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An embedded Wi-Fi talking robot for natural voice interaction: design, implementation, and experimental validation

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ABSTRACT

Voice and robotic controlled systems that can function in connected environments are now rapidly gaining in popularity, and the demand for intelligent human-robot interaction has been growing. This study focuses on the design and development of a low-cost, voice-assisted interactive robotic system that uses an ESP8266 Wi-Fi module for wireless communication, a JLH-AT106 Bluetooth MP3 decoder for listening to music, a microphone and speaker for speech interaction, an L298N motor driver with TT geared motors for locomotion, and a rechargeable lithium-ion power system. Under various acoustical environments and distances of communication, experimental analyses were performed on speech response, audio quality, wireless connectivity, power consumption, and overall system stability. The developed Wi-Fi talking robot performed well in terms of voice interaction accuracy of 98%, stable Wi-Fi connectivity over standard local networks (up to 15 meters) and good audio quality (in the range of 60 to 72 dB). Also, the experimental results demonstrate that the 5 V, 2 A supply has sufficient capacity as maximum dynamic power requirement observed as 7.07 W under simultaneous locomotion, audio playback and Wi-Fi communication. The developed robotic platform is an economical and user-friendly platform for educational laboratories, assistive technologies, smart homes, customer assistance, and human–machine interaction research. Its simplified architecture of the hardware and its expandability make it a feasible alternative to commercially available service robots and a solid basis for further intelligent applications in robotics. However, the experimental findings also indicate that performance can deteriorate under acoustically challenging conditions and at extended communication distances. The modular architecture provides a communication foundation for future integration with more computationally capable edge devices or cloud-based services for advanced speech recognition, multilingual interaction, and the Internet of Things (IoT).

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1. INTRODUCTION

The rapid advancement of robotics, embedded systems, and wireless communication technologies has fundamentally altered how people engage with intelligent devices. The design of modern robotic

platforms is no longer limited to repetitive industrial tasks, but is now tailored to intuitive human–robot interaction (HRI) via speech, gesture and multimodal communication approaches [1]. Speech based communication has proven to be one of the most natural, accessible and user-friendly interaction paradigms as it requires minimal physical controls to be used and helps users of different physical abilities and technical expertise [2]. The recent advances in speech recognition, text to speech (TTS) synthesis, Internet of Things (IoT) technologies and embedded wireless communication have contributed to the rapid developments in voice enabled robotic systems for domestic, educational, healthcare and customer services applications [3], [4]. These systems allow for voice control of robots and enable users to give voice commands which the robot can interpret and voice back to the user. This interaction increases user engagement and decreases the need for using the old-fashioned methods of keyboard, touch screens or remote controllers [5].

Wireless connectivity is also becoming a key demand for today's robotic systems. The advantages of Wi-Fi over conventional wired communication are greater operational flexibility, wider communication coverage, higher data transmission capability and seamless integration with the existing network infrastructure [6]. The above features allow the robots to receive commands, share data, and facilitate remote monitoring without any physical limitations and are suitable for use in smart homes, educational buildings, health care centers, and industrial use [7]. In addition, Wi-Fi communication is more scalable than short-range technologies like Bluetooth, especially when the communication needs to be network-wide accessible.

Despite the advancements in communication capabilities of commercially available service robots, the integration of artificial intelligence, machine-learning algorithms, and intelligent robotic functionalities can introduce considerable technical complexities in system development and implementation. These complexities highlight the need for simplified, cost-effective robotic architectures that can provide effective human–robot interaction without relying on unnecessarily sophisticated computational infrastructure [8]. This makes them not ideal for educational labs, prototyping or low-budget research labs. Furthermore, most current robotic platforms are complex and require advanced programming skills, making them inaccessible for students, hobbyists and small-scale developers [9]. Lots of research has focused on speech-enabled robots in the healthcare assistance domain, in education, in customer service and assistive technology [10]. Yet, there are relatively few studies dedicated to the development of a low cost, modular and hardware based robotic platform with reliable Wi-Fi communication and voice interaction, with minimal software complexity. Furthermore, the current low-cost robots show low reliability in communication accuracy, poor speech quality in noisy environment, small expansion ability, and not enough flexibility for further functional development [11], [12].

Robot operating system (ROS)-based architectures are highly beneficial for modular and computationally intensive robotic applications, but their associated computational and software infrastructure is not essential for the relatively simple motion-control and communication requirements of the proposed platform. Similarly, cloud-based speech or intelligence services can provide advanced recognition capabilities but introduce dependence on Internet connectivity, additional communication latency, and external computational resources. Therefore, in this research the ESP8266 was selected because it provides integrated Wi-Fi connectivity, adequate embedded processing capability for the intended command-and-control tasks, compact hardware, low cost, and straightforward integration with the mobile control interface.

