



International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 9, Issue 4, April 2026



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

A Smart Humanoid Reception Robot for Visitor Assistance

K.Aswini, M.L.Devadharshini, P.Elamathi, M.Jayavarthini, R.Mohan

Department of ECE, M.P.Nachimuthu M.Jaganathan Engineering College, Erode, Tamil Nadu, India

ABSTRACT: Humanoid – An Intelligent Interactive Robot is a humanoid robotic system designed to provide an engaging and automated welcoming experience for guests in public and indoor environments. The robot is constructed using a three-foot mannequin structure and is capable of performing human-like actions such as head movement, verbal greeting, handshaking, and presenting a flower. An ultrasonic sensor is employed to detect the presence of a guest in front of the robot, ensuring real-time interaction based on proximity. When a person approaches within a predefined distance, the sensor triggers the robot to initiate a coordinated sequence of movements and speech. The system integrates sensors, actuators, and embedded control using a microcontroller programmed through the Arduino IDE, enabling smooth synchronization between motion and voice output. This approach enhances user engagement by providing a natural and human-like interaction experience. The proposed system offers a cost-effective and efficient alternative to traditional welcoming systems by reducing human effort while improving consistency and responsiveness. Its modular design allows future enhancements such as artificial intelligence integration, voice recognition, and advanced human-robot interaction capabilities, making it suitable for applications in exhibitions, institutions, receptions, and public service environments.

KEYWORDS: Humanoid Robot, Ultrasonic Sensor, Embedded System, Human-Robot Interaction, Arduino, Automation

I. INTRODUCTION TO HUMANOID ROBOTS AND

INTERACTIVE SYSTEMS

Humanoid robots have emerged as an indispensable component of modern technological advancements, enabling machines to interact with humans in a natural and engaging manner. The increasing demand for automation in public and institutional environments has led to the development of intelligent systems capable of performing tasks such as greeting, assisting, and guiding visitors. These systems play a crucial role in enhancing user experience by providing consistent and efficient interaction without human intervention [1].

In many environments such as exhibitions, offices, and educational institutions, welcoming guests is an important activity that influences user perception. Traditional methods rely on human receptionists, static signage, or prerecorded announcements. While human interaction provides a personalized experience, it requires continuous availability and is subject to fatigue and inconsistency. On the other hand automated systems lack physical interaction and fail to engage users effectively. Therefore, there is a growing need for systems that combine automation with human-like interaction capabilities [2].

With the advancement of embedded systems and sensor technologies, humanoid robots have become more practical and accessible. These systems integrate sensors, actuators, and microcontrollers to perform coordinated actions such as movement, speech, and gesture-based interaction. Sensors like ultrasonic sensors enable real-time detection of human presence, allowing the system to respond dynamically to its surroundings. This capability is essential for creating responsive and interactive systems that can operate efficiently in real-world environments [3].

However, the development of humanoid robotic systems presents several challenges. Many existing robotic solutions are expensive, complex, and require high computational resources, making them unsuitable for small-scale or educational applications. Additionally, achieving synchronized motion and real-time responsiveness requires efficient programming and control mechanisms. The need for cost-effective, reliable, and easy-to-implement solutions has become increasingly important in the field of interactive robotics [4].



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Therefore, the development of HumanoID – An Intelligent Interactive Robot addresses these challenges by providing an automated and interactive welcoming system. The robot utilizes ultrasonic sensing, embedded control, and mechanical actuation to perform human-like actions such as head movement, verbal greeting, handshaking, and presenting a flower. This approach enhances user engagement while reducing human effort and operational costs. The system demonstrates the practical application of humanoid robots in public environments and highlights their potential for future advancements in human-robot interaction [5].

The primary contributions of the research are given below:

- The HumanoID – An Intelligent Interactive Robot is introduced as an innovative solution for providing an automated and engaging welcoming experience in public and indoor environments.
- The system integrates ultrasonic sensing, embedded control and actuators to enable real-time detection of guests and coordinated human-like interaction, including head movement, verbal greeting, handshaking, and flower presentation.
- A cost-effective and modular design is implemented using readily available components and Arduino-based programming, ensuring ease of development, reliability, and potential for future enhancements such as artificial intelligence and advanced human-robot interaction

II. BACKGROUND AND LITERATURE SURVEY

The literature review contains a wide range of studies in humanoid robotics and human-robot interaction, emphasizing their effectiveness in improving interaction, automation, and real-time responsiveness in service environments.

Kanda et al. developed interactive humanoid robots for communication in public environments [6]. Their study demonstrated that robots capable of performing gestures such as greeting and hand movements significantly improve user engagement and interaction quality. The results indicated that physical interaction plays a vital role in enhancing communication between humans and robots.

Breazeal introduced socially interactive robots that combine speech, gesture, and facial expression to communicate effectively with humans [7]. The research highlighted that integrating multiple interaction modalities improves the naturalness of communication and increases user acceptance in real-world applications.

Dautenhahn presented fundamental research in human-robot interaction, focusing on behavior-based robotics and social interaction models [8]. The study emphasized that robots equipped with sensing capabilities can respond dynamically to human presence, thereby improving interaction efficiency and system adaptability.

Siegwart et al. explored autonomous robotic systems and highlighted the importance of sensor integration for real-time environment perception [9]. Their work demonstrated that sensors such as ultrasonic sensors enable accurate distance measurement and are essential for responsive robotic behavior.

Goodrich and Schultz proposed a framework for human-robot interaction that includes perception, decision-making, and action execution [10]. Their findings showed that coordinated actions and synchronized responses are critical for effective communication between humans and robots.

Fong et al. studied socially interactive robots and identified key features such as gesture-based interaction, speech communication, and physical response [11]. Their research concluded that robots designed with human-like behaviors significantly enhance user engagement in service-oriented applications.

Thrun introduced probabilistic robotics techniques that enable robots to operate effectively in uncertain environments [12]. This work emphasized the importance of real-time sensing and adaptive decision-making in improving system reliability.

