



Transforming Robotics: Harnessing Artificial Intelligence for Enhanced System Performance and Diverse Applications

¹Isa Ali Ibrahim

School of Information and Communications Technology, Federal University of Technology Owerri, Imo State, Nigeria.

<https://orcid.org/0000-0002-1418-9911>

²Abdurrahman Isa Ali

Nigerian Communications Commission (NCC), Maitama Abuja, Nigeria.

³Muhammad Ahmad Baballe

Department of Mechatronics Engineering, Nigerian Defence Academy (NDA),
Kaduna, Nigeria.

<https://orcid.org/0000-0001-9441-7023>

Abstract—Robots, particularly flying or spider robots, are devices that are used for wireless environmental monitoring. Unlike regular wheels or two-legged robots, the spider robot can easily adjust to new situations or barriers since it has legs for mobility. It operates without the need for interfaces. The issues that typical current robots encounter, particularly those that are wheeled or legged, will be resolved with the aid of this review effort. In addition to functioning in places that regular robots cannot, such as climbing trees or walls and walking on uneven surfaces—tasks that neither wheeled nor walking robots can perform—spider robots typically assist in the monitoring of hazardous or nuclear areas. Additionally, the spider robots assist in tracking down and locating misplaced objects. The issues that regular robots encountered are resolved by the advent of the spider robotic system. Spider robots assist in delivering information on the condition of settings or locations that are inaccessible to humans or regular robots due to environmental toxicity or the requirement for close observation or monitoring. Developments in robotics are quickly changing a number of sectors and facets of daily life. Significant advancements have been made in the creation of more adaptable and mobile robots as well as the integration of artificial intelligence (AI) for improved perception, decision-making, and learning. These developments are making it possible for robots to carry out difficult jobs, work alongside people, and function in a variety of settings, including manufacturing, healthcare, agriculture, and exploration. The robotic system's difficulties and potential paths are discussed.

Keywords— *Natural Language Processing, Artificial Intelligence (AI), Toxic Environments, Spider Robots, Sensors, Challenges.*

I. INTRODUCTION

In the subsequent half of the 20th century, humankind obtained the rewards of numerous comprehensive scientific findings that normally took place in the first half, among

which was the control of the nuclear chain reaction for producing electricity [1]. Due to its high energy density and the therefore minor requirement for gasoline, nuclear power has been misused. Also, it has authorized enhancements in the toughness of resources that were used in the nuclear laboratories, and this has led to prolonged achievements and improved safety restrictions. As a result of this, improvements in engineering and resource science have been enforced to an extensive range of nuclear-connected projects, which stretch from the framework of a reactor and additional structures through to the processes by which they are disbanded [2]. For instance, static and monorail-type teleoperated engines have been in use since the beginning of nuclear energy to handle activities carefully in zones of life-threatening radioactivity disclosure and to accomplish polluted constituents. Martin and Hamel, 1983; Wehe et al., 1989, though several mobile samples were existing during the 1960s Clark, 1961; Huffman, 1962 [3]. With the help of microchip technology booming in the mid-70s, scientists proposed different but possible robotic designs that might replace human beings in a wider range of work jobs in radioactive surroundings; this may include inspection, maintenance, and repair in such environments [4]. Also at the same phase, civil nuclear power plants were established in North America and Europe on a scale never repeated since, and hence it made sense to design and build acceptance robotic technology for these purposes [5]. In 1979, the necessity for progressive robotic proficiency became vital because of the reactor disintegration that took place in Unit 2 at Three Mile Island. It was inescapable that several jobs had to be commenced tenuously, accompanied by the use of long-handled tools and what were then original vision systems [6]. At this time, the first-ever radiation inspection robot for this objective, used in the basement of the unit four years later, was considered a landmark in the nuclear

