Design and Implementation of a Highly Articulated 17-DOF Bipedal Robot with Arduino Control

Dr. Chiluka Ramesh[1] **Dr. K.Gouthami[2]**

Ms. SK. Gousiya Begum[3] **Mr. K.Ravi Kumar[4]**

[1]Associate Professor, Dept of ECE, Malineni Lakshmaiah Women's Engineering College, Guntur, A.P, India, Pin – 522017
drchilukaramesh@gmail.com
[2]Professor, Dept of ECE, Dean R&D, Malineni Lakshmaiah Women's Engineering College, Guntur, A.P, India, Pin – 522017
malineni.ece@gmail.com
[3]Assistant Professor, Dept of ECE, Dean R&D, Malineni Lakshmaiah Women's Engineering College, Guntur, A.P, India, Pin – 522017
gousya402@gmail.com
[4]Associate Professor, Dept of ECE, Malineni Lakshmaiah Women's Engineering College, Guntur, A.P, India, Pin – 522017
kundurthi.ravikumar@gmail.com

ABSTRACT

Humanoid robots are robots designed to resemble and mimic human characteristics. They are built with a human-like body structure, including a head, torso, arms, and legs. This paper describes the design and implementation of a highly articulated 17-degree-of-freedom (DOF) bipedal robot, controlled using an Arduino microcontroller that can interact with humans in a more natural and intuitive way. These robots often have sensors, cameras, and other components that enable them to perceive and understand their environment. They can use this information to navigate, recognize objects, and even communicate with people through speech or gestures. Humanoid robots have a wide range of applications. They can be used in research and development, education, entertainment, and even in healthcare. For example, they can assist with tasks like care giving, therapy, or exploring hazardous environments where it may be unsafe for humans to go[1]. Overall, humanoid robots are an exciting field of robotics that aims to bridge the gap between humans and machines, bringing us closer to a future where robots can seamlessly integrate into our daily lives.

This paper uses an Arduino board, which is a popular microcontroller platform, to develop the control system for a bipedal robot. The robot will have 17-DOF (degrees of freedom) which means it can move in various ways, mimicking human leg movements. With Bluetooth control, you can connect your smart phone or device to the robot and send commands wirelessly. This allows you to control the robot's movements, such as walking, turning, and even dancing, from a distance [2]. The Arduino board will act as the brain of the robot, processing the commands received via Bluetooth and sending signals to the robot's servo motors. These servomotors are responsible for moving the robot's joints, enabling it to walk and perform other actions.

By combining Arduino technology, Bluetooth control, and a 17-DOF bipedal robot, you'll have an exciting project that explores robotics, programming, and the potential for creating lifelike movements. It's a great way to dive into the world of robotics and unleash your creativity. This paper advances bipedal robotics by offering insights into the essential design considerations and implementation strategies required to develop highly articulated robots controlled by Arduino microcontrollers and provide a great way to dive into the world of robotics and unleash your creativity.

Keywords: Servo Controller, DC Motors, Arduino Micro Controller, Sensors

1. INTRODUCTION

The design of the highly articulated 17-DOF bipedal robot is inspired by the need to replicate human-like walking and movements. This design includes a complex arrangement of joints and limbs, each controlled by a servo motor, allowing for precise movements and balance. The mechanical structure of bipedal robot consists of the following:

1. Head:

- 1 DOF: The head can rotate side-to-side for visual scanning and balance adjustments. This is for Horizontal rotation of the robot.

2. Arms:

- 6 DOF (3 per arm): Each arm has three degrees of freedom, enabling forward/backward movement, lifting/lowering, and rotation. This allows the robot to maintain balance and perform simple tasks.
- Shoulder joint: 2 DOF (forward/backward lifting and rotation movement)
- Elbow joint: 1 DOF (bending)

3. Legs:

- 10 DOF (5 per leg): Each leg has five degrees of freedom, crucial for walking, balancing, and other lower-body movements.
- Hip joint: 3 DOF (forward/backward lifting, rotating, and side-to-side movement)
- Knee joint: 1 DOF (bending)
- Ankle joint: 1 DOF (Titling for balance adjustments)

Control System [3]

Arduino Microcontroller: The brain of the robot, responsible for processing inputs from sensors and controlling the servos. The Arduino receives commands from the control software and adjusts the servos accordingly.

