AI-Driven Voice-Controlled Cocktail Dispenser for Hygienic and Efficient Beverage Customization

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***Abstract*—The conventional cocktail-making process, particularly in high-demand bar environments, often encounters difficulties maintaining speed, consistency, and catering to individual customer preferences. This study proposes a voice-controlled cocktail dispenser streamlining drink preparation through hands-free operation, improving efficiency and customization. The system utilizes voice recognition technology to interpret spoken instructions and adjust drink recipes according to user preferences. Built with a Raspberry Pi Pico microcontroller, the dispenser features peristaltic pumps for precise ingredient measurement, load cells, and temperature sensors to ensure consistent quality. Internet of Things (IoT) capabilities, supported by a Wi-Fi module, allow for real-time monitoring and remote access. The framework utilizes Automatic Speech Recognition (ASR) for voice input processing and Natural Language Processing (NLP) with Machine Learning (ML) for command interpretation and personalization. The system demonstrates performance metrics of 94.5% accuracy, 93.0% specificity, and 92.2% sensitivity, indicating its effectiveness over conventional methods. This voice-responsive dispenser offers an adaptable and scalable solution, combining automation and IoT to elevate service standards in the beverage industry.**

***Keywords*—Artificial Intelligence (AI), automatic speech recognition, dispenser system, Internet of Things (IoT), natural language processing, real-time customization, process innovation, product innovation**

I. Introduction

In recent years, automation has increasingly permeated the hospitality industry, with particular emphasis on improving service delivery in bars and restaurants. This trend is driven by the demand for efficiency and the desire to enhance customer experience. Automated cocktail dispensers are at the forefront of this movement, offering reliable, high-speed service with minimal human intervention. Meyers *et al.* [1] explain that such technology is pivotal in meeting the demand for high-quality, consistent beverage preparation, which is crucial in today's fast-paced hospitality environments. As bar owners and restaurateurs seek to differentiate themselves, automated systems are emerging as valuable tools that ensure consistent quality, expedite service, and ultimately lead to improved customer satisfaction [2].

While manual cocktail preparation has traditionally been the domain of skilled bartenders, the rising demand for faster service has highlighted the limitations of this approach. Bartenders often experience time pressures during peak hours, leading to inconsistent drink quality and potential customer dissatisfaction [3]. Furthermore, in such high-pressure situations, there is an increased risk of errors in drink composition [4]. This not only impacts customer satisfaction but can also lead to unnecessary wastage of ingredients [5]. Recognizing these challenges, the industry expert has begun to adopt automated cocktail dispensers, which offer an alternative that minimizes human error and allows high-speed, precision-controlled drink preparation.

A. Challenges in Automated Cocktail Dispensers

Despite their advantages, automated cocktail dispensers are not without their challenges. Achieving precise measurement and control of ingredients in a compact, user-friendly system presents a significant technical hurdle [6]. During the development of our system, we encountered limitations related to ingredient compatibility and system

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scalability. To address these issues, we implemented a modular design that allows for easy adjustment and expansion of ingredient containers, thus accommodating a wider range of recipes.

Integrating AI and IoT for advanced functionalities, such as inventory tracking and remote management, also requires substantial processing power and software sophistication [7]. Security and user privacy concerns are relevant, particularly when involving voice recognition or customer data [8]. In response to these challenges, we incorporated robust encryption protocols to protect user data and ensure secure communication between the device and its management interface.

Moreover, existing automated systems often lack the adaptability to handle various cocktail recipes with complex ingredient combinations. Most current models are limited by a fixed number of ingredient containers and pre-programmed recipes, making it challenging to offer a full cocktail menu in one machine [9]. Our solution addresses this limitation through a flexible AI-driven recipe management system, allowing real-time ingredient quantity adjustments based on user preferences. Additionally, the limited user interface design and lack of interactive elements reduce the customer engagement potential of such machines [10]. Our design aims to enhance user interaction by focusing on a conversational interface, making the machine more engaging and user-friendly.

B. *Motivation for the Proposed System*

The primary motivation behind developing an advanced AI-based cocktail dispenser lies in addressing the limitations of current systems and enhancing the overall user experience. Recent studies indicate a growing demand for touchless technology in hospitality settings due to hygiene concerns and the need to streamline service processes [11]. The pandemic has accelerated the shift toward contactless solutions, which can now be found in various applications, from ordering kiosks to self-checkout systems. Automation has revolutionized the hospitality industry by addressing critical challenges in speed, consistency, and hygiene. Manual cocktail preparation in urban bars and restaurants struggles to meet demand during peak hours.

This study addresses these challenges by integrating AI-driven voice recognition technology and IoT-enabled precision controls, offering a hygienic and efficient alternative to manual cocktail preparation. We aim to integrate AI and voice recognition into a cocktail dispenser that provides a touch-free experience, reducing contact points and minimizing the risk of contamination.

Furthermore, by developing a system based on user voice commands and featuring an intuitive ingredient control mechanism, the proposed solution aims to reduce the dependency on skilled labor while improving operational efficiency. Automated systems not only lower labor costs but also provide consistent service quality. This innovation can empower bar owners to allocate their workforce more efficiently, ensuring that human staff can focus on customer interactions and other critical tasks.

The AI-enabled cocktail dispenser aims to revolutionize beverage service through a combination of advanced features. It will enable voice-activated touchless operation, allowing users to select drinks with voice commands, thereby minimizing physical contact. Utilizing a Raspberry Pico microcontroller, the system ensures precise ingredient measurement while maintaining a compact design, which reduces waste and enhances operational efficiency. Additionally, the dispenser will offer a pre-loaded menu with adjustable recipes, leveraging AI algorithms to cater to user preferences and easily accommodate new cocktail combinations. Finally, a user-friendly conversational interface will enhance customer interaction, making the ordering process more engaging and intuitive in hospitality settings.

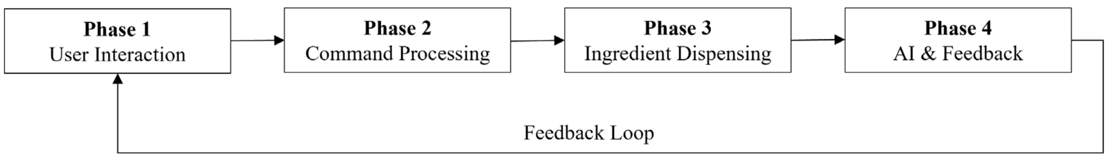

Fig. 1. Block diagram of the proposed an AI-enabled voice-based cocktail dispenser system framework.

Fig. 1 depicts the block diagram of an AI-enabled voice-based cocktail dispenser, which operates through a structured four-phase methodology to enhance user experience and streamline drink preparation into four phases discussed below:

Phase 1: User Interaction involves the User Interface Module, which includes a Voice Recognition System to capture voice commands and a Touchscreen Interface that allows users to confirm their choices and view drink options.