In order to overcome these disadvantages, this study introduces the design and development of a talking robot using Wi-Fi technology that focuses on ease of design, low-cost and modular hardware integration. The system is designed to be a compact platform that can communicate wirelessly and interact with users through speech, with components including an ESP8266 Wi-Fi module, audio playback hardware, rechargeable power management circuitry, and embedded control components. The architecture is intentionally designed to reduce the cost of hardware with satisfactory operational performance for educational demonstrations, prototype development and indoor service applications. The developed prototype has been tested experimentally with various operating conditions to examine the reliability of communication, speech response characteristics, wireless communication and the performance of the overall system.

2. LITERATURE REVIEW

Intelligent service robots with natural interaction with users have been developed due to the rapid advancement of wireless communication, embedded controllers, artificial intelligence (AI), and human–robot interaction (HRI). Talking robots that are connected through Wi-Fi are a leap forward from most robotic platforms as they are capable of autonomous interaction, mobile control and speech synthesis, all in a small, low-cost architecture. Recent research has focused on enhancing the reliability of communication, natural language interaction, the acceptance of robot use by the user, and connecting robots with the cloud to allow the efficient operation in domestic, educational, healthcare, and industrial settings.

Lee [13] delivered a systematic review of service robots and emphasized on the increasing role of Wi-Fi and Bluetooth technologies for remote monitoring and control via a smart phone. In the review, the speech recognition, voice interaction, and autonomous operation were found to be important characteristics of present-day service robots. It was also highlighted that the designs must be user-friendly, modular and low cost to facilitate practical deployment and commercialization.

Rodríguez-Guerra *et al.* [14] discussed human–robot interaction in collaborative industrial applications, emphasizing the need for wireless communication, intelligent perception and information exchange in real time to facilitate the human–robot collaboration. The study revealed that communication latency and environmental uncertainty were important challenges and that adaptive interaction mechanisms were important to improve operational flexibility. The results have implications for the development of Wi-Fi-controlled talking robots for education and domestic robots. The ROS offers a modular and scalable solution for integrating all these technologies into robotic systems [15]. It was shown that ROS improves interoperability and decreases development time. While not necessary for robots using the ESP8266, the modular design of ROS can be applied to enhance the scalability and future expandability of Wi-Fi-enabled robot platforms.

In a review of multimodal human–robot interaction, Yang *et al.* [16] found that speech and vision and gesture-based perception work together to greatly enhance the accuracy, robustness and user experience of communication. Their results confirm the significance of deep learning for creating adaptive and context-aware human–robot interaction. In the same way, Cooper *et al.* [17] proved that the social robot with speech function is effective at promoting healthy ageing by improving the participation of older adults, their emotions, and social interaction .The above analysis indicates that the use of multimodal communication and natural voice interaction may significantly influence the functionality and usability of low-cost Wi-Fi Talking Robots in educational and assistive applications. Jing *et al.* designed socially assistive robot named SAR-Connect that could improve social interaction and activity participation of older adults. The experimental results showed that intelligent conversational interaction and autonomous task management had a positive effect on user engagement, communication frequency and acceptance [18]. The study emphasizes the need to have powerful speech synthesis, dialogue management, and wireless network connectivity when designing socially assistive robotic systems.

Munster *et al.* [19] showed that the adaptive interaction using fuzzy logic can help customize communication based on user preferences, which can lead to better interaction quality and user satisfaction. Alyassi *et al.* [20] emphasized the benefits of autonomous navigation and obstacle avoidance in dynamic environments with AI-driven social navigation techniques, such as reinforcement learning and deep learning. According to these studies, an adaptive interaction and an intelligent navigation can increase the usefulness of future Wi-Fi talking robots considerably. Yang *et al.* [16] pointed out that speech, vision, contextual reasoning and adaptive learning are integrated together to make human–robot interaction much better. Their work can be used to develop intelligent, reliable, and cost-effective communication via wireless connection where multimodal perception plays a crucial role by enabling robots to communicate with humans using Wi-Fi technology.