Servo Motors: Each joint is powered by a servo motor, allowing for precise control over the robot's movements. The servos are programmed to move to specific angles, enabling the robot to perform complex motions.

Sensors: Typically, sensors like gyroscopes and accelerometers are used to maintain balance and provide feedback to the Arduino for real-time adjustments.

Power Supply

Battery Pack: A rechargeable battery pack powers the servos and the Arduino. The power supply needs to be robust enough to handle the simultaneous operation of multiple servos.

2. LITERATURE OVERVIEW

- In Lie Zi described about automation 250BC on which Robots works.
- Greek mathematician Hero of Alexandria described a machine to automatically pour wine for partyguests 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 stories in1941- 42.
- Honda developed P1 (Prototype Model 1) through P3, an evolution from E series, with upper limbsin 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).

Existing bipedal robot designs vary widely in complexity and application. Here's an overview of some notable designs and their characteristics:

1. **ASIMO by Honda**: One of the most famous bipedal robots, ASIMO is known for its advanced mobility and human-like walking capabilities. It features multiple DOFs in its legs and arms, allowing it to perform tasks such as walking, climbing stairs, and interacting with humans.

2. **PETMAN by Boston Dynamics**: Designed primarily for testing chemical protection clothing, PETMAN is a bipedal robot capable of dynamic balance and walking on various terrains. It incorporates advanced control algorithms and sensor feedback systems for stability.

3. **HRP-4 by Kawada Industries**: This humanoid robot is designed for research in human-robot interaction and bipedal locomotion. It features a lightweight yet robust design with multiple DOFs in its limbs, enabling it to mimic human movements and gestures.

4. **Atlas by Boston Dynamics**: Originally developed for the DARPA Robotics Challenge, Atlas is a highly agile bipedal robot designed for various tasks, including disaster response and industrial applications. It integrates advanced control systems and perception sensors for navigation and manipulation tasks.

5. **NAO by SoftBank Robotics**: Although smaller in size, NAO is a popular bipedal robot used in education and research. It features a compact design with multiple DOFs in its legs and arms, facilitating basic locomotion and interaction with its environment.

6. **MIT Cheetah Robot**: While primarily known for its quadrupedal version, MIT has also developed a bipedal variant of the Cheetah robot. It focuses on achieving high-speed running and dynamic balance through advanced control algorithms and lightweight materials.

7. **ANYmal by ANYbotics**: Originally a quadrupedal robot, ANYmal has been adapted into a bipedal configuration for specific applications. It utilizes advanced control strategies and sensor fusion techniques for robust locomotion and interaction in challenging environments.

These designs showcase the diversity in bipedal robot capabilities, ranging from humanoid robots designed for human-like tasks to specialized robots for specific applications like disaster response or testing. Each design incorporates various degrees of freedom, control strategies, and sensor integration to achieve stable and efficient bipedal locomotion.

3. HARWARE REQUIREMENTS

For the design and implementation of a highly articulated 17-DOF bipedal robot with Arduino control, the below list of hardware components are required [4]:

Mechanical Components

1. Servo Motors:

- 17 Servo Motors: High-torque servo motors are needed for precise control of each joint. Recommended servos include the MG996R or similar, capable of handling the load and providing smooth movement.

2. Structural Materials:

- Aluminium/Plastic Frame Components: Lightweight and sturdy materials to construct the robot’s frame and limbs. Custom CNC-machined parts or 3D-printed components can be used.
- Screws, Nuts, and Bolts: Various sizes for assembling the frame and attaching servos.

3. Joints and Connectors:

- Servo Horns: Connectors that attach servo motors to the robot's limbs.
- Ball Bearings: For smooth and stable joint movements.

Electronic Components

1. Arduino Microcontroller:

Arduino Mega 2560: Recommended for its ample I/O pins and processing power to handle multiple servos and sensors.

2. Servo Controller:

PCA9685 Servo Driver: A 16-channel PWM/servo driver that can be used to control multiple servos from a single I2C interface.

