International Journal of Research and Development in Engineering Science
ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/
Regular Issue, Vol. 6, Issue. 4 (July - August), 2024 , Pages: 26 - 32
Received: 27 May 2024 ; *Accepted:* 25 June 2024 ; *Published:* 18 August 2024
https://doi.org/10.63328/IJRDES-V6RI4P5
Original Paper : Classification Research – Problem Solution Research Paper

Design and Fabrication of First Responder Hexapod

A. Harshavardhan [1], J. Vijay [2], Mariya Rose Joseph [3], P. Vinay Reddy [4], P. V Prasad Reddy [5,*], S. Madhava Reddy [6*]

[1*, 2, 3, 4, 5] Department of Mechatronics Engineering, Mahatma Gandhi Institute of Technology, Hyderabad, India;
[1] aharshavardhan_mct201404@mgit.ac.in , [2] jvijay_mct201414@mgit.ac.in , [3] mrosejoseph_mct201424@mgit.ac.in ,
[4] pvinayreddy_mct201431@mgit.ac.in , [5] pvprasadreddy_mct@mgit.ac.in , [6] smadhavareddy_mct@mgit.ac.in

* *Corresponding Author:* pvprasadreddy_mct@mgit.ac.in , smadhavareddy_mct@mgit.ac.in

Abstract: Within the domain of calamity reaction, quick and viable arrangement of assets is foremost for relieving the effect of disastrous occasions. Conventional reaction strategies regularly confront challenges in getting to unsafe and complex landscapes, subsequently requiring inventive arrangements. In spite of the fact that a wide extend of plans and usage of robots were displayed within the field of rescue operations, implanting the portability and location of survivors beneath the collapsed structures is still troublesome. Quick localization of harmed survivors by rescue group is another challenging issue and working a rescue operation beneath a collapsed structure and challenging situations which can be unsafe to the rescue team. This research is outlined in a way to play down the unsafe circumstances for rescue group and maximize the look operations for finding survivors beneath the rubbles using a Hexapod Robot. In this project the parts of Hexapod robot (Coxa, Femur, Tibia, Upper and lower body) are 3D printed by employing a 3D printer. To assist the disaster response team, the robot is remote controlled by the disaster response team to detect the presence of any survivors under a collapsed structure, it uses Co2 gas sensors to detect the Co2 concentration present in the disaster area. It also uses a non-contact thermal sensors to detect the temperature of the survivors under the rubbles. It gathers all the information from the sensors and sends it to the disaster team. The hexapod is remotely controlled by response team utilizing Blynk app through Esp8266 module. The benefits of utilizing the first responder hexapod are to diminish the sparing time in rescue operations, detecting the survivors beneath the rubbles, sending the data rapidly to the reaction group, so that the group can protect the survivors. It aims at enhancing its effectiveness and contribution to disaster response efforts.

Keywords: Disaster Response, Hexapod, Rescue Team, Co2 Sensor, Esp8266 Module, Blynk App.

1. Introduction

A As the frequency and severity of natural and man-made disasters continue to escalate, the demand for efficient and technologically advanced search and rescue mechanisms has never been more pressing. Traditional methods often fall short in navigating complex and hazardous terrains, leaving first responders with limited access to critical information and impeding their ability to reach victims swiftly. The First Responder Hexapod responds to this critical need by introducing a robotic platform that transcends the limitations of wheeled or tracked counterparts. In the face of growing challenges in emergency response scenarios, the need for innovative and versatile robotic solutions has become increasingly evident. The project "First Responder Hexapod" aims to address the limitations of existing response mechanisms in situations such as natural disasters, hazardous environments, or search and rescue missions. Addressing these challenges requires a holistic approach that encompasses mechanical design, sensor integration, intelligent control systems, and effective human-robot interaction. Hexapods found applications in various fields, including research and exploration. They were deployed in environments that were challenging for traditional wheeled or tracked vehicles, such as rough terrain, disaster-stricken areas, and even extraterrestrial surfaces in space exploration missions. Hexapod-type rescue robots gained attention for their ability to navigate challenging environments, including rubble, debris, and confined spaces. The hexapod's capacity to climb over obstacles, adapt to uneven surfaces, and maintain stability in unpredictable conditions made it an attractive candidate for search and rescue missions. In recent years, hexapod technology has continued to advance. Modern hexapods often feature advanced materials, more powerful actuators, and sophisticated control systems. These robots are employed in a wide range of applications, from search and rescue missions to agricultural tasks and beyond.