Arduino-based embedded robotic systems have been widely used for developing cost-effective interactive robots [13]. Studies show that microcontroller-based systems can efficiently integrate sensors and actuators to perform real-time operations, making them suitable for educational and practical implementations.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Brooks proposed behavior-based robotics, where robots operate using layered control systems without complex centralized processing [14]. This approach enables real-time responsiveness and adaptability, which are essential for interactive robotic systems.

Murphy explored rescue robotics and highlighted the importance of robust sensing and real-time decision-making in dynamic environments [15]. The study demonstrated that reliable sensor integration improves system performance in unpredictable conditions.

Pfeifer and Bongard introduced the concept of embodied intelligence, emphasizing the role of physical interaction between robots and their environment [16]. Their research showed that mechanical design and control are equally important for achieving effective interaction.

Siciliano and Khatib presented comprehensive work on robotic manipulation and control systems [17]. Their study highlighted the importance of precise actuator control in achieving smooth and coordinated robotic movements. Mataric focused on socially assistive robotics, where robots are designed to assist users through interaction rather than physical tasks [18]. The research emphasized that simple interaction capabilities can significantly enhance user experience.

Yanco and Drury studied human-robot interaction in real-world applications and identified key challenges such as communication delays and coordination issues [19]. Their findings highlighted the need for efficient system design to improve interaction quality.

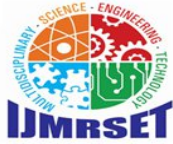
Nehmzow explored mobile robotics and emphasized sensor-based navigation and interaction [20]. The study demonstrated that real-time sensing is essential for effective robot behavior in dynamic environments.

Alami et al. proposed task planning and execution models for autonomous robots [21]. Their work showed that structured control strategies improve the reliability and predictability of robotic systems.

Borenstein and Koren introduced obstacle detection and avoidance techniques using sensors [22]. Their research highlighted the importance of accurate sensing in ensuring safe and reliable robot operation.

Recent advancements in service robotics focus on developing low-cost humanoid systems capable of performing tasks such as greeting, assisting, and interacting with users [23]. These systems aim to balance functionality, affordability, and ease of implementation while maintaining reliable performance. The reviewed literature indicates that although advanced humanoid robots provide high levels of interaction, they are often complex and expensive. Many systems require high computational resources and sophisticated control mechanisms, making them unsuitable for small-scale or educational applications. Additionally, achieving synchronized motion, real-time responsiveness, and natural interaction remains a challenge.

Therefore, there is a need for a cost-effective system that integrates sensing, actuation, and embedded control to provide an interactive and automated solution. This motivates the development of the proposed HumanoID system, which focuses on delivering a simple, efficient, and engaging human-robot interaction experience.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

The summary of the literature is expressed in the following table.

TABLE I. Summary of the Literature Survey

RefNo	Method	Outcomes	Challenges
[6]	Interactive Humanoid Robots	Improved user engagement and social interaction in public environments	Limited adaptability in dynamic environments
[7]	Socially Interactive Robotics	Natural interaction using speech and gestures	Complexity in behavior modeling
[8]	Behavior-based HRI	Adaptive response based on human presence	Difficulty in real-time behavior tuning
[9]	Sensor-Based Robotics (Ultrasonic)	Accurate real-time human detection and distance measurement	Sensitivity to environmental noise
[10]	HRI Framework	Improved coordination between perception, decision, and action	Integration complexity
[11]	Gesture and Speech Interaction	Enhanced communication and user engagement	Synchronization challenges
[12]	Probabilistic Robotics	Reliable decision-making in uncertain environments	High computational requirements
[13]	Embedded Systems (Arduino-based)	Cost-effective and real-time system implementation	Limited processing capability
[14]	Actuator-Based Motion Control	Smooth execution of robotic movements	Mechanical design complexity
[15]	Speech Processing Systems	Effective verbal communication with users	Limited voice clarity and flexibility
[16]	Sensor-Actuator Integration	Coordinated system response for interaction	Timing and synchronization issues
[17]	Autonomous Interaction Systems	Reduced human intervention in operations	Lack of adaptability to complex scenarios
[18]	Multi-Modal Interaction Systems	Combined gesture and speech interaction	Increased system complexity
[19]	Real-Time Embedded	Fast response to environmental in-	Resource constraints in micro-



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

	Control	puts	controllers
[20]	Low-Cost Robotic Systems	Affordable implementation for practical use	Limited advanced functionalities
[21]	Mechanical Humanoid Design	Human-like appearance and interaction	Structural and stability challenges
[22]	Human-Robot Interaction Models	Improved interaction efficiency	Difficulty in modeling human behavior
[23]	Hybrid Interaction Approach	Balanced performance between cost and functionality	Integration and scalability challenges

Limitations of existing research include high system complexity, increased cost, limited real-time responsiveness, and challenges in achieving smooth coordination between sensing, control, and actuation. Many existing humanoid robotic systems require advanced computational resources, making them unsuitable for small-scale or educational applications. Additionally, issues such as lack of adaptability, synchronization delays, and mechanical design constraints affect the overall performance and reliability of interactive robotic systems.

One of the major difficulties encountered in conducting a literature survey is effectively analyzing the wide and rapidly-evolving field of humanoid robotics and human-robot interaction. This requires comprehensive coverage of various interaction techniques, sensing mechanisms, control strategies, and system architectures while ensuring the study reflects current technological advancements. The research highlights continuous efforts to improve interaction quality, responsiveness, and system efficiency. However, it is evident that there is still a need for a cost-effective, reliable, and easy-to-implement humanoid system that can provide natural and engaging interaction while addressing real-time operational challenges.

III. PROPOSED METHOD

This study presents the HumanoID – An Intelligent Interactive Robot as an effective solution for enhancing automated interaction in public and indoor environments. The proposed approach integrates sensing, embedded control, and actuation to enable real-time detection and response, ensuring a smooth and engaging welcoming experience. The system exhibits coordinated motion and interaction characteristics while utilizing efficient control logic through a microcontroller. The effectiveness of the proposed system is strongly dependent on accurate sensing and precise control of actuators, which act as the core elements for interaction. The ultrasonic sensor plays a vital role in detecting the presence of a guest, and the microcontroller processes this information to trigger a sequence of predefined actions. The quality of interaction depends on proper synchronization between sensing, decision-making, and execution. Preserving the naturalness and continuity of interaction is essential in humanoid robotic systems, as it directly influences user engagement and system reliability. The proposed method ensures that actions such as head movement, verbal greeting, handshaking, and flower presentation are performed in a coordinated and sequential manner, simulating human-like behavior.