3. Power Supply:

- Battery Pack: A rechargeable battery pack (e.g., 7.4V LiPo battery) with sufficient capacity to power all servos and the Arduino.
- Voltage Regulator: Ensures a stable voltage supply to the servos and Arduino.

4. Sensors:

- IMU (Inertial Measurement Unit): Such as the MPU-6050, for measuring the robot's orientation and balance.
- Foot Pressure Sensors: Optional sensors for detecting ground contact and balance adjustments.

4. SOFTWARE INSTALLATION AND USAGE

To successfully implement and control your 17-DOF bipedal robot using Arduino, follow this detailed software installation procedure [5]:

1. Install the Arduino IDE

Step 1: Download the Arduino IDE

- Go to the official Arduino website Arduino Software Page (https://www.arduino.cc/en/software)
- Choose your operating system: Select the appropriate version for Windows, macOS, or Linux.
- Download the installer: Click on the download link to get the installer file.

Step 2: Install the Arduino IDE

Windows:

- Run the downloaded installer file and complete the installation process

macOS:

- Open the downloaded .zip file and drag the application folder

Linux:

- Extract the downloaded .tar.xz file.
- Open to the extracted folder.
- Run `./install.sh` to install the Arduino IDE.

2. Install Necessary Drivers

Step 1: Connect the Arduino Board using a USB cable to computer

Step 2: Install USB Drivers (if required)

Windows:

- The drivers should install automatically. If not, follow the prompts to install the drivers manually.

macOS and Linux:

- Drivers are usually pre-installed. If you encounter issues, refer to the Arduino troubleshooting guide.

3. Install Required Libraries

Step 1: Open the Arduino IDE

Launch the Arduino IDE on the computer.

Step 2: Install the Servo Library

- Navigate to Sketch > Include Library > Manage Libraries.
- Search for Servo and click on Servo library and install it.

Step 3: Install Additional Libraries

If additional libraries are required (e.g., for IMU sensors), repeat the process above for each library.

- Common libraries include:
  - Adafruit PCA9685 Library: For the servo driver.
  - MPU6050 Library: For the IMU sensor.

4. Set Up the Arduino Sketch

5. Upload the Sketch to the Arduino

6. Testing and Calibration

Step 1: Initial Tests

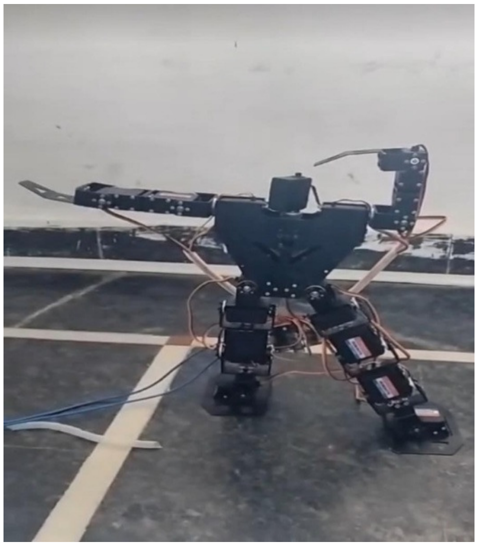
- Verify that each servo moves to the specified position when the sketch runs.

Step 2: Calibration

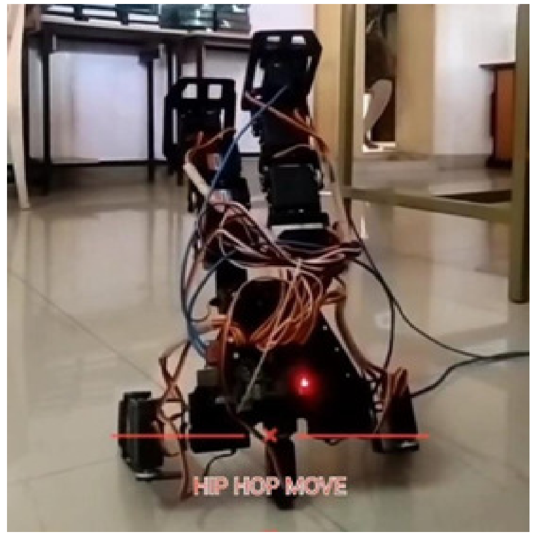
- Adjust servo positions as needed to ensure correct and smooth movement.