2. Related Work

The research focuses on designing and manufacturing a six-legged robot that can perform basic tasks such as walking back and forth, turning right and left, turning 180 degrees and walking on uneven surfaces. The six-legged design offers additional stability and flexibility compared to wheeled robots. The structure of each member has three degrees of freedom. The robot acts as a platform to which additional sensory components can be added for tracking and autonomous navigation on rough surfaces. The article details the hardware design of the structure, the selection of all the parts and components used, and the design of the software that controls all functions, including the robot's walking style and balancing on uneven surfaces.[1].This article discusses the ideal solution to problems such as ground movement (falling of roof/sides), floods, air explosions, etc., in addition to gas explosions and dust explosions, which are limited to coal mines. Whatever the cause and type of the accident or the extent of the damage, the task of the rescue team is to reach the trapped miners. In addition to the lack of oxygen, the accident/asphyxiation zone contains harmful gases such as carbon dioxide and carbon monoxide and explosive gases such as methane. An entire gallery or road is full of dust and smoke or, in case of flooding, water, which hinders the visibility of rescue workers. So it is not an ideal situation for the rescue team to take action. The first hours after a disaster are critical moments that can make the difference between life and death for trapped miners. The ideal solution in such cases would be to deploy a wireless 6-foot robot equipped with various gas sensors, ultrasonic sensors, PIR sensors and a vision system that facilitates visibility even in very dark conditions. This project looks at some notable examples from the past and highlights the design and development of a 6-legged robot that meets the requirements for such mine rescue robots and some of the limitations encountered in designing such robots.[2].

This review article aims to address general research questions in the field of hexapod robotics. How can we build intelligent autonomous six-legged robots that can use their biomechanics, morphology and computational systems to achieve autonomy, adaptability and energy efficiency comparable to small creatures like insects? Are insects good models for building such intelligent six-legged robots, since they are the only six-legged animals? This review article is divided into three main parts to address these questions and help roboticists identify relevant and future directions for hexapod robotics in the next decade. After the introduction, the sections respectively cover the following three key areas: biomechanics, focusing on the design of smart feet; control of movement; and control of advanced cognition. These interconnected and interdependent areas are critical to improving the effectiveness of hexapod robotics in terms of energy efficiency, terrain adaptation, autonomy, and range. We also discuss how next-generation biorobots can transfer information from biology to robotics and vice versa.[3].

This article provides an overview of the state of the art in six-legged walking robots, citing both early designs and the most recent achievements. Attention is paid to key design issues and limitations that affect technical feasibility and performance. A design procedure is outlined for the systematic design of a six-legged walking robot. The proposed design procedure specifically considers the most important features such as mechanical structure and leg structure, driving and operating systems, payload, traffic conditions, and walkway. A case study is presented to demonstrate the effectiveness and feasibility of the proposed design procedure.[4]

This article discusses the coordination of leg movements, which is an important function of any multi-legged robot locomotion. The time required to coordinate the legs depends on the number of legs and services and the complexity of the selected algorithm. This paper proposed a tripod-pavement motion algorithm for a hexapod defined by simple geometry and inverse kinematics. The Hexapod has 3 servos on each leg, for a total of 18 servos, which should be able to perform several movements, including turning forward, backward, left, and right as fast as possible. Experiments showed that the proposed method worked well for hexapod leg coordination. Additionally, this simple approach can move six legs twice as fast as the conventional inverse kinematics method.[5]

This paper presents a new six-legged robot with legs distributed radially freely around the body. Compared with radially symmetrical or rectangular symmetrical robots, the legs of radially free distribution hexapods can rotate around the robot body and redistribute their positions due to the designed radial free distribution mechanism. To study the performance of the designed robot, the kinematically accessible workspace is analyzed in a three-dimensional coordinate system and enlarged thanks to the redistribution mechanism. The fault tolerance and stability of the robot are then analyzed to ensure the effectiveness of the proposed radial free delivery mechanism theory. In

