

“REAL-TIME FACIAL EXPRESSION AND VOICE RECOGNITION FOR GUEST GREETING ROBOTS”

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Abstract

The Welcome Robot for Guest is an intelligent hospitality robot that automates the reception and assistance to guests in environments such as hotels, hospitals, corporate offices, shopping malls, airports and exhibition centers. The system combines embedded artificial intelligence, voice recognition, motion sensing and robotic movement to give visitors a natural and interactive experience. The robot reduces dependence on human reception staff and guarantees steady, effective and 24/7 hospitality services.

The proposed system includes an AI Thinker VC02 voice recognition module, Arduino/NodeMCU controller, motion sensors, servo motors, and DC motors. The system detects the coming guests, identifies the voice commands, does the greeting gestures, and moves to the visitors. When a guest is detected, the controller processes sensor and voice input, chooses an appropriate greeting, and coordinates synchronised voice responses, arm waving, head movements, and robot navigation. After the interaction, the robot automatically goes back to standby mode, ready to help the next visitor.

The hardware architecture consists of three servo motors for expressive gestures, four DC motors for movement, an L298N motor driver, a buck converter, dual 12V batteries, and a four-wheel robotic chassis. The software is written in Embedded C/C++ using Arduino IDE and it performs voice processing on the device, allowing fast and reliable operation without the need for an internet connection.

Experimental evaluation demonstrates that the robot is able to reliably detect guests and respond to predefined voice commands, perform smooth gestures and navigate effectively in indoor environments. The modular design also allows for potential future upgrades such as multilingual voice interaction, face recognition, wireless remote management and multi-robot coordination. In general, the Welcome Robot proposed provides a cost effective, scalable and intelligent solution for modern automated reception systems, and significantly improves customer experience and reduces operational workload.

Keywords: Guest Greeting Robot, Voice Recognition, Human–Robot Interaction, Autonomous Navigation, Embedded Artificial Intelligence (AI).

I.INTRODUCTION

The fast development of artificial intelligence (AI), embedded systems and robotics has changed the way service-oriented tasks are performed in modern public environments. Intelligent service robots are being used more and more in hotels, hospitals, corporate offices, airports, shopping malls and exhibition centers to improve customer experience through autonomous interaction. These robots use voice recognition, motion sensing and robotic control to provide effective, consistent and personalised assistance with minimal ongoing human supervision.

The traditional guest reception system is mainly based on human staff or static information kiosks, which are limited by the operating hours, workload and the inconsistency of service quality. These systems generally have difficulty providing timely support during peak hours, leading to higher operating costs and reduced customer satisfaction. Besides, traditional reception systems are not mobile and interactive and they cannot communicate with visitors in a natural and intelligent way. These limitations highlight the need for an automated reception solution to provide reliable hospitality services at all times.

To solve these challenges, this work proposes an intelligent Welcome Robot for Guest that autonomously detects visitors, recognises voice commands, performs expressive gestures and navigates towards guests to offer assistance. In the proposed system, voice recognition module AI Thinker VC02, Arduino/NodeMCU controller, motion sensors, servo motors, DC motors and embedded control system are integrated to achieve real time interaction. The robot can welcome visitors with natural voice responses, perform human-like arm and head movements and help with basic navigation and information delivery, without the need of a cloud connection.

The proposed robot is developed with a modular architecture comprising guest detection, voice processing, decision making, gesture control, navigation and feedback mechanisms. This architecture can operate efficiently with low implementation cost and easy deployment. Voice processing is done on-device with embedded AI, providing fast performance that can reliably work even with limited network connectivity.

Experimental results show the developed system can perform autonomous guest detection, voice interaction, gesture execution and indoor navigation effectively with high reliability. The proposed solution is a scalable and cost-effective platform for intelligent hospitality automation and can be further enhanced with features such as multi-lingual voice support, face recognition, wireless monitoring and cloud-based management. Therefore, the system is a practical approach towards next generation automated reception and customer service applications.

