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A REVIEW ON DESIGN AND FABRICATION OF HUMANOID ROBOT

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ABSTRACT
The design and fabrication of humanoid robots have become a focal point of research and development, driven by the potential to create machines that can replicate human movements, tasks, and interactions. This review provides an overview of the key aspects involved in the design and fabrication of humanoid robots, emphasizing the integration of mechanical, electrical, and software systems. The design process involves the selection of appropriate materials and actuators to achieve human-like motion, as well as the implementation of sensors for perception and control. Advanced techniques in kinematics, dynamics, and control systems are discussed, highlighting the challenges in achieving stability, flexibility, and responsiveness.Fabrication techniques, including 3D printing, CNC machining, and rapid prototyping, are evaluated for their effectiveness in producing complex robot components. The review also explores the role of artificial intelligence in enhancing the robot's ability to learn, adapt, and interact with its environment. Current trends, such as the use of lightweight materials and energy-efficient actuators, are examined for their impact on the robot's performance and autonomy.Finally, this review addresses the ethical considerations and potential societal impacts of humanoid robots, recognizing the need for responsible innovation. Through this comprehensive examination, the review aims to provide insights into the future directions and challenges in the field of humanoid robotics, contributing to the advancement of more capable and versatile robotic systems.

KEYWORDS:
Biped, Solid Works, 3D printer

I. Introduction
Humanoid robots, designed to resemble and mimic human form and function, have garnered significant attention in recent years due to their potential applications across various domains, including healthcare, entertainment, manufacturing, and service industries. The development of these robots is driven by the ambition to create machines that can perform complex tasks with human-like dexterity, autonomy, and intelligence. This endeavor requires a multidisciplinary approach, combining principles from mechanical engineering, electronics, computer science, and artificial intelligence.
The design of humanoid robots involves several critical considerations, such as the selection of appropriate materials, actuators, and sensors to achieve realistic motion and interaction capabilities. Kinematic and dynamic analyses are essential for ensuring that the robot can move smoothly and maintain balance while performing tasks. Additionally, the integration of sensors and control systems enables the robot to perceive its environment and respond appropriately, making real-time decisions based on sensory input.Fabrication plays a pivotal role in bringing the design to life, involving advanced manufacturing techniques such as 3D printing, CNC machining, and rapid prototyping. These methods allow for the creation of complex, lightweight structures that are essential for the robot's mobility and functionality. The inclusion of artificial intelligence further enhances the robot's capabilities, enabling it to learn from experience, adapt to new tasks, and interact with humans more naturally.

As humanoid robots continue to evolve, addressing challenges such as energy efficiency, durability, and ethical implications becomes increasingly important. This review aims to explore the current state of humanoid robot design and fabrication, providing insights into future developments and potential applications.