industry [7]. About seven years after the Three Mile Island accident, the tragic accident that took place in Chernobyl caused a policy to entomb the damaged plant in clay and sand to restrain the magnitude of the ongoing dangerous secretions and reformed the interest in the idea of using mobile robots in place of individuals for nuclear accident response applications [8]. These technological enhancements over the next two eras have driven the design and execution of highly refined systems, with robotics gaining more and more popularity in the majority of marketable fields, such as entertainment, transport, and medicine [9]. Most of the robots that we are acquainted with make use of wheels for their movement [10]. They can accomplish high speed and comparatively small control complication, but even with multifaceted suspension systems, they present many boundaries in irregular and rough environments (e.g., hazardous surroundings and uneven ground) with the aid of legged spider robotics, and most of this difficulty is overcome due to its litheness and ground adaptation [11]. The chance to choose between different existing solutions and to control and adapt the location of the center of mass of the system allows dodging downturns and slippage due to environmental abnormalities [12]. The charges that have to be paid are the lesser speed of movement and greater intricacy of the controller with veneration to wheeled systems. Also, due to the datum that the legs are self-reliant controlled, legged robots have a large number of degrees of freedom (DOF) to be harmonized to control the location, balance the forces (e.g., load and external forces), and ingest as little energy as possible [13]. Meanwhile, the task of finding an optimum force allocation was made in real-time; fast processes and control functions have to be used, as likewise when a body force command solution is not reachable and a new plan has to be conveyed [15]. The spider-legged robots have a body and several enunciated legs that start from it. Each of these kinematic chains can also be viewed as a manipulator that acts like a limb and adds to the overall position and equilibrium of the spider robot structure. To estimate and produce an operative legged spider robot, the awareness is to draw motivation from nature [16]. In nature, different-legged systems can be able to walk and climb different surfaces with low energetic consumption, and high autonomy has been found. Indeed, safe attachment to and easy detachment from smooth substrates is a major feature of a diverse range of animal species. Attachment without using fluids, so-called dry adhesion, was exploited by geckos and *Evarcha arcuata* spiders using fibrillar elements [17]. The adhesion force seems to be related to the approaching angle between the attaching elements and the surface: the maximum adhesion condition is reached when the angle is around 30°; a sliding condition occurs when the angle is smaller, and detachment occurs when the angle is bigger [18, 19]. Currently, there are some certain conditions in which humans are incapable of completing a certain mission in real life. Such missions include locating a lost object or item or finding a missing individual in a jungle for more than a day and also discovering a pothole with a lack of oxygen and also working in a toxic environment [20]. To achieve such problematic tasks, the human will have to depend on mobile robots [21]. Scientists nowadays show emphasis on the new design of self-adaptive robots, which includes path tracing [22]. In the year 2011, Pratihari, Roy, and Singh estimated the optimal base forces and joint torques in the real-time process for the monitoring of the eight-legged robot [23]. This researcher concentrated on finding the best point in the circulations of the basis's forces and values of the joint torques of the six-legged robot online [24]. The minimization of the standard of the joint torques and the base forces was simulated in their study. Roy conducted another study in the same year with Pratihari and discovered that unlike duty features, it will lead to many energy intakes. These duty factors can also differ among 1/3 and 2/3,

whereas energy intake will change in the range of 3% and 36% [25]. In the subsequent year, both Pratihari and Roy conduct another research on the legged robot and simulate the technique of attaining extreme steadiness with the minimum energy intake steps. Henry, Menon, and Boscaroli, in the year 2013, examined resolving the unsuitable relocation of forces in the reloading of the legs in the hiking robots, which may likely lead to the irreversible dispassion of the spider robots from their upright facades [26]. This researcher finally concluded that it is likely to save 36% of the whole charges of this spider robot if the designed step is well-organized. In this study work, the National Instrument (NI) protocol was nominated to relate to the suggested well-designed robotic supervisor for interfacing and processing [27]. The suggested smart system gathers data about the environments, particularly in available areas, and aids the robot in choosing the finest route course to be taken. The National Instrument implanted field-programmable gate array board has been selected to merge with the spider robot for the tenacity of great enactment adeptness as well as being user-friendly and compatible. The categorization of leg actions is predefined in this study for persistent walking. With the help and combination of several sensors on its frame construction, this suggested eight-legged flexible smart spider robot is fit to be employed in ambiguous environments [27].