The literature reviewed showed that there have been great advances in the field of service robotics, human–robot interaction, social assistance and intelligent communication technologies. However, the majority of the current systems are based on expensive robotic platforms, high-performance computing hardware; ROS based architectures or complex AI algorithms which makes the implementation expensive and the computational requirements higher. In addition, there are relatively few studies dedicated to designing a lightweight, low-cost Wi-Fi talking robot that integrates mechanical design, speech interaction, embedded microcontroller-based implementation and wireless control in a single platform with a smartphones. This is the reason why it is necessary to develop a system based on a robot that is economical, modular, with reliable wireless communication, real-time voice interaction, and with a simple hardware architecture and ease of deployment for education, home and assistive applications. To fill this gap in research, the developed Wi-Fi talking robot consists of an ESP8266 Wi-Fi module, a mobile architecture with a small form factor, rechargeable battery operation and smartphone control, all in an affordable robotics platform for practical, real-world use.

3. METHODOLOGY

The methodology focuses on modular hardware-based design to build a cost-effective robotic platform that can communicate wirelessly and interact with people via voice communication with minimal complexity of the system. The overall research design is presented in Figure 1.

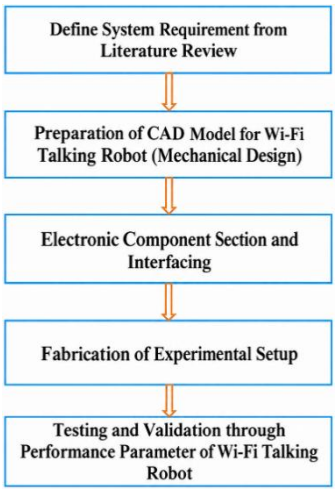


Figure 1. Development methodology for a Wi-Fi-controlled talking robot

3.1. Defining system requirement

The functional requirements of the Wi-Fi Talking robot are first proposed in consideration of the limitations found in the literature. Requirements of this system are as follows: Wireless operation with Wi-Fi communication, bidirectional voice communication with audio playback, low manufacturing cost using commercially available components, modular architecture for future upgrade, and low power consumption for battery operation.

3.2. Mechanical design and CAD model preparation

The mechanical structure was designed to provide adequate structural rigidity while maintaining portability and ease of assembly. Wi-Fi talking robot was modelled using Autodesk Fusion 360 (Version v.2.0.16985, Autodesk Inc., USA) design software. Computer-aided design (CAD) model of Wi-Fi talking robot provide a brief idea about the robot chassis and component mounting locations before fabrication as shown in Figure 2. The chassis dimension is measured as 200×220 mm and height of 190 mm as shown in Figure 3. Special consideration was given to proper placement of the Wi-Fi antenna to maximize signal strength, isolation of the speaker enclosure for improved acoustic performance, compact routing of electrical wiring, easy accessibility for battery charging and maintenance, modular arrangement allowing replacement of individual components. Selected enclosure components were manufactured using additive manufacturing techniques to achieve dimensional accuracy and rapid prototype development. Programmable logic array (PLA) material was used for the primary housing, whereas heat-sensitive regions employed acrylonitrile-butadiene-styrene (ABS) components to improve thermal resistance. ABS base plate has density 1040 kgm^3, Young's modulus 2.1 GPa, Poisson ration 0.35 and tensile yield strength 40 MPa while PLA has density 1240kgm^3, Young's modulus 3.5GPa, Poisson ration 0.36 and tensile yield strength 60 MPa.