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P5

addition, several comparative experiments are conducted to investigate the excellent performance of the proposed six-legged robot in terms of stability, climbing, and energy consumption. The results show that a six-legged, radially freely stretched robot can improve various performance parameters when lifting a weight or walking on a slope.[6]

3. Methodology

The First Responder Hexapod is an innovative project designed for emergency response scenarios, combining robotics, sensor technologies, and IoT connectivity. This hexapod utilizes advanced components such as Arduino Mega, micro servo motors, servo motor drivers, Node MCU, a CO2 sensor, and a non-contact thermal sensor, and is powered by a LiPo battery. The integration of these components enables the hexapod to navigate through environments, detect potential hazards, and transmit crucial information through the Blynk platform. In this comprehensive overview, we'll delve into the working principles of the First Responder Hexapod, highlighting its key features, functionalities, and the synergy between its components.

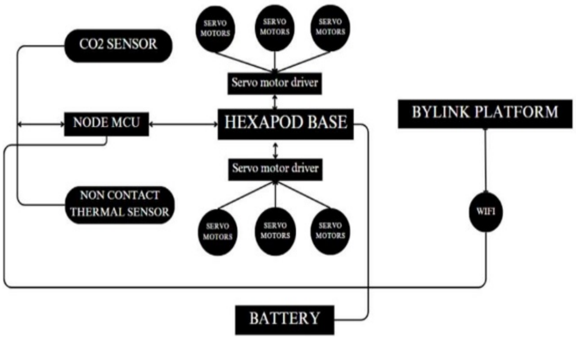


Figure.1 Block Diagram of Hexapod

3.1. Working Principle

In the hexapod, the components are interconnected to enable communication, control, and sensing functionalities. The Node-MCU serves as the central microcontroller, responsible for processing data and managing the interactions between different components. The 18 micro servomotors, which are controlled by the PCA9685 16 channel 12-bit servo drivers, are connected to the Node-MCU via I2C communication. The Node-MCU sends commands to the PCA9685 drivers to control the movement of the servomotors, which in turn actuate the legs of the hexapod for locomotion. The Li-ion battery provides power to the Node-MCU, PCA9685 drivers, and servomotors, ensuring uninterrupted operation of the hexapod. The ACD10 CO2 sensor and MLX non-contact temperature sensor is connected to the Node-MCU's GPIO pins for data acquisition. The Node-MCU communicates with these sensors using their respective communication protocols (e.g., UART or I2C) to collect CO2 concentration and temperature data. Overall, the Node-MCU serves as the central hub, orchestrating communication between the various components of the hexapod. It sends control signals to the servomotors through the PCA9685 drivers for movement, reads sensor data from the CO2 and temperature sensors, and processes this data to provide feedback or trigger specific actions, such as adjusting the hexapod's behaviour based on environmental conditions. The Locomotion of Hexapod is operated by Blynk console, where there is joystick which moved will move the hexapod, and for co2 and temperature sensor readings we have created a chart and labels which shows the readings.

3.2. Design of Hexapod

The main body of a Hexapod can be divided into two parts Base and its legs, the legs are further divided based on the joints, it has 3 joints/parts Coxa, femur, and tibia.

COXA: The coxa is the hip joint, connecting the leg to the hexapod's body. It allows the leg to move in different directions, providing flexibility and stability.

FEMUR: Also known as the thigh bone, it is the most proximal (closest to the centre of the body) portion of the leg. It is the strongest portion of the body.

TIBIA: Also known as the shinbone or the shank bone, it is one of the larger and stronger portions of the leg. it is situated below the knee joint. It bears most of the weight of the robot structure

BASE: It is the main body of the robot situated on top of the legs. It consists of the complete circuit board; i.e. it is the brain of the robot. The circuit board is to be sandwiched between twobase plates.

The Design of the hexapod is done in Fusion 360 software, Fusion 360 is a powerful, cloud-based Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), and Computer-Aided Engineering (CAE) software developed by Autodesk. It is widely used by engineers, designers, and manufacturers for product development, 3D modelling, simulation, and collaboration.