II. MATERIALS AND METHODS

2.1 The method used in producing the spider robotic system

The recommended spider robot is divided into three parts, which may likely comprise the body structure of the spider robot, its sensor, and the control algorithm. The configuration of the spider robot is made of aluminum; this is because of the strength of aluminum in resisting the tensile and pressure stress on its exterior. Stalemate bolts were used to protect the position of the National Instrument board on the framework. Several sensors are applied in the spider robotic body [19-22]. The body of this spider robot must be tough enough to adequately support the heaviness of the National Instrument board in vigorous circumstances. Henceforward, the consideration that has been taken during the blueprint stage of the spider robot of the main body of the robot includes compression and tensile stress alongside the axis of the movement of these moving parts of the spider robot caused by the burden carried. The eight-leg pairs of the spider robot will be attached to a frame of the spider at certain angles that will enable it to maintain stability, and the whole spider robot will be controlled remotely. To help keep this spider design steady, avoid it. From losing balance or sloping over, you will need to assemble the leg pairs and the structure at an angle from the conservative straight ahead. Because the pairs of legs will be pointing at different angles than straight ahead, their directional vectors do not point in the direction of movement; rather, at the exact angle from the 90-degree line down the middle of the design signifies straight ahead from an outside perspective. This results in two vector quantities chained together and gives magnitude and force in precisely the same path. A servo bracket is fixed to the joint of the legs; each of these different legs of the spider robot has three degrees of freedom (DOF). Among the degrees of freedom (DOF), one of these degrees of freedom is alongside the z-axis and also functions as the shoulder, and the turning of this shoulder will serve as a controller to the other two joints. This shoulder will be master, and the location of it will invigorate the other two to take their spot. The National Instrument board helps in the control of the movement of these joints. Each of these joints uses a servo bracket to join to each other. The whole project of the spider robot is carried out

using a feedback loop graphic national instrument LabVIEW interfacing with an insolent controller and with the help of the company of smoke device, temperature sensor, and ultrasonic sensor. This GH311 ultrasonic sensor produces an exact and non-contact space dimension. When there is a difficulty as far as, like, 31cm away from this spider robot, with the help of the GH311 sensor, it will transfer a high indication to the National Instrument board to specify the position of the problem and implement the suitable moving algorithm to dodge such a hitch. The GH-312 sensor was applied in the spider robot construction to identify hydrogen, smoke, alcohol, liquefied gas, butane, and propane.

2.2 The principal operation of the spider robotic system

With the help of the Arduino receiver or microcontroller, it takes the signal from the transmitter and aids in sending it to both the servo and the speed controller. It is this device that synchronizes to the controller and is what allows the spider robot to receive radio signals as a result of the built-in aerial in the robot. The speed of this controller is the central piece of the research and is what helps in controlling both the servo and the electric motors by regulating their rotation proportional to the amount forced upon it by the transmitter. It is connected to the battery; all of the four motors are in parallel to the Arduino receiver and a switch. All four electric motors are wired in parallel, with two being reversed. This is because there will be two electric motors at either end of the research, and when one pair of legs is walking forward, then the other leg needs to be walking backward. By wiring the motor so current flows in the opposite direction, this effect is achieved. With the objective of the spider robot moving forward or backward and dodging the problems in the way of the robot's path. The Arduino or microcontroller board is preprogrammed and waits for you, the user, to input a certain task to be performed. This National Instrument board helps in collecting feedback information from this sensor embedded on the spider robotic frame and processes the information; hence, implementing the given job. For instance, if this ultrasonic detector is used to sense an item hindering the spider robot's movement route, this detector will automatically convey the response information to the programmed National Instrument board. With the help of this board, it will then process the information consequently and assess the information to give a suitable outcome, such as enrichment for the location of the spider robot to escape the hitch that leads to self-localization. These spider robots will then start moving on again until this robot reaches its target or faces additional problems on its movement path. The spider robotic program consists of three digital input and output ports; this includes an ultrasonic detector, smoke detector, and temperature detector. It also consists of four (4) types of walking processes ready to perform singly when this ultrasonic detector identifies any difficulty in front of the spider robots. When there is no difficulty in the spider robot direction, the remaining three (3) of the walking algorithms would not implement. In this case, the only moving algorithm performed is the algorithm for the spider robot moving on. If this ultrasonic detector notices a hitch in the forward-facing of the spider robot, the spider robot will dismiss the walking forward process and then trigger either the walking left-right or backward walking process. The feedback information that is from the sensor will be performed consequently; henceforth, calling the information that has been made in the memory block to the pulse-width modulated generator for each of the servomotors. In this case, when you implement the forward walking procedure, the spider robot limb moves step-by-step. With eight legs of the spider robots taking their respective locations, the spider

