PAPER • **OPEN ACCESS**

Design & Development of a Voice-Enabled Vending Machine for Green Buildings

To cite this article: Vaibhav Bisht *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **573** 012041

Design & Development of a Voice-Enabled Vending Machine for Green Buildings

Vaibhav Bisht[1], Patri Sanjana[2] and V G Sridhar[1]

[1]School of Mechanical Engineering, Vellore Institute of Technology, Chennai 600127, India

[2]School of Electrical Engineering, , Vellore Institute of Technology, Chennai 600127, India

Email: patri.sanjana2017@vitstudent.ac.in

Abstract. Green buildings form a milestone technology for a sustainable and eco-friendly atmosphere. A sophisticated process management and control with advanced warning systems and sustainable user-friendly buildings is their existing norm, as per the Indian Green Building Council. With efficient resource utilization and waste management along with different user-friendly working systems, these optimized building spaces reduce various utilization costs, parallelly increasing the safety, hygiene, and comfort standards. Their norms for the future eye at a sustainable development scheme using different renewable energy technologies with solar energy having developed as a fast-growing alternative due to its usability in various rural and urban dwellings. This paper discusses the concept of an automated voice recognition based vending machine powered by solar energy. The sophisticated Voice Recognition System (VRS) changes the role of humans in the associated process and hence, should be an integral part of future green buildings. Intelligence to the working system is incorporated by Machine Learning (ML) and its flexible Internet of Things (IoT) platform entails high customizability with a good Prognostics & Health Management (PHM) media. An implementation of the framework is worked upon, discussing the design of a food-dispensing unit that can be used in hostels, restaurants, and other areas of medium to a large gathering. Food can be served without any human intervention whilst maintaining high levels of cleanliness, minimizing waste, and reducing operating costs.

1. Introduction

With the ever-growing technological development in today's date, there is a constant focus on making life easier for men. Machine Learning, which Lee et al. [1] say was once called a black-art technique, now gives human-like or even greater thinking capabilities to modern-day machines. The Internet of Things (IoT) generates a decentralized working environment with a data-sharing platform for remote operation and efficient collaboration, Kamble et al. [2]. Pratap et al. [3] say IoT also develops an interconnection of computer tactics, digital and mechanical devices. With this technological feat, man now demands a safe, healthy, and convenient way of life with minimal hit on his pocket. Though contrary to popular belief, Green Buildings today boast of high inmate safety, good hygiene standards, resource-efficiency, and effective waste management systems, all adding up to create a flexible and convenient living or working space. Wang et al. [4] call these similar to intelligent buildings. They also add that Green Buildings adopt various automated systems that provide an interconnected, efficient, and optimized operation control, management, and maintenance environment of all building appliances and facilities. With regard to creating an efficient operating environment, there is a prime focus on renewable energy technology to power the sophisticated working systems of Green Buildings. As the concept of Green Buildings is now spreading to more and more urban installations, solar energy has developed as one of the most feasible alternatives, primarily due to it not being very site-specific like the other kinds. Wind energy is not expected to generate a considerable yield due to comparatively poor wind flow patterns being observed between the packed urban dwellings. Other sources such as nuclear and hydroelectric power need several years of construction time, major financial investments and disturb the surrounding ecosystem along with its living population.

Vending Machines have had a significant impression among the masses due to their ease of use, high portability, minimal waste generation, and low operating costs. Though, the most important is their versatility as we see how these are being used in an array of operations, from the humanitarian aid programs in Africa to bolstering the automation spree in Europe. Vending machines can be a significant part of the Green Building working mechanism, with the building not only being a residential complex but anything like a residential hostel or a corporate office. Growing health and sanitation concerns have also inflicted a new working system for using such machines without the spread of any contagious diseases. The proposed contactless voice-enabled vending machine model comes as an automated system with a user-friendly interface for the customer and a convenient working environment for the employed operator, laden with a great deal of flexibility for use in various scenarios.

2. Literature Review

The study of the use and scope of vending machine technology has a significant historical background. It finds use in an array of businesses, offering several items from raw meat to cooked pizzas. Hwan [5] also adds other items like beverages, paper, sanitary utensils, postage stamps, and toys.Pereira et al. [6] propose the term “vending supply chains” where items like fresh milk can be sold straight from vending machines, eliminating intermediate investment on the packaging, transportation, and distribution, posing an environmental as well as monetary advantage to the stakeholders.