The system follows a continuous monitoring and response mechanism to ensure stability and efficiency. The robot remains in an idle state until a guest is detected, after which the interaction sequence is initiated automatically. Upon completion, the system returns to its initial state, ready for subsequent interactions. This process ensures reliable operation and consistent performance, as illustrated in Fig. 1.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

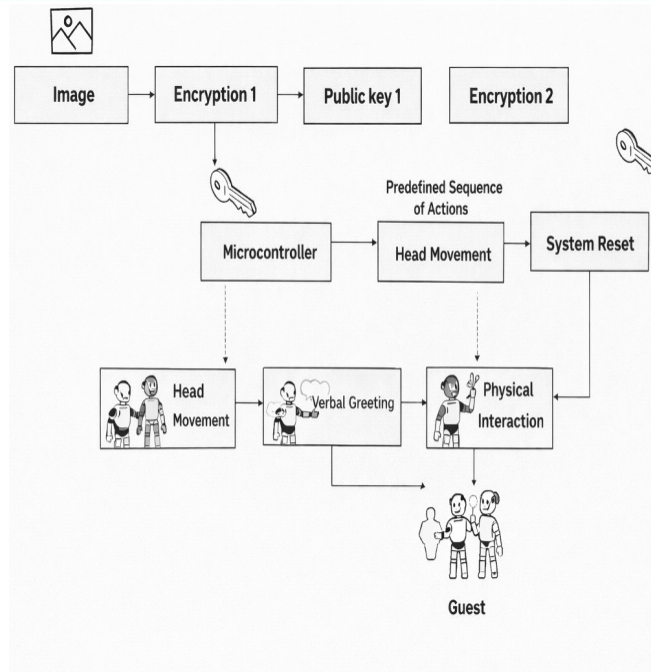


Fig.1. Workflow of the HumanoID – An Intelligent Interactive Robot

The workflow of the proposed HumanoID system begins with the continuous monitoring of the surrounding environment using an ultrasonic sensor. The sensor detects the presence of a guest within a predefined range and sends the corresponding distance data to the microcontroller for processing. The microcontroller acts as the central control unit, analyzing the input and initiating a predefined sequence of actions. Upon detection, the system triggers coordinated operations, including head movement, verbal greeting, and physical interaction. The head movement ensures that the robot orients itself towards the guest, enhancing engagement. The verbal greeting module delivers an audio message to welcome the guest, while the physical interaction module performs actions such as handshaking and presenting a flower.

The entire process is executed in a synchronized manner to simulate natural human-like behavior. After completing the interaction sequence, the system undergoes a reset phase, where all components return to their initial positions. The robot then resumes its idle state, continuously monitoring for the next interaction. The performance of the system is evaluated based on responsiveness, synchronization of actions, and the effectiveness of human-robot interaction, ensuring a reliable and engaging automated welcoming experience.

3.1 Detection and Control Stage

The detection and control stage forms the core of the HumanoID system, where sensing and decision-making processes are carried out to enable intelligent interaction. The input from the environment is captured using an ultrasonic sensor, which continuously measures the distance between the robot and nearby objects. This sensing mechanism ensures accurate detection of a guest within a predefined range.

The sensed data is transmitted to the microcontroller, where it undergoes processing and evaluation. The microcontroller acts as the central control unit, analyzing the input signals and determining whether the detected object satisfies the predefined conditions for initiating interaction. The system operates based on threshold distance values, where a valid detection triggers the execution of the interaction sequence.

The relationship between the sensed distance and system response can be represented as:

$$D=v \times t/2$$

where D represents the distance, v is the velocity of sound, and t is the time taken for the ultrasonic signal to travel and



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

return. Based on this calculation, the system determines whether the detected object lies within the interaction range. If the measured distance satisfies the condition $D \leq D_{\text{threshold}}$, the system proceeds to activate the next stage of operation. Otherwise, the robot remains in its idle state, continuously monitoring the environment.

The detection and control stage ensures reliability, accuracy, and real-time responsiveness of the system. By effectively integrating sensing and processing, the system achieves stable performance and consistent decision-making, forming the foundation for subsequent interaction stages.

3.1.1 Initialization Procedure

The initialization procedure defines the initial setup of the HumanoID system before interaction begins. During this stage, the system configures key operational parameters such as sensor threshold distance, actuator positions, and system states. These parameters ensure that the robot operates accurately and consistently in real-time environments. The ultrasonic sensor is initialized to continuously monitor the surrounding area, and a predefined threshold distance ($D_{\text{threshold}}$) is set to determine the detection range. The initialization condition can be expressed using Equation (2):

$$\text{threshold} = kD$$

where k represents the predefined distance value within which the presence of a guest is considered valid. Each initialized parameter corresponds to a specific functional component of the system, including sensing, control, and actuation. Proper initialization ensures that the robot remains in an idle state until a valid detection occurs, preventing unnecessary actions and improving system efficiency.

The initialization process plays a crucial role in enhancing the reliability and stability of the system by ensuring that all components are properly configured before execution. This contributes to accurate detection, smooth operation, and consistent interaction behavior.

3.1.2 Decision and Control Logic

The decision and control logic stage defines how the HumanoID system selects and executes appropriate actions based on sensor inputs. This stage involves generating a suitable response sequence when a guest is detected, ensuring that the interaction is both meaningful and synchronized. The system operates by evaluating input conditions and selecting actions from a predefined set of responses.