Figure.2 3D view of Coxa

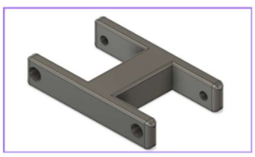


Figure.3 3D view of Femur

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P5

Figure.4 Isometric view of tibia

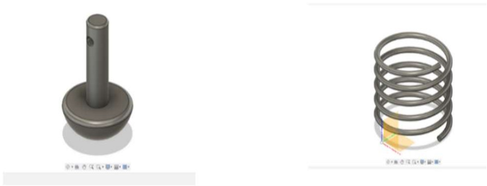


Figure.5 Tibia tip and spring part.

Figure.6 Upper frame of hexapod

Figure.7: Base of hexapod

Figure.8 3D model of First Responder Hexapod

3.3. Fabrication process of hexapod

The fabrication process of the hexapod is done by 3D printing these models. 3D printing is being preferred for the fabrication of the hexapod because of it's flexibility to customization, helps create intricate geometries to achieve optimal performance, supports a wide range of material selection, enables the creation of lightweight structures by optimizing internal geometries and using lightweight materials. With 3D printing, it's possible to integrate additional features directly into the leg design, such as mounting points for sensors and other components.

3D Printing Procedure: The 3D printing process involves designing a digital 3D model, slicing it into layers, and setting up the printer with the appropriate printing material. The printer uses STL files, and we used 15% infill of PLA. The printing process can begin after calibrating the printer and loading the material. According to the digital model, the printer follows the G-code instructions to deposit or solidify the material layer by layer depending on the object's complexity and size, this process can take minutes to days. Post-processing, such as removing support structures, smoothing rough edges, and applying surface finishes, may be necessary to enhance the quality and functionality of the printedobject

Material Used PLA: PLA stands for Polylactic Acid, which is a biodegradable thermoplastic polyester derived from renewable resources such as corn starch or sugarcane. It's one of the most commonly used materials in 3D printing due to its ease of use, low cost, and environmentally friendly properties.

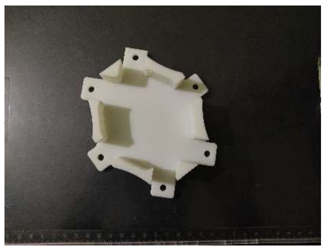


Figure.9 3D Printed Base of Hexapod

Figure.10 3D Printed Upper frame of Hexapod

Figure.11 3D Printed Coxa, Femur and tibia

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P5

3.4. Interfacing of components

The hexapod's components are interconnected, with the Node- MCU serving as the central microcontroller. It controls 18 servomotors through 16-channel servo drivers, powering the hexapod's movement. The Li-ion battery provides uninterrupted power. CO2 and temperature sensors communicate with the Node-MCU for data acquisition. The Blynk console operates hexapod locomotion using a joystick and displays CO2 and temperature sensor readings on a chart with labels. Hexapod uses two sensors: the ACD10 CO2 sensor and the Non-Contact Temperature sensor. Here is how to connect the sensors and the code parameters required for their proper functioning.

ACD10 CO2 Sensor:

- VCC Pin: Connects to the 3.3V pin of the Node-MCU forpower.
- GND Pin: Connects to the GND pin of the Node-MCU for theground connection.
- TX Pin: Connects to any digital pin (e.g., D1) of the Node-MCU for serial communication.

Non-Contact Temperature Sensor:

- VCC Pin: Connect to the 3.3V pin of the Node-MCU forpower supply.
- GND Pin: Connect to the GND pin of the Node-MCU for theground connection.
- SDA Pin: Connect to the D2 pin of the Node-MCU for I2Cserial data.
- SCL Pin: Connect to the D1 pin of the Node-MCU for I2Cserial clock.

Interfacing with Blynk platform:

The process of connecting the hexapod to the Blynk app involves the following steps:

Step-1: Set up the Blynk App: Download and install the Blynk app. Create a new project and add widgets for controlling the hexapod.

Step-2: Set up the Blynk Library: Install the Blynk library in the Arduino IDE.

Step-3: Obtain the Auth Token: Note down the Authentication Tokenprovided in the Blynk app.

Step-4: Write the Arduino Sketch: Include the Blynk library and define connection parameters. Implement BLYNK_WRITE () functions to handle incoming commands. Use Blynk.virtualWrite() to send sensor data or feedback.