Along with the monetary benefits, vending machines also help in tackling different social issues and promote ideas for a better way of living. Obadia et al. [7] speak about Syringe Vending Machines (SVM) that are being used in countries like Australia and Germany. These take contaminated syringes and give a sterilized one in return, aiding the ongoing fight against drug abuse. Though, as per a study performed by Philbin et al. [8], easy access to such machines can also increase the number of such IDUs. Han-Markey et al. [9] show how being part of a national wellness policy, vending machines were used to sell low-sugar drinks in schools, creating a low-calorie intake for the students and also helping the schools make good revenue. Rosi et al. [10] show a study on how vending machines, using iconographic messages, can be used for an easy sale of healthy eating items whilst discouraging unhealthy diets.

To meet customer personalization needs and reduce waste, vending machines are also coming with pre-installed systems using new concepts of data analytics and machine learning. Cheng et al. [11] have proposed a framework for the recommendation of localized products from the transaction data of the past, using the Bayesian Network, Decision Tree, and *k*-means clustering. This intelligent system analyses the products and their attributes to pick the items that would be preferred the most by the local crowds.

3. Vending Machine Working Framework

The proposed voice-enabled vending machine primarily consists of a contactless transaction method. It’s working framework consists of three basic parts:

3.1 Consumer Interface

Acting as the foreground of the machine, the consumer interface establishes the interaction of the machine with the customer from ordering to collection of the final order. The first system in the Consumer Interface is the Voice Recognition System(VRS). The VRS system, developed using Arduino Nano 33 BLE Sense and Machine Learning, is used for contactless identification and ordering of items to be purchased by the user. An integrated payment and identification panel has also been developed to provide multiple means of ordering. The consumer interface also consists of a primary 15-inch LCD screen installed on the front end for presenting the customer with relevant ordering and transaction details like payment status and stock availability. It does not come enabled with any touch features in order to sustain the aforementioned contactless ordering procedure.

3.1.1 Voice Recognition System (VRS)

The process of development of voice recognition is divided into four stages, shown in Figure. 1. The first stage is called the Data collection stage. Around 1000 sets of data must be collected to train the model. Google command data is used as our data set, it consists of multiple samples of vocal inputs which are used for the initial training of the Machine Learning algorithm to recognize different kinds of voices. To add other different words, a folder is created in the dataset directory and a bunch ofsamples of people saying that word is taken. The second stage is the extraction of certain features of the data. Since raw data cannot be used directly into the model due to various external acoustic disturbances, post-processing of the data using Fourier transform or power spectral density must be performed to find the power components of the signal.

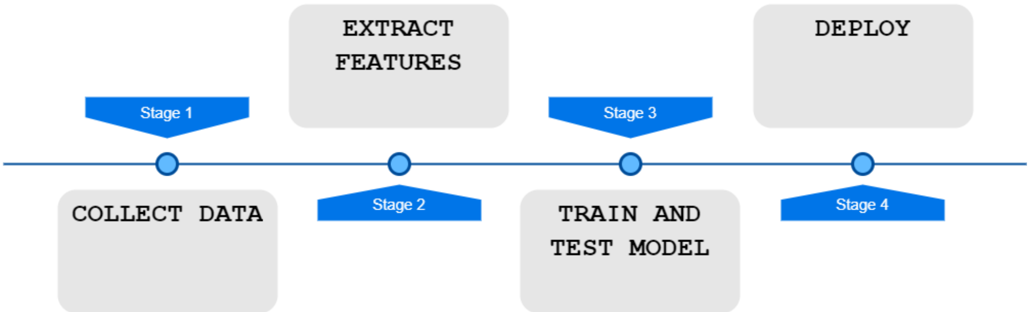

Figure 1. Stages in development of VRS.

The human brain identifies frequencies over a period of time to identify the voices around it. For machine learning algorithms to identify such frequencies, the Mel Frequency Cepstral Coefficient (MFCC) is used. It is a Fast Fourier Transform (FFT) of a moving window of the audio signal, which is taken to indicate the power at each frequency component for that particular time segment. The power graph is then filtered by a Mel-spaced filterbank which is spaced at linear (under 1 kHz) and logarithmic (over 1 kHz) intervals across the frequency spectrum. The output of these operations provides us with the Mel Frequency Cepstral Coefficient (MFCC) terms. The next window is taken and the process is repeated to calculate all the MFCCs for the audio signal.