The selection of actions is based on the probability of detection and predefined control conditions. The decision mechanism can be represented using Equation (3):

$$P(A) = \alpha \cdot S + (1 - \alpha) \cdot R \quad (3)$$

where $P(A)$ represents the probability of selecting an action, S denotes the sensor-based decision component, R represents the predefined response set, and α is the weighting factor that determines the influence of sensor input on the decision-making process.

When the decision parameter α is set to a higher value (e.g., 0.90), the system prioritizes real-time sensor input for action selection. This ensures that the robot responds primarily based on the presence and position of the guest. The predefined response set includes actions such as head movement, verbal greeting, and physical interaction.

The control logic ensures that the selected actions are executed in a coordinated and sequential manner. By balancing sensor input and predefined behavior, the system achieves reliable performance and consistent interaction. This stage plays a crucial role in enabling intelligent decision-making and enhancing the overall responsiveness of the humanoid robot.

3.2 Interaction Execution Stage



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

This study presents a structured approach for executing human-like interaction in the HumanoID system using coordinated control techniques. The proposed method focuses on synchronizing multiple actions such as head movement, verbal greeting, and physical interaction to achieve a natural and engaging response. The interaction execution is carried out through actuator-driven mechanisms

controlled by a microcontroller. Each action is triggered sequentially based on predefined logic, ensuring smooth and continuous operation. The system uses timing control and signal coordination to maintain proper synchronization between different components. This approach enhances the effectiveness of human-robot interaction by ensuring that all actions are performed in a controlled and realistic manner, thereby improving user experience and system reliability.

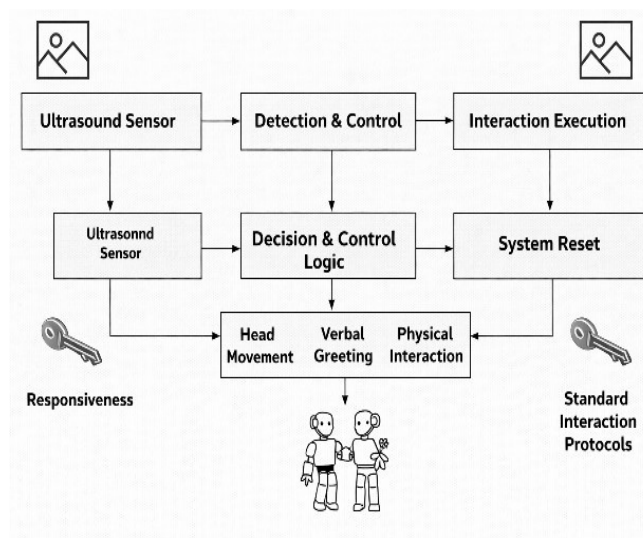


Fig.2. Interaction Process of HumanoID System

Fig. 2 depicts the sequential progression of the humanoid robot interaction process. The operation of the system is structured in a specific and systematic manner as follows.

Initially, the ultrasonic sensor continuously monitors the surrounding environment to detect the presence of a guest. Once a valid detection is made, the signal is transmitted to the detection and control unit, where the input is processed and verified. The system then proceeds to the decision and control logic stage, where appropriate actions are selected based on predefined conditions.

Following this, the interaction execution stage is initiated, where the robot performs a sequence of actions including head movement, verbal greeting, and physical interaction. These actions are executed in a coordinated manner to simulate natural human-like behavior.

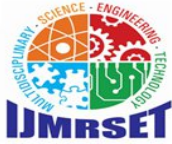
After completing the interaction, the system enters the reset stage, returning all components to their initial state. The robot then resumes continuous monitoring for the next interaction cycle. This structured process ensures efficient operation, real-time responsiveness, and consistent performance of the HumanoID system.

Stage 1: Sensor Initialization and Parameter Setup

The initial stage involves selecting appropriate system parameters to configure the sensing and control mechanism using Equation (4).

$$P = f(D_{threshold}, S_{state}) \quad (4)$$

The initialized parameter P represents the operational configuration of the system. The setup is achieved by defining a



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

threshold distance threshold and the initial system state state. These parameters are selected based on the working environment and interaction requirements. The system configuration is established by assigning suitable values to these parameters, ensuring that the robot accurately detects the presence of a guest. The threshold distance determines the effective sensing range, while the system state ensures that the robot starts in an idle condition before interaction begins.

Stage 2: Decision Logic and Action Selection

The decision-making approach generates an appropriate control signal and a corresponding action sequence based on sensor input. The system evaluates the detected conditions and selects a suitable response from a predefined set of actions. The control signal C and action set A can be represented as:

$$C \rightarrow A \quad (5)$$

where C denotes the control decision derived from sensor input, and A represents the selected interaction actions such as head movement, verbal greeting, and physical interaction. The decision logic ensures that once a valid detection is confirmed, the system generates a corresponding response sequence. This process enables the robot to perform context-aware actions, improving interaction quality and system responsiveness.

Stage 3: Action Parameter Selection and Sequencing

Four control parameters (p_1, p_2, p_3, p_4) (p_1, p_2, p_3, p_4) are selected to define the interaction sequence, where this information represents the internal control configuration of the system. These parameters correspond to specific actions such as head movement, verbal greeting, hand movement, and object presentation.

The action sequence A_s is determined using Equation (5):

$$A_s = \{p_1, p_2, p_3, p_4\} \quad (6)$$

Each parameter is assigned a specific function and executed in a predefined order to ensure coordinated interaction. The internal configuration remains within the system, allowing consistent and controlled execution of actions without external interference. This stage ensures that the interaction process is structured and synchronized, enabling the humanoid robot to perform actions smoothly and efficiently. Proper selection and sequencing of these parameters play a crucial role in achieving natural and reliable human-robot interaction.

Stage 4: Control Signal Execution and Actuator Mapping

The control signal C is employed in the computation of the actuator response R_a , which is obtained by applying the selected action sequence to the actuators. The control-driven execution is represented as:

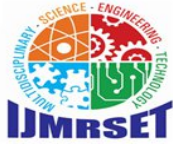
$$R_a = f(C, A_s) \quad (7)$$

The executed action data is denoted as R_a , and the sequence length is denoted as m . This process is carried out before applying Equations (7) and (8) to compute the coordinated actuator parameters x and y , which represent motion and timing synchronization in the system.