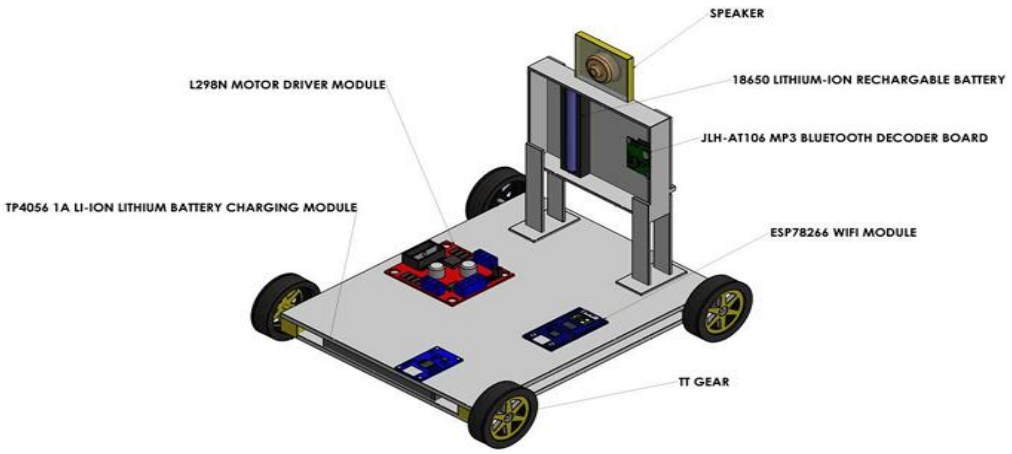


Figure 2. CAD model of Wi-Fi talking robot

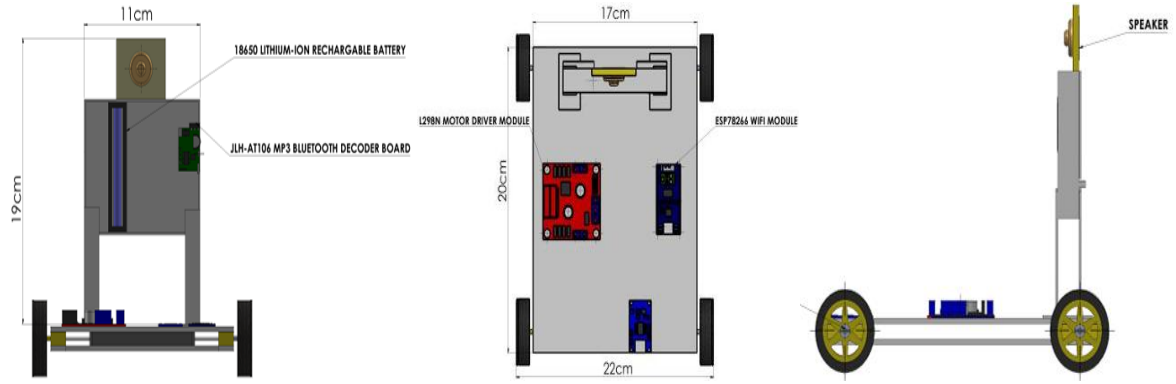


Figure 3. Dimensions of Wi-Fi talking robot

3.3. Electronic component selection and interfacing

The electronic hardware of Wi-Fi talking robot consist of JLH-AT106 MP3 Bluetooth decoder, 18650 Lithium-Ion rechargeable battery, L298N motor driver module, ESP8266 Wi-Fi module, TP4056 Lithium-Ion battery charging module and TT DC gear motor. The electronic components hardware configuration was selected to achieve an effective compromise between system functionality, reliability, portability, and cost. Table 1 illustrates the selection criteria, specification and function of the selected electronics components.

Table 1. Electronic components selection and specification chart

Sr. No.	Component	Selection criteria	Technical Specification	Function
1	JLH-AT106 MP3 Bluetooth Decoder [21]	Type of audio playback interfaces, ability to decode common audio formats	Supply voltage – up to 5 V, Audio formats MP3, WAV, WMA, communication Range 10-meter, Storage – USB flash / Micro SD Card	Enabling audio functionality and allows the robot to play MP3 audio files through Bluetooth
2	18650 Lithium-Ion Rechargeable Battery [22]	energy to weight ratio, rechargeable capability, and stability of discharge characteristics	Capacity 2200-3400 mAh Nominal voltage:3.7volt, fully charged 4.2 volts, 500-1000 charging cycle	It provides sufficient energy for continuous operation
3	L298N Motor Driver Module [23]	Dual H-bridge circuitry, enabling independent control of two DC motors while supporting pulse-width modulation (PWM) speed regulation.	Operating voltage 5–35 V, Motor channels 2, PWM control	Role as translator between the control system and the motors, allowing the robot to move Forward, backward, and even turn smoothly.
4	ESP8266 Wi-Fi Module [24]	Bit capacity, wireless networking capability, compactness and affordability.	Processor 32-bit Tensilica L106, Clock frequency Up to 80/160 MHz, Operating voltage 3.6 V, Flash memory 4 MB	It allows users to interact with the robot without needing physical wires or complicated setups.
5	TP4056 Lithium-Ion Battery Charging Module [25]	Constant current/constant-voltage (CC/CV) charging with automatic charge termination.	Single cell Li-ion I/P voltage 5 V, max current 1 A, full charge voltage 4.2 V.	It provides constant current/constant-voltage (CC/CV) charging with automatic charge termination.
6	TT DC Gear Motor [26]	Gear ration, torque capacity, weight, Speed and cost	Torque 1.2 Kg-cm, rated voltage 3 to 6 V,150-250 rpm, gear ration 1:48	It provides an appropriate balance between rotational speed and torque, allowing the robot to achieve stable

Figure 4 illustrates the complete electrical architecture of the Wi-Fi talking robot, integrating the power management, wireless communication, motor drive, and audio playback subsystems. For improving system reliability, all electronic modules share a common ground plane, reducing ground potential differences and improving communication integrity. The use of dedicated filtering capacitors at the power inputs of the battery module, motor driver, and audio decoder minimizes electromagnetic interference generated by motor commutation and wireless transmission.