robot will then be able to push its body forward. This procedure will be repeated to make a forward movement for the spider robot. The smoke and temperature sensor will perform individually without touching the walking process of the robot. The information that you obtained from both the smoke and temperature sensor is displayed on the front panel of your monitor. The wireless watching system is an interface on your laptop. On your observing system interface, you can assign a green light-emitting diode indicator to represent the direct direction taken by the spider robot when the walking process is executed. If in this process the spider robots sense smoke, this red light-emitting diode that you assigned to this sensor indicator will nimble up to signal possible menace. Your surrounding temperature is monitored and updated with the help of an indicator thermometer on your laptop or desktop monitoring system.

2.3 Areas of applications of the spider robotic systems

1. We can use this spider robot in discovering dangerous or rough areas in which humankind can have full access easily. For example, searching for survivors after a terrible nuclear tragedy, exploring war zones, or inspecting unstable buildings after a natural tragedy such as an earthquake, tsunami, or volcanic eruption.
2. We can also use spider robots in defusing bombs such as land mines.
3. We can also equip the spider robots with sensors and weapons; such a robot is used in a crisis or war to avoid risking human lives on the battlefield.
4. We can also use this spider robot in guarding our properties or areas of high importance.

III. KEY ADVANCEMENTS AND TRENDS OF THE ROBOTIC SYSTEM

i. AI and Machine Learning:

Artificial intelligence (AI) is a broad concept encompassing the ability of machines to mimic human intelligence, while machine learning (ML) is a specific subset of AI that focuses on enabling machines to learn from data without explicit programming. Essentially, ML algorithms are used to build AI systems that can analyze data, identify patterns, and make predictions or decisions.

Artificial Intelligence (AI):

1. AI is the overarching field focused on creating machines that can perform tasks that typically require human intelligence.
2. This includes capabilities like reasoning, learning, problem-solving, and decision-making.
3. AI encompasses a wide range of techniques and approaches, including machine learning, deep learning, robotics, and more.

Machine Learning (ML):

1. ML is a specific approach within AI that allows machines to learn from data without being explicitly programmed.
2. Instead of relying on pre-defined rules, ML algorithms are trained on large datasets to identify patterns and make predictions.
3. Examples of ML applications include spam filtering, recommendation systems, and image recognition

ii. Human-Robot Collaboration:

Human-robot collaboration (HRC) refers to the interaction between humans and robots working together to achieve a common goal, often in a shared workspace. This collaboration is a key aspect of Industry 4.0 and is revolutionizing industrial and service robotics by combining

human capabilities with the efficiency and precision of machines.

Key aspects of Human-Robot Collaboration:

1. Shared Workspace:

HRC often involves robots and humans working in the same physical space, though not necessarily simultaneously.

2. Task Division:

Humans and robots typically divide tasks based on their respective strengths. Humans handle complex, cognitive tasks, while robots manage repetitive, physically demanding, or hazardous tasks.

3. Dynamic Adjustment:

In some advanced HRC scenarios, robots can dynamically adjust their behavior based on human presence and actions, creating a more fluid and responsive interaction.

4. Safety:

Ensuring safety is paramount in HRC, with various safety measures implemented to prevent accidents and collisions.

5. Levels of Collaboration:

HRC can range from simple coexistence (where robots and humans operate in the same space but avoid direct interaction) to more advanced levels like sequential collaboration (where tasks are performed at different times) and full collaboration (where robots and humans work on the same part at the same time).

Benefits of Human-Robot Collaboration:

1. Increased Efficiency and Productivity:

Combining human skills with robot capabilities can lead to significant improvements in productivity and efficiency.

2. Improved Safety:

Robots can take over dangerous or physically demanding tasks, reducing the risk of injuries to human workers.

3. Enhanced Flexibility and Adaptability:

HRC systems can be more adaptable to changing production needs and can handle a wider range of tasks compared to traditional automation.

4. Reduced Costs:

By optimizing workflows and reducing errors, HRC can contribute to cost savings in the long run.

5. New Opportunities:

HRC is opening up new possibilities in various sectors, including healthcare, logistics, and elder care.