5. EXPERIMENTAL RESULTS

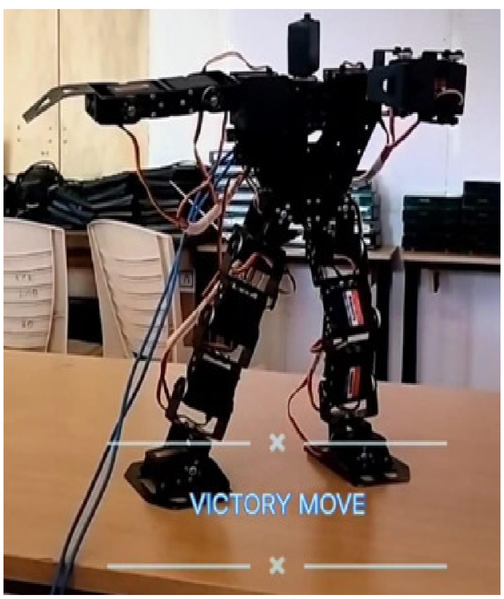
COME ON



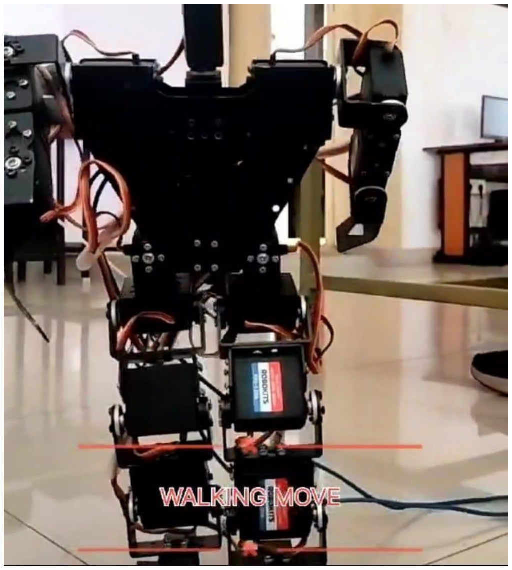
HIP-HOP



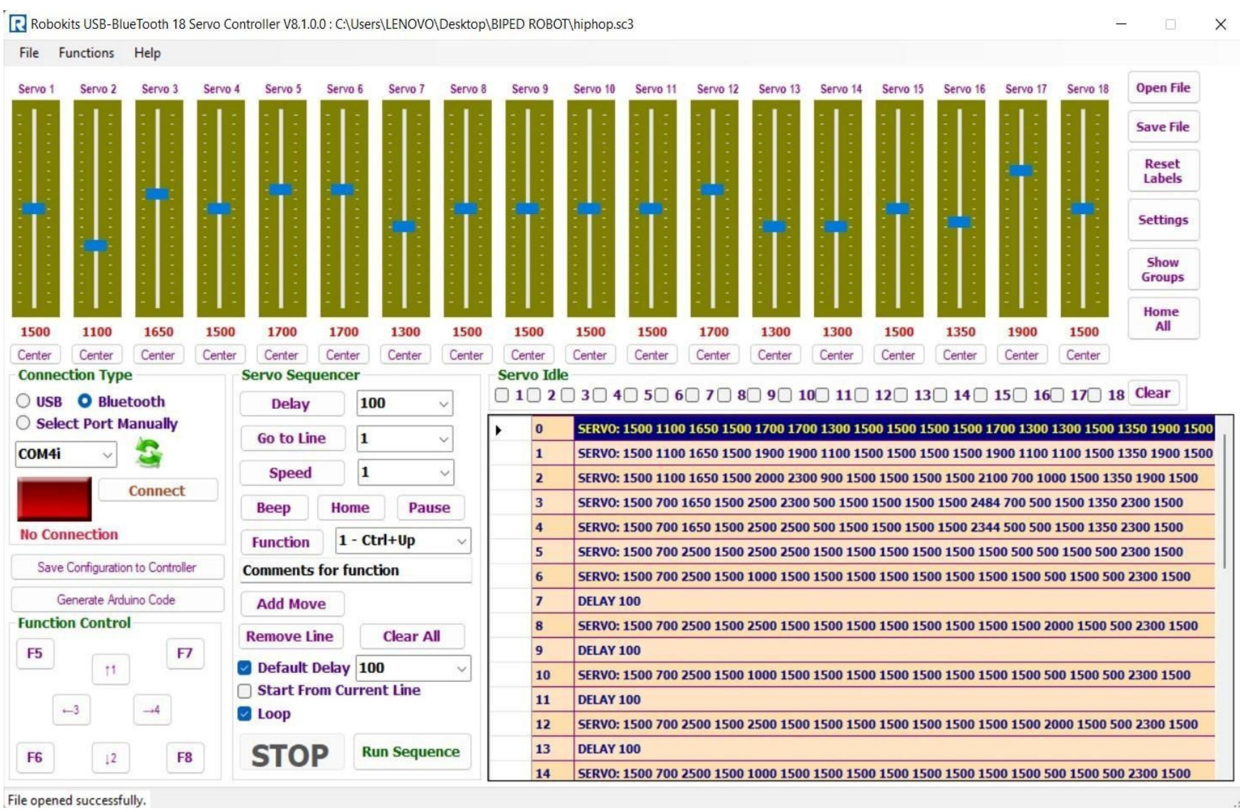
VICTORY



PUSH UP



WALK **ONE LEG MOVEMENT**



ADVANTAGES & APPLICATIONS OF HUMANOID ROBOT

- One can use these robots for many purposes, like testing motions, detecting or simulating challenging environments for testing, and other purposes.
- Humanoids are perfect to work for challenging outer-space missions. Also, some can even function as partners in research. Also, humanoids can help tackle catastrophic human-made situations like wars, etc [6,7].
- Due to the increase of automation in the fast-paced world, businesses are planning to invest in humanoids. It will increase efficiency, save human resource costs, and may increase the profitturnover positively.
- With the advancements of military weapons, it's now essential to deploy humanoids to cope with the pace and reduce the bloodshed of human soldiers. Some military-grade humanoids can move and gather data, process, and work efficiently, aiding the nation's military system. But there's still a lot of research and development needed to bridge the gap completely [8-11].

1. **Research and space exploration:** Most of the humanoid robots are used in research and space exploration in outer space.
2. **Personal assistance and care giving:** These humanoid robots also work as personal assistance work for individuals, especially the medically ill elderly patients.