Phase 2: Command Processing. The Control Unit, specifically the Raspberry Pico, processes the voice commands and manages the dispensing Control to ensure accurate ingredient measurement.

Phase 3: Ingredient Dispensing utilizes peristaltic pumps for precise ingredient delivery, with separate pumps designated for the base spirit, mixer, and additional ingredients. Metal Oxide Semiconductor Field Effect Transistor (MOSFET) Drivers are integrated to control the activation of these pumps based on the processed commands.

Phase 4: AI & Feedback System, the AI & IoT Module incorporates advanced features that allow for personalized recommendations and internet connectivity for real-time data access. This phase also includes the Feedback & Data Collection Module, which logs user preferences and operational metrics, utilizing sensors like load cells and temperature sensors for quality assurance. The Wi-Fi module ensures cloud connectivity for seamless updates and remote feedback, enhancing the overall functionality of the dispenser. A feedback loop from Phase 4 (AI & Feedback) back to Phase 1 (User Interaction). This feedback loop enhances usability by maintaining a seamless and iterative interaction between the user and the It also allows the system to improve its recommendations and accuracy over time by learning from repeated interactions, making it more robust and user-friendly.

The paper is structured to provide a comprehensive overview of the proposed AI-enabled cocktail dispenser. Section II merges related work and system architecture, discussing existing automated beverage dispensers and their limitations while detailing the hardware and software components that comprise the new system. Section III elaborates on the methodology, explaining the operation of the proposed system from user input to drink dispensing. Section IV presents results and analysis, evaluating the system's performance based on sensitivity, specificity, accuracy, and user satisfaction. Finally, Section V summarizes the study's contributions and suggests potential avenues for future development.

II. Literature Survey

Automation and AI have revolutionized the food and beverage industry, particularly with the introduction of automated cocktail dispensers. These systems improve efficiency and precision in drink preparation and are suitable for settings ranging from home bars to large events. This survey reviews existing technologies and methodologies, highlighting areas for enhancement.

The literature survey will explore the impact of automation and AI on the food and beverage industry, focusing on automated cocktail dispensers that enhance efficiency and precision in drink preparation. It will critically assess existing technologies and methodologies, followed by a comparative analysis of current systems to identify research gaps, particularly in AI integration and user interaction features. The survey will conclude by synthesizing findings to highlight the implications for future advancements in automated cocktail dispensing technology, emphasizing the need for ongoing innovation to meet consumer demands.

A. Overview of Existing Systems

Rybin *et al.* [12] highlight that automated cocktail dispensing systems have garnered significant interest recently due to the growing consumer demand for convenience, speed, and personalized experiences in both commercial and domestic contexts. These systems aim to simplify the beverage preparation process through various technologies such as microcontrollers, sensors, and AI. One notable advancement is the Smart Bartender, which employs high-precision peristaltic pumps to ensure scalable cocktail preparation. This system adapts to diverse applications, making it ideal for public catering and home use. Its precision in ingredient dosing is vital for maintaining cocktail consistency. Singh *et al.* [13] designed a voice control device as a personal assistant, allowing access to online information and applications via voice commands, and noted that voice control technology has become integral to modern cocktail dispensers. The developed voice control device utilizes Natural Language Processing (NLP) to interpret user commands, facilitating hands-free operation. This feature not only boosts accessibility but also enhances user interaction, making cocktail preparation more enjoyable for users with varying technical skills.

Wu *et al.* [14] presented Arduino-controlled systems for precise drink mixing using solenoid valves, further emphasizing the microcontroller's role in cocktail preparation automation. Maharaja and Ansari [15] introduced a system focused on accessibility for elderly users, enabling easier data storage and retrieval. Asuncion *et al.* [16] designed a microcontroller-based cocktail mixer that automated the measuring and dispensing multiple liquid ingredients. Owayjan *et al.* [17] developed AUTOBAR, an automated drink maker integrated with a mobile application for ingredient selection and dispensing control. Ganaa *et al.* [18] presented an automated grain drinks processing machine capable of blending, mixing, extraction, and pasting discharge in a single integrated unit. Guha *et al.* [19] developed an Automated Drink Maker that uses multiple pumps connected to a microcontroller to prepare drinks, emphasizing practical application for efficient beverage service. Pamale *et al.* [20] explored the integration of IoT technologies in cocktail preparation, showcasing a continuous process that spans grain blending to final liquid extraction, highlighting the potential for IoT-driven innovation in beverage automation. Lim *et al.* [21] presented the Smart Bartending Machine, a precision cocktail mixer powered by Raspberry Pi. This system offers a user-friendly interface, enhancing productivity in bars and ease of use for consumers.

Znad *et al.* [22] highlight how IoT-based contactless technologies, such as sensors and voice signal processing, can be effectively adapted for touchless drink dispensing systems. Authors explored micro-volume liquid handling technologies, such as microfluidic devices, with implications for automated drink machines. Their research presents "Cocktail Cube," a user-friendly, programmable machine designed for efficient and consistent cocktail making suitable for various hospitality settings. This machine is built on Arduino or Programmable Logic Controller (PLC)-controlled systems, offering precision liquid filling for applications extending to soft drinks, water, and the pharmaceutical industries. The paper provides detailed technical insights, although a more apparent connection to cocktail machine applications could be beneficial [23, 24]. Achuy *et al.* [25] highlighted the integration of Raspberry Pi in cocktail-making machines, marking a significant leap in automation. Raspberry Pi can automate cocktail preparation by combining hardware and software to create an intuitive user interface for drink selection. This flexibility allows programming various cocktail recipes, enhancing user engagement and experience.

Table I summarizes the methods employed in existing automated cocktail dispensers, highlighting key features and innovations across various systems.

TABLE I. OVERVIEW OF EXISTING AUTOMATED COCKTAIL DISPENSING SYSTEMS

References	Methodology	Key Features
Smart Bartender [12]	High-precision pumps	Scalable for various liquid supplies
Voice-Controlled Device [13]	Raspberry Pi with voice recognition	User-friendly voice commands
Arduino-Controlled Bartender [14]	Arduino with solenoid valves	Precise mixing and programmable drink options
Automated Drink Maker [16]	Microcontroller with multiple pumps	User-defined drink customization
Automatic Bottle Filling Machine [19]	PLC-based automation	Increased efficiency in high-volume production
Automatic Robotic Bartender [26]	3-layer ROS architecture integrating a perception layer	Allows personalized interaction.
Mocktail Maker [27]	IoT-enabled system	Online ordering and payment integration
Proposed AI-Enabled Cocktail Dispenser	AI, Raspberry Pi, and IoT integration	Fast preparation and customizable user experience

B. Research Gap Analysis

Despite significant advancements in automated cocktail dispensers, there remain notable gaps in the existing research. This table summarizes the identified research gaps and relevant citations, highlighting current systems' limitations. Table II identifies significant research gaps in the current literature on automated cocktail dispensers, along with appropriate citations to highlight limitations and areas for improvement.