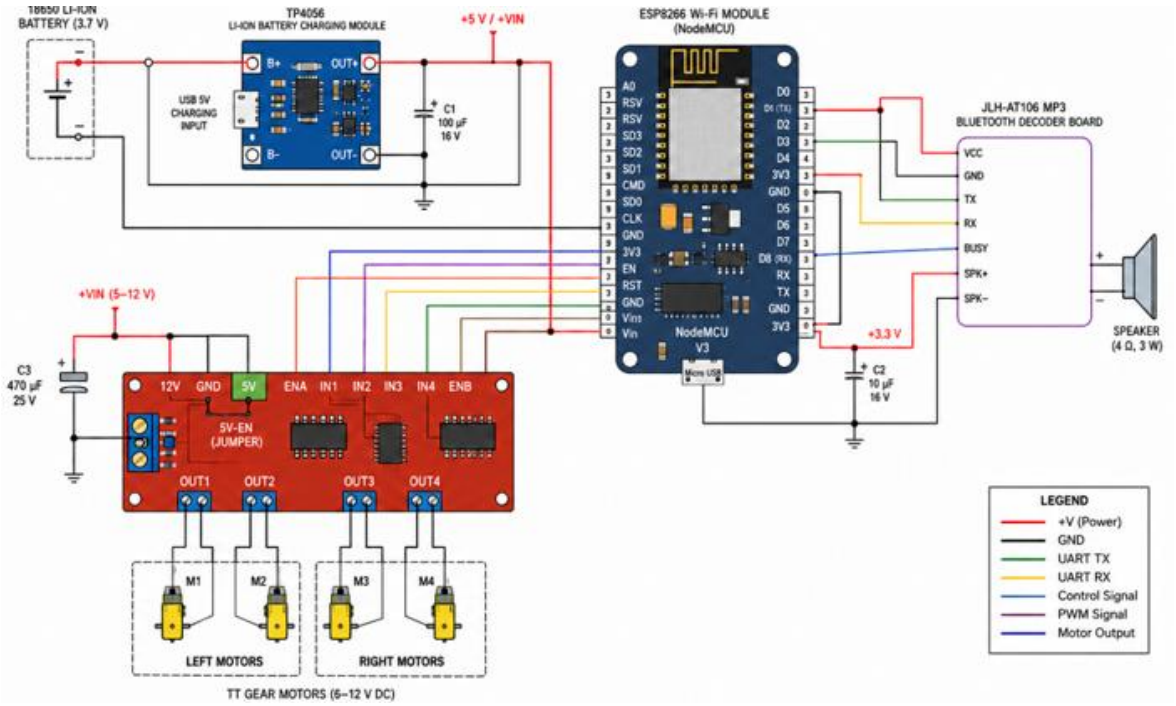


Figure 4. Electrical circuit interfacing of the Wi-Fi talking robot

3.4. Fabrication of experimental set up

The experimental of the robot with Wi-Fi wireless mobility was manufactured by systematic integration of mechanical, electrical, and communication subsystems, which guaranteed wireless mobility and voice interaction as illustrated in Figure 5. The chassis was designed to be lightweight to fit the electronic modules, power supply, drive motors, and audio system. Two TT geared DC motors were fitted symmetrically on the back of the chassis to enable differential drive while a free-wheel caster was fitted at the front for stability and maneuverability. This allowed the boat to move forward, backward, and turn easily while being relatively simple mechanically.