II. Literature

Mr. K. Ramadurai .et.al., [1] Robots are virtual or mechanical agents that follow instructions from electronic circuitry or computer algorithms. The field of robotics include computer systems for information processing, control, and sensory feedback in addition to the design, building, use, and operation of robots. The field of bio-inspired robotics is influenced by the designs of several robots. Another more recent development in the field of robotics is soft robotics. With the usage of an Arduino UNO, Arduino Mega, servo motor, HC06 Bluetooth module, DC motor, wheel, Deep Grove ball bearing, SD module, WiFi camera, and speaker, this work focuses on creating a bipedal walking approach for a full-sized humanoid robot. The objective is to create intelligent devices that can take the place of people in hazardous work conditions or production lines.
Alec Burns.et.al., [2] The design, performance assessment, cost, and safety issues of a fully functional humanoid are the main topics of discussion in this paper's discussion of the potential applications of humanoids in mental therapy. With three rectangular prims for protection, the robot's upper body and skin sensor were created to resemble the rib cage and spine of a person. Ecoflex rubber, a silicone catalysted by platinum, and PZT discs were used to create the artificial skin sensor. The mechanism enables the robot to point, hold objects with two hands, and engage in gesture-based gaming. A fully humanoid robot with 15 degrees of freedom and a mobile platform is designed and shown in this study. The majority of its components were 3D printed. Because of its carefully planned positioning, the robot's joints articulate successfully, enabling it to sense its surroundings and respond appropriately.
Alok Nath.et.al., [3] The adaptability of robots is investigated in this study, with a particular emphasis on how well they can imitate human movements, hand gestures, and facial expressions. The robot's body structure, joints, limbs, and general physical framework are all designed out of 0.5mm thick acrylic plastic sheet. Six metal gear servos allow the robot to move its ankles, knees, and hips. The project focuses on the design and development of a humanoid explorer robot that uses sensors to detect temperature, relative humidity, methane, carbon dioxide, and carbon monoxide in order to explore uncharted territory. The robot is appropriate for unprepared terrain where wheeled-based robots can encounter challenges since it can offer a clear grasp of the surroundings.
RagibAmin Nihal.et.al., [4] A valuable method for reducing communication gaps between the general public and those with hearing and speaking impairments is sign language (SL). But a lot of folks don't know much about SL. This difference can be filled in part by an automatic sign language recognition (SLR) system. In order to recognize and record motions in sign language, convert them into spoken language, and produce spoken language output, researchers are creating SLR systems with machine learning algorithms. With a test score of 87.5% and a validation result of 90.48%, the system has demonstrated great accuracy.
P. Siva Raman.et.al., [5] The multidisciplinary field of robotics includes computer systems for information processing, control, and sensory input in addition to the design, construction, operation, and use of robots. The goal of research is to develop a robotic hand that functions and seems like a human hand. For the arm, this technology makes use of 3D printing and polylactic acid (PLA), which is easily used, has mechanical qualities, and is renewable. Thanks to quick prototyping processes, the arm's effective finger and wrist actuations result in a lower fabrication cost. This method offers a humanoid robotic arm with many actuations and enhanced functionality at a reasonable price.
Naga Sudha Rani.B.et.al., [6] Biped robots are designed to navigate various man-made environments, such as staircases and sloping surfaces. Researchers have investigated gait generation and optimization to reduce energy consumption. Studies have focused on passive dynamic walking, feedback control laws, and trajectory generation to achieve stable locomotion and minimize energy consumption. A

kinematic and dynamic model is developed to describe the robot's movement and interaction with the environment. The model incorporates the compliance of the soft sole, which affects the interaction with the stairs. Two global optimization algorithms, Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC), are used to generate dynamically balanced gaits for a 7-DOF biped robot with a soft sole ascending a staircase. Simulation results show that the dynamic balance of the biped robot is high, and the average power consumption is low when compared to a biped robot with a hard sole. The correction to the deformation of the soft sole contributes to the improved performance. This research contributes to the development of efficient and stable biped robots for various applications.
Charles M.et.al., [7] The pursuit of revolutionizing human work and interaction has led to significant research in humanoid robots, particularly in the DARPA Robotics Challenge. However, current approaches relying on position-controlled robot arms for manipulation have limitations. This paper presents a novel approach using a soft, humanoid robot platform that is inherently robust to contact with the environment, humans, and other robots. The system utilizes an Arduino Micro-controller, compressed air, and sensors to control joint movements. The inflatable humanoid robot, named King Louie, demonstrates the viability of Linear Quadratic Regulator and Model Predictive Control in achieving precise movement control. The soft robot's compliance and low inertia show great potential for high levels of human-robot interaction. This preliminary work is a crucial step towards achieving improved performance in soft robot control and realizing the goal of humans and robots working together to perform various tasks. The innovative approach and control methods presented in this paper pave the way for future advancements in humanoid robotics.
J. Azeta.et.al., [8] The development of robots for infectious disease treatment in hospitals is an underexplored area, despite the growing field of robotics. Healthcare service robots can aid medical professionals, improving the quality of life for both healthcare providers and patients. A prototype humanoid robot was designed with a payload of 500g, remote-controlled arm motion, and a mobile platform for stability and navigation. The robot's body, made of lightweight Polylactic acid (PLA) material, provides stability for the arms and withstands stress. Finite element analysis confirmed that the stress distribution on the shoulder and torso support is within the material's yield strength, preventing failure. This robot aims to support healthcare personnel in delivery and related tasks, demonstrating the potential for humanoid robots in infectious disease treatment. The design and simulation results show promise for further development and implementation in healthcare settings.
Manyatha N.et.al., [9] The integration of robotics in education has transformed traditional procedures, and the use of humanoid robots in college admissions is a significant advancement. This study explores the design and construction of a humanoid robot for college admissions, highlighting its advantages and development challenges. The robot's framework was created using CAD modeling, and its motions were simulated. The frame was constructed from aluminum alloy components, and servomotors were securely attached to enable precise joint movement. The hand components were fabricated using 3D printing and equipped with adaptable grippers and sensors for gentle document handling. The robot can perform tasks such as managing paperwork, engaging with applicants, and providing information and assistance. The combination of modern mechanical components, sophisticated electronics, and intelligent software enables the robot to execute human-like motions and simplify the admissions process. Thorough testing and calibration are crucial for ensuring the proper functioning of all subsystems. The successful development of this humanoid robot marks a significant progress in automating and improving administrative tasks in college admissions.
Mathew Schwartz .et.al., [10] Humanoid robotics has long fascinated society, with cultural references shaping our perception of robots as surrogates for humans. This paper presents TOCABI, a novel humanoid robot design that draws inspiration from human anatomy while maintaining a unique robotic form. TOCABI's design prioritizes weight reduction and easy component access, with a densely packed torso containing most electronic components. The robot's arms are designed to carry a 3kg payload per hand, with motor drives located within the torso to minimize arm link mass. The design compromises between mechanical and manufacturing costs, acknowledging the intricate relationship