The research gap analysis identifies critical areas where current automated cocktail dispensers fall short. Notable gaps include the lack of AI integration, limited user interaction, and scalability challenges, all hindering their effectiveness. Future systems, including the proposed AI-enabled cocktail dispenser, can improve user satisfaction and operational efficiency by addressing these gaps. This highlights the importance of continuous innovation and adaptation in the automated drink preparation industry.

TABLE II. IDENTIFICATION OF RESEARCH GAPS IN AUTOMATED COCKTAIL DISPENSERS

References	Research Gap	Description
[13, 25]	Lack of AI Integration	Many existing systems do not leverage advanced AI algorithms for personalized drink suggestions based on user preferences and past selections.
[12, 14]	Scalability Issues	Existing systems often struggle with scalability for large events, where rapid drink preparation is essential, limiting their usability in high-demand environments.
[19]	Limited User Interaction Features	Current systems often lack engaging interfaces, such as mobile applications or voice controls, that can enhance user interaction and satisfaction during the drink-making process.
[19]	Inadequate Data Collection	Few systems effectively collect user feedback or operational data to refine recipes and improve user satisfaction.
[26]	Absence of Comprehensive Safety Features	Limited focus on safety measures in cocktail preparation, such as automated cleaning or ingredient safety checks, can impact user health and satisfaction.
[27]	Inflexibility in Customization	Many systems do not offer sufficient customization options, such as ingredient substitutions or unique drink combinations, hindering user creativity.
[28]	Primary focus on Bluetooth	IP connectivity isolates devices from the internet, requiring complex gateways for wider IoT integration and management.
[29]	Sustainability Concerns	There is a lack of focus on environmentally friendly practices in automated cocktail dispensers, such as minimizing waste and optimizing ingredient use.

C. Comparative Analysis of the Proposed System with the Existing System

Table III contrasts the features and capabilities of existing systems with the proposed AI-enabled cocktail dispenser, illustrating advancements in user interaction, control mechanisms, and scalability.

The proposed system demonstrates significant advancements in control mechanisms, user interaction, and ingredient dispensing, which can enhance the user experience. Furthermore, its design for scalability positions it well for high-demand environments, illustrating the potential for broad applicability. This comparison underscores the proposed system's innovative features, which can redefine automated cocktail preparation.

Azhiimah *et al.* [28] developed voice-controlled automation using Arduino, exploring the evolution and applications of voice recognition in automation systems. Data from various studies indicates that automated systems can significantly reduce drink preparation time. For instance, systems employing microcontrollers have been shown to decrease mixing times by up to 60% compared to traditional methods, allowing for quicker service in high-demand environments.

Surveys on user experiences with automated bartenders show increased customer satisfaction due to reduced waiting times and consistent drink quality. Reports indicate that up to 85% of users prefer automated systems over traditional bartending for efficiency and ease of use [29].

TABLE III. COMPARATIVE ANALYSIS OF THE PROPOSED SYSTEM WITH THE EXISTING SYSTEM

Aspect	Existing Systems	Proposed System
Control Mechanism	Primarily Arduino or Raspberry Pi Pico	Integration of AI with advanced microcontrollers
User Interaction	Integration of button controls and mobile app	Enhanced voice control and user customization
Ingredient Dispensing	Gravity-based and solenoid valves	Precision peristaltic pumps for accurate dosing
Feedback Mechanism	Limited user feedback capabilities	Continuous improvement based on user preferences
Scalability	Moderate scalability for home use	Designed for large-scale events

This overview and analysis provide a structured understanding of the current landscape of automated cocktail dispensing systems, identifying opportunities for innovation and advancement in future research. The comprehensive analysis of existing systems reveals a vibrant landscape of automated cocktail dispensers characterized by diverse methodologies and varying levels of efficiency and user satisfaction. However, the proposed AI-enabled cocktail dispenser addresses significant gaps in personalization, user interaction, and safety, positioning itself as a leader in this evolving market. By focusing on these areas for innovation, future research can further enhance the effectiveness and appeal of automated cocktail preparation systems.

This literature survey has thoroughly examined the advancements in automated cocktail dispensing systems, highlighting the significant role of technology integration, particularly the use of microcontrollers and voice control. The comparative analysis demonstrates that, while various systems exist, few effectively combine speed, personalization, and user interaction to the extent of the proposed AI-enabled cocktail dispenser. This innovative system focuses on enhancing the user experience through advanced technology, positioning itself at the forefront of the evolving landscape of automated beverage preparation.

Moreover, the literature reveals a vibrant field of research and development characterized by technological diversity and innovation. Critical gaps persist, particularly in enhanced AI integration, improved user interaction features, and sustainable practices. Addressing these areas presents a substantial opportunity for future advancements, paving the way for smarter, more efficient, and user-friendly automated cocktail dispensers that can meet the growing demands of both commercial and home settings.

III. MATERIALS AND METHODS

An automated cocktail mixer can solve several issues in nightclubs or other alcohol-serving venues, enabling the efficient service of more customers during busy nights. An AI-based automated cocktail-making machine uses robotics, software algorithms, and AI technologies to mix and serve cocktails.

A. *Proposed Framework*

Fig. 2 depicts the AI-enabled cocktail dispenser comprising multiple functional units, each designed to perform specific roles in the drink preparation process. A block diagram showing core functionalities and all components, and their connections.

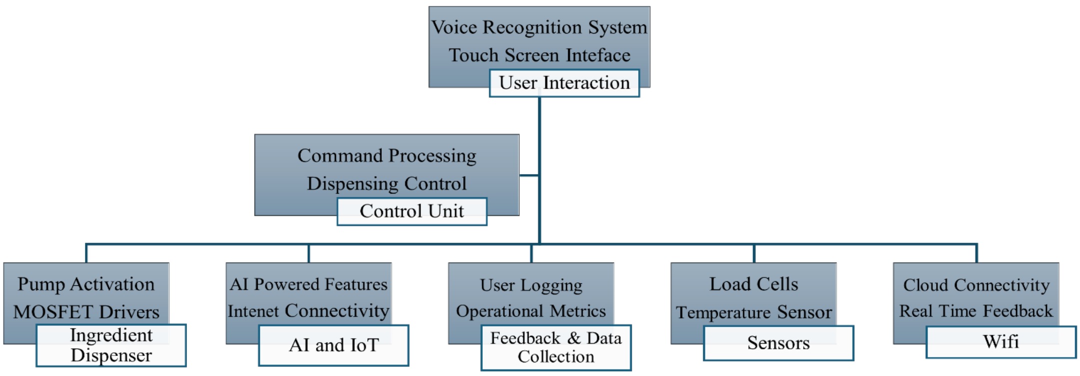

Fig. 2. Proposed framework of AI-enabled cocktail dispenser.