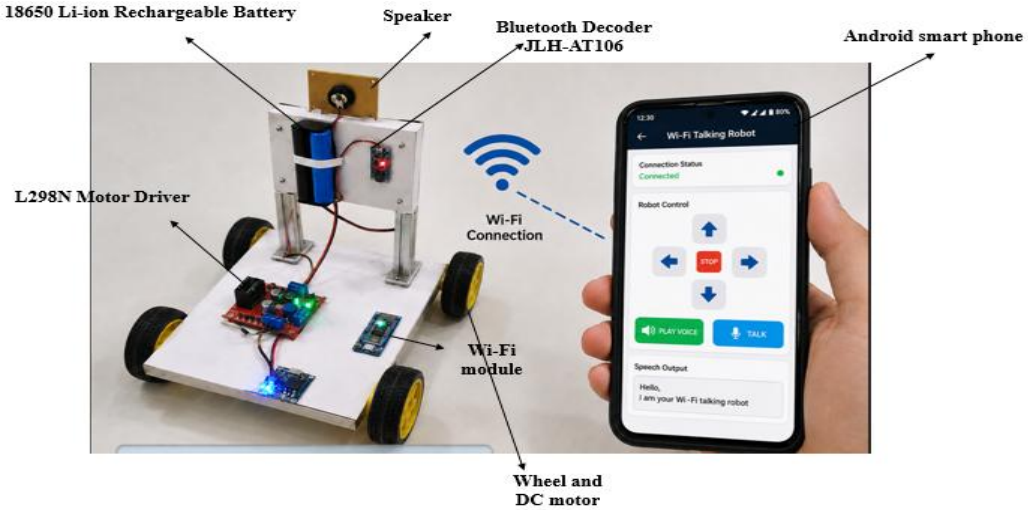


Figure 5. Experimental set up of Wi-Fi talking robot

The upper side of the chassis was used to mount the electronic equipment so that it would be easier to wire and maintain the equipment. The ESP8266 Wi-Fi module receives instructions sent via wireless LAN from an Android-based smartphone application and produces the control signals that are used to control the

robot. A JLH-AT106 MP3 Bluetooth decoder board was used with a small speaker to enable voice communication. The loudspeaker was placed at the front part of the robot to ensure maximized sound output and clearer speech intelligibility when interacting with the user. The power subsystem was made up of an 18650 lithium-ion rechargeable battery and a TP4056 battery protection/charging module. TP4056 offers overcharge, over discharge and short circuit protection and allows easy USB charging. A two-motor drive module (L298N) was used for motion control.

3.5. Experimental test environment

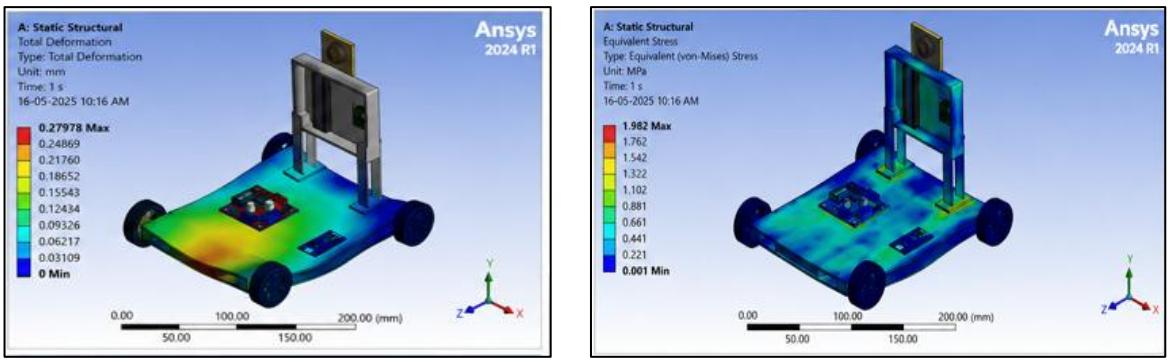
The experimental evaluation of the Wi-Fi talking robot was conducted in an indoor laboratory environment under controlled operating conditions. The robot was placed on a level floor and operated using an Android-based smartphone connected to the same wireless local-area network. The ESP8266 module installed on the robot acted as the wireless communication interface. The Wi-Fi access point and robot antenna were maintained at approximately the same height throughout the experiment to minimize variations caused by antenna orientation. For the wireless-range assessment, distances of 5, 10, 15, 20, 25, 30 and 35 m were considered. At each test position, a fixed number of command packets was transmitted, and the number of successfully received commands, lost packets and communication latency were recorded. The tests were conducted with the robot stationary and subsequently repeated during normal robot movement to identify the influence of motor operation on wireless communication. Particular attention was given to the presence of physical obstructions such as walls, doors and laboratory furniture because these objects can attenuate the received Wi-Fi signal and increase packet loss. For power-consumption evaluation, voltage and current were recorded simultaneously under different operating states.

4. RESULTS AND DISCUSSION

4.1. Structural analysis

A finite element-based structural rigidity assessment was performed using ANSYS Workbench 2024 R1 to evaluate the mechanical integrity of the proposed Wi-Fi talking robot chassis under the expected operating load as shown in Figure 6. The robot chassis consisted of an ABS base plate (220×200 mm) with a PLA electronic support structure having an overall height of 190 mm. A uniformly distributed vertical load equivalent to 1.2 kg (11.8 N) was applied over the electronic component mounting region, while the wheel mounting locations were constrained using fixed boundary conditions. The total deformation contour indicates that the maximum displacement is concentrated near the front section of the chassis, whereas the wheel support regions remain nearly undeformed due to the applied boundary conditions.