between design and control algorithms in complex systems like humanoid robots. To facilitate future research, the robot's design is made available in multiple formats and resolutions, enabling comparison of control algorithms. TOCABI's development contributes to the advancement of humanoid robotics, moving closer to integrating robots into our daily lives while acknowledging the complexities of design and control.

Yuze QIU .et.al., [11] With technology advancements, robots are increasingly being used as greeters and guides in companies and libraries. These robots can spark curiosity and showcase the company's or library's strength. Building on previous works in robot navigation, greeting, and human-robot communication, this study presents a bipedal robot designed to greet and guide guests. The robot's interaction system is integrated with RaspberryPi and Arduino microcontrollers, connected via a USB cable. The robot's structure consists of an actuator part with four wheels, two DC motors, and a timing belt chain, and a control part. The robot uses sensors and transducers to navigate and recognize faces. While experiments showed successful face recognition and navigation under ideal conditions, further testing is needed to ensure the robot's performance in real-world scenarios. The study's findings contribute to the development of robots as effective greeters and guides, enhancing visitor experiences and showcasing companies' and libraries' innovative capabilities.

Ali Fawzi Abdul Kareem Ahmed Abdul Hussein.et.al., [12] Al Bipedal robots, also known as humanoid robots, have two legs and can navigate unpaved terrain, making them a significant replacement for other types of robots. However, they are the most difficult to stabilize during walking or when one leg is in the swing phase and the other is on the ground. To address this, a projection-based monitoring system has been developed, adapted for various industrial conditions, with single modular projection units providing flexibility and customizability. The bipedal robot's fabrication involves moving the right roll hip joint to the right and the left roll hip joint to the left, while the right shoulder moves backward. The control unit transmits control codes to the servomotor board, producing pulse width modulation (PWM) signals to rotate the servos with specific angles and speed. Simulation and experimental results confirm the stability of the 10 and 17 degrees of freedom bipedal robots, with simulations indicating experimental results and experimental results carried out using the KHR-2HV simulation model by Webots.

K Aishwarya .et.al., [13] The introduction of robotic arms has transformed the way humans work, making tasks easier and more efficient. However, existing robotic arms have limitations in terms of accuracy. To address this, a new robotic arm model has been proposed, featuring a camera module that enables image processing capabilities such as auto white balance, automatic exposure, and automatic gain control. This model is more cost-effective and efficient than existing ones. The working principle involves the camera module performing advanced image processing techniques, including image enhancement and noise reduction. Experimental results have shown high accuracy with various subjects, and future work aims to improve the algorithms to enhance performance and apply them to real-world scenarios. The ultimate goal is to achieve efficient mapping, enabling online multi-hypothesis tracking and predicting potential occlusions.

Cristina Zaga1.et.al., [14] Robotic technology is increasingly being used to support children's development in various areas, including care, education, entertainment, social assistance, and therapy. However, research has shown that technologies that do not consider children's needs, abilities, and developmental characteristics may have limited or even negative impacts on their development. To address this, a workshop aims to bring researchers together to discuss how a developmental perspective can inform smart and natural interaction between robots and children. The workshop focuses on various topics related to child-robot interaction (CRI) applications, research areas, and design considerations. The goal is to make the workshop proceedings and discussion outcomes accessible online, creating an open-access resource for researchers and practitioners. Depending on the outcome, a Special Issue may be considered. By taking a developmental perspective, the workshop aims to ensure that robotic technology supports children's physical, cognitive, social, emotional, and moral development.