The third stage is to train them and develop the algorithm using the data available. Each word is represented with a number and arranged in alphabetical order. These numbers are used to check if the predictions match the actual value. Convolution Neural Network (CNN) is used to identify specific words. The neural network is then implemented into code. An optimizer is used to change weight and biases for more accuracy. The fourth and final stage of the VRS is the deployment of the developed model on the Arduino Nano 33 BLE Sense Board. The .tf file written in python is converted into .h file using a built-in function in python. This file is downloaded and copy-pasted into the directory of the Arduino sketch for use.

3.1.2 Payment/ Identification Machinery

For cash payment using the in-built panel, an NV10 USB note acceptor (run by Arduino Uno) is used which sends a pulse signal to Arduino as output when cash is fed into it. To detect this output, an interrupt input is used in Arduino. Inputs are detected by the microcontroller at an interval of one minute. If the input is not given for one minute, the interrupt pin stays untriggered causing the loop to break and the total amount to be displayed.

For places where the payment is made beforehand, RFID tags can be used for identification. Each individual is provided with a unique tag (transponder) which is detected by the RFID reader. As shown in Figure 2, the RFID reader generates a high-frequency electromagnetic field which induces a voltage in the antenna of the tag due to electromagnetic induction. This causes the transponder to power up and enables it to send messages to the RFID reader. Each tag has a unique UID number and access to the machine is granted only to those individuals whose UID number is approved.

Figure 2. Electromagnetic Induction between Tag and Reader.

3.2 Microcontroller Web

Due to the use of multiple microcontrollers and microprocessors for several applications, a central point of contact between the programmer and the system is established using a Raspberry Pi (Model B+, RAM - 512 MB). This ensures an easier and efficient way of communication between all the microcontrollers. The various controlling devices involved include1) Arduino Uno: RFID identification, NV10 operation, and control of physical devices/ actuators such as motors and solenoid valves, 2) Arduino Nano BLE 33 Sense: functioning of the Voice Recognition System (VRS) and 3) NodeMCU: IoT applications such as display in Mobile Application and Database maintenance.

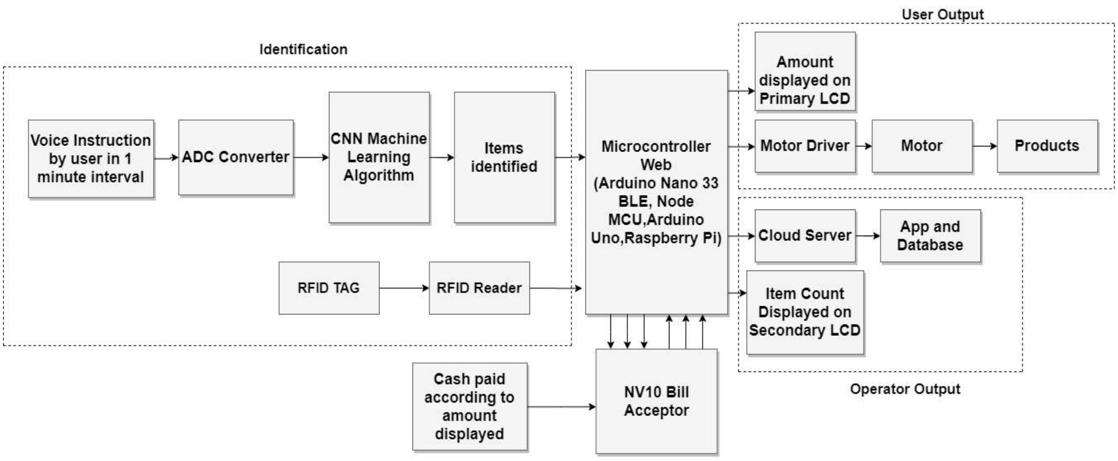

Figure 3. Flow of information in voice-enabled vending machine.

All these devices together act as UUGear devices (from UUGear Solution) with unique IDs to Raspberry Pi. The programming library on the Raspberry Pi side provides APIs in C and Python to identify particular UUGear devices and interact with their digital/analog pins. A 7 port USB Hub for Raspberry Pi from UUGear is used to integrate multiple microcontrollers. Each microcontroller has a unique ID provided to it at the time of manufacturing. For easier identification of the device by the Raspberry Pi, this ID can be stored in EEPROM of the device. After this, each device then receives commands and sends reports to the Raspberry Pi via a serial port. This interconnected system functions as a central operating unit as shown in Figure 3. and is named as *The Microcontroller Web.*

3.3 Operator Interface

Since a vending machine is an automated system that functions without any human assistance, Blough [12] says keeping track of inventory and working conditions of such machines is difficult, leading to failures that may render the machine useless and unattended for long periods of time. The discussed machine design respects the inherent role of the human operator. The Microcontroller Web constantly presents him/her with real-time information like remaining item count and battery percentage to plan and work according to system requirements.