The simulation predicts a maximum total deformation of 0.27978 mm as shown in Figure 6(a). A small distance ensures the alignment of the ESP8266 module, display, PCB, motors and sensors are kept constant during the robot operation so that reliable wireless communications and motion accuracy is preserved. The von-Mises stress distribution indicates the highest stresses in the area where the vertical support columns meet the base chassis, where there is the greatest bending moment. As shown in Figure 6(b), the simulation result shows the maximum equivalent stress of 1.982 MPa which is still significantly lower than the yield strength of ABS (40MPa) and PLA (60MPa).



(a) (b)

Figure 6. Finite element static structural analysis Wi-Fi talking robot: (a) total deformation and (b) Equivalent (von-Mises) stress distribution

In summary, the ANSYS simulation confirms that the hybrid ABS base chassis and PLA electronic support frame structure is lightweight and strong enough to support the 1.2 kg payload without significant deformation or material failure. The results confirm that the proposed robot chassis is structurally suitable for long-term operation and that the durability of the robot is ensured for practical applications in indoor services.

4.2. Performance parameter evaluation

4.2.1. Voice response evaluation

It offered the evaluation of the accuracy and response time of the voice-controlled interface used in the walking robot with the help of Wi-Fi. The voice-command experiment used 30 independent trials for each command. The sample size was selected to provide repeated observations of the robot response under the same environmental and operating conditions while maintaining a practical experimental workload. Five functional commands were considered: forward, backward, left, right and stop. Response time were reported as the mean ± standard deviation to quantify both the typical command execution time and measurement variability. Each command was issued independently, and the successful execution, recognition accuracy and response time were recorded as indicated in Table 2.

The voice recognition accuracy of Wi-Fi walking robot is more than 98% on average, which is reliable to operate. The average response time was less than 250 ms, which shows that there was no significant delay between user input and robot execution.

Table 2. Wi-Fi talking robot voice response test

Sr. No.	Voice Command	Trials (N)	Successful Executions N(s)	Accuracy (%) {N(s)/N}*100	Response time (ms) Mean±S.D.
1	Forward	30	30	100	238.6±7.39
2	Backward	30	29	96.7	245.2 ± 4.5
3	Left	30	29	96.7	239.3 ± 9.18
4	Right	30	30	100	231.8 ± 8.80
5	Stop	30	30	100	220.6 ± 6.23

4.2.2. Wireless communication test

This test is to determine the reliability and communication range of the ESP8266 Wi-Fi module to wirelessly control the robot. The robot was tested at increasing distances from the wireless access point in the indoor environment. The distance was tested 10 times for each distance and monitored for packet loss, communication latency, and whether the command was executed successfully as indicated in Table 3. Stable wireless link up to about 15 m inside was achieved with the ESP8266-based wireless communication system. The communication latency was within 100 ms for the tested range and packet loss was slightly above 20 m due to reduction in received signal strength with increasing propagation distance and additional attenuation caused by indoor obstructions such as walls, doors and laboratory furniture. The results show that the proposed wireless architecture is used for reliable real-time control of robots in indoor environments up to 15 m distance.

Table 3. Wireless communication test result

Sr. No.	Distance (m)	Packet transmitted	Successful Commands (%)	Packet Loss (%)	Latency (ms) Mean±S.D.
1	5	100	100	0	45±2
2	10	100	100	0	55±1.5
3	15	100	100	1	70±2.5
4	20	100	98	2	88±3
5	25	100	95	5	105±2.2
6	30	100	91	9	128±3
7	35	100	82	18	165±4

4.2.3. Power consumption analysis

We have worked out to evaluate dynamic and empirical power measurement when the robot is operating simultaneously states including standby with Wi-Fi connected, audio playback, robot locomotion, and simultaneous locomotion, audio playback and Wi-Fi communication. The electrical supply to the robot was monitored using an external digital power meter/current measurement device. Each operating condition was repeated five times and the mean value and standard deviation were calculated. The voltage, current, and power (W) recorded for each condition is displayed in Table 4.