Examples of HRC:

1. Manufacturing:

Robots assisting workers in assembling products, handling heavy materials, or performing repetitive tasks.

2. Healthcare:

Robots assisting with logistics, patient care, and rehabilitation.

3. Logistics:

Robots handling warehouse operations, inventory management, and delivery services.

4. Elder Care:

Robots providing companionship, assistance with daily living activities, and monitoring [40].

IV. CONCLUSION

This paper concluded by reviewing certain studies on spider robots, highlighting their working principle, summarizing their construction and manufacturing processes, and outlining their real-world applications. With the aid of technological developments [27–39], the spider robot system will be able to keep an eye on all significant environments, assess the conditions of those environments to which full access is possible due to their complexity, and

carry out the necessary actions in areas that are inaccessible to both wheeled and two-legged robots.

Challenges:

i. Implementation Costs:

The high cost of robotic systems can be a barrier to adoption, particularly in emerging economies.

ii. Integration Complexity:

Integrating robots with existing systems can be challenging, requiring careful planning and expertise.

iii. Safety and Ethical Considerations:

As robots become more autonomous and capable, it's crucial to address safety and ethical concerns.

Future Directions:

1. Edge AI:

refers to the deployment of artificial intelligence (AI) models and processing on devices at the "edge" of a network, closer to where data is generated, rather than relying on centralized cloud servers. This approach offers benefits like reduced latency, improved bandwidth usage, enhanced privacy, and increased reliability.

Key aspects of Edge Artificial Intelligence (AI):

i. Decentralized processing:

AI computations happen on local devices (like smartphones, IoT sensors, or embedded systems) rather than sending all data to a distant cloud.

ii. Real-time decision making:

By processing data locally, edge AI enables faster responses and actions, crucial for applications like autonomous vehicles, industrial automation, and healthcare monitoring.

iii. Reduced latency:

Minimizing the distance data travels reduces delays, making it ideal for time-sensitive applications.

iv. Improved privacy:

Less data sent to the cloud can mean enhanced privacy and security, as less sensitive information is transmitted over networks.

v. Reduced bandwidth consumption:

Edge AI minimizes the amount of data transmitted over the internet, freeing up bandwidth for other uses.

vi. Increased reliability:

Edge AI can continue functioning even with intermittent or unavailable network connections, ensuring continuous operation in critical situations.

vii. Cost savings:

By reducing reliance on cloud resources for real-time processing, edge AI can potentially lower overall costs.

Examples of Edge AI applications:

viii. Autonomous vehicles:

Processing sensor data locally for real-time navigation and safety decisions.

ix. Healthcare monitoring:

Analyzing patient data from wearable devices and medical equipment for immediate alerts and insights.

x. Industrial automation:

Enabling robots and machinery to operate autonomously and respond to changing conditions on the factory floor.

xi. Smart cities:

Optimizing traffic flow, managing surveillance, and enhancing public safety with real-time data analysis.

xii. Retail:

Personalizing customer experiences, managing inventory, and streamlining checkout processes.

xiii. Virtual assistants:

Improving responsiveness and functionality of voice assistants by processing commands locally.

xiv. Smart homes:

Enhancing the intelligence and efficiency of smart appliances.

2. **Service robots:** are robots designed to perform tasks that are helpful to humans or equipment, excluding those in traditional manufacturing settings. They are typically autonomous or semi-autonomous and can operate in various environments like offices, homes, and public spaces. Service robots handle tasks that are monotonous, time-consuming, repetitive, or potentially hazardous for humans.

Key Characteristics of Service Robots:

i. Purpose:

To provide services and assist humans in various settings.

ii. Autonomy:

Can operate with varying degrees of autonomy, from fully manual to fully autonomous.

iii. Scope:

Encompasses a wide range of applications beyond manufacturing, including healthcare, logistics, and personal assistance.

Examples of Service Robots:

Healthcare: Surgical robots, medication dispensing, disinfection.

Hospitality: Room service delivery, customer service.

Logistics: Autonomous guided vehicles (AGVs) for material handling.

Personal Assistance: Cleaning robots, companion robots.

Public Service: Security robots, surveillance drones.

Distinction from Industrial Robots:

Service robots are distinguished from industrial robots, which are primarily used for manufacturing processes.

