IoT-based Conversational Solar Vending Machine

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Abstract

In vending machine retail settings, there are major challenges it encounters: lack of real-time monitoring capabilities, continuous electricity consumption, and a lack of human interaction. To address this, the researchers developed an IoT-based vending machine with solar panels and conversational AI assistance that allows real-time monitoring of stocks of the vending machine that allows the operator to manage the vending machine online and even gets notified once a certain product is almost out of stock, solar panels and voice recognition command are also implemented. By implementing these, the systems utilize a more sustainable alternative energy source as opposed to traditional energy sources and also provides a way for the customer to interact with the vending machine system. The IoT was evaluated with the ISO/IEC 25010:2023 standards, focusing on Functional Suitability, Performance Efficiency, Interaction Capability, Reliability, and Maintainability. The results show a favorable score of 4.86 in Functional Suitability, 4.86 in Performance Efficiency, 4.95 in Interaction Capability, 4.83 in Reliability, and 4.70 in Maintainability. These results show that the IoT developed for monitoring the vending machine was dependable and highly favorable. By developing an IoT-based vending machine with solar panels and conversational AI assistance, the system provided a significant advancement in automated retail settings.

Keywords

Conversational AI, Internet of Things, Solar Panel, Vending Machines, Voice-activation

1. Introduction

Vending machines on their own are already a state-of-the art idea in retail automation. These kiosks are self-service and placed in key spots that provide seamless shopping experience. In addition to their quick and simple transactions, they also offer a variety of options, from tasty snacks and cool drinks to necessary personal hygiene products, so every customer can find something that suits their particular need on the go. For vending machine operators, they need to manually check the system from time to time to see if inventory's doing good. Internet of Things could address this challenge by implementing a seamless connection between the vending machine and humans [1, 2]. With the introduction of the Internet of Things, it will help the vending machine operators to have real-time monitoring capability. They will be notified once a slot in the vending machine is almost out of stock, they can also modify the information and inventory of the products the vending machine contains. This will help the vending machine operator to keep a track on when to restock the products. In addition to this, the operator will be able to see which products are the best-sellers of a certain timeframe. This will allow them to have an insight into which products should be on the vending machine more often and how frequently it needs restocking.

While vending machines provide convenience in retail settings, one main problem with this is its substantial electricity consumption linked to their continuous operation. Given this difficulty, vending machines can introduce and adopt creative ways to address and solve this issue to not only transform energy footprint of the industry, but to also reduce ends. Instead of paying electricity bills, this payment could be saved as a profit. This shows room for improvement and innovation to find sustainable alternatives to electricity consumption. Looking into renewable energy as an alternative energy source could provide a way to lessen environmental impact and cut carbon emissions– to encourage a more

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sustainable and environmentally friendly practice. As an example, the use of solar electricity and panels can provide a sustainable and eco-friendly way to address the issues with vending machine electricity consumption [3, 4]. Solar power is a flexible energy source that can also be utilized for energy storage, excess solar energy generated during the hours of maximum sunlight can be saved for use at a later time.

In addition to this, due to the simplistic nature of vending machines, it needs little to no human interactions. Conversational AI systems may provide precise, timely, and contextually relevant information that improves user experience and encourages well-informed decision-making by utilizing the power of AI-driven analytics and data processing [5, 6]. The swift growth of conversational AI is indicative of its significant influence in transforming the digital communication and engagement scene, paving the way for improved interaction and information sharing in the artificial intelligence space. This could provide a new level of engagement and interaction with the customers in automated retail settings.

2. Related Work

IoT has rapidly emerged as a versatile technology with broad applications across various industries, significantly influencing numerous sectors. Ranging from wearable gadgets and smart vehicles to industrial use cases, IoT has introduced a new era of interconnected devices, enabling seamless interaction between machines and humans previously only seen in futuristic movies. The paper explored real-world examples of how retail brands have integrated IoT technology and the resulting opportunities for retailers [1].

Retailers are actively exploring novel ways to engage with customers and various channels of interaction. Forecasts indicate that the Internet will play an increasingly pivotal role in everyday life, leading to a future where inanimate objects are interconnected and possess computing capabilities, giving rise to the concept of 'smart objects.' Internet of Things serves as a comprehensive tool for fostering innovation in service-centric retail industries. IoT presents a novel approach that elevates the traditional shopping experience by making it more convenient, enjoyable, interactive, and personalized, thereby revolutionizing the retail landscape [2].