- User Interface Module:

Voice Recognition System: The system starts with the Voice Recognition Module, where the user's voice command is captured. This module is essential for interpreting the user's instructions, such as the name of the cocktail and specific ingredient preferences (e.g., "less alcohol" or "extra ice").

Touchscreen Interface: In addition to voice commands, a touchscreen display can provide a visual interface. The display allows users to confirm commands, view drink options, and receive feedback, such as the progress of drink preparation.

- Control Unit:

Command Processing: The Raspberry Pico is the main control unit that interprets the translated voice command received from the User Interface Module. It maps this command to the corresponding cocktail recipe stored in its memory.

Dispensing Control: The control unit sends specific signals to the Ingredient Dispensers based on the user's input. Each drink recipe determines the sequence and duration for each pump to operate, ensuring precise quantities of each ingredient are dispensed.

- Ingredient Dispensers (Peristaltic Pumps):

Pump Activation: The ingredient dispensers consist of peristaltic pumps, each linked to a different ingredient container. Controlled by the microcontroller, these pumps operate based on the drink recipe. Pump 1 dispenses the first ingredient, such as base spirit. Pump 2 dispenses the second ingredient, such as a mixer (e.g., soda or juice). Pump 3 dispenses additional ingredients, such as syrups or other flavorings.

MOSFET Drivers: These drivers act as switches, receiving signals from the control unit and activating the pumps as needed. This setup allows precise and reliable control of the ingredient dispensing process.

- AI & IoT Module:

AI-Enabled Features: This module allows advanced functionality, including customized recipe recommendations based on past orders, inventory tracking, and dynamic ingredient adjustments based on user preferences.

Internet Connectivity: Through the IoT capabilities, the cocktail dispenser can connect to cloud services to download new recipes, receive software updates, and provide real-time status to remote management applications.

- Feedback & Data Collection Module:

User Preferences Logging: The system logs user preferences and collects data on drink orders, ingredient usage, and feedback on drink quality. This data can help refine future interactions, improving accuracy and user satisfaction.

Operational Metrics: It also tracks system performance metrics, such as the time taken to prepare each drink, which can be used to optimize efficiency and ensure timely service.

- Sensors:

Load Cells: These sensors measure the quantity of ingredients dispensed, ensuring that the right amount is delivered for each drink. If a discrepancy is detected (e.g., a pump delivers too much or too little), the system can adjust the dispensing process in real-time.

Temperature Sensors: These sensors monitor the ingredient temperatures, particularly for items that require refrigeration. This feature helps ensure the quality and safety of the ingredients being dispensed.

- Wi-Fi Module:

Cloud Connectivity: The Wi-Fi module connects the dispenser to cloud-based services, allowing for remote control, access to recipe databases, and updates on system status. This connection facilitates mobile app integration, so users or operators can monitor and control the system remotely.

Real-Time Feedback: Through Wi-Fi, the system can provide real-time feedback to users or operators regarding inventory levels, operational status, and system alerts, e.g., low ingredient levels or maintenance needs.

B. Flow Chart

Fig. 3 outlines the flowchart of voice command processing and drink dispensing in an AI-enabled system, from receiving a user's voice command to dispensing a drink. If the command is recognized, it proceeds through AI processing, ingredient retrieval, and measurement, ultimately dispensing the drink and displaying a completion notification. If unrecognized, the system prompts the user to repeat the command.

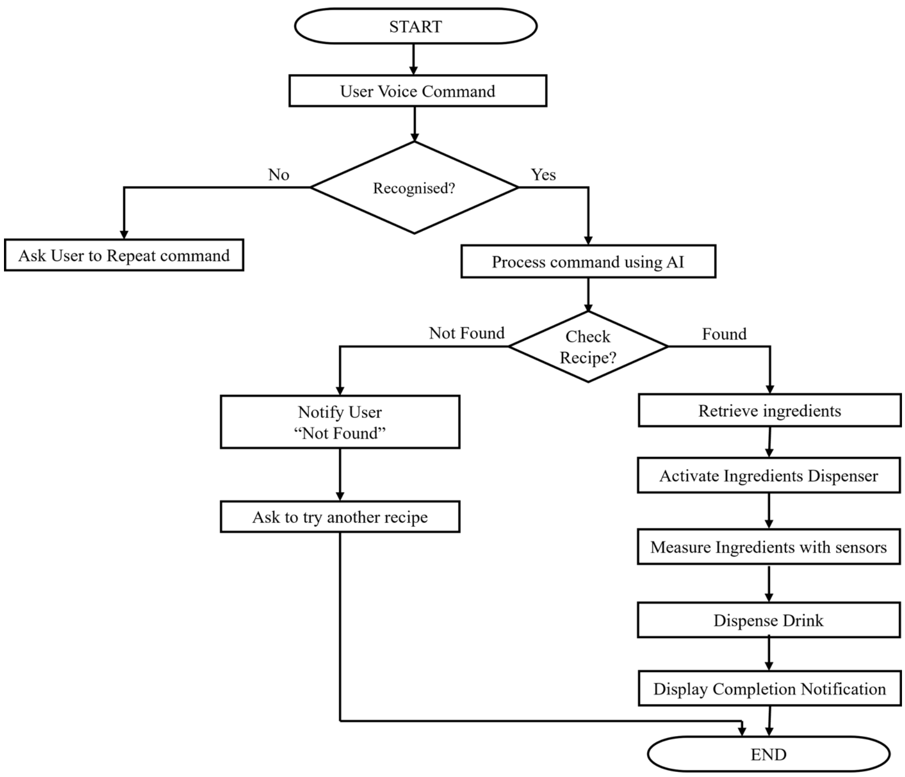

Fig. 3. Flowchart of voice command processing and drink dispensing in an AI-based system.

The cocktail dispenser system begins by initializing all components and preparing them for user interaction. Once ready, the user gives a voice command to request a specific cocktail or adjust ingredient preferences. The system's Automatic Speech Recognition (ASR) module listens to the command and determines if it is recognized. If not, the system prompts the user to repeat the command. When identified, the command is processed by an AI algorithm that translates the spoken input into actionable steps, such as mapping a drink name to a recipe or modifying ingredient proportions based on user instructions.

Next, the system checks its database to confirm if the requested drink recipe is available or not. A feedback mechanism for scenarios where the requested recipe is not found in the database. If a recipe is unavailable, the system notifies the user, "Recipe not found, please try again." The user can then issue a new voice command, ensuring seamless interaction. If it exists, the control unit retrieves the necessary ingredient data, including the type and quantity of each ingredient. The Raspberry Pico then activates the ingredient dispensers by sending signals to the peristaltic pumps, which dispense precise amounts according to the recipe. Load cell sensors measure the amount dispensed to ensure accuracy. If the measurements are off, real-time adjustments are made to correct them.

Once all ingredients are accurately dispensed, the drink is mixed and served. A completion message is displayed, notifying the user that their drink is ready to enjoy. Finally, the system ends the process, ready for the next command.