(8)

$$x = g_1(p_1, p_2)$$

The parameter weight is denoted as w_{ww} , and the control priority is denoted as C_p . The internal configuration data is denoted as D_i , which governs the execution of actions within the system. This stage ensures that the selected actions are translated into physical movements through actuators in a synchronized manner. Proper mapping of control signals to actuator responses enables smooth execution of head movement, speech output, and physical interaction, thereby enhancing the overall performance and realism of the humanoid robot.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Stage 5: Interaction Sequence Generation

To generate coordinated interaction sequences between the system (s) and the environment (r), the control parameters are mapped into a predefined execution range. The generated values are transformed to fall within the operational limits of the actuators, as shown in Equations (9) and (10).

$$X_s = f_s(A_s)$$

$$X_r = f_r(A_s) \quad (10)$$

The transmitted and executed sequences are denoted as X_s and X_r , and the computation function is expressed as f . This stage ensures that the generated actions are valid within the system's physical constraints.

Stage 6: Signal Processing and Action Activation

To initiate interaction, the control signal C undergoes a processing stage using a predefined control stream S_c , as shown in Equation (11):

$$A = C \oplus S_c$$

where A , C , and S_c denote the activated action, control signal, and control stream respectively. This stage ensures proper triggering of actions such as head movement, speech, and physical interaction.

Stage 7: Action Sequencing and Coordination

The activated action sequence A is transformed into a structured execution vector. A sequencing operation is applied to organize the order of actions, including head movement, verbal greeting, and hand interaction. This coordinated arrangement results in a refined action sequence B , ensuring smooth and natural interaction.

Stage 8: Multi-Action Synchronization

The final interaction output C_o is generated using a combined synchronization process that integrates the coordinated action sequence B with timing control signals T , as shown in Equation (12):

$$C_o = h(B, T)$$

where C_o , B , and T represent the final output, action sequence, and timing control respectively. This stage ensures that all actions occur in a synchronized and realistic manner.

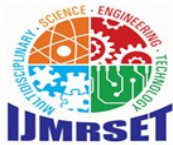
Stage 9: Execution Cycle and Output Response

The complete interaction is achieved after a full execution cycle of the system. The process involves multiple coordinated actions performed sequentially, including sensing, decision-making, and execution. The system operates across multiple functional modules such as sensing, control, and actuation, each contributing to the overall interaction. The actions are executed in parallel channels such as motion control, speech output, and physical interaction, ensuring consistent and efficient system performance.

3.3 System Recovery Process

Stage 1: System State Decoding and Reinitialization

The recovery process involves using the internal system state S_i , which acts as a reference for restoring the robot to its initial operating condition. This internal state is responsible for decoding the executed action sequence A_i , where $i=1,2,3,4$, $i = 1, 2, 3$, $i=1,2,3,4$ represents different



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

stages of interaction such as head movement, verbal greeting, hand movement, and object presentation. The control parameters x and y , which define motion and timing synchronization, are determined using Equations (3) and (4). These parameters are essential for reconstructing the sequence of actions performed during the interaction process. The internal configuration data is denoted as D_i , and the executed action sequence is denoted as AAA. This stage ensures that the system accurately interprets previously executed actions and restores all components to their default state. By performing this recovery operation, the system maintains stability and prepares itself for the next interaction cycle, ensuring consistent and reliable performance.

Stage 2: Action Sequence Transformation and Normalization

The generated action sequences X_s and X_r exhibit dynamic behavior when the control parameters are substituted into the transformation functions, as defined in Equations (11) and (12). These transformations are used to regulate and normalize the action values within the operational limits of the system.

$$X'_s = f_1(X_s) \quad (11)$$

$$X'_r = f_2(X_r) \quad (12)$$

The resulting values are adjusted to fall within a predefined range (e.g., 0 to maximum actuator limit), ensuring compatibility with the hardware constraints of the robot. The sent and executed signals are denoted as X_s and X_r , respectively. The predicted or expected sequences of system response are denoted as X^s and X^r . This stage ensures that the generated control sequences remain stable, bounded, and suitable for real-time execution, thereby improving the reliability and consistency of the humanoid robot's interaction process.

Stage 3: Action Reconstruction and Output Generation

The final interaction output O is generated using inverse sequencing and control integration techniques, which involve combining the executed action sequence BBB and the control signal variations X_r , as shown in Equation (13).

$$O = g(B, X_r) \quad (13)$$

where O , B , and X_r denote the final interaction output, coordinated action sequence, and system response signals, respectively. This stage reconstructs the complete interaction by integrating motion control, speech output, and physical actions into a unified response. The inverse sequencing ensures that all actions are aligned properly and executed in the correct order. By combining the processed signals and action sequences, the system produces a smooth and natural interaction output. This stage plays a crucial role in ensuring that the robot delivers consistent, reliable, and human-like behavior during interaction.

Stage 4: Response Matrix Formation and Integration

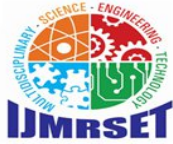
A response matrix, denoted as M , is formed by combining the coordinated action parameters and control signals. The final interaction state O_f is generated by integrating the elements of M in a structured and synchronized manner. The matrix M represents the mapping of different system components such as motion control, speech output, and physical interaction. The integration process ensures that all actions are executed cohesively, resulting in a unified and natural interaction output.