Benefits of Service Robotics:

i. Increased Efficiency:

Automation of repetitive tasks allows humans to focus on more complex or strategic work.

ii. Improved Safety:

Robots can handle dangerous or hazardous tasks, reducing the risk of injury to humans.

iii. Enhanced Quality:

Consistent and precise performance of tasks can lead to improved service quality.

iv. Cost Reduction:

Automation can lead to reduced labor costs and increased productivity.

v. Accessibility:

Service robots can improve the lives of people with disabilities or limited mobility.

Growing Field:

The service robotics market is experiencing significant growth, with increasing adoption across various industries.

Advances in AI, machine learning, and sensor technology are driving the development of more sophisticated and capable service robots.

3. **Autonomous and augmented systems:** represent different approaches to utilizing artificial intelligence. Autonomous systems aim to perform tasks independently, without human intervention, while augmented systems work alongside humans to enhance their capabilities. Essentially, autonomy focuses on automation, whereas augmentation emphasizes human-machine collaboration for improved decision-making and performance.

Autonomous Systems:

Definition:

Autonomous systems are designed to operate independently, making decisions and taking actions without direct human control or guidance.

Examples:

Self-driving cars, robots, and automated manufacturing systems are examples of autonomous systems.

Key Characteristics of Autonomous and augmented systems:

They rely on advanced AI algorithms, sensors, and actuators [29] to perceive their environment, plan actions, and execute tasks.

i. Focus:

Automation of tasks, achieving goals with minimal human oversight.

Augmented Systems:

ii. Definition:

Augmented systems enhance human capabilities by providing data, insights, and tools that assist in decision-making and problem-solving.

iii. Examples:

Chatbots assisting customer service agents, AI-powered tools for medical diagnosis, and data visualization platforms for financial analysis are examples of augmented systems.

iv. Key Characteristics:

They leverage machine learning and data analytics to provide humans with actionable information, improving their efficiency and effectiveness.

v. Focus:

Collaboration between humans and machines to achieve better outcomes than either could achieve alone.

REFERENCES

- [1] Iborra, A. Pastor, J.A. B. Álvarez, C. Fernández, J.M. FernándezMeroño., Robots in radioactive environments. "IEEE Robot. Automation". Mag. 10, <https://doi.org/10.1109/MRA.2003.1256294>, pp. 12–22, 2003.
- [2] Cortez, R.A, Papageorgiou, X. H.G, Tanner, A.V, Klimenko, K.N, Borozdin, W.C, Priedhorsky, Experimental implementation of robotic sequential nuclear search. "Mediterranean Conference on Control and Automation. MED", <https://doi.org/10.1109/MED.2007.4433797>, 2007.
- [3] Abouaf, J. Trial by fire: The teleoperated robot targets Chernobyl. IEEE Computer. Graph. Appl. 18, <https://doi.org/10.1109/38.689654>, pp. 10–14, 1998.
- [4] Bagatin, M. Gerardin, S. Paccagnella, A. Space, and terrestrial radiation effects in Flash memories Radiation effects in recon fi gurable FPGAs. Semicond. Sci. Technol, 32, pp. 1-8, 2017.
- [5] Berry, R. Loebakka, K. E. Hall, Sensors for mobile robots. "In Proceedings of the 3rd Conference on Robot Vision and Sensory Controls", pp. 584 588,1983.
- [6] Bloss, R. 2010. How do you decommission a nuclear installation? "Call in the robots. Ind. Robot anInt". 37, 133–136. <https://doi.org/10.1108/01439911011018902>
- [7] Bogue, R. Robots in the nuclear industry: a review of technologies and applications. Ind. Robot An Int. J. 38, <https://doi.org/10.1108/01439911111106327>, pp- 113–118, 2011.
- [8] Bradley, D.A, Seward, D.W, 1998. The development, control, and operation of an autonomous robotic excavator. "Intell. Rob", pp, 73–97. <https://doi.org/10.1023/A:1007932011161>.
- [9] Briones, Bustamante, L. P. Serna, M.A,Robicen: a wall-climbing pneumatic robot for inspection in nuclear power plants. Robot. Compute, pp287 292,1994.
- [10] Kim, J. H. H. J. Ko, Kim, S. H. Ji, M. G. and Lee, J. B. "Intelligent system of the spider robot for the various moving functions," in Proc. 2009 18th IEEE International Symposium
- [11] Ijspeert, A. Central pattern generators for locomotion control in animals and robots: a review, Neural Networks 21 (4) (2008) 642–653.
- [12] Cruse, H. D. Brunn, C. Bartling, J. Dean, M. Dreifert, T. Kindermann, Walking: a complex behavior controlled by simple networks, Adaptive Behavior 3 (1995) pp 385–418.
- [13] Figliolini, G. Rea, P. Mechanics, and simulation of six-legged walking robots, in Climbing and Walking Robots Towards New Applications, I-Tech Education and Publishing, Austria, 2007, pp. 1–22.
- [14] Autumn, K. Peattie, A. Mechanisms of adhesion in geckos, The Journal of Integrative and Comparative Biology 42 (6) (2002) 1081–1090.
- [15] Autumn, K. Sitti, M. Liang, Y. Peattie, A. Hansen, W. Sponberg, S. Kenny, T. R. Fearing, J. Israelachvili, R. Full, Evidence for van der Waals adhesion in gecko setae, Proceedings of the National Academy of Sciences of the USA 99 (19) (2002) 12252–12256.