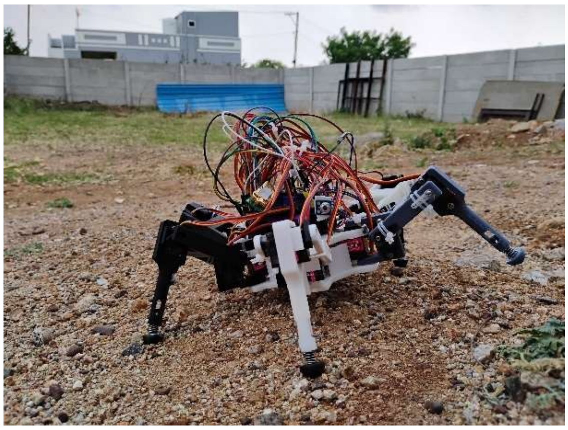
Step-5: Deploy the Code: Upload the Arduino sketch to the Node-MCU microcontroller connected to the hexapod.

Step-6: Control the Hexapod from the Blynk App: Connect to theproject in the Blynk app and use the widgets to send commands.

Step-7: Receive Feedback: View real-time feedback on the Blynkapp if implemented in the Arduino sketch.

We have set up the Blynk app with the following widgets:

- Joystick Widget for Hexapod Control
- Chart Widget for CO2 Sensor Readings
- Label Widgets for Temperature and CO2 Level



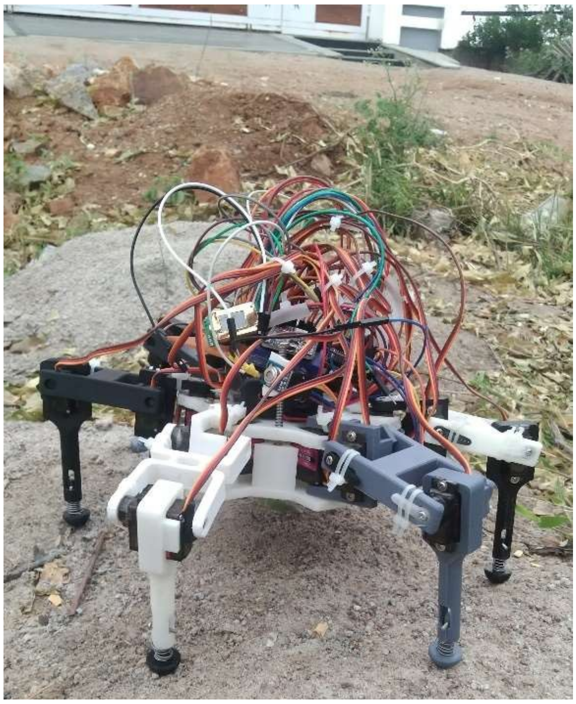


Figure 12 Prototype Model of Hexapod

The first responder hexapod robot project integrates servo motors, CO2 sensors, non-contact thermal sensors, and Node MCU to create a versatile hexapod robot equipped with environmental sensors. It is controlled through Blynk software for remote operation and sensor data monitoring. The fabrication process involved 3D printing of the robot parts and assembly of components. The robot's design allows for stable movement, showcasing the advantages of

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P5

hexapod locomotion in navigating challenging terrains and aiding in disaster response.

4. Results and Discussion

The first responder hexapod robot project integrates servo motors, CO2 sensors, non-contact thermal sensors, and Node MCU to create a versatile hexapod robot equipped with environmental sensors. It is controlled through Blynk software for remote operation and sensor data monitoring. The fabrication process involved 3D printing of the robot parts and assembly of components. The robot's design allows for stable movement, showcasing the advantages of hexapod locomotion in navigating challenging terrains and aiding in disaster response.