Tolga OLCAY .et.al., [15] Recent years have seen growing interest in walking biped robots, which offer higher mobility in various environments due to their human-like motion. However, controlling biped robots is a challenging problem due to their unbalanced, nonlinear, and dynamically time-variant nature. This paper presents the design of a biped robot, RUBI, and its walking pattern generation using the Linear Inverted Pendulum Model (LIPM) and fixed Zero Moment Point (ZMP). The method involves finding the center of mass position with ZMP reference to generate the walking pattern. RUBI was developed with a human-like shape, compact size, and low power design philosophy. For robot stability, ZMP should be on the supporting foot area while the swing foot is moving, and this action is repeated in walking. The walking pattern generation method is applied to RUBI, a small biped robot with simple sensor structures and relatively low complexity. This paper presents a walking pattern generation method for biped robots, which can be applied to small biped robots like RUBI.
Ashwin Sushil Kumar.et.al., [16] Bio-inspired robotic locomotion is a growing field, with bipedal robots being a key area of research. These robots emulate human walking motion, offering higher mobility in various environments. The study of bipedal robots has rapidly increased in recent years. This paper presents a bipedal robot design with a unique leg structure, combining mobility and lightness. The robot uses an Internal Centre of Gravity Shifter (ICGS) and Zero Momentum Point to maintain balance. The leg has three degrees of freedom (DOF) at the hip joint, with hip pitch being the most important for forward motion. The robot is initialized in a balanced position and uses sensors to determine the correct direction and mode of walking. While robotics has the potential to make life easier, it is still a developing field that requires further research. This bipedal robot design can be improved by modifying its gait to walk on inclined surfaces or rough terrain, offering possibilities for future development.
DFKI-RIC.et.al., [17] Industrial robots have proven their value in various applications, offering dexterity, accuracy, and efficiency. However, when collaboration between robots and workers is required, standard industrial robots are not feasible due to safety concerns. To address this, highly customizable robotic solutions are being developed for safe and effective human-robot collaboration in manufacturing. The design features modular actuators with embedded electronics and sensors, enabling speed, force, and torque monitoring. The controller reduces control effort by considering zero-dynamics behavior, aiming to match the performance of standard robots. A timeline-based planning approach is used, relying on the APSI-TRF, to deploy a continuous task planning and adaptation system with humans in the loop. The framework involves a Production Engineer defining the collaborative production process, characterizing tasks according to specific settings. The robot's learning module uses ergonomics states to create a rewards function, enabling it to respond accordingly. This innovative approach enables safe and efficient collaboration between robots and workers, expanding the potential of industrial robots in manufacturing.
Gerald Wahyudi Setiono .et.al., [18] Bipedal robots have been developed to mimic human walking motion, with the goal of achieving a similar walking algorithm. However, human walking algorithms are diverse and complex, making it challenging to replicate. This study focuses on designing a bipedal robot that can move freely like a human, using a complex mathematical calculation to find the perfect formula for stability. The robot's motion is repeated to create a non-stop walking motion, with the left and right legs synchronized by an angle. The gait movement is observed qualitatively, and the ergonomic design of the leg needs further consideration. The results show that the bipedal robot achieves one step forward at the beginning and end of the starting motion, with changes in hip height, swinging leg height, and step distance value. The robot's motion is supported by a cable tied to the hip part. Overall, this study contributes to the development of bipedal robots that can mimic human walking motion, with potential applications in robotics and artificial intelligence.
Christian Ott .et.al., [19] Bipedal locomotion is a major research field in humanoid robots, offering an alternative to wheel-based systems for domestic service robotics. This study focuses on the hardware aspects of a biped robot with integrated joint torque sensors, developed as an experimental platform for studying biped balancing and walking. The robot's joint modules were rearranged to meet the