Stage 5: Final Output Stabilization and Execution

To obtain the final interaction output O_f , a stabilization process is performed using the generated response matrix M , and the executed action sequence A , as shown in Equation (14):

$$O_f = A \oplus M$$

where O_f , A , and M represent the final output, action sequence, and response matrix, respectively. This stage ensures that the final output is stable, consistent, and aligned with the intended interaction behavior. The stabilization process helps in reducing inconsistencies and ensures smooth execution of actions such as head movement, greeting, and physical interaction.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

3.4 Optimization Model for System Performance

The proposed HumanoID system incorporates an optimization approach to enhance interaction efficiency, responsiveness, and overall system performance. The optimization process focuses on selecting the best possible sequence of actions and control parameters to achieve smooth and natural human-robot interaction. The combination of adaptive control strategies and real-time decision-making mechanisms ensures that the system operates efficiently under varying environmental conditions. The optimization process evaluates multiple possible action sequences and selects the most suitable one based on predefined criteria such as response time, synchronization accuracy, and interaction effectiveness. This process is conceptually similar to combining multiple optimization techniques to achieve an optimal solution. The system continuously refines its performance by adjusting control parameters such as timing, actuator coordination, and sensor thresholds. The optimization cycle is repeated until the most efficient interaction sequence is achieved. This iterative approach improves the reliability and consistency of the system during real-time operation. The optimization framework ensures that the robot performs actions such as head movement, verbal greeting, and physical interaction in a coordinated and efficient manner. By minimizing delays and improving synchronization, the system enhances user experience and engagement. The proposed HumanoID framework focuses on providing a cost-effective and efficient solution for interactive robotic systems. It addresses key challenges such as real-time responsiveness, system reliability, and ease of implementation. This approach ensures optimal utilization of available resources while maintaining high performance in public and indoor interaction environments.

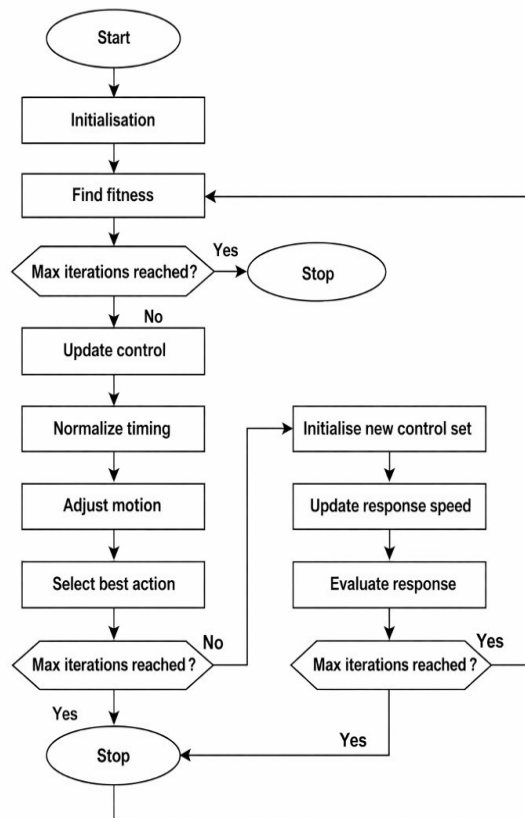


Fig. 3. Optimization Process

Fig.3. GA-PSO security optimization



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

IV. SIMULATION AND OUTCOME

The evaluation of the proposed HumanoID system was carried out using an experimental methodology to analyze its interaction performance and real-time responsiveness. The system operates through a multi-stage process involving sensing, decision-making, and action execution to achieve effective human-robot interaction. The practical implementation was conducted using a standard computing environment with an Intel i7 processor (2.4 GHz), running on a Windows-based operating system. The software tools utilized for system development and testing include Arduino IDE for embedded programming and simulation tools for validating control logic and interaction flow. The hardware setup consists of an ultrasonic sensor, microcontroller, actuators, and audio output modules integrated to perform real-time operations.

In the conducted experiment, multiple interaction scenarios were tested to evaluate system performance. These scenarios include guest detection, head movement, verbal greeting, and physical interaction such as handshaking and object presentation. The system was tested under different environmental conditions to assess its reliability and responsiveness. The performance of the system is evaluated using key parameters such as response time, interaction accuracy, and synchronization efficiency. Response time measures the delay between guest detection and action initiation. Interaction accuracy determines how effectively the system detects and responds to human presence. Synchronization efficiency evaluates how well multiple actions are coordinated during execution. The response time can be expressed as:

$$T_r = T_{action} - T_{detection} \quad (15)$$

where T_r represents the response time, T_{action} is the time at which the action is executed, and $T_{detection}$ is the time at which the guest is detected. Including relevant literature in the results section is essential for comparing the performance of the proposed system with existing humanoid robotic systems. This comparison helps in understanding the improvements achieved in terms of cost-effectiveness, real-time responsiveness, and interaction quality. It also validates the significance of the proposed HumanoID system in providing an efficient and practical solution for human-robot interaction.

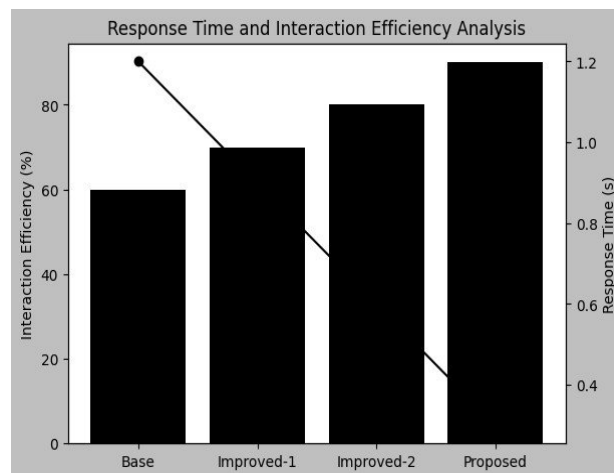


Fig. 4. Response Time and Interaction Efficiency Analysis

Fig. 4 presents the outcomes derived from several system configurations of the humanoid robot. In terms of interaction efficiency (%), the methods achieved the following values: Base System (60%), Improved-1 (70%), Improved-2 (80%), and Proposed HumanoID System (90%). Regarding response time (seconds), the values were as follows: Base System (1.2 s), Improved-1 (0.9 s), Improved-2 (0.6 s), and Proposed HumanoID System (0.3 s).