Solar energy is harnessed by converting sunlight into electricity using solar panels. These panels absorb solar thermal energy and convert it into electrical energy, which can then be stored in batteries or converted to alternating current (AC) using an inverter. Excess electricity can be stored for later use, making solar power a reliable energy source. Solar energy systems can be passive or active. Passive systems do not require special tools and can be as simple as parking a vehicle in the sun to absorb heat. Active systems, on the other hand, require specific methods and resources to collect and store energy efficiently. Both solar thermal and photovoltaic plants use an active solar energy system. The application of solar power plants, especially rooftop solar power plants, is gaining popularity in urban areas. Rooftops of buildings can be utilized to collect and store solar energy, contributing to energy security and promoting the use of renewable energy sources. The rooftop solar power plant has become a national priority program, supported the goal of energy distribution and promoted the use of new and renewable energy sources [7].

Rommila et al. developed an interactive artificial intelligence agent using deep learning techniques like Long Short-Term Memory, Gated Recurrent Units, and Convolution Neural Networks to predict an appropriate and automatic response to customers' queries. This allowed for the automatic generation of conversation between a computer and a human. They found many examples of users feeling that the chatbot offers companionship and emotional support, and that it is understanding, approachable, and capable of meeting users' communication needs [8].

Particularly in the field of information and communication technology (ICT), the pandemic has increased the demand for creative online learning solutions. Using chatbot technology to improve learning experiences is one suggested remedy. Deeper comprehension of the course material is made possible by this integration, which also promotes active engagement in real-world situations and considers different learning preferences and intelligences. The positive impact of chatbot technology

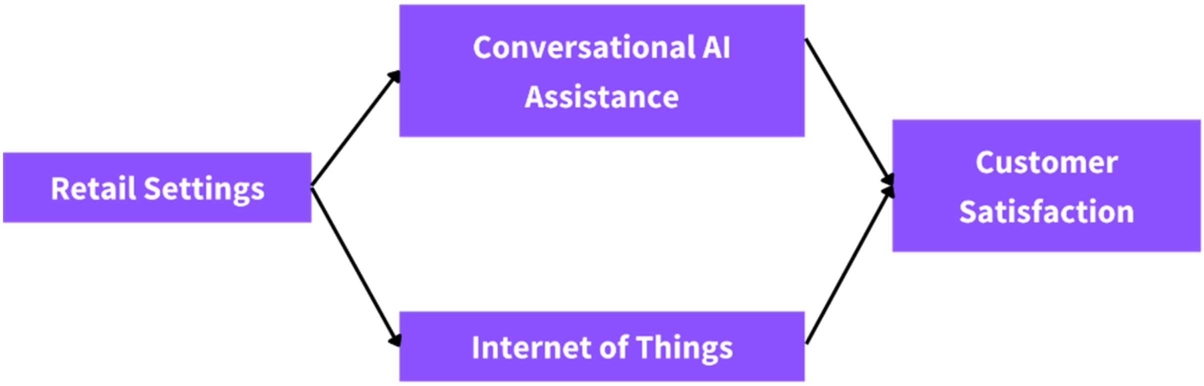

Figure 1: Theoretical Framework

on learners' academic performance, demonstrating significant improvements in scores before and after chatbot implementation. Chatbots offer personalized support, helping to clarify and expand subject knowledge through interactive content like texts, graphics, audio, and videos. Chatbots and other conversational AI are essential for increasing client satisfaction, decision-making processes, and engagement. Chatbots may effectively fulfill consumer requirements and preferences by offering personalized, interactive experiences [9].

3. Methodology

3.1. Theoretical Framework

Business Intelligence Systems explores the idea of implementing Internet of Things to physical things and other electronic appliances for the purpose of enabling connection and exchange of data. This data can then be used to retain businesses for an analytical view for better decision making, thus enhancing customer experience and increasing their sales (Ved, 2020). IoT services provide new and innovative approaches to the existing services, and this significantly increases the positive impact on customers' satisfaction. Not only that, but this implementation also helps the employees in the retail sector to ease inventory services [10].

With this study's background and Figure 1, the IoT-based vending machine with solar panel and Conversational AI assistance aligns with this method focusing on easing inventory services while also promoting user engagement and satisfaction. The vending machine system uses IoT functionality to provide real-time monitoring services to the operator. It also implements Conversational AI assistance to allow user engagement, improve experience, and even promote sales.