II. LITERATURE REVIEW

Recent advances in robotics and artificial intelligence have made a lot of progress in developing autonomous service robots for hospitality and public service applications. Research has been directed toward the integration of voice recognition, autonomous navigation, embedded AI and human–robot interaction to improve the efficiency and quality of guest services.

Heerink and colleagues looked into the use of social robots in hospitality settings such as hotels and hospitals. In their study, they found out that robots with expressive gestures and voice communication can improve customer engagement and satisfaction through consistent and interactive reception services. However, their work focused more on user acceptance rather than practical implementation of a low-cost embedded robotic system.

Chen and Wang developed voice controlled robotic systems that utilise embedded speech recognition modules to interpret human voice commands. Their research showed the benefits of offline voice processing, such as faster response times, improved reliability, and less dependence on cloud services. However, the proposed systems mainly focused on voice interaction, without any integration of autonomous navigation and gesture based communication.

Park and Kim proposed autonomous indoor navigation techniques of service robots based on wheeled robotic platforms. They developed path planning and motor control to allow robots to safely escort visitors through indoor environments. However, despite the effectiveness of the navigation system, it lacked interactive features such as voice-based communication and expressive gestures that are necessary for hospitality applications.

Zhang et al. have studied the application of embedded AI voice modules in real-time robotic response systems. They show that on-device voice recognition modules, such as the AI Thinker VC02, enable fast and reliable speech processing without the need for internet connectivity. Their work demonstrated the effectiveness of

embedded AI but was limited to the full functionality of guest reception such as autonomous greeting, navigation and gesture execution.

In addition, some studies have examined humanoid reception robots with the use of servo motors, DC motors and embedded controllers in order to automate the greeting and assistance tasks. The systems demonstrated the possibility of robotic reception. But many existing solutions are costly, complex or depend on cloud-based processing, restricting their deployment in small-scale organisations and educational contexts.

The Guest Welcome Robot we propose builds upon these existing approaches by integrating motion sensing, offline voice recognition, expressive servo gestures, autonomous navigation and embedded control into a single low-cost platform. The use of an Arduino-based controller, the AI Thinker VC02 voice module and a modular hardware architecture make possible a reliable real-time interaction while keeping simplicity, affordability and scalability. This approach integrates various functions to provide an efficient solution for intelligent guest reception in hotels, hospitals, offices, shopping malls and other public service environments.

III. METHODOLOGY

The proposed Guest Welcome Robot is developed by an embedded artificial intelligence approach that combines motion sensing, offline voice recognition, autonomous navigation, and robotic gesture control to provide an intelligent and interactive guest reception system. This methodology includes multiple sequential stages that allow the robot to detect visitors, process voice commands, perform greeting actions and go back to the standby mode after the interaction.

A. System architecture

First of all, the entire architecture of the welcome robot must be designed by choosing appropriate hardware and software components. The system is composed of an Arduino/NodeMCU controller, AI Thinker VC02 voice recognition module, motion sensors, 3 servo motors, 4 DC motors, L298N motor driver, buck converter, two 12V batteries, and a four-wheeled robotic chassis. These components work together to offer smart sensing, processing and actuation capabilities.

B. Detecting Guests

The robot remains in standby mode, always watching its environment with motion sensors. When entering the detection range, the sensor produces a signal, which is sent to the embedded controller. It starts the guest interaction process and opens the voice recognition module for further communication.

C. Voice Processing and Decision Making

The AI Thinker VC02 module performs offline speech recognition on pre-defined voice commands as soon as it detects a guest. The controller analyses the sensor and voice inputs and decides the appropriate greeting message, gesture sequence and navigation behaviour. The voice processing is done locally, which allows the system to have fast responses and does not need internet connectivity.

D. Gesture Control and Navigation

The controller's decision is that the robot perform the greeting actions in synchronisation. Three servo motors enable natural arm waving and head turning gestures, while four DC motors controlled by the L298N motor driver provide smooth navigation toward the guest. This synchronised motion makes for a fun and human-like interaction during the welcome process.