3. **Education and entertainment:** These types of robots are used in educational institutions for educational and entertainment purposes.
4. **Search and rescue:** Some robots can aid heavily in security administrations like traffic controls, police administrations, etc. Humanoids can also help conduct time-sensitive search and rescue operations and curb menaces like child trafficking, etc., with high efficiency.
5. **Manufacturing and maintenance:** These robots are the most widely used because industries have to use robots for hazardous work.

FEATURES OF BIPEDAL ROBOT:

The development of bipedal robot features is a fascinating field! Bipedal robots aim to mimic human walking and balance, which is incredibly complex. Some key features and challenges include: Balance and Stability: Bipedal robots must maintain balance while walking, which requires advancedcontrol algorithms and sensors to detect and correct deviations.

- **Gait Generation:** Developing natural-looking walking gaits involves intricate algorithms to determine the sequence of movements for each leg while maintaining stability.
- **Terrain Adaptation:** Robots need to adapt to different terrains and obstacles, requiring sensors andalgorithms to adjust their walking patterns accordingly.

- **Energy Efficiency:** Efficient movement is crucial for prolonged operation, so optimizing the robot'smovements to conserve energy is a key consideration.

- **Human-Robot Interaction:** As bipedal robots may be used in environments with humans, ensuring safe and intuitive interaction is important, including collision avoidance and natural motion.