To integrate conversational AI into the vending machine, a voice is first input from a microphone which is then sent to Google Speech-to-Text (STT) which transcribes the audio to text. Dialogflow then analyzes the text to extract the user's intent or command. Based on this understanding, the vending machine then takes the appropriate action. For example, if the user requests a product, Dialogflow triggers the action to check if the product is available in the vending machine. Once the action is performed, a pre-programmed response is played through the vending machine's speaker. Google Text-to-Speech (TTS) system is used to convert the response back into speech for confirmation of the process. This process ensures smooth interaction with the vending machine entirely through voice, creating a hands-free user experience.

In order to train the Natural Language Understanding (NLU) Dialogflow, the developers first defined the core intents and entities on possible queries and actions the user might have when interacting with the vending machine system like ordering, checking availability, making payment, or asking for assistance. The developers collected phrases like "Order Rebisco" and In order to train the Natural

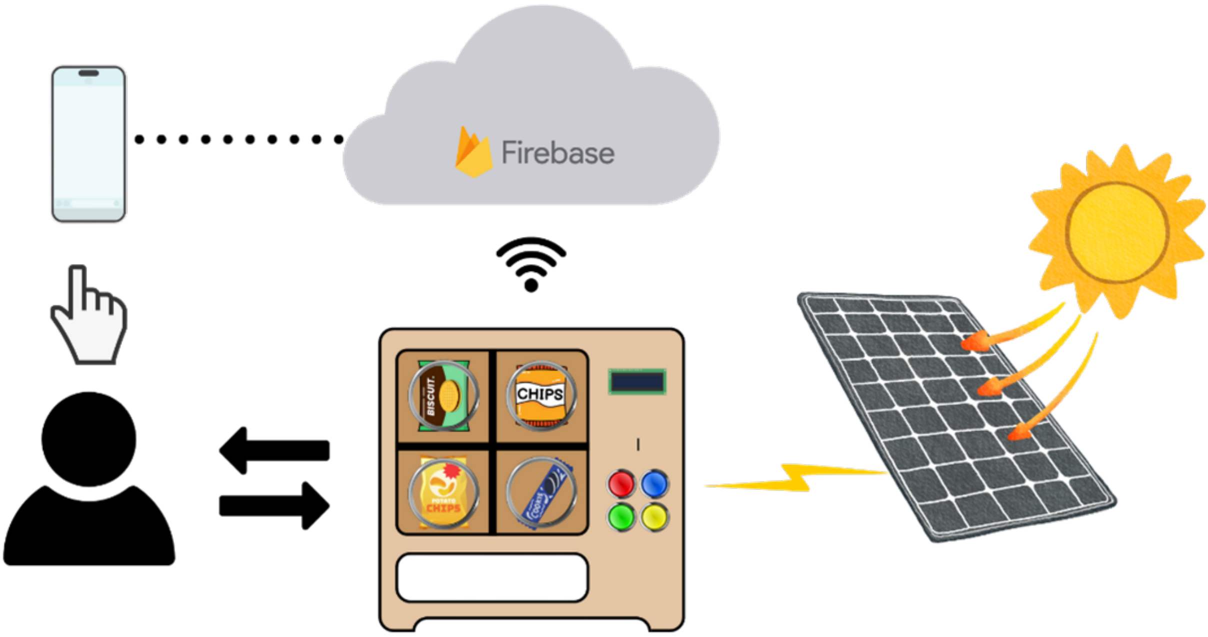

Figure 2: Conceptual Framework

Language Understanding (NLU) Dialogflow, the developers first defined the core intents and entities on possible queries and actions the user might have when interacting with the vending machine system like ordering, checking availability, making payment, or asking for assistance. The developers collected phrases like "Order Rebisco" and "Order Combi" to teach Dialogflow to recognize different variations of similar commands. Once the intents and entities are defined with relevant training phrases, the developers were able to configure responses that the vending machine will deliver based on the user input.

3.2. Conceptual Framework

Figure 2 shows the conceptual framework of the system proposed. It shows the Internet of Things implementation to the vending machine, it is connection to Firebase for the real-time monitoring capabilities for its inventory. In addition, the solar panel integrated is an added alternative to the conventional power sources, allowing sustainable and renewable consumption. The user may interact with the vending machine and the vending machine operator can access the mobile application to monitor its activities.