To present real-time data to the operator, a secondary 15-inch LCD screen is installed on the operator's side. It comes with a capacitive touch screen feature that will only be enabled at the time of system reconfiguration and maintenance checks.

Blynk, a platform that the different IoT-based devices use to interact and present all real-time information directly on one's mobile phone. Durani et al. [13] say it provides a personal dashboard to the users on their mobile phones which enables them to create a graphical interface consisting of different widgets to view and store the collected information. It can also be used to customize the machine's settings and update machine status while being at some remote or faraway location, Pranay et al. [14].For access to the data on the application, an authentication code is generated by the Blynk platform's mobile application which is sent to the application user's email ID. It is included in the Arduino IDE file, which holds the code for the Node MCU. The Wi-Fi Username and password are then included in the code to connect the system to the internet.

3.4 Power Source

For an uninterrupted power supply to the system, a solar panel is attached to ensure continuous operation and to develop a renewable, self-reliant system. The main power supply is provided to the Microcontroller Web using Raspberry Pi (Rpi). as shown in Figure 4. The components included to develop this system are a 12W solar panel, PiJuice power management board (UPS) with attached 1820mAh Lithium-Ion battery. The ratings of the components are decided based on the amount of power required by the Rpi to operate three microcontrollers along with external loads such as sensors and motors. The average current drawn by these components will be around 2A, which gives us the power requirement of 10W. To accommodate external losses a 12W solar panel is used.

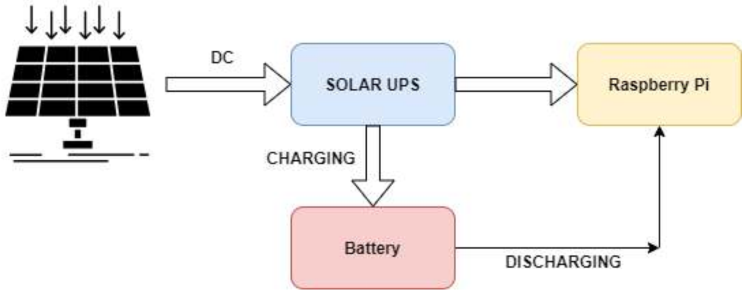

Figure 4. Solar power transfer framework.

A power management board, attached to the solar panels, is used to regulate the voltage and current coming from solar panels. The board performs a safe shutdown if the power gets too low. The device has self-protecting features with an in-built temperature sensor to monitor the temperature of the battery. The UPS is connected to Raspberry Pi for operation.

4. Implementation: Food Dispenser

The current food distribution system used in large food & dining halls comes with certain flaws. Looking at the considerable amount of human workforce associated with an array of tasks, there turns out to be minimal regard for hygiene in many cases. Wastage due to spillovers or mishandling is quite common. The manual payment or identification processes for such a big population might be frustrating for a lot of people. Serving multiple items to such big populations also takes a considerable amount of floor space.

The proposed vending machine technology provides food using a voice-enabled contactless distribution system, creating safe and hygienic serving standards. With most of the tasks, including payment/identification being controlled by the autonomous systems, wastage of time and food is cut-down to minimum levels. Being portable and serving multiple items from a single machine, it can be easily moved to different places, feeding different food items to several people.

4.1 Working

Once the payment or identification for the meal is confirmed, the plate or the collection tray is to be kept in the collection bay for the respective food item. An Ultrasonic Sensor (HC-SR04) is installed below the base of the platform of every bay to confirm the presence of the mentioned plate or collection tray. The individual can mention the item and quantity in the Voice Recognition System (VRS).

For countable items like ice-cream, a regular input of the number the individual wants is given, which is then dispensed using a conveyor system (run by a 12V DC Dual shaft Motor). For uncountable items like curry, each of the given items is stored in a container and vented using a 12 V solenoid valve.