requirements of legged locomotion, using benchmark motions such as squatting and walking. The 7 degrees-of-freedom LWR arm was used as a basis, with customized motors and high gear ratios. The bipedal robot has a complex mathematical calculation to find the perfect formula for stability. Future work will focus on torque sensing, joint flexibility, and impedance control in biped walking, as well as modifying the simple flat foot design. The goal is to achieve human-like biped locomotion for domestic service robotics scenarios, with potential applications in robotics and artificial intelligence. The study contributes to the development of bipedal robots that can move freely like human beings, with a focus on hardware design and experimentation.
Marek Peca .et.al., [20] This paper presents the development of an electromechanically actuated biped robot with integrated joint torque sensors. The robot design aims to implement position-based walking control laws and compliant joint torque control to study joint torque sensing and impedance control in biped walking. The mechanical construction is inspired by human legs, with a system of order 24. The robot is controlled using a SISO type P controller, and a trajectory playback system allows for recording and playing back trajectories. The paper presents experimental results showing a 12 DOF walk using a simple proportional controller and fixed trajectory. The ultimate goal is to develop more advanced MIMO controllers and automatic trajectory generation. The robot is designed as an open experimental system to test various controllers, and this paper demonstrates its fully operational walking capabilities.
MR. Kiran Somisetti.et.al., [21] The study of robotics involves designing, manufacturing, assembling, and controlling robots using sensors and actuators. Robotics has evolved significantly from ancient civilization to the 21st century. This paper focuses on the hardware aspects of robotics, specifically the design and fabrication of a biped robot. The design process involves considering factors such as degrees of freedom (DOF), joints, torque, and trajectory planning. The robot's DOF is determined by the number of independent motions it can perform, which is crucial for its functionality. The choice of motors and materials depends on the robot's size and requirements. The paper demonstrates the implementation of a humanoid robot with more than 6 DOF, designed using SOLIDWORKS software and tested for 15 DOF. The robot recognizes human objects and produces human expressions through an LCD display and camera. The computer vision implementation was done in Python with predefined library functions. The prototype robot performs operations efficiently, and future improvements include increasing motor torque for more effective movement. This research contributes to the development of robots for real-time applications.
S. Roccella.et.al., [22] Japan's aging population and declining birth rate have led to expectations that next-generation Robot Technology (RT) will support this aging society. To achieve successful human-robot interaction, particularly for home and personal assistance, robots must adapt to their partners and environment and communicate naturally with humans. This paper presents the mechanical design and working principle of a novel humanoid platform, WE4R_n, with a focus on hand design and grasping capabilities. The hand is designed to perform basic gestures and grasping tasks, such as cylindrical, spherical, and lateral grasping, and is capable of single-hand grasping of small objects and two-hand grasping of large objects. The palm is composed of a carbon fiber shell and an inside frame, with optional son padding for increased compliance. The total weight of the hand is approximately 320 grams. The paper concludes by presenting the first experimental results of the WE-4R11 humanoid platform, which integrates the WEAR humanoid platform with the RCH-I artificial hand, demonstrating enhanced communication between robots and humans.
STEFANOROCCELLA,MARIA .et.al., [23] The aging population and reduced child birth rate in industrialized countries, particularly in Japan and Italy, have led to expectations that next-generation Robot Technology (RT) will support this aging society. Grasping and expressing human-like emotions are essential capabilities for robots to assist humans. This paper presents a methodology for designing an anthropomorphic artificial hand using a 3D printing process. The system observes and learns human hand postures and replicates them with the robotic hand. While separate modules have been developed, they have not yet been implemented in a humanoid robotic platform to evaluate their impact on human-

robot communication. Other artificial hands have been used in research for "fingerspelling" to communicate with deaf-blind individuals. The design process involved analyzing human gestures and grasping capabilities to develop a new hand assembled on the Waseda Humanoid Robot WE-4R. The goal is to enhance human-robot communication through more natural and intuitive interaction.

Nikos G. et.al., [24] The first modern humanoid, WABOT-1, was developed in 1973 and has since influenced the design of subsequent humanoids. Most current humanoids use non-backdrivable, stiff transmission systems and high-gain PID controllers, which improve precision but limit flexibility and safety. To address this, the robotic community has explored compliant actuation and drive systems, leading to the development of the "cCub" robot. The cCub has a modular, anthropomorphic leg design with a range of motion similar to or exceeding that of humans. The robot's waist joint has an extended range to compensate for a rigid spine and enhance manipulation capabilities. This paper presents the design, development, and initial testing of the cCub's lower body, which incorporates passive compliance actuator groups for safer interaction, energy efficiency, and damage-safe learning. The cCub is an experimental variant of the iCub humanoid and aims to address the limitations of traditional stiff transmission-actuators. By using compliant actuation, the cCub has the potential to interact more safely and efficiently with humans and its environment.