3.3. System Architecture

The proposed system's physical components are depicted in the figure 3. This illustration helps to better understand the connection of each component and how they will function in order to execute the proposed system. The Raspberry Pi acts as the microcontroller that controls and commands each component. The 12V solar cell is connected to a solar charge controller that regulates solar energy. The battery can also be charged either through AC by plugging it in an outlet or through the solar charger. Between all the components and the battery, a relay channel is placed to allow the operator to use solar energy directly or the battery as a power source. The PIR Sensor will trigger the initialization of the system, when motion is detected, the transaction starts. The 360-degree continuous rotation servo motors rotate the string thus pushing the item. A bill and coin acceptor are also integrated for the payment of items. The keyboard matrix is one medium where the user can input the choice of their preference.

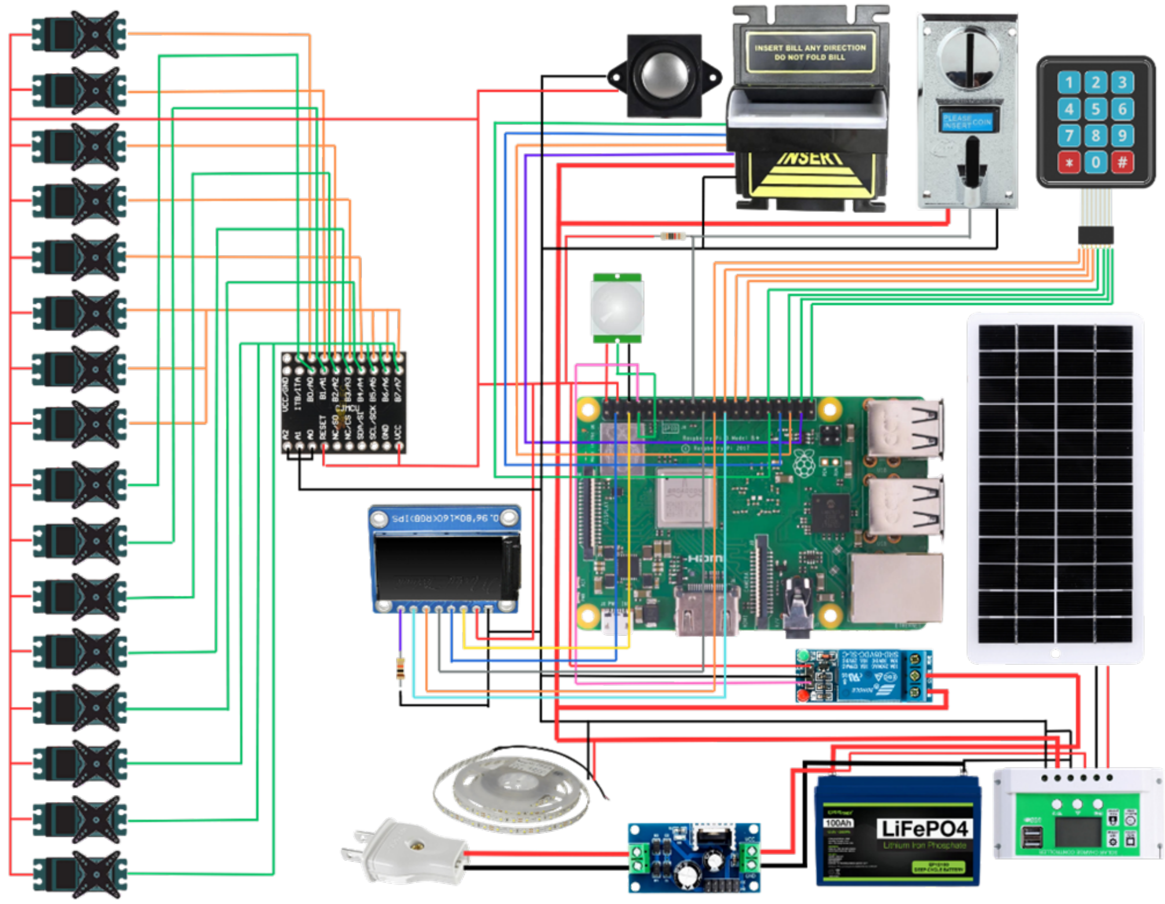

Figure 3: System Architecture

3.4. System Prototype Implementation

This figure 4 shows the prototype implemented by the developers to showcase and demonstrate the functionality and efficiency of an IoT-based vending machine using solar-powered energy. This integration ensures eco-friendly and sustainable power usage, as an alternative to traditional power sources. In addition, the vending machine system is equipped with Conversational AI assistance allowing user interactions through voice commands for a seamless and hands-free experience. This mix of IoT technology, renewable energy, and AI-driven interaction demonstrates automated vending systems' future potential for boosting consumer convenience while reducing energy use.