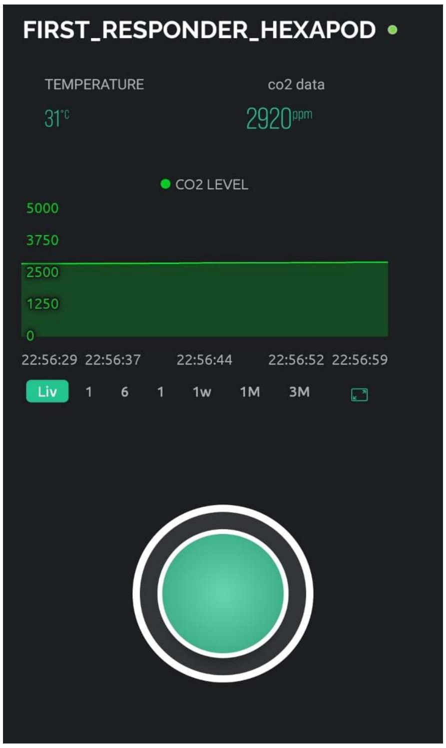


Figure.13 Blynk app output console

5. Conclusion and Future Scope

The development of a hexapod robot for first-responder applications involves combining robotics, mobility, and sensing capabilities to navigate challenging environments. Such robots could be used in risky situations, such as disaster areas or hazardous environments. The "First Responder Hexapod" project combines robotics and IoT technologies, featuring micro servo motors, servo motor drivers, Node MCU, CO2 sensor, non-contact thermal sensor, and powered by a Li-ion battery. The hexapod's innovative design and sensors enhance situational awareness for first responders. Control and monitoring through the Blynk platform and wireless connectivity through Node MCU enable efficient operation and remote accessibility. The integration of a Li-ion battery as the power source adds to the hexapod's portability, addressing the need for a reliable power supply in emergency response situations. Future developments will focus on optimizing energy efficiency, refining human-robot interaction, and exploring scalability and cost-effectiveness.

Authors' Contributions

A. Harshavardhan : Team Leader, Research Co-ordination, Project Conceptualization, Prototype Building, Assistance in Designing.
J. Vijay: Material sourcing and procurement, Assistance in prototype Building, Quality Control.
Mariya Rose Joseph: Data Collection, Literature Review, Documentation integrity.
P. Vinay Reddy : Designing, Coding Assistance and Electronics Assistance. **P.V Prasad Reddy, Dr.**
S. Madhava Reddy: Guidance, Mentorship, Research Methodology Expertise.

Declaration

We Declare with our best of Knowledge that this research work is purely Original Work and No third-party material Not used in this article drafting. If any such kind material found in further online publication, we are responsible only for any judicial and copyright issues.

References

[1]. Abhilash Krishna, Krishna Nandan, S.S Pradeep Kumar, Srihari K.S, Shivraj P, “Design and Fabrication of Hexapod Robot”, International Conference on Embedded Systems - (ICES 2014)
[2]. Katakam Prashanth, Dr.K.Ankamma Rao. “Design and Development of Six-Legged Robot for Mine Rescue System”, Science Technology and Development Journal – (Volume IX issue5-2020)
[3]. “Insect-Inspired Robots: Bridging Biological and Artificial Systems” by Poramate Manoonpong, Luca Patanè, Xiaofeng Xiong, Ilya Brodoline, Julien Dupeyroux, Stéphane Viollet, Paolo Arena and Julien R. Serres.
[4]. Franco Tedeschi, Giuseppe Carbone, “Design issues for Hexapod Walking Robots”, Robotics ISSN 2218-6581 pp. 181-206, 2014.
[5]. “Hexapod Leg Coordination using Simple Geometrical Tripod-Gait and Inverse Kinematics Approach” by Karlisa Priandana, Agus Buono, Wulandari.
[6]. “A Performance Oriented Novel Design of Hexapod Robots” by Guoliang Zhong, Member, IEEE, Long Chen, and Hua Deng, Member, IEEE

ISSN: 2582 - 4201(Online) , http://www.ijrdes.com/ IJRDES, Vol. 6, Issue 4 , 2024 , https://doi.org/10.63328/IJRDES-V6RI4P5

Authors Profile

A . Harshavardhan: Student of Mechatronics Engineering at Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad.(2020-2024).

J. Vijay: Student of Mechatronics Engineering at Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad.(2020-2024) .

Mariya Rose Joseph: Student of Mechatronics Engineeringat Mahatma Gandhi Institute of Technology, Gandipet, Hyderabad. (2020-2024).

P. Vinay Reddy: Student of Mechatronics Engineering atMahatma Gandhi Institute of Technology, Gandipet, Hyderabad. (2020-2024).

P.V Prasad Reddy: Assistant Professor in Department ofMechatronics Engineering at Mahatma Gandhi Institute ofTechnology, Gandipet, Hyderabad.

Dr. S. Madhava Reddy: Professor in Department of Mechatronics Engineering at Mahatma Gandhi Institute ofTechnology, Gandipet,.