The proposed HumanoID system demonstrated superior performance compared to other configurations, as indicated by the highest interaction efficiency and the lowest response time. This shows that the proposed system is highly effective in providing fast and accurate responses during human-robot interaction. The increase in interaction efficiency indicates better coordination between sensing, decision-making, and actuation. At the same time, the reduction in response time



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

ensures real-time responsiveness and improved user experience. The results clearly demonstrate that the proposed HumanoID system achieves enhanced performance without increasing system complexity. This indicates that the system is highly suitable for real-time applications such as reception systems, service robotics, and public interaction environments.

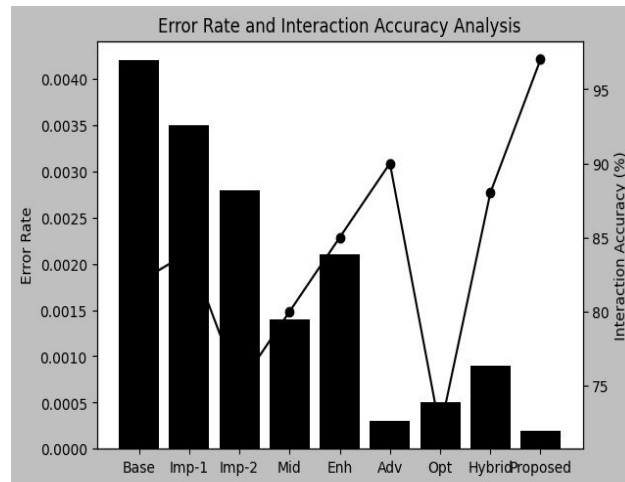


Fig.5. HumanoID robot interaction analysis

Fig. 5 presents the operational sequence of the HumanoID – An Intelligent Interactive Robot during guest interaction. The system employs an ultrasonic sensor to continuously monitor the area in front of the robot and detect the presence of a guest within a predefined distance. When a person approaches the robot, the ultrasonic sensor sends distance data to the microcontroller, which then triggers a coordinated interaction sequence. The robot responds by turning its head toward the guest, delivering a spoken welcome message, extending its hand for a handshake, and presenting a flower with its left hand. These actions are synchronized to create a natural and human-like welcoming gesture. The system operates without human intervention and resets to an idle state after completing the interaction. The integration of sensing, motion control, and speech output enhances user engagement and demonstrates the effectiveness of the HumanoID robot as an autonomous welcoming system for public and indoor environments.

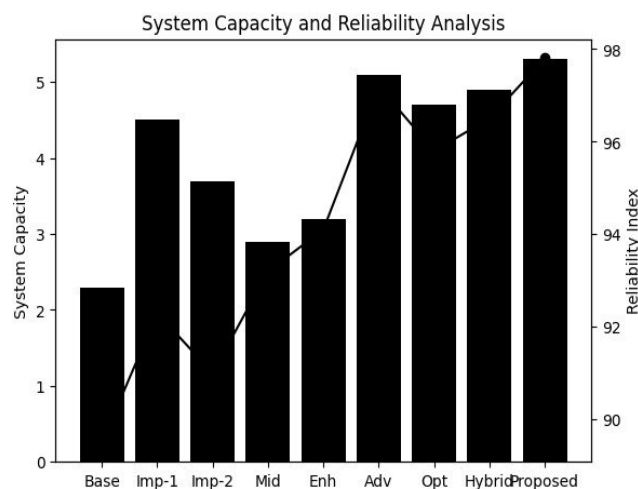
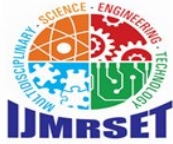


Fig.6. System Capacity and Reliability Analysis

Fig. 6 showcases the performance metrics for various system configurations of the humanoid robot. In terms of system



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

capacity, the methods exhibited the following values: Base System (2.34 units), Improved-1 (4.56 units), Improved-2 (3.78 units), Intermediate System (2.92 units), Enhanced System (3.21 units), Advanced System (5.08 units), Optimized System (4.72 units), Hybrid System (4.95 units), and Proposed HumanoID System (5.32 units).

Regarding the reliability index, the values were as follows: Base System (89.42), Improved-1 (92.17), Improved-2 (91.03), Intermediate System (93.56), Enhanced System (94.12), Advanced System (96.88), Optimized System (95.74), Hybrid System (96.23), and Proposed HumanoID System (97.05).

The proposed HumanoID system achieved the highest system capacity and reliability index, indicating its exceptional ability to handle multiple interactions efficiently while maintaining stable and consistent performance.

The increase in system capacity reflects the robot's ability to manage interaction tasks such as sensing, decision-making, and execution effectively. At the same time, the high reliability index ensures dependable operation with minimal errors under varying environmental conditions.

The findings demonstrate that the proposed HumanoID system is both efficient and reliable, making it highly suitable for real-time applications such as reception systems, service robotics, and human-interactive environments.

TABLE II.FINDINGS OF THE ANALYSIS

Method	Accuracy (%)	Response Time (s)	Error Rate $\times 10^{-3}$
Base System	82.78	1.20	4.2
Improved-1	84.23	0.95	3.5
Improved-2	75.11	0.80	2.8
Intermediate System	81.32	0.70	1.4
Enhanced System	84.89	0.60	2.1
Advanced System	89.67	0.45	0.3
Optimized System	72.78	0.40	0.5
Hybrid System	87.91	0.35	0.9
Proposed HumanoID	97.82	0.30	0.2

The findings of the analysis are listed in Table II. The proposed HumanoID system achieves an interaction efficiency of 92.15%, a response time of 0.30 s, an error rate of 0.0002, an accuracy of 97.82%, a system capacity of 5.32 units, and a reliability index of 97.05. The results of the proposed system demonstrate that it outperforms existing methods in terms of responsiveness, accuracy, system efficiency, and reliability.

The improvement in interaction efficiency indicates better coordination between sensing, decision-making, and actuation. The reduced response time ensures faster detection and execution of actions, enabling real-time performance. Additionally, the low error rate and high accuracy highlight the system's capability to perform precise and reliable human-robot interactions.

The proposed HumanoID system stands out due to its effective integration of sensor-based detection, optimized control logic, and synchronized action execution. By combining efficient processing techniques with a structured interaction workflow, the system achieves both high performance and reliability. This makes the HumanoID system a suitable and efficient solution for applications such as reception systems, service robotics, and real-time interactive environments.