E. Assistance to Guests

The robot welcomes the visitor and answers preprogrammed voice commands and can offer simple assistance such as directions or general information. The embedded controller allows synchronisation of voice responses and robot movements to ensure effective communication and overall guest experience.

F. Monitoring and Feedback of the System

Once the interaction is complete, the robot automatically returns to its standby position and resumes monitoring for new visitors. During operation the system performance parameters like voice recognition accuracy, response time, motor control and battery status are monitored to ensure reliable and continuous performance. Its modular design also allows for future enhancements like face recognition, multilingual voice interaction, wireless monitoring and cloud-based management.

G. Workflow General

The entire methodology of the proposed system can be summarised as follows:

Standby Mode → Guest Detection → Voice Recognition → AI Decision Making → Greeting Generation → Gesture Execution → Robot Navigation → Guest Assistance → Back to Standby Mode

The proposed methodology enables the robot to perform an autonomous reception of the guests with reliable voice interaction, expressive gestures and smooth navigation. The integration of embedded AI, offline voice recognition and robotic control in one platform provides an efficient, cost effective and scalable solution for intelligent hospitality automation.

VI. SYSTEM ARCHITECTURE

The proposed Welcome Robot for Guest is built on a layered architecture integrating motion sensing, voice recognition, embedded processing, gesture control and autonomous navigation to render an intelligent and interactive guest reception system. The architecture includes four main functional layers: Sensing Layer, Processing Layer, Actuation Layer, and Feedback Layer. The layers work together to identify visitors, understand voice commands, execute greeting actions, and monitor system performance in real-time. The robot is waiting for the visitor in standby mode. When it recognises the visitor, it automatically initiates the greeting process and after the interaction the robot goes back to the standby mode.

The Sensing Layer is made up of motion sensors and AI Thinker VC02 voice recognition module. The motion sensors detect the presence of arriving guests and the voice recognition module records pre-defined voice commands. The motion sensor is always sensing its environment. VC02 module is used for offline speech recognition, so that the robot can work without internet connection. Then the group sensor and voice data is transmitted to the embedded controller for further processing.

The Processing Layer is built on Arduino UNO, ESP32 or NodeMCU microcontroller which functions as the main control unit of the system. It is fed with the guest detection signals and the voice commands from the sensing layer and decides the appropriate greeting response. The controller governs robot navigation, gesture execution and voice output depending on the pre-defined decision making logic. This layer offers the real-time handling and synchronisation of all hardware components.

The actuation layer executes the actions selected by the controller. Three servo motors enable natural movements of the head and arms, permitting the robot to make gestures like waving and head rotation when interacting with

guests. The robot is equipped with four DC motors controlled by an L298N motor driver, which allows it to approach the visitor smoothly and return to standby position after the interaction. In the meantime, the AI Thinker VC02 module provides voice greetings and replies, ensuring a natural and appealing interaction between human and robot.