3.5. Mobile Application

This figure 5 shows the dashboard of the mobile application developed. This shows the overall analysis of the consumption of the IoT-based vending machine. It shows two graphs: quantity of sales and revenue for the current week. It shows the number of sales made per day along with its revenue. This could provide the vending machine operators with a summary of the usage of the system: how much they earned and the frequency of sales.

This figure 6 shows the Inventory Tab of the application. This provides real-time monitoring capability for the vending machine operator. It gets updated every purchase made by the consumer. The operator can also edit out the inventory and the information of the product in each slot. In addition, the operator will be notified once a product is almost out of stock. This will help them be updated to the inventory of the vending machine and they can refill it even before it fully runs out of stock.

In the Notifications Tab, the vending machine operator will be able to see all the notifications they

Figure 4: System Prototype Implementation

Table 1
Five-point Likert Scale

Criteria	Numerical Value
Excellent	4.21 - 5.00
Very Good	3.41 - 4.20
Good	2.61 - 3.40
Fair	1.81 - 2.60
Poor	1.00 - 1.80

received based on the transaction with the system. They will be notified if a product is almost out of stock, if it's out of stock, and if they were able to refill or update the product inventory.

The figure 8 shows information about the user. The Account Tab also contains the Settings Tab wherein the user can configure the Wi-Fi connection of the vending machine system, add products for future references, log out of their account, and delete their account.

3.6. System Evaluation

To assess the system's performance, 100 respondents were asked to answer a survey based on ISO 25010:2023 standard. The assessment form provided allowed respondents to gauge the overall impact and effectiveness of the system. The effectiveness of the system was evaluated using a five-point Likert scale with the focus on Functional Suitability, Performance Efficiency, Interaction Capability, Reliability, and Maintainability shown in Table 1:

1 Functional Suitability: Evaluated the system's ability to provide real-time monitoring capabilities to the vending machine, utilize solar panels as an alternative energy source, and conversational AI to provide user engagement.
2 Performance Efficiency: Evaluated the system's ability to perform its function and efficiency in the use of its resources under specified conditions.
3 Interaction Capability: Evaluated the system's ability to be interactable and complete specific tasks based on the conversational AI.

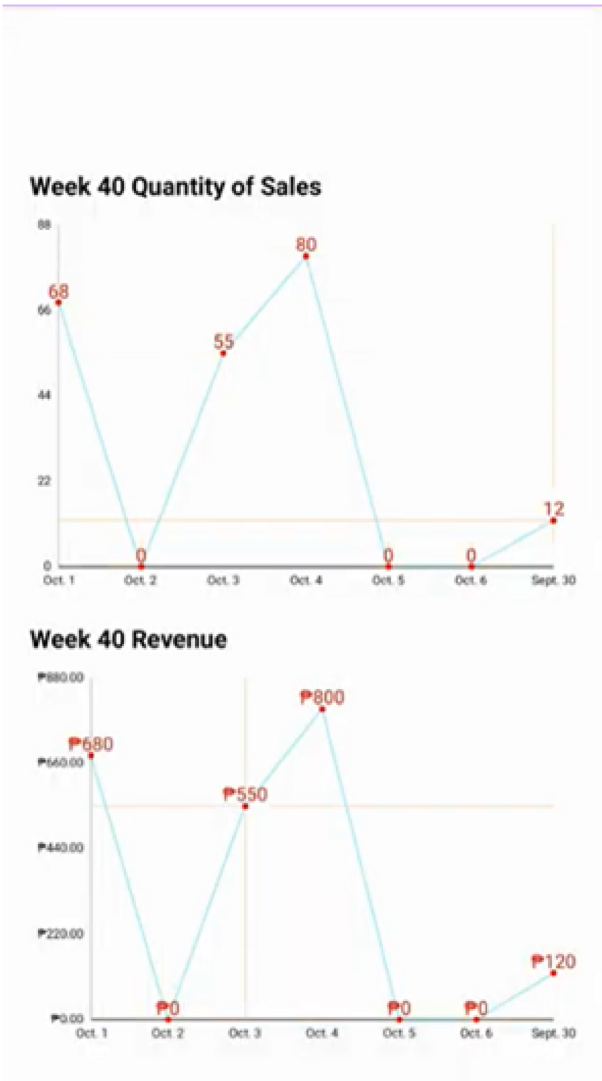

Figure 5: Dashboard Tab

Table 2
Population and Sample

Criteria	Numerical Value	Percentage	Sampling Method
Vending Machine Users	50	90.91%	Purposive
Poor	5	9.09%	Sampling

4 Reliability: Evaluated the system's ability to perform its functionality under specified conditions for a specified period of time.
5 Maintainability: Evaluated the system's effectiveness and efficiency to be modified and adapted to changes with little to no compromise.