S. NAVEENKUMARI.et.al., [25] Robotics involves the design, construction, and operation of robots, including computer systems for control, sensory feedback, and data processing. Robots can replace humans in dangerous environments or manufacturing processes and may resemble humans in appearance, behavior, and cognition. Many robots are inspired by nature, contributing to the field of bio-inspired robotics. This project aims to improve the design and fabrication of humanoid robots, addressing issues such as instability, energy inefficiency, and limited dynamic walking capabilities. The development of a humanoid walking robot seeks to achieve fast and autonomous bipedal locomotion, generating flexible motion in realistic environments. The project requires aluminum alloy sheets, connecting wires, Raspberry Pi 3, RC servo motors, screws, ultrasonic sensors, and web cameras. Software requirements include Windows, Raspbian OS, embedded C programming, and servo controller software. By addressing the mechanical design and hardware limitations of current humanoid robots, this project aims to make significant advancements in humanoid robotics.

Alexander Alspach.et.al., [26] Robotic systems are increasingly interacting with humans in various settings, requiring compliance and reactivity to ensure safety and productivity. This robot features a 6 DOF arm with soft, air-filled force sensing fingertips, allowing for physical interaction and feedback. The arm is covered by an inflated polyethylene bag, and the hand is 3D printed with force sensing modules that provide independent contact force feedback via pressure sensors. The robot's base houses a power supply, computer, air blower, and other necessary electronics. The arm's configuration and components are designed for impact absorption and flexibility. An internal projector displays information onto the cover, visible from the outside. This robot aims to enhance human-robot communication, productivity, and affinity in diverse settings, such as entertainment, education,

Ravinder S. et.al., [27] Humanoid robots require advanced interaction with their environment, including touch sensing and tactile sensing. Tactile sensing involves detecting and measuring the spatial distribution of forces perpendicular to a sensory area and interpreting the spatial information. This project presents a tactile sensing system using piezoelectric materials, which produce a charge or voltage in response to applied stress. The system's design and fabrication involve integrating a taxes array and active devices using a reliable and economical process. A test structure with a 32-element microelectrode array has been developed, and preliminary designs have been created to test piezoelectric polymers separately. This technology has potential applications in humanoid robots and biomedical fields. Temperature variations can be compensated for by incorporating a temperature sensing device on the chip. The goal is to develop a tactile sensor system that enables humanoid robots to interact with their environment in a more human-like way, with applications in areas such as entertainment, education, therapy, and physical assistance.

M.C. Chou.et.al., [28] The development of tactile sensors is crucial for autonomous humanoid robots to interact with their environment and humans effectively and safely. This study focuses on designing a simple-structured capacitive tactile sensor that can measure both normal and shear forces. A new process technology called laser-induced metallization (LIM) is used to create the sensor directly on the curved surface of a humanoid robot finger. The LIM process involves spraying a metal-free laser-activatable polymer solution onto the substrate, which contains epoxy or PU, ceramic nanoparticles, and solvent. The sensor has been successfully created and tested, verifying that it responds to human fingers and external forces. This technology has the potential to enable humanoid robots to automatically recognize object size, shape, material, and temperature, and to properly control grasping force. Future work will focus on improving the dielectric polymer material used in the LIM process to enhance the sensor's performance.

S. Sowmiya. et.al., [29] Actuators are the motors that enable humanoid robots to move and mimic the human body. These robots can have electric, pneumatic, or hydraulic actuators that act like muscles and joints. The goal is to create robots that can connect with humans on a deep level, with good aesthetic design, rich personalities, and social cognitive intelligence. This robot is created using 3D printing and is designed to encourage people to consider it as a human child. The evaluation approach compares physical movement interactions between humans and robots, finding links between subjective assessment and body movements. The robot's ability to engage in face-to-face, rich, and emotional contacts is highlighted. Humanoid robots are complex machines that can travel on difficult terrain and perform tasks like humans, but with challenging control and planning issues. The entry score estimates moments in body movements, allowing computers to reflect human emotions and identify physically expressed emotions. Movement should be neurologically and psychologically based.

Chao Yuan.et.al., [30] Legged locomotion is essential for robots to navigate challenging terrain, and sensing forces and moments on the foot is crucial for stable locomotion. However, commercial force/moment sensors can be expensive and may not meet specific application requirements. Therefore, a custom six-axis force/moment sensor has been designed and developed using strain gages. The sensor is horizontally mounted on an experiment platform with a loading hat and rod to apply forces and moments. The bridge connection mode of the sensor is determined by the arrangement of strain gages. The newly designed sensor is thinner (12 mm) and has a smaller radius than most commercial sensors, making it more suitable for use underfoot. Additionally, the use of inexpensive materials and strain gages makes it a cost-effective solution. The sensor's design and development details are presented, offering a promising solution for robotic systems requiring force and moment sensing in challenging terrain.