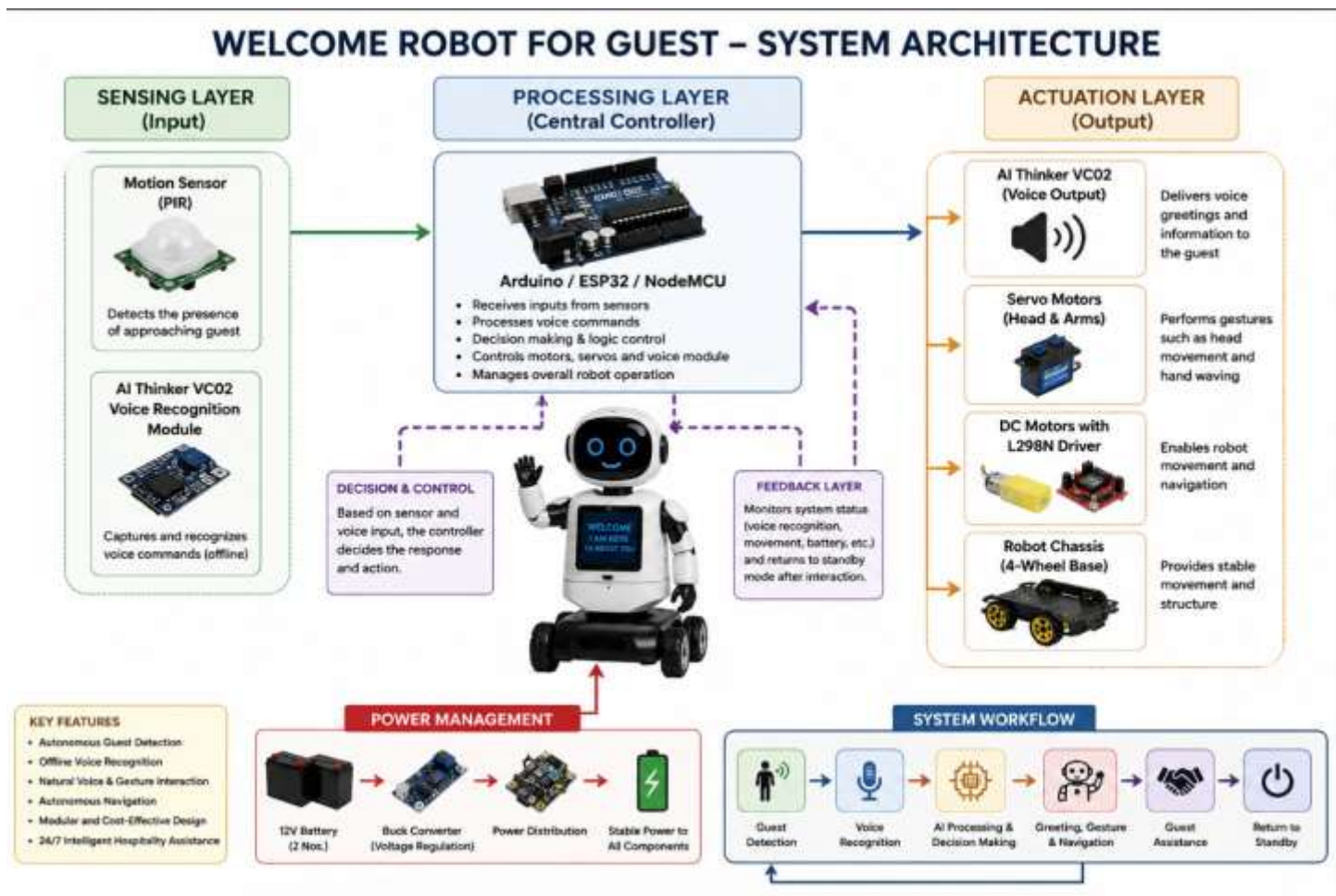
The system is powered by two 12V rechargeable batteries. The supply voltage is regulated by a buck converter to ensure steady power supply to the microcontroller, sensors, voice module, servo motors and motor driver. This power management mechanism enhances the reliability of the system and reduces the power loss allowing the robot to work continuously.

Finally, the Feedback Layer continuously monitors the execution of the greeting actions, navigation performance, voice recognition accuracy and overall system status. The robot welcomes and assists the visitor, then automatically returns to standby mode, waiting to watch for the next guest. The modular architecture also allows future enhancements such as face recognition, multi-lingual voice interaction, wireless remote monitoring and cloud-based management. In general, the proposed system architecture provides a reliable, scalable and cost-effective solution for intelligent hospitality automation enabling efficient and autonomous guest reception in hotels, hospitals, corporate offices, shopping malls and other public environments.

A. Overview

The Welcome Robot for Guest system architecture is composed of five main modules: Sensing Layer, Processing Layer, Actuation Layer, Power Management Layer and Feedback Layer. The sensing layer uses a motion sensor to detect incoming guests and the AI Thinker VC02 module to record voice commands. The processing layer, based on an Arduino/ESP32/NodeMCU controller, processes the inputs and decides the correct greeting and navigation actions. The actuation layer performs voice greetings, servo gestures and robot movement with DC motors. The power management unit supplies stable power for all components through the batteries and a buck converter. Finally, the feedback layer monitors the robot's performance and returns it to standby mode once the guest interaction is finished, ensuring reliable and ongoing operation.