6. CONCLUSION

In conclusion, the development of bipedal robot features is a multidisciplinary field that combines aspects of robotics, biomechanics, control theory, and artificial intelligence. It is a challenging yet exciting area of research with the potential to revolutionize industries such as manufacturing, healthcare, and search and rescue.
The 17-DOF bipedal robot is designed to mimic human movements as closely as possible. With articulated joints controlled by an Arduino microcontroller, this robot can perform a range of motions essential for walking, balancing, and simple manipulations. The design emphasizes both mechanical complexity and control precision, making it a sophisticated piece of engineering in the field of robotics.

Humanoids are efficient, but they don't have a conscience or a complex thinking capacity like humans, which is still debatable globally. There are many talks about whether humanoids will take over the world or be a friend to humans. It's difficult to determine, but we can safely conclude that humanoids will change the market world. Whether it's the entertainment industry or the medical industry, the humanoid robots will play a key instrument in businesses' growth graphs without fail.

REFERENCES

1. Abras, Chadia, Maloney-Krichmar, Diane, and Preece, Jenny. User-centered design. In Bainbridge, William Sims, editor, Berkshire encyclopedia of human-computer interaction, volume 2, pages 763–767. Sage, Great Barrington, MA, 2004. ISBN 9780974309125.
2. Admoni, Henny and Scassellati, Brian. Social eye gaze in human-robot interaction: A review. Journal of Human-Robot Interaction, 6(1):25–63, 2017. doi: 10.5898/JHRI.6.1.Admoni.
3. Alaerts, Kaat, Nackaerts, Evelien, Meyns, Pieter, Swinnen, Stephan P., and Wenderoth, Nicole. Action and emotion recognition from point light displays: An investigation of gender differences. PloSOne, 6(6):e20989, 2011. doi: 10.1371/journal.pone.0020989.
4. Brian Wilson Aldiss. Supertoys last all summer long: And other stories of future time. St. Martin's Griffin, New York, NY, 2001. ISBN 978-0312280611.
5. Alemi, Minoo, Meghdari, Ali, and Ghazisaedy, Maryam. Employing humanoid robots for teaching English language in Iranian junior high-schools. International Journal of Humanoid Robotics,11(03):1450022, 2014. doi: 10.1142/S0219843614500224.
6. Alexander, Christopher. A pattern language: Towns, buildings, construction. Oxford UniversityPress, Oxford, UK, 1977. ISBN 978-0195019193.

7. Althaus, Philipp, Ishiguro, Hiroshi, Kanda, Takayuki, Miyashita, Takahiro, and Christensen, Henrik I.. Navigation for human-robot interaction tasks. In IEEE International Conference on Robotics and Automation, volume 2, pages 1894–1900. IEEE, 2004. ISBN 0-7803-8232-3. doi: 10.1109/ROBOT.2004.1308100.
8. Aly, Amir and Tapus, Adriana. A model for synthesizing a combined verbal and nonverbal behavior based on personality traits in human-robot interaction. In Proceedings of the 8th ACM/IEEE International Conference on Human-Robot Interaction, HRI'13, pages 325–332, Piscataway, NJ, USA, 2013. IEEE Press. ISBN 978-1-4673-3055-8. doi: 10.1109/HRI.2013.6483606.
9. Andersen, Peter A. and Guerrero, Laura K.. Principles of communication and emotion in social interaction. In Andersen, Peter A. and Guerrero, Laura K., editors, Handbook of communication and emotion: Research, theory, applications, and contexts, chapter 3, pages 49–96. Academic Press, 1998. ISBN 0-12-057770-4. doi: 10.1016/B978-012057770-5/50005-9.
10. Andrist, Sean, Tan, Xiang Zhi, Gleicher, Michael, and Mutlu, Bilge. Conversational gaze aversion for humanlike robots. In ACM/IEEE International Conference on Human-Robot Interaction, pages 25–32. ACM, 2014. ISBN 978-1-4503-2658-2. doi: 10.1145/2559636.2559666.
11. Argall, Brenna D., Chernova, Sonia, Veloso, Manuela, and Browning, Brett. A survey of robot learning from demonstration. Robotics and Autonomous Systems, 57 (5):469–483, 2009. doi: 10.1016/j.robot.2008.10.024.