Sang-Ho Hyon.et.al., [31] Creating humanoid robots is valuable for scientific research on human sensory-motor control. Past projects have focused on building high-performance, life-sized humanoid robots with durability and power autonomy. However, achieving functional equivalence with humans is not required. Compromised solutions, such as pneumatic artificial muscles, are needed to implement human-like musculoskeletal functions in robot joints. This paper presents a methodology using 3D CAD software and a working principle similar to hydraulic excavators, where cylinders constitute the members of a closed-loop linkage. The use of carbon fibre reinforced plastic (CFRP) enables the creation of a lightweight robot with specified strength. The paper reports on the development of a fast torque-controlled hydraulic humanoid robot, TaeMu, with 13 active joints. The robot's design and manufacturing process are detailed, highlighting the use of CFRP for lightweight and strength. The successful prototype demonstrates the potential for humanoid robots in scientific research and other applications.

Tatsuhito Aono.et.al., [32] The increasing presence of robots in society demands diverse exterior designs to distinguish individual robots and create a sense of identity. People tend to feel more affinity with robots than machines, leading to a desire for personalized robot design. This paper discusses the importance of exterior design in representing a robot's identity and the potential for users to design their own robot's exterior. The methodology uses 3D CAD software, and the working principle involves approximating the stress-strain characteristics of cellular polymeric materials as proportional. The design prioritizes a thin inner mechanism, securing driving mechanisms, and providing paths for cables and cooling air. The maximum allowable diameter of the cover around joints depends on actuator performance and joint mobility. The paper concludes by highlighting the significance of exterior design in robot development and the potential for user customization.

Yang Chen .et.al., [33] Research on humanoid dexterous robotic hands has led to the development of various novel and powerful grasping functions. This paper presents a modular humanoid robotic hand driven by Shape Memory Alloy (SMA) actuators, fabricated using 3D printing technology. The hand consists of five fingers, including four identical fingers and one thumb, with a design similar to a human hand. The modular design allows for easy assembly and disassembly, reducing prototype development time. Each finger is an open-loop kinematic chain of two links in series, and the hand's state is defined as "palm plane" when all fingers are fully extended. The use of SMA actuators enables the hand to perform grasping functions. The paper concludes by highlighting the benefits of the modular design and the potential for further research and development in humanoid robotic hands.

Jaehoon Sim .etal., [34] Robots are increasingly being explored for their feasibility in various service and industry settings, where interaction with humans or environments is required. Humanoid robots, with their similar kinematic structures to humans, can be very effective in these applications. This paper presents the development of the JET humanoid robot, based on the THORMANG platform, with the goal of achieving effective application in industrial and service fields. The JET robot has 32 DOF, excluding the LiDAR actuator, and features a power system, regulators, and a battery. The lower body design aims to achieve a wide range of motion (ROM). The development of JET considered the limitations of THORMANG, which were revealed through experiences at the DRC. THORMANG has the advantage of easy maintenance due to its use of Dynamixel commercial modular actuators. The JET robot aims to achieve compliance, whole-body motion capability, and easy maintenance, making it suitable for various applications.

Joseph Andrew Pepito RN.et.al., [35] The advancement of technology has led to the increased involvement of humanoid robots (HRs) in healthcare settings, enabling new forms of interaction between humans and HRs. Robots are being used in exercise programs, recreational activities, and other healthcare applications, presenting benefits to human healthcare workers. Research in perception formation, social and emotional intelligence, and human deduction has enabled robots to respond in humanlike ways, recognizing voices, emotions, and faces. The development of social robots aims to assist the growing elderly population. Artificial empathy is crucial for human-machine interaction and the adoption of secure technology. The strategy for integrating HRs into healthcare services involves developing their ability to understand and respond to human emotions and thoughts. Empathy improves sociability, and HRs are being designed to comprehend and react to human feelings, enhancing their role in healthcare settings.