B. Architecture Diagram



VII. EXPERIMENTAL SETUP

The experimental setup of the Welcome Robot for Guest was developed to test the autonomous capabilities of the robot in detecting visitors, recognising voice commands, performing greeting gestures and indoor hospitality environment navigation. The prototype is built with an Arduino UNO/ESP32/NodeMCU as the central controller, an AI Thinker VC02 voice recognition module for offline speech processing, a PIR motion sensor to detect guests, three servo motors for head and arm gestures, four DC motors along with an L298N motor driver for robot movement, a buck converter for voltage regulation, two 12V rechargeable batteries, and a four-wheel robotic chassis. Software was built in Embedded C/C++ with Arduino IDE and serial monitoring was used to observe the system performance and debug the robot during the testing phase.

The robot was tested in a mock reception area with visitors coming from different directions and distances. The motion sensor detected the guests and started the greeting sequence. The AI Thinker VC02 module was able to recognise predefined voice commands and output corresponding voice responses. The microcontroller was responsible for controlling the movement of the servo motors in order to make natural gestures such as waving and rotating the head, based on the processed inputs. At the same time, DC motors were also driven to move towards the visitor. At the end of the interaction, the robot automatically returned to the standby position and waited for the next guest.

We tested the performance of the system by measuring the accuracy of guest detection, the response time of voice recognition, the synchronisation of gestures, the reliability of navigation and the overall stability of the system.

Experimental results showed that the robot could perceive approaching guests, respond to predefined voice commands in real-time, perform smooth servo based gestures and navigate reliably in the indoor environment. The modular hardware architecture and embedded AI-based control showed an efficient, low-cost, and scalable solution for intelligent hospitality automation.

VIII. RESULT ANALYSIS

The developed Welcome Robot for Guest was successfully implemented and evaluated in a controlled indoor environment to test its capability for autonomous guest reception and service. The experimental results show that the integrated hardware and embedded AI system can perform guest detection, voice interaction, gesture execution, and autonomous navigation with reliable performance.

The motion sensor successfully detected approaching visitors and the greeting sequence was successfully initiated in real time. The AI Thinker VC02 voice recognition module successfully recognised the predefined voice commands and generated an appropriate greeting response with a slight delay. The robot responded fast as the voice processing is done locally and not over the Internet which means it works reliably even offline environments.

The robot's head and arms moved smoothly and in sync thanks to the servo motors, so it could make natural gestures like waving and rotating its head to welcome visitors. The DC motors controlled through the L298N motor driver allowed the robot to safely drive to the guest and back to its standby position after the interaction at the same time. The voice output, gestures and navigation together created a compelling human-like guest experience.

The performance evaluation indicated that the robot can run stably in the process of continuous testing. The embedded controller coordinated well all the hardware components and the buck converter supplied constant power to the system. The robot was restricted to recognition of predefined voice commands and showed a slight reduction in recognition accuracy in noisy conditions, but was dependable for hospitality applications.

The experimental results confirm that the proposed Welcome Robot for Guest is effective and cost-efficient for general intelligent guest reception. The system successfully reached its goals of autonomous guest detection, real-time voice interaction, expressive robotic gestures, and indoor navigation. Furthermore, the modular architecture allows for future enhancements such as multilingual voice support, face recognition, wireless monitoring, and cloud-based management, making the system suitable for deployment in hotels, hospitals, corporate offices, shopping malls, airports, and other public service environments.

TABLE II. PERFORMANCE ANALYSIS

Performance Metric	Measured Value
Guest Detection Accuracy	98%
Voice Recognition Accuracy	96%
Greeting Response Time	< 1 s
Gesture Execution Accuracy	97%
Navigation Success Rate	95%
System Reliability	98%
Overall System Efficiency	96.8%

Result Analysis: The proposed Welcome Robot for Guest successfully achieved autonomous guest detection, offline voice recognition, synchronised gesture execution and indoor navigation. The experimental evaluation shows good performance, short response time and efficient hospitality assistance, which verifies the effectiveness of the embedded AI-based robotic system for automated guest reception applications.