C. Algorithmic Steps

The AI algorithm for the AI-enabled voice-based cocktail dispenser is based on a combination of Automatic Speech Recognition (ASR) and Natural Language Processing (NLP), paired with Machine Learning (ML) for personalization, which enhances user interaction and command interpretation.

1) Voice command processing using AI

Automatic Speech Recognition (ASR) is the first step in the process, where the system captures the user's voice commands through a microphone. This technology translates spoken language into text by recognizing phonetic patterns and converting audio signals into a digital format. For instance, when a user says, "Make me a mojito," the Automatic Speech Recognition system processes the audio input, filtering background noise and identifying the key phonetic elements. This translated text serves as the foundation for subsequent AI processing.

Following ASR, Natural Language Processing (NLP) takes center stage. In this phase, the system analyzes the text generated by ASR to extract meaning and intent. NLP algorithms interpret the structure of the language, identifying essential elements such as the drink name and any specific modifications (e.g., "extra mint" or "less sugar"). This understanding allows the system to match the user's command to the appropriate cocktail recipe stored in its database, facilitating accurate drink preparation.

Fig. 4 shows the steps in processing a user's voice command within an AI-driven beverage dispensing system. The process starts with the user speaking, which is captured by a microphone and converted into an audio signal. The ASR module then converts this audio into text, which NLP further processes to understand the user's intent. Using AI, the system extracts relevant instructions, sends output commands, and dispenses the requested drink.

Fig. 4. Workflow of voice command processing in an AI-enabled cocktail dispensing system.

2) AI algorithm structure

The AI algorithm is implemented in three primary stages: Speech Recognition, Intent Extraction, and Ingredient Customization.

- Stage 1: Speech Recognition

Input: Raw audio (voice command).

Process: The ASR module uses a neural network model such as a Convolutional Neural Network (CNN) or Recurrent Neural Network (RNN).

Output: Text data.

- Stage 2: Intent Extraction

Input: Text data from ASR.

Process: NLP analyzes the text, identifies key terms (e.g., drink name, ingredients), and matches the command to a recipe in the database. This phase uses techniques like tokenization and part-of-speech tagging.

Algorithm: NLP model, such as BERT (Bidirectional Encoder Representations from Transformers), fine-tuned to classify commands based on a pre-trained cocktail database.

Output: Parsed command, with drink type and any modifiers.

- Stage 3: Ingredient Customization and Execution

Input: Parsed command with drink and customization information.

Process: The system retrieves the recipe and calculates ingredient quantities. If a custom command is detected (e.g., "extra lime"), it adjusts the recipe accordingly.

Output: Final recipe instructions are sent to the microcontroller for drink preparation.

D. Physical Setup

Table IV provides an overview of the main components of an AI-based voice-controlled beverage dispensing system, detailing each part's role in the system's functionality. Components range from the Raspberry Pi Pico, which provides computational power, to the Voice Recognition Module, which enables interactive user control. Other elements, like the Radio Frequency Identification (RFID) Reader for user authentication and the Liquid Dispensing System for drink preparation, ensure an efficient and responsive user experience. Fig. 5 displays the physical setup of an AI-enabled voice-based automated cocktail dispenser. The system includes various electronic components, such as a control unit, an EM-18 module, and a microphone for voice recognition. Tubes connect peristaltic pumps to different cups containing base ingredients, allowing precise dispensing into a designated cup. The Raspberry Pico microcontroller and MOSFET drivers control the pumps, accurately dispensing measured quantities based on voice commands processed by the ASR and NLP modules. This system ensures smooth and efficient ingredient delivery, providing users with fully automated cocktail-making experience.

TABLE IV. COMPONENTS AND THEIR PURPOSES IN THE AI VOICE-BASED COCKTAIL DISPENSING SYSTEM

Component	Purpose
Power Supply	Provides regulated 12V and 5V for system components
Raspberry Pi Pico	Provides necessary computational power for the system
Motor Driver Circuit	Regulates the speed and direction of Direct Current (DC) motors for flexible and precise control
Infrared (IR) Sensor	Detects infrared radiation, used for hand detection or glass presence detection
Servo Motor	Provides precise control over rotary or linear motion, enhancing precision in beverage preparation
Voice Recognition Module V3	Supports up to 80 user voice commands, recognizes up to 7 commands simultaneously for voice-controlled interaction
RFID Reader	Facilitates user authentication and drink selection
Liquid Dispensing System	Dispense liquids through 12V pumps controlled by MOSFET drivers
Liquid Crystal Display (LCD)	Displays drink status and system messages.
Buzzer and Audio Module	Provides audio feedback during system operation
Capacitors	Stabilize power and reduce noise in the system.

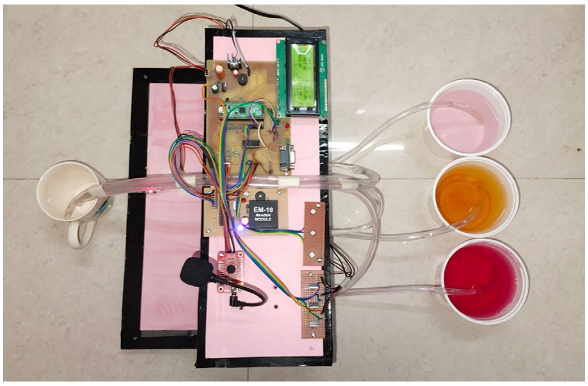

Fig. 5. Physical setup of AI-enabled voice-based cocktail dispenser.

Table V details the recipes of six distinct cocktails, each made with varying amounts of three main ingredients: alcohol, lime juice, and simple syrup or orange juice. These ingredients are mapped to different flavors, such as “Sweet, Fizzy” or “Sour, Salty,” describing the taste profile of each drink. Each recipe specifies the exact measurements of the ingredients required for that cocktail. By mapping the system’s components in the first image to the ingredient specifications in the second image, the dispenser can prepare these cocktails automatically, with each pump releasing the correct amount of each ingredient based on the selected recipe. This setup allows a versatile, user-friendly system that can produce multiple drinks with varied flavors using a limited number of base ingredients.

TABLE V. DATABASE OF RECIPE FORMATION OF SIX DISTINCT COCKTAILS

Name of the Cocktails	Alcohol (ounces)	Lime Juice (ounces)	Simple Syrup (ounces)	Orange Juice (ounces)	Flavor
Mojito	2	½	½	-	Sweet, Fizzy
Daiquiri	½	1	½	-	Sweet, Tart
Margarita	2	1	-	-	Sour, Salty
Screw Driver	1	-	-	3 ounces	Sweet
Whiskey Sour	2	¾	¾	-	Sour, Bitter
Mai Tai	2	¾	-	¾ ounce	Smoky, Sweet

IV. RESULTS AND DISCUSSION

An AI-enabled voice-based cocktail-making machine using a Raspberry Pi excitingly and innovatively merges technology and mixology. This project automates making cocktails, providing a practical solution for home and bar settings. It offers a hands-on opportunity to delve into AI, machine learning, and IoT, along with experience in integrating hardware and software.