Table 4. Componentize power consumption calculations

Sr. No.	Operating condition	Voltage (V) In Volts	Current (I) In Ampere	Power (W)	Mean Power (W)	S.D. (W)	Duration (Sec)
1	Standby, Wi-Fi connected	5.02	0.24	1.20	1.20	0.04	60
2	Wi-Fi communication only	5.01	0.31	1.55	1.55	0.05	60
3	Audio playback only	4.98	0.72	3.59	3.59	0.08	60
4	Robot moving forward	4.91	1.05	5.16	5.16	0.12	60
5	Robot moving + Wi-Fi	4.89	1.14	5.57	5.57	0.14	60
6	Robot moving + audio	4.87	1.38	6.72	6.72	0.17	60
7	Moving + audio + Wi-Fi	4.84	1.46	7.07	7.07	0.18	60

The maximum power consumption of the system was reported approximately 7.07 Watts. As we have a 5 V, 2 A power supply (with a total capacity of 10 watts), which is more than enough to comfortably run all components together, even with minor power fluctuations.

4.2.4. Sound audibility performance

We have measured how loud the robot's voice output was in real-world conditions using a decibel meter app. The JLH-AT106 module used in the prototype primarily provides Bluetooth/audio decoding and playback functionality; therefore, its measured audio-output level should not be interpreted as a speech-recognition noise threshold. Table 5 illustrate that the measurements were taken at three common distances to check how well the robot could be heard in an average-sized room.

As per psychoacoustic studies, 50-65 dB measured range of sound is clearly audible for normal human being. So measured levels indicate that the robot's responses are clearly audible within typical indoor spaces, even when users are standing a few meters away. The sound remained intelligible and pleasant, without being too quiet or loud.

Table 5. Wi-Fi talking robot sound measurement

Sr. No.	Distance (m) from Robot	Measured Loudness (dB)
1	At 1 meter	~72 dB
2	At 2 meters	~66 dB
3	At 3 meters	~60 dB

4.2.5. Wi-Fi range estimate

We have tested how far the robot could stay reliably connected to the Wi-Fi network, and we have summarized the results of our range test in Table 6. Within a typical indoor range of 12 to 15 meters, the robot maintained a stable and responsive connection, with only minimal delays (latency of about 150–200 milliseconds). Outside this distance, particularly if there were several walls in between, there was a gradual decrease in performance and the connection was not as strong for most tasks.

Table 6. Wi-Fi performance measurement

Sr. No.	Distance Range (m)	Connectivity status (Latency in ms)
1	12–15 meters (indoors)	Stable connection (~150–200 ms latency)
2	Beyond 15 meters / multiple walls	Slight drop in performance (higher latency, occasional disconnections)

Quigley *et al.* [12]'s proposed prototype demonstrates a comparable combination of communication, voice interaction, and power-efficiency characteristics while retaining a relatively simple embedded architecture. The results of these performance parameters were found to be satisfactory, indicating that the robot is well balanced in terms of power efficiency, clear audio and reliable wireless communication and can be used in real world scenarios in home, educational and commercial environments. Future experiments should evaluate command-recognition accuracy and response latency at systematically varied background-noise levels and signal-to-noise ratios to establish the operational acoustic limits of the system.

5. CONCLUSION

This study demonstrated the development and experimental evaluation of a low-cost Wi-Fi-enabled talking robot integrating wireless communication, voice interaction, audio playback, mobile control, battery-powered operation, and a lightweight modular mechanical structure. The combined simulation and experimental results indicate that the proposed architecture is capable of supporting the intended indoor

human–robot interaction functions while maintaining a relatively simple and economical hardware configuration. The developed robotic platform integrates an ESP8266 Wi-Fi module, embedded control hardware, audio playback circuitry, rechargeable power management, and a modular mechanical structure into a unified system capable of responding to user commands wirelessly. The simulation result from ANSYS shows that the ABS base chassis and the electronic support frame of the hybrid material is lightweight and can well bear the load of 1.2 kg without obvious deformation and failure of material. Experimental investigations showed that voice recognition accuracy of talking robot (Wi-Fi) is about 98%, the response time is less than 250 milliseconds. The stable Wi-Fi range was measured up to 15 meters. Besides, it has been noticed that the robot's reaction is definitely distinguished inside typical indoor spaces (the sounds level observed is in the range of 72 to 60 dB). However, some constraints must be noted such as the fact that the accuracy might degrade in acoustically challenging environments, and autonomous navigation, environmental perception causes missing network. Future development should investigate integration with external edge-computing or cloud-based AI services for advanced speech recognition, multilingual interaction, and contextual human–robot interaction. Because the ESP8266 has limited computational and memory resources, these computationally intensive AI functions should be implemented on a more capable external processor or cloud platform, with the ESP8266 serving primarily as the Wi-Fi communication and control gateway.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

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