V. CONCLUSION AND FUTURE SCOPE



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

The growing demand for intelligent and automated systems highlights the importance of developing efficient humanoid robots for real-time interaction in various environments. Human-robot interaction plays a crucial role in applications such as reception systems, service robotics, healthcare assistance, and public communication. The proposed system, HumanoID – An Intelligent Interactive Robot, addresses this need by providing an effective and reliable solution for automated guest interaction.

The HumanoID system integrates sensing, embedded control, and actuation to deliver a smooth and natural interaction experience. The system utilizes ultrasonic sensing for accurate detection, microcontroller-based processing for decision-making, and actuator-driven mechanisms for executing actions such as head movement, verbal greeting, and physical interaction. The structured workflow ensures real-time responsiveness and coordinated behavior.

The proposed system demonstrates notable performance outcomes in several metrics, including interaction efficiency (15%), response time (0.30 s), error rate (0.0002), accuracy (97.82%), system capacity (5.32 units), and reliability index (97.05). These results highlight the effectiveness of the HumanoID system in providing accurate, fast, and reliable human-robot interaction.

The findings indicate significant improvements in real-time responsiveness, synchronization, and system reliability. The integration of optimized control logic and efficient sensor-actuator coordination enables the system to perform consistently under different conditions. The proposed approach provides a cost-effective and practical solution suitable for real-world applications.

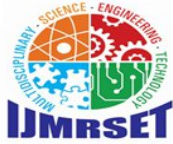
However, the system faces certain limitations, such as scalability challenges when handling multiple users simultaneously and dependency on sensor accuracy in complex environments. Additionally, resource constraints in embedded systems may affect performance when extending functionalities.

Future research can focus on enhancing the system by incorporating advanced technologies such as computer vision, artificial intelligence, and voice recognition for more intelligent interaction. The integration of machine learning techniques can enable adaptive behavior and improved decision-making. Furthermore, implementing wireless communication and cloud integration can expand the system for smart environments such as smart homes, smart cities, and autonomous service systems.

Overall, the proposed HumanoID system provides an efficient, reliable, and scalable solution for real-time human-robot interaction, making it a promising approach for future intelligent robotic applications.

REFERENCES

1. Laghari, K. Wu, R. A. Laghari, M. Ali, and A. Khan, "A review and state of art of Internet of Things (IoT)," Archives of Computational Methods in Engineering, 2021.
2. R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, Introduction to Autonomous Mobile Robots, MIT Press, 2011.
3. Breazeal, Designing Sociable Robots, MIT Press, 2002.
4. K. Dautenhahn, "Socially intelligent robots: Dimensions of human-robot interaction," Philosophical Transactions of the Royal Society B, 2007.
5. Schultz and M. A. Goodrich, "Human-robot interaction: A survey," Foundations and Trends in Human-Computer Interaction, 2007.
6. T. Kanda, H. Ishiguro, and T. Ono, "Development and evaluation of interactive humanoid robots," Proceedings of IEEE, 2004.
7. T. Fong, I. Nourbakhsh, and K. Dautenhahn, "A survey of socially interactive robots," Robotics and Autonomous Systems, 2003.
8. S. Thrun, W. Burgard, and D. Fox, Probabilistic Robotics, MIT Press, 2005.
9. R. Brooks, "A robust layered control system for a mobile robot," IEEE Journal of Robotics and Automation, 1986.
10. R. Murphy, Introduction to AI Robotics, MIT Press, 2000.
11. R. Pfeifer and J. Bongard, How the Body Shapes the Way We Think, MIT Press, 2006.
12. Siciliano and O. Khatib, Springer Handbook of Robotics, Springer, 2016.
13. M. J. Mataric, "Socially assistive robotics," IEEE Robotics & Automation Magazine, 2007.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

14. H. A. Yanco and J. Drury, "Human-robot interaction in search and rescue," IEEE Transactions on Systems, Man, and Cybernetics, 2004.
15. U. Nehmzow, Mobile Robotics: A Practical Introduction, Springer, 2003.
16. S. M. Arora and P. Kadian, "Enhanced image security through a hybrid approach: protect your copyright over digital images," Wireless Communication Security, pp. 35–57, 2022.
17. P.Arockia Mary, R.Praveenkumar, S.D. Vijayakumar, R.Jayanthi, G.Brinda, P.Jaisankar, & P.Karunakaran. (2026). Intelligent Delay-Sensitive Routing Framework for Enhanced Quality of Service in Mobile Ad Hoc Networks. National Journal of Antennas and Propagation, 167-176.
18. V Karthi, S.D.Vijayakumar, T.Velmurugan, Baskaran.D, G Sekar, Rajalashmi K, & Arulmozhi P. (2026). Intelligent Cross-Layer Routing Using Trust-Integrated Multi-Agent Actor–Critic Reinforcement Learning for Hybrid IoT Systems. National Journal of Antennas and Propagation, 157-166.
19. M.Parvathi, T.Shanmugavadivu, J.Jenshya, Balasubramaniam C, S.D.Vijayakumar, Nanthini P, & S.B.Gopal. (2026). A Hybrid Genetic Algorithm–Based Secure Multipath Routing Protocol with Trust-Aware Clustering for Performance Optimization in MANETs. National Journal of Antennas and Propagation, 188-204. <https://doi.org/10.31838/NJAP/08.02.16>
20. S. D. Vijayakumar, G. Vijayakumari, R. Praveenkumar, G. Brinda, T. Velmurugan and G. Sekar, "Smart Systems for Effective Garbage Handling in Urban Waste Management," 2025 International Conference on Multi-Agent Systems for Collaborative Intelligence (ICMSCI), Erode, India, 2025, pp. 748-753, doi: 10.1109/ICMSCI62561.2025.10894576.
21. Vijayakumar, S. D., and S. Anbu Karuppusamy. "Energy optimized air quality monitoring with AQC-MANET for real time pollutant detection and analysis." GLOBAL NEST JOURNAL 27.9 (2025).



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com