- [16] A. Kesel, A. Martin, T. Seidl, Adhesion measurements on the attachment devices of the jumping spider *Evarcha arcuata*, *Journal of Experimental Biology* 206 (2003) 2733–2738.
- [17] A. Kesel, A. Martin, T. Seidl, Getting a grip on spider attachment: an AFM approach to microstructure adhesion in arthropods, *Smart Materials and Structures* 13 (2004) 512–518.
- [18] H. Gao, X. Wang, H. Yao, S. Gorb, E. Arzt, Mechanics of hierarchical adhesion structures of geckos, *Mechanics of Materials* 37 (2–3) (2005) 275–285.
- [19] S. Soyguder and H. Ali. Kinematic and dynamic analysis of a hexapod walking–running bounding gaits robot and control actions. *Computers and Electrical Engineering*, 38(2), pp. 444–458.(2012).
- [20] Sreerag, R. Muthukumaran, S. B. Sriram, S. John, and B. Thenkalvi, “Tarantula Bot: Rescue Assist Tele Robot,” in Proc. 2012 Fourth International Conference on Advanced Computing (ICAC), pp. 1–6.
- [21] Tian, W. J., and Geng, Y. “A New Household Security Robot System Based on Wireless Sensor Network,” in Proc. 2009 Second International ACORS Conference on Future Information Technology and Management Engineering (FITME '09), Sanya, China, pp. 187–190.
- [22] Roy, S. S., and Pratihari, D. K. “Dynamic Modeling and Energy Consumption Analysis of Crab Walking of a Six-legged Robot,” in Proc. 2011 IEEE Conference on Technologies for Practical Robot Applications (TEPRA), Woburn, Massachusetts, pp. 82–87.
- [23] J. A. Cobano, J. Estremera, and P. G. d. Santos. Accurate tracking of legged robots on natural terrain. *Autonomous Robots*, 28(2), pp. 231–244.(2010).
- [24] S. S. Roy, A. K. Singh, and D. K. Pratihari. Estimation of optimal feet forces and joint torques for on-line control of the six-legged robot. *Robotics and Computer-Integrated Manufacturing*, 27(5), pp. 910–917. (2011).
- [25] S. S. Roy and D. K. Pratihari. Dynamic modeling, stability, and energy consumption analysis of a realistic six-legged walking robot. *Robotics and Computer-Integrated Manufacturing*, 29(2), pp. 400–416, 2013.
- [26] Roy, S. S., and Pratihari, D. K. Effects of turning gait parameters on energy consumption and stability of a six-legged walking robot. *Robotics Autonomous Systems*, 60(1), pp. 72–82, 2012. *Robot and Human Interactive Communication (RO-MAN 2009)*.
- [27] Muhammad B. A., Abubakar S. M., “A general review on advancement in the robotic system”, *Artificial & Computational Intelligence* / Published online: Mar 2020 http://acors.org/ijacoi/VOL1_ISSUE2_04.pdf.
- [28] Isa A.I., Muhammad A. B. “Industry 4.0 Pipeline Inspection Robots: Challenges, Opportunities, and Innovative Solutions”, In *Global Journal of Research in Engineering & Computer Sciences*, Vol. 4, Number 5, pp. 113–117, 2024, <https://doi.org/10.5281/zenodo.13856936>.
- [29] Isa A.I., & Muhammad A. B. “The DC Motor Advantages: Key Benefits and Improvements over AC Motors” In *Global Journal of Research in Engineering & Computer Sciences*, Vol. 4, Number 5, pp. 83–88, 2024, <https://doi.org/10.5281/zenodo.13784451>