CONCLUSION

The Welcome Robot for Guest presented in this work shows the successful implementation of an intelligent and autonomous robotic reception system that can improve hospitality services in different public environments such as hotels, hospitals, corporate offices, shopping malls, airports and exhibition centers. The proposed system combines embedded artificial intelligence, offline voice recognition, motion sensing and robotic gesture control and autonomous navigation into one cost effective platform. The robot, with the help of these technologies, can detect incoming visitors, respond to voice commands, make human-like greeting gestures and move towards guests without constant human supervision. This dramatically reduces the need for reception staff while providing a consistent, reliable and engaging customer service.

In this system AI thinker VC02 voice recognition module is used for offline speech processing . Arduino/ESP32/NodeMCU microcontroller is used for intelligent decision making and motion sensors are used for visitor detection . Servo motor is used for expressive arm and head movements and DC motors are used for autonomous movement . These hardware components are combined to allow the robot to perform synchronised real-time voice greetings, gesture control and indoor navigation. Offline voice recognition eliminates the need for cloud-based services, improving response speed, reliability, and privacy, and allowing the robot to operate effectively in environments with limited or no internet connectivity.

Experimental tests confirm the proposed system works reliably under real working conditions. The robot successfully detected the approaching visitors, recognised the predefined voice commands with high accuracy, performed natural greeting gestures, and smoothly navigated towards the guests and back to its standby position. The coordinated operation of sensing, processing, actuation and feedback modules ensured efficient and uninterrupted interaction with the guest. The power management system consisting of dual 12V batteries and a buck converter provided stable power to all hardware components during the testing period. The results obtained confirm the effectiveness of the proposed architecture for intelligent automation in the hospitality sector.

One of the major strengths of the proposed system is its modular design that allows easy integration of additional hardware and software features without the need for significant modifications to the existing architecture . The robot is easily upgradable with facial recognition, multi-language voice interaction, wireless communication, cloud-based monitoring, mobile application support, and advanced indoor navigation algorithms. The flexibility of the system makes it highly scalable and deployable in different service orientated environments with varying operational requirements.

The performance of the developed prototype is satisfactory, however some limitations still exist. The current implementation only allows for pre-defined voice commands, limiting the robot's ability to have a conversation. Furthermore, the performance of voice recognition may be affected in environments with high level of background noise and efficient battery management is needed for long term operation. These limitations open up possibilities for future improvements through the incorporation of sophisticated artificial intelligence methods, natural language processing, adaptive learning algorithms, and more efficient power management systems.

The proposed system is a contribution to the fast developing research field of intelligent service robotics providing a practical, inexpensive and user friendly solution for automated guest reception. The robot developed also offers 24/7 operation, stable service quality, reduced operational costs, and increased customer satisfaction compared to conventional reception systems that rely on human operators. The successful integration of embedded AI, voice recognition, robotic movement, and autonomous decision making illustrates the viability of deploying smart hospitality systems using low-cost hardware components and embedded control technology.

In summary, the Welcome Robot for Guest successfully accomplishes the main goal of autonomous guest detection, real-time voice interaction, expressive robotic gestures and intelligent navigation. The system offers a reliable and scalable framework for next-generation hospitality automation and has a great potential for practical

deployment in modern smart buildings and public service environments. Such enhancements in the future can include face recognition, speaking multiple languages, cloud connectivity, remote monitoring and intelligent conversational capabilities. The proposed robot can further evolve into a full-fledged autonomous reception assistant that can provide personalised, efficient and high-quality hospitality services. This work provides a strong foundation for the development of intelligent service robots to increase operational efficiency, improve visitor experience, and promote the widespread adoption of AI-driven automation in the hospitality industry.

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