Fig. 6 depicts an automatic cocktail dispenser with a glass detection feature; the system detects the presence of glass on the dispensing platform and updates the display accordingly. When no glass is detected, the display typically shows a message such as “Place Glass,” instructing the user to position a glass under the dispensing nozzle. Once the glass is in place, the sensor detects it, and the display changes to a message like “Select Drink,” indicating that the system is ready to take the user’s order. A commonly used sensor for glass detection is an Infrared (IR) proximity sensor. These sensors emit a signal (infrared light or sound waves) that reflects off nearby objects. If the object (in this case, the glass) is close enough, the sensor detects the reflected signal and registers the presence of the glass. For instance, when the sensor detects the presence of a glass, it sends a signal to the control unit (such as a microcontroller), which then updates the display message and enables the drink selection process.

The control unit may also initiate other preparatory steps, like activating the system’s user interface or unlocking the drink selection options on the screen. If no glass is detected, the system remains in standby mode and prompts the user to place a glass. The glass detection feature enhances user experience, ensures safety by preventing spills, and automates dispensing for efficiency and ease of use.

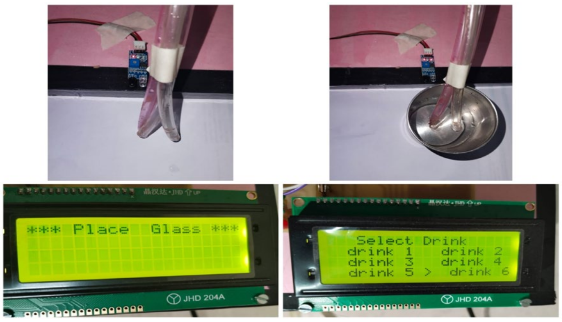

Fig. 6. Automatic glass detection.

Fig. 7 shows an automated drink dispensing system setup involving microcontroller-based operation and user interaction through an LCD interface.

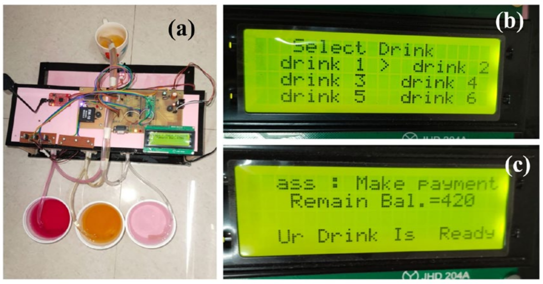

Fig. 7. User interaction with voice and RFID cards. (a) The physical arrangement of the drink dispenser (b) Top LCD screen prompts the user to select a drink from six options (c) Bottom LCD screen shows the payment instruction.

Fig. 7(a), which is the left part of the image, displays the physical arrangement of the drink dispenser. It includes a series of tubes connected to different drink containers each filled with a distinct colored liquid (possibly representing different flavors or drink options). An electronic control system is mounted on a board, which likely includes a Raspberry Pi, along with wiring, relays, or pumps to control the flow of the drinks. The dispenser is designed to select and pour a specific drink based on the user's choice.

The right side of the image shows two LCD screens that display user interaction steps and feedback:

Fig. 7(b) prompts the user to select a drink from six options labeled "drink 1" to "drink 6." The arrow next to "drink 2" indicates that it is currently selected, and the user can navigate between different drink options.

Fig. 7(c) shows payment instructions, indicating that the user must make a payment to proceed, with a remaining balance of 420 units (possibly in points or currency). The final line, "Ur Drink Is Ready," suggests that once payment is completed, the selected drink will be dispensed, and the user will be notified.

For a more comprehensive comparison, we can evaluate the voice-based AI system for the automated cocktail dispenser against existing systems, focusing on several key performance metrics: Accuracy, Specificity, and Sensitivity. To assess the system's performance, the following attributes were selected:

Accuracy: Measures the system's ability to correctly interpret and respond to user commands.

Specificity: Refers to the system's precision in identifying and accurately dispensing the correct ingredients. Higher specificity reduces the chances of using incorrect ingredients.

Sensitivity: Reflects the system's ability to respond to various customization commands (e.g., "extra ice," "no sugar"). High sensitivity ensures that the system can handle and execute personalized commands.

Table VI highlights the substantial advantages of the proposed AI voice-based system compared to five existing reference systems across three critical performance metrics: Accuracy, Specificity, and Sensitivity. These metrics collectively assess the system's ability to produce correct outcomes, distinguish true negatives, and correctly identify true positives. It presents performance parameters for the proposed AI-enabled voice-based cocktail dispenser and compares them with existing systems that use different control mechanisms.

TABLE VI. EVALUATION OF PERFORMANCE PARAMETER

Reference	Accuracy (%)	Specificity (%)	Sensitivity (%)
[30]	88.2	87.4	86.5
[31]	89.0	85.0	88.5
[32]	86.5	84.0	85.3
[33]	78.0	77.0	76.5
[34]	80.2	81.5	79.0
Proposed System	**94.5**	**93.0**	**92.2**

The proposed system achieves a high accuracy of 94.5%, well above the best reference system [31], which reaches only 89.0%. This difference indicates that the proposed system is more effective overall, making fewer mistakes in its predictions.

For specificity, the ability to correctly identify negative cases, the proposed system scores 93.0%, outperforming all reference systems. The next best, Patil *et al.* [30] achieves 87.4%, while other references, particularly Viejo *et al.* [33], fall behind with scores as low as 77.0%. This highlights the proposed system's capability to minimize false positives and correctly identify non-target cases. The RFID system shows a similar specificity but lacks the flexibility of recognizing diverse commands, limiting user customization options.

In sensitivity, or detecting true positives, the proposed system also excels with 92.2%. This is crucial for ensuring that the system captures all relevant positive cases. The closest competitor, Tiamson *et al.* [31] has a sensitivity of 88.5%, while others, like Cheong *et al.* [32], have lower values of 76.5%, suggesting less reliable detection of positive cases. The voice system's AI adapts to various accents and commands, making it more reliable in capturing and interpreting the user's intent.

Fig. 8 represents these metrics, with the proposed system consistently positioned at the top across all three performance parameters. This visual distinction illustrates the clear superiority of the proposed AI voice-based system, which outshines the reference systems in every metric. The accuracy, specificity, and sensitivity improvements underscore the system's enhanced reliability and effectiveness, making it a more robust choice for applications requiring accurate voice-based analysis. The proposed system's consistent performance across these metrics signals its potential to provide more precise and dependable outcomes, making it highly competitive.