The target population of the system had experience in using vending machines or at least familiar with the concept of who can provide observations for the needed information for the study. To ensure a sufficient sample size. The developers target at least fifty vending machine consumers and five IT professionals. In addition, purposive sampling, a non-probability technique, was used to select vending machine users based on specific criteria that are relevant to the research objectives. This focus and relevant sample are expected to provide valuable insights into meaningful conclusions.

In order to examine the data gathered by the developers, the following statistical tools were used in

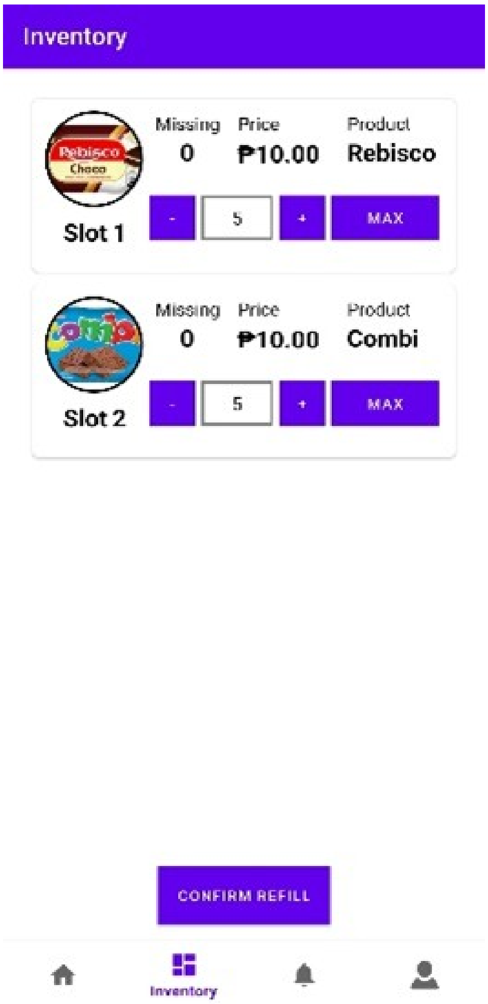

Figure 6: Inventory Tab

this study. The developers will use the following statistical treatments for this study:

1 Percentage: used to get the percentage of the distribution of respondents in each of the categories considered. This was used to show the profile of the data gathered from the respondents.
Formula:

$$P = \left(\frac{f}{n}\right) \times 100\%$$

Where:

- P = Percentage (in %)
- f = Frequency of each group of respondents in the sample size
- n = Total sample of respondents

2 Mean: used to find the average value of a specific variable in the data. It allows developers to understand the typical value of the parameter being studied.
Formula:

$$\bar{x} = \frac{\sum x}{n}$$

Where:

- $\bar{x}$ = Sample Mean
- x = Frequency of each group of respondents in the sample size n

Figure 7: Notifications Tab

- n = Total sample of respondents

3 Mode: the value that has a higher frequency in a given set of values. It is the value that appears to be the greatest number of times.

4. Results and Discussion

The results are shown in tabular form, with the average score for each goal and its subcategories according to the ISO/IEC 25010:2023 framework. Functional Suitability, Performance Efficiency, Interaction Capability, Reliability, and Maintainability are some of these categories.