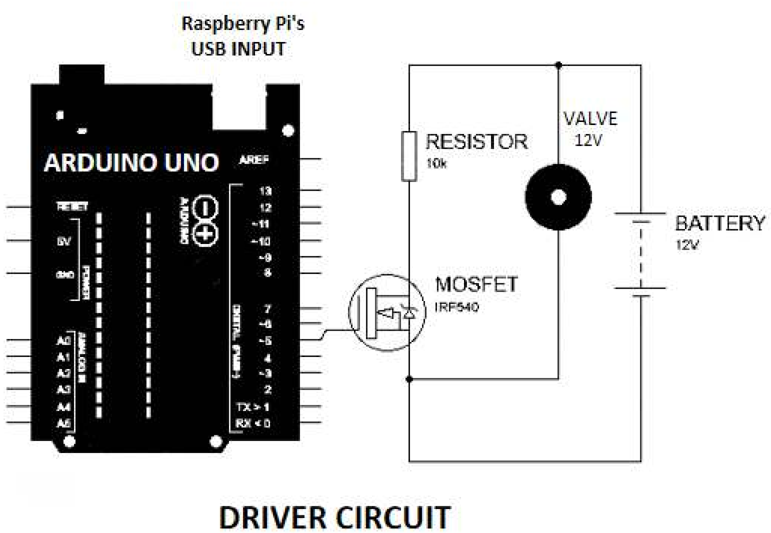

Figure 5. Driver circuit for Solenoid Valve.

A driver circuit (shown in Figure 5.) is used for the operation of the solenoid valves while protecting the Arduino from a short circuit. The driver circuit is made up of IRF540 Mosfet and 10k resistor, the drain of the MOSFET is connected in series with the valve since the rating of the

MOSFET is higher, it saves the Arduino from any likely failure or damage. The standard serving sizes, namely ‘Regular’, ‘Medium’ and ‘Large’ have been defined based on the time the valve is open (code is shown in Figure. 6) and the required size is supposed to be given by the individuals in the Voice Recognition System (VRS).

```
Solenoid_Valve §
int x=1000;
int Solenoid_Valve_Pin = 5;          /* Connecting Solenoid Valve's
                                     Pin To Pin-5 of Arduino Uno */
void setup() {
  pinMode(Solenoid_Valve_Pin,OUTPUT);
  Serial.begin(9600);
}

void loop() {
  if(Serial.available()){                /* For Serial Communication
                                            with Raspberyy Pi */
    if(Serial.readString()=="Large")          /* large sized
                                                 serving */
    {
      digitalWrite(Solenoid_Valve_Pin,HIGH);
      delay(3*x);
      digitalWrite(Solenoid_Valve_Pin,LOW);
    }
    else if(Serial.readString()=="Medium")      /* Medium sized
                                                   serving */
    {
      digitalWrite(Solenoid_Valve_Pin,HIGH);
      delay(2*x);
      digitalWrite(Solenoid_Valve_Pin,LOW);
    }
    else if(Serial.readString()=="Regular")     /* Regular sized
                                                   serving */
    {
      digitalWrite(Solenoid_Valve_Pin,HIGH);
      delay(1*x);
      digitalWrite(Solenoid_Valve_Pin,LOW);
    }
  }
}
```

Figure 6. Code for standard serving sizes (Software : Arduino IDE).

4.2 Real-Time Notification System

Real-time monitoring of the system for maintenance and hygiene is done through the operator interface.

HC-SR04 (Ultrasonic Sensor) is used for monitoring the level of uncountable items like curry. These are placed on the lids of the respective containers.

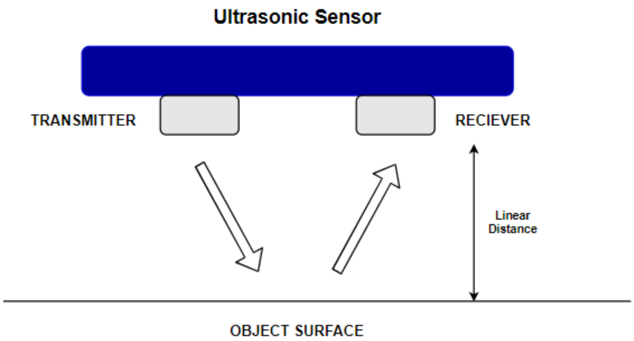

Figure 7. Working of Ultrasonic Sensor.

As shown in Figure 7., the transmitter emits an ultrasonic signal which is reflected by the item and collected by the receiver. The time taken is used to determine the linear distance traveled by this wave. Change in distance traveled signifies a change in item levels.

Food items are not supposed to be exposed to moisture and should not be put in the wrong surrounding temperature as they are bound to lose taste and texture in such conditions. DHT22 sensors are installed to monitor humidity and temperature to avoid such scenarios. For humidity, the sensor has two electrodes with a moisture-holding substrate between them. When there is