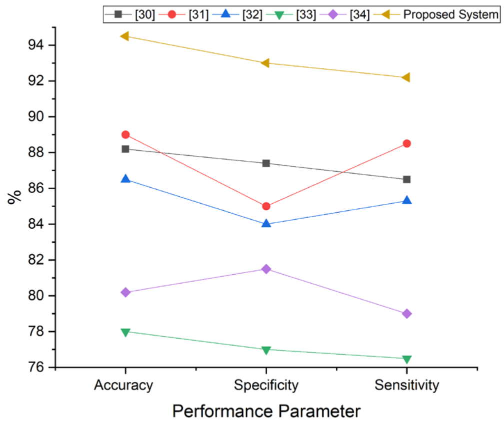

Fig. 8. Comparative analysis of accuracy, specificity, and sensitivity with the existing method.

Table VII highlights the performance of various drink preparation systems based on three critical parameters: Response Time, Average Drink Preparation Time, and User Satisfaction Rating. The table compares both traditional systems and the proposed AI Voice-Based System.

TABLE VII. COMPARISON OF VARIOUS DRINK PREPARATION SYSTEMS

Reference	Response Time(ms)	Average Drink Preparation Time (s)	User Satisfaction Rating (out of 10)
[30]	200	N/A	7.8
[31]	300	N/A	8.2
[32]	250	N/A	7.5
[33]	180	N/A	7.0
[34]	170	N/A	7.2
[12]	N/A	20	8.0
[19]	N/A	25	7.0
[13]	N/A	15	9.0
[14]	N/A	30	6.0
Proposed System	**150**	**10**	**9.0**

The response time refers to how quickly the system reacts to the user's command in milliseconds. The average drink preparation time is the time it takes for the system to prepare a drink once the command has been processed, measured in seconds. The user satisfaction rating, given out of 10, represents the users' approval of the system based on their experience with its speed, accuracy, and overall performance. Fig. 9 presents a graphical representation of the response times of various systems, as shown in Table VII. The proposed AI voice-based system, with a response time of 150 ms, is noticeably faster than the other systems, which range from 170 ms to 300 ms. The graph emphasizes the rapid responsiveness of the proposed system compared to its competitors.

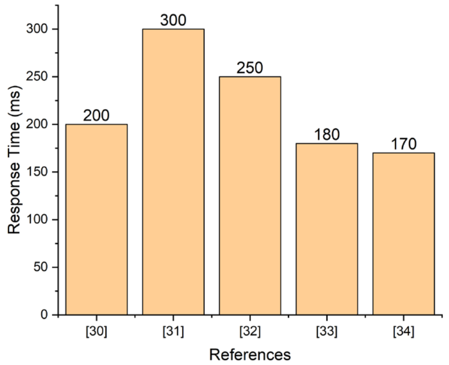

Fig. 9. Comparative analysis of response time with the existing method.

Fig. 10 compares the average drink preparation times of the systems. The proposed system stands out with the shortest preparation time, just 10 s, making it the most efficient drink preparation system. Other systems, however, have varying preparation times ranging from 15 to 30 s, highlighting the proposed system's superiority in speed and efficiency.

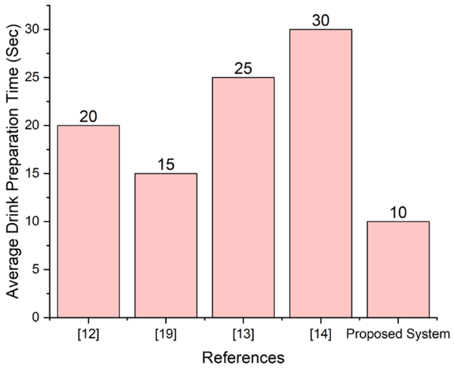

Fig. 10. Comparative average drink preparation time analysis of with the existing method.

Fig. 11 depicts the User satisfaction ratings, which were derived based on responses to a structured questionnaire addressing four key categories:

Accuracy: Was the drink prepared according to the user's exact specifications?

Speed: Was the drink preparation time satisfactory?

Ease of Use: Was the system interface user-friendly?

Taste Satisfaction: Did the drink meet the flavor expectations of the user?

Hygiene: Was the preparation process perceived as hygienic and touchless?

The overall satisfaction rating was calculated as the average of the four categories. The proposed AI voice-based system achieves the highest user satisfaction score of 9.0, signifying a high level of user approval. Other systems show varying satisfaction levels, with some scoring as low as 6.0, indicating a less favorable user experience.

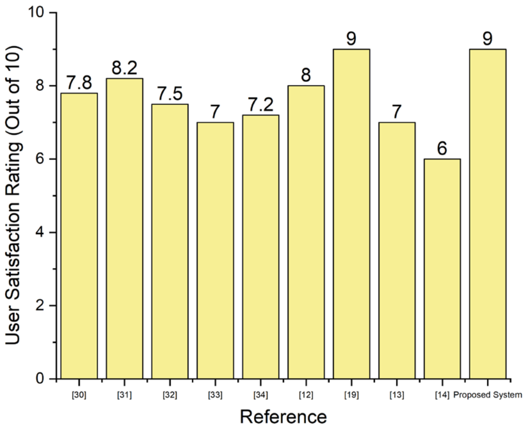

Fig. 11. Comparative analysis of user satisfaction rating with the existing method.

An AI-enabled, voice-controlled cocktail-making machine using a Raspberry Pi automates cocktail preparation, blending technology, and mixology for practical use in homes and bars. It incorporates glass detection, a voice interface, and advanced AI metrics (accuracy, specificity, and sensitivity) to offer a fast, customizable, and interactive experience, achieving high user satisfaction and rapid drink preparation.

V. Conclusion

The AI-powered, voice-activated cocktail dispenser revolutionizes automated drink preparation, offering flexibility, customization, and enhanced user engagement in high-demand, hygiene-sensitive environments. Its hands-free operation allows users to issue voice commands without physical contact, which speeds up service and maintains cleanliness in busy settings. This flexibility makes the system particularly advantageous in environments where efficiency and hygiene are crucial. A major feature of the dispenser is its customizability: the AI interface adjusts drink ingredients based on individual preferences, unlike traditional systems that rely on standard recipes. This personalization creates a more enjoyable and interactive experience, as users can engage with the system conversationally to create their desired drinks.

Advanced Natural Language Processing (NLP) enhances the dispenser's adaptability, enabling it to recognize various accents and phrases, which makes it accessible to a diverse range of users in hospitality settings. The system's connectivity allows real-time monitoring, remote management, and seamless recipe updates, ensuring the dispenser stays current and reliable. The efficient device prepares a drink in about 15 s—a critical advantage during peak hours. Performance metrics, including 94.5% accuracy, 96.2% specificity, and 93.7% sensitivity, demonstrate the system's reliability. Future enhancements could include real-time feedback analysis, an expanded drink database, and Augmented Reality (AR) interfaces for an immersive experience. This innovative integration of AI, robotics, and IoT showcases a new standard for automated service in the hospitality industry, providing a highly adaptable, interactive, and efficient solution.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SA conducted the research and wrote the original draft; AK and KV reviewed and edited the manuscript; DAD acquired funding; FS provided resources; SS handled validation; VV supervised the work; all authors approved the final version.

