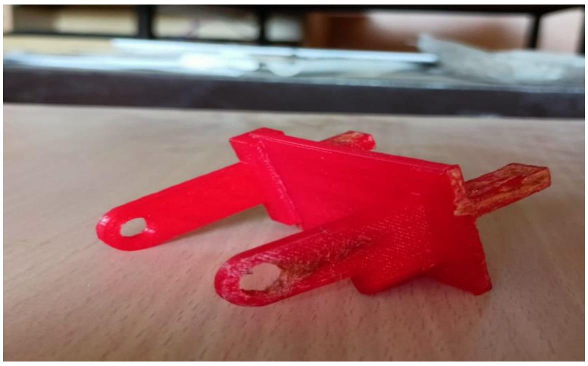


Figure 3.12 Supporting link

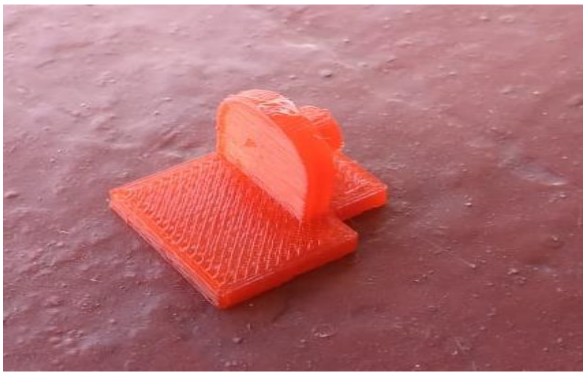


Figure 3.13 Foot link

Similarly, all the parts are printed in the 3D printer and all the parts are collected together, and sharp edges and uneven surfaces are filed with the help of knife-edge file and sand paper.

3.3 COMPONENTS USED

1 MG995 Servo Motor
2 Arduino UNO
3. Bread Board
4 Jumper wires

3.4 ASSEMBLY OF PARTS

Fig. 3.14 Sub-Assemblies of Robot

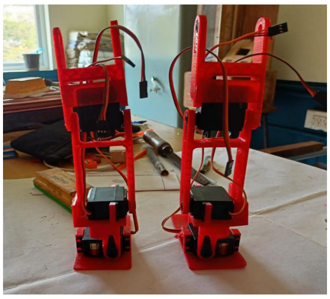


Fig 3.15. Assembling the Robot

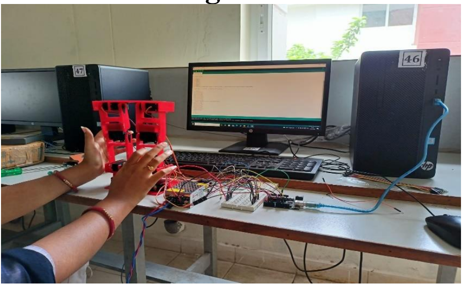
Fig 3.16. Final Assembly of Robot

IV. WIRING AND PROGRAMMING

4.1 WIRING

All the wiring is done between the Arduino Uno, Power Source and Motors, and Initially all the Servo motors are fixed at 90 degrees for obtaining the flexible movement of motors.

Fig 4.1. Connecting Motor with Arduino



Fi 4.2. Wiring between Power source, Arduino and Servos

4.2 TESTING OF HUMANOID ROBOT

1. All the servos are connected to the Arduino Uno using jumper wires. The jumper wires provide the necessary electrical connections between the servo signal pins and the corresponding pins on the Arduino board.
2. The power supply for the servos is connected to the breadboard, and the ground and power pins of the servos are connected accordingly on the breadboard. This ensures that the servos receive the required power for their operation.

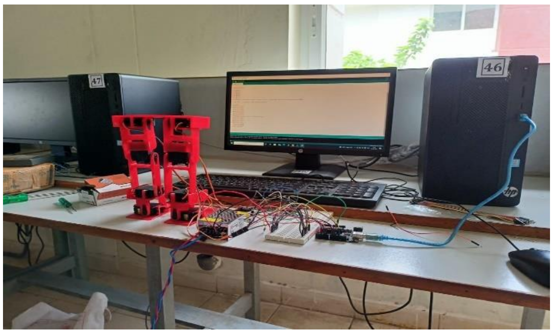


FIG.4.4 Testing the Humanoid Robot

3. The signal pins of the servos are connected to specific pins on the Arduino board. These signal pins are used to send input instructions to the servos, controlling their movement and position.
4. The programming is done using the Arduino IDE (Integrated Development Environment) and the Servo library. The Servo library provides convenient functions to control the servos connected to the Arduino. The program is written to specify the desired angles or positions of the servos and is then uploaded to the Arduino board.
5. The balancing and walking program is written by defining the angles or positions of the servos at different stages of the motion. By adjusting the angles of the servos in a coordinated manner, the robot can achieve balance and perform walking motions. The program takes into account various factors such as weight distribution, center of gravity, and timing to ensure stable and controlled movements.

V. RESULTS AND DISCUSSION

The humanoid robot is programmed to achieve balance while walking by implementing a specific code. The code is written in Arduino IDE using the Servo libraries, allowing control over the angles of the servos.

To achieve balance, the centre of gravity of the robot's legs is determined, and the code is written accordingly. Figures 5.1 and 5.2 illustrate the robot standing on individual legs and then demonstrate the forward motion of the legs. These figures visually depict the progress and movement of the robot during the balancing and walking.

FIG.5.1 Robot standing on left leg

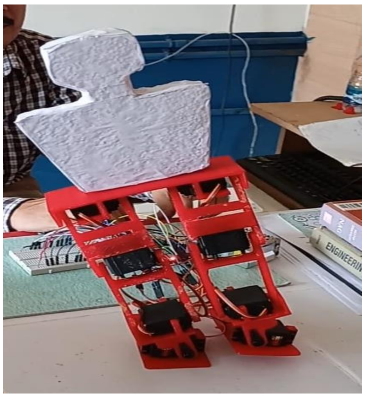


Fig.5.2 Robot standing on Right leg

CONCLUSION

Wheeled robots face limitations when it comes to navigating obstacles, making them less suitable for terrains such as rocky surfaces, steep declines, or low-friction areas. To overcome these challenges, legged robots offer a more advantageous solution. In this project, we have successfully developed a legged humanoid robot to address these drawbacks.

By utilizing servo motors, we were able to achieve the walking motion of the robot. The use of motors allows for precise control over the movement of the legs, enabling the robot to navigate various terrains and overcome obstacles more effectively. Through this implementation, we have demonstrated that walking motion can be obtained with the help of motors, effectively mitigating the limitations of wheeled robots.

In conclusion, legged robots provide a viable alternative to wheeled robots, particularly in scenarios where obstacles and challenging terrains need to be traversed. The successful fabrication and functioning of the legged humanoid robot in this project exemplify the potential of using motors to enable walking motion and overcome the disadvantages associated with wheeled robots.

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