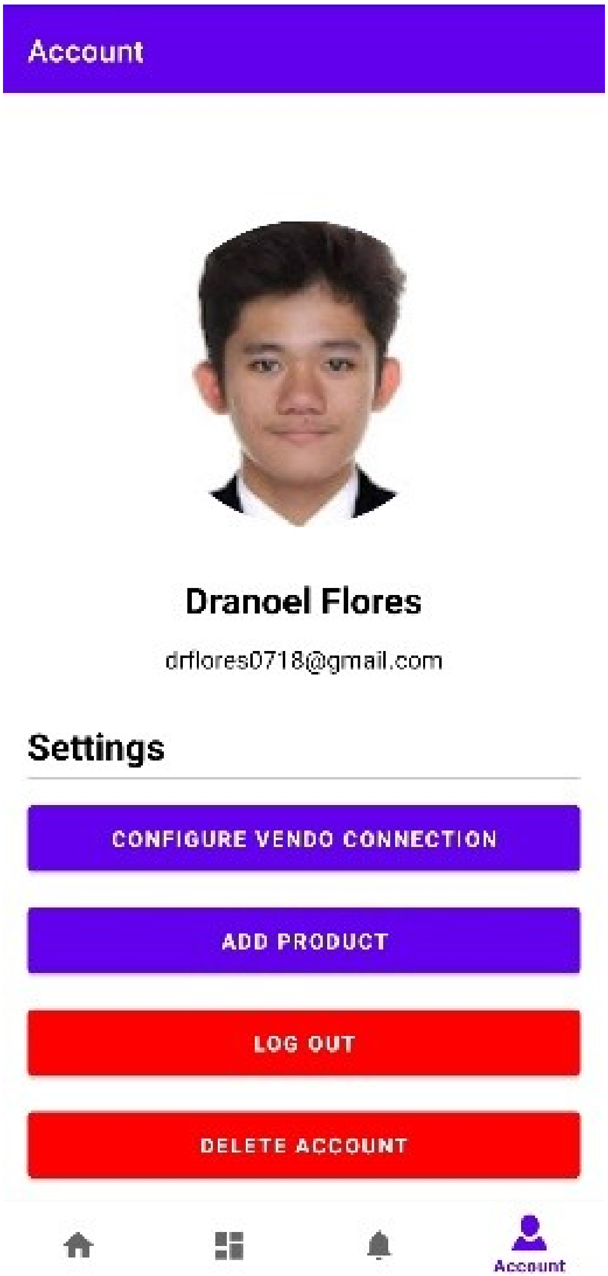

Figure 8: Account Tab

4.1. Evaluation Results

The ISO/IEC standards offer a framework for assessing software quality, which were implemented in this study. This model contains ten quality attributes in total that can be used to evaluate the overall software quality. The following data were obtained from an ISO 25010:2023 analysis of the paper "An Internet of Things Based - Revolutionizing Vending Machine System with Solar Panel and Conversational AI Assistance." With the score of 4.86 for Functional Suitability, a score of 4.86 for Performance Efficiency, 4.95 for Interaction Capability, 4.83 for Reliability, and 4.70 for Maintainability; the system has demonstrated its effectiveness in meeting the users' needs and expectations and interpreted as Excellent.

Table 3
Summary of System Evaluation Results

Criteria	Numerical Value	Interpretation
Functional Suitability	4.86	Excellent
Performance Efficiency	4.86	Excellent
Interaction Capability	4.95	Excellent
Reliability	4.83	Excellent
Maintainability	4.70	Excellent
Overall Mean	4.84	Excellent

Table 4
Functional Suitability Testing

Criteria	Numerical Value	Interpretation
Functional Completeness	4.74	Excellent
Functional Appropriateness	4.98	Excellent

Table 5
Performance Efficiency Testing

Criteria	Numerical Value	Interpretation
Time Behavior	4.86	Excellent

Table 6
Interaction Capability Testing

Criteria	Numerical Value	Interpretation
Operability	4.92	Excellent
User Engagement	4.98	Excellent

4.2. System Evaluation

The table below shows the numerical summary of the evaluation results for the system according to the ISO 25010:2023 as evaluated by the respondents. The overall mean of 4.84 underscores the system's exceptional satisfaction, asserting its suitability, efficiency, interaction capability, reliability, and maintainability. This feedback from respondents hence indicates the system's success in fulfilling its objectives.

The table above shows the numerical summary of the evaluation results for the system according to the ISO 25010:2023 as evaluated by the respondents. The overall mean of 4.84 underscores the system's exceptional satisfaction, asserting its suitability, efficiency, interaction capability, reliability, and maintainability. This feedback from respondents hence indicates the system's success in fulfilling its objectives.

Table IV above shows the summary of the evaluation results for the system in terms of Functional Suitability. Functional Completeness shows a score of 4.74 while Functional Appropriateness gained a score of 4.98, both indicating an Excellent score.

Table V above shows the summary of the evaluation results for the system in terms of Performance Efficiency. Time Behavior shows a score of 4.86 indicating an Excellent score.

Table VI above shows the summary of the evaluation results for the system in terms of Interaction Capability. Operability shows a score of 4.92 while User Engagement gained a score of 4.98, both indicating an Excellent score.