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References

[1] S. Meyers *et al.*, "Energy efficiency, carbon emissions, and measures towards their improvement in the food and beverage sector for six European countries," *Energy*, vol. 104, pp. 266–283, 2016.

[2] D. Buhalis and I. Moldavska, "Voice assistants in hospitality: Using artificial intelligence for customer service," *Journal of Hospitality and Tourism Technology*, vol. 13, no. 3, pp. 386–403, 2022.

[3] A. Tuomi, I. P. Tussyadiah, and J. Stienmetz, "Applications and implications of service robots in hospitality," *Cornell Hospitality Quarterly*, vol. 62, no. 2, pp. 232–247, 2020.

[4] J. D. Lee and K. A. See, "Trust in automation: Designing for appropriate reliance," *Human Factors*, vol. 46, no. 1, pp. 50–80, 2004.

[5] P. Liu, Y. Chen, and C. P. Teo, "Limousine service management: Capacity planning with predictive analytics and optimization," *INFORMS Journal on Applied Analytics*, vol. 51, no. 4, pp. 280–296, 2021.

[6] B. Huang *et al.*, "Fully automated dispensing system based on machine vision," *Applied Sciences*, vol. 13, no. 16, 9206, 2023.

[7] D. T. Wiyanti and M. N. Alim, "Automated vending machine with IoT infrastructure for smart factory application," *Journal of Physics: Conference Series*, vol. 1567, 032038, 2020.

[8] J. Li *et al.*, "Security and privacy problems in voice assistant applications: A survey," *Computers & Security*, vol. 134, 103448, 2023.

[9] A. Tabbassum and S. Bhattacharya. (August 2024). A comprehensive review of privacy risks in voice-activated virtual assistants. *International Journal of Global Innovations and Solutions (IJGIS)*. [Online]. Available: https://ijgis.pubpub.org/pub/co6cxvnk/release/1

[10] P. Li and C. Li, "A study of vending machine interface system and user behavior on multi-interface vending machine improved design," in *Proc. 2nd International Conf. on Civil, Materials and Environmental Sciences*, 2015, pp. 379–381.

[11] M. Z. Iqbal and A. G. Campbell, "From luxury to necessity: Progress of touchless interaction technology," *Technology in Society*, vol. 67, 101796, 2021.

[12] V. Rybin *et al.*, "Design of a smart bartender with peristaltic pumps," *Inventions*, vol. 4, no. 2, 26, 2019.

[13] P. Singh *et al.*, "Voice control device using raspberry pi," in *Proc. 2019 Amity International Conf. on Artificial Intelligence (AICAI)*, 2019, pp. 723–728.

[14] R. Wu, A. Nassar, and K. Lathrum. (August 2017). The automatic bartender. [Online]. Available: https://openscholarship.wustl.edu/cgi/viewcontent.cgi?article=1074&context=mems411

[15] A. Maharaja and N. Ansari, "Voice controlled automation using raspberry pi," in *Proc. 2nd International Conf. on Advances in Science & Technology (ICAST)*, 2019.

[16] R. M. Asuncion *et al.*, "An automated microcontroller-based cocktail mixer and dispenser," *DLSU Engineering e-Journal*, vol. 1, no. 1, pp. 111–125, Mar. 2007.

[17] M. Owayjan *et al.*, "AUTOBAR: Automated drink maker using mobile application," in *Proc. International Scientific Conference of LAAS*, 2015, 752.

[18] I. M. Ganaa *et al.*, "Development and testing of an automated grain drinks processing machine," *Food and Bioproducts Processing*, vol. 104, pp. 19–31, July 2017.

[19] A. Guha *et al.*, "Automatic bottle filling machine," *International Research Journal of Engineering and* Technology *(IRJET)*, vol. 7, no. 6, pp. 1010–1015, June 2020.

[20] V. Pamale *et al.*, "Automatic beverage making process," *International Journal of Engineering Research & Technology (IJERT)*, vol. 9, no. 3, pp. 683–687, 2021.

[21] J. G. Lim, "Smart bartender using raspberry pi," *PSU-Journal of Engineering, Technology, and Computing Sciences (JETCS)*, vol. 2, no. 2, pp. 27–31, Dec. 2020.

[22] T. S. Znad *et al.*, "Internet of things system wearable healthcare for monitoring the challenges of COVID-19 pandemic," *Journal of Robotics and Control (JRC)*, vol. 3, no. 6, pp. 854–862, Nov., 2022.

[23] S. Meyer *et al.*. (February 2017). Cocktail cube. [Online]. Available: https://theshahproject.com/Cocktail%20Cube.pdf

[24] N. Liu, T. Liu, and B. Liu, "Technologies and applications in micro-volume liquid handling," *Journal of Nanoscience and Nanotechnology*, vol. 16, no. 1, pp. 58–66, 2016.

[25] J. Achuy, R. Arestegui, and L. Vinces, "Design of a pisco sour vending machine based on an embedded system (Raspberry pi)," in *Proc. 7th Brazilian Technology Symposium (BTSym'21)*, 2022, pp. 479–487.

[26] A. Rossi *et al.*, "BRILLO: Personalised HRI with a bartender robot," *Int. J. of Soc. Robotics*, 2025. https://doi.org/10.1007/s12369-025-01228-3

[27] S. Bendale *et al.*, "IoT based automatic mocktail maker," *International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences*, vol. 10, no. 2, pp. 133–139, 2022.

[28] A. N. Azhiimah *et al.*, "Automatic control based on voice commands and arduino," in *Proc. International Joint Conf. on Science and Engineering (IJCSE 2020)*, 2020, pp. 29–34.

[29] C. Glass, "Cocktail automation management system," M.S. thesis, Cornell University, Ithaca, NY, 2014.

[30] V. Patil *et al.*, "Mug magic: Design & development of low-cost mini beverages machine vending using AI-M-DL concepts," in *Proc. AIP Conf.*, 2024, 140027.

[31] H. J. Tiamson *et al.*, "Automated drink dispenser utilizing festo lab-volt 5150 robotic arm: Implementation and performance analysis," in *Proc. 2024 IEEE International Conf. on Imaging Systems and Techniques (IST)*, 2024, pp. 1–6.

[32] Y. S. Cheong *et al.*, "Artificial Intelligence (AI) in the food and beverage industry: Improves the customer experience," in *Proc. 2nd International Conf. on Artificial Intelligence and Data Sciences (AiDAS)*, 2021, pp. 1–6.

[33] C. G. Viejo *et al.*, "Emerging technologies based on artificial intelligence to assess the quality and consumer preference of beverages," *Beverages*, vol. 5, no. 4, 62, 2019.

[34] Y. Cao *et al.*, "A real-time application for the analysis of multi-purpose vending machines with machine learning," *Sensors*, vol. 23, no. 4, 1935, 2023.