Sebastien Dalibard.et.al., [36] Controlling humanoid robots requires careful consideration of their dynamic stability, as they are highly redundant and underactuated kinematic systems. Integrating walking control systems into whole-body motion planning architectures is challenging. Current methods approximate either the robot's geometry or its environment, guaranteeing collision avoidance only at a footstep level. This work combines randomized whole-body motion planners and walk pattern generators based on the Zero Momentum Point (ZMP) formalism, relying on prioritized inverse kinematics (IK). However, these methods are prone to local minima, and global motion planning is the focus of this paper. The curse of dimensionality is a significant challenge when planning whole-body motion for humanoid robots. The paper concludes that achieving small-space controllability for walking humanoid robots requires advancements in control algorithms, sensor integration, mechanical design, and energy management. Further development in these areas will enhance the capabilities and applications of humanoid robots in complex, real-world environments.

Sebastien Dalibard et.al., [37] Humanoid robots, with their anthropomorphic body plan and human-like senses, are gaining popularity as a research tool. They are used to understand human intelligence and address various skills simultaneously, exceeding the current state of the art. While today's humanoid robots display capabilities in limited tasks, they are designed to interact with human-centric environments. Many research projects focus on human-robot interaction, leveraging intuitive techniques like speech, eye gaze, facial expressions, and gestures. These modalities are easily interpreted by humans, making communication more natural. The development of humanoid robots has made significant strides, with advanced robots resembling science fiction machines. Figure 01 showcases one such robot, highlighting progress in creating robots with human-like appearance and capabilities. These robots have the potential to interact with humans in a more natural and intuitive way, revolutionizing various fields

Widodo Budiharto.et.al., [38] The development of autonomous humanoid robots for various tasks, including teaching and learning, is a popular and challenging research topic. Human-robot interaction (HRI) is an interdisciplinary study of interaction dynamics between humans and robots, which has received significant attention in recent years. This paper proposes a speech recognition system for humanoid robots using stemming and tokenization, which can recognize commands with more than one word. The system is designed to be fun and engaging for kids, as they learn best when relaxed and focused. The proposed system is compared to the NAO Robot's speech recognition system using Coreographe, which has limitations in accepting only single-word commands. The development of intelligent humanoid robots for education is challenging, but natural interaction is crucial. The proposed system has the potential to positively impact student learning and is an improvement over existing systems.

David O et.al., [39] Recent robotic research projects have deployed assistive robotic solutions in real home settings to provide care for the elderly. A study evaluated the use of a Mobile Robotic Platform (MRP) robot in a senior center home in Austria. Participants rated the robot positively, but indicated a need for varying levels of autonomy, especially for difficult operations. The study involved short-term and long-term trials, with participants interacting with the robot in a real-life setting. Most participants chose to sit on a couch during the test, and the robot started each test case at the entrance door. The results showed that short-term interaction (2 sessions) did not cause anxiety, likely due to the robot's small size and shape. The study demonstrates the potential of assistive robots in elderly care and highlights the need for further research on user acceptance and long-term interaction. The small humanoid robot's socially assistive features were well-received by participants, and the study suggests that such robots can provide a range of services, from home chores to interactive cognitive training and companionship.

Cengiz Kahraman. et,al., [40] Humanoid robots have emerged as a significant area of research, transforming from factory automation to human-friendly systems that assist in everyday environments. They are designed to mimic human activities, both physical and mental, and are well-suited for indoor environments. Unlike industrial robots, which are limited to specific tasks and require human instruction, humanoid robots can interact with humans and adapt to new situations. However, industrial robots have been widely used in manufacturing since the 1960s, performing tasks such as welding and assembly with high speed and accuracy. Despite their potential danger to humans, humanoid robots have become increasingly popular, with various types emerging through advancements in control theory. Fuzzy sets have played a crucial role in dealing with imprecise data and information processes in generating humanoid robots. This study presents a literature review on humanoid robots, highlighting their past, present, and future developments.

I. Conclusion

The design and fabrication of humanoid robots represent a remarkable convergence of multiple engineering disciplines, including mechanical, electrical, and software engineering. Throughout this review, it is clear that significant advancements have been made in the construction and functionality of humanoid robots, driven by improvements in actuation systems, sensor integration, AI, and material science. In conclusion, while the design and fabrication of humanoid robots have come a long way, ongoing research and innovation are essential to overcome current limitations and achieve the next generation of robots capable of seamlessly integrating into various aspects of human life. Continued focus on interdisciplinary collaboration will play a key role in shaping the future of humanoid robotics, ensuring that these machines become more functional, adaptable, and accessible.

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