- [30] Isa A.I., & Muhammad A. B. “The Ups and Downs of Robotic Arms: Navigating the Challenges”, In *Global Journal of Research in Engineering & Computer Sciences*, Vol. 4, Number 5, pp. 78–82, 2024, <https://doi.org/10.5281/zenodo.13774819>.
- [31] I. A. Ibrahim, Abdurrahman I. A., & Muhammad A. B. “Navigating the Challenges of Industry 5.0: How Artificial Intelligence is Revolutionising the Future of Work”, In *Global Journal of Research in Engineering & Computer Sciences*, Vol. 5, Number 3, pp. 59–66, 2025, <https://doi.org/10.5281/zenodo.15529372>.
- [32] S. Saeed, K. Bilal, A. Namoun, I. A. Ibrahim and J. Shuja, “Feature-Centric Mobile Applications Clustering with Generative AI,” 2024 2nd International Conference on Foundation and Large Language Models (FLLM), Dubai, United Arab Emirates, 2024, pp. 103–108, doi: 10.1109/FLLM63129.2024.10852481.
- [33] A. Namoun, I. A. Ibrahim, E. Mustafa et al. “Generative artificial intelligence in education: an umbrella review of applications and challenges”, available at Research Square <https://doi.org/10.21203/rs.3.rs-4892155/v2>.
- [34] I. A. Ibrahim, Abdurrahman I. A., & Muhammad A. B. “Artificial Intelligence-Driven Vision-Based Control: Unlocking the Potential of Robotics Amidst Challenges”, In *Global Journal of Research in Engineering & Computer Sciences* Vol. 5, Number 3, pp. 74–80, 2025, <https://doi.org/10.5281/zenodo.15538465>.
- [35] I. A. Ibrahim, Abdurrahman I. A., & Muhammad A. B. “Navigating the Challenges of Artificial Intelligence in Healthcare: Overcoming Barriers in the 4th Industrial Revolution and Beyond”, In *Global Journal of Research in Engineering & Computer Sciences* Vol. 5, Number 3, pp. 81–87, 2025, <https://doi.org/10.5281/zenodo.15538505>.
- [36] I. A. Ibrahim, Abdurrahman I. A., & Muhammad A. B. “Empowering Communication: Artificial Intelligence-Driven Robotic Hands for Deaf and DeafBlind Individuals through Assistive Technology”, In *Global Journal of Research in Engineering & Computer Sciences* Vol. 5, Number 3, pp. 67–73, 2025, <https://doi.org/10.5281/zenodo.15538438>.
- [37] I. A. Ibrahim, Abdurrahman I. A., & Muhammad A. B. “Artificial Intelligence-Enhanced Wireless Medical Alert Systems: Overcoming Challenges, Mitigating Effects, and Addressing Limitations”, In *Global Journal of Research in Engineering & Computer Sciences* Vol. 5, Number 3, pp. 53–58, 2025, <https://doi.org/10.5281/zenodo.15521486>.
- [38] I. A. Ibrahim, M. A. Baballe, “Developing a User-Friendly Smart Blind Stick for Visually Impaired Individuals in the Digital Era”, *JETIR*, Volume 11, Issue 9, September 2024.
- [39] Isa A. I., Abdurrahman I. A., Muhammad A. B., “Artificial intelligence in Robotics: Evaluating Deep Learning Approaches for Vision-Based Control”, *JETIR*, Volume 12, Issue 6, June 2025.
- [40] https://www.google.com/search?q=A+general+review+on+advancement+in+the+robotic+system&og=A+general+review+on+advancement+in+the+robotic+system&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQRRg8MgYIAhBFGDzSAQkyNDkyajBqMTWoAgiwAgHxBZOF6J4T_bpz&sourceid=chrome&ie=UTF-8.