Table VII above shows the summary of the evaluation results for the system in terms of Reliability. Faultlessness shows a score of 4.84 while Availability gained a score of 4.82, both indicating an Excellent

Table 7
Reliability Testing

Criteria	Numerical Value	Interpretation
Faultlessness	4.84	Excellent
Availability	4.82	Excellent

Table 8
Maintainability Testing

Criteria	Numerical Value	Interpretation
Modularity	4.74	Excellent
Modifiability	4.66	Excellent

Table 9
Solar Panel Reliability Testing

Day	Weather Condition	Solar Power Duration (Hours)	Observation
Day 1	Sunny	10	Optimal charging and powering conditions with direct sunlight.
Day 2	Cloudy	5	Reduced sunlight led to shorter powering time.
Day 3	Cloudy	6.2	Similar conditions to the previous day.
Day 4	Sunny	11.2	Direct sunlight resulted in efficient charging and powering of the machine.
Day 5	Partly Cloudy	7.1	Some interruptions in sunlight caused moderate delays.
Day 6	Partly Cloudy and Brief Rain	4.2	Rain and intermittent clouds impacted charging.
Day 7	Mostly Cloudy	3.9	Limited sunlight led to the shortest operation of the week.

score.

Table VIII above shows the summary of the evaluation results for the system in terms of Maintainability. Modularity shows a score of 4.74 while Modifiability gained a score of 4.66, both indicating an Excellent score.

4.3. Solar Panel Reliability

To test the capability and reliability of the solar panel to power the vending machine prototype as an alternative power source instead of traditional power sources, the researchers charged the vending machine numerous times and recorded the performance metrics during each cycle. These measures were then contrasted with the vending machine's specifications. The data that was gathered provided insight into the viability of using solar energy as a substitute for powering vending machines.

The table above shows how long the vending machine can be sustained by the solar panel only. On days with optimal sunlight, the vending machine was powered for longer time frame, demonstrating the solar panel's efficiency under ideal conditions. The impact of weather fluctuation on the charging process was also demonstrated by the considerable decrease in powering the machine during cloudy days or times with less sunlight. This table illustrates the dependency of the charging time on weather conditions, emphasizing the importance of stable and ample sunlight for efficient operation of the solar-powered vending machine. It is important to note that this data was gathered from the vending machine prototype. In a larger machine, which requires more power to operate, a bigger and more robust solar panel would be necessary to meet the increased power requirements for both machines and their battery. In addition, charging time is influenced by the weather and environmental conditions such as temperature and physical placement of the vending machine. If the vending machine is placed in an area with consistent exposure to direct sunlight it would perform better compared to one located in a shaded or less sunny area.

5. Conclusions and Recommendations

This section delves into the research's findings, draws conclusions based on the results and discussions, and provides recommendations for further enhancing the system. In addition, suggestions for system improvement and enhancement will be made in order to direct the upcoming direction and maximize the usefulness of the system. By taking a comprehensive approach, we hope to offer clear comprehension of the research findings and open the door for strategic improvements in the effectiveness of the system.

5.1. Conclusions

With the system evaluation and in alignment with the project's objectives, the developers reached the following conclusive findings:

1 The development of the mobile application as a platform to monitor the vending machine proved as an effective way to remotely gain access to check its status. Showcasing the vending machine's inventory also provided the vending machine's operator about the activity of the vending machine: sale, revenue, and inventory. This advancement contributes to a smarter and efficient academic technology beneficial to vending machine operators.

2 Through the study, the developers successfully addressed the continuous electricity consumption of vending machines. The vending machine was able to utilize solar cells as an alternative to traditional power source while at the same time being more sustainable. This part of the study highlights the importance of using renewable energy sources as an alternative.

3 User engagement and involvement were greatly increased by the usage of Conversational AI support. Voice commands enabled conversational communication between users and the system, enabling real-time interactions and smooth platform navigation, resulting in an enhanced and user-friendly experience.

5.2. Recommendations

Based on the analysis of the study's findings, the developers offer the following recommendations to further improve the Internet of Things Based - Revolutionizing Vending Machine System with Solar Panel and Conversational AI Assistance:

1 To enhance the availability of the system, consider implementing more products in the vending machine. This will allow consumers to have more options to choose from when ordering. In addition, the system can also have a cooling system to introduce more items like soft drinks.

2 Future researchers may also implement a bigger solar cell for bigger system or introduce other renewable energy as an alternative to traditional power generation.

3 To broaden the scope of Conversational AI, it is recommended that future researchers focus on enhancing its capabilities beyond simple command recognition, exploring more advanced interactions and functionalities.

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Declaration on Generative AI

The authors have not employed any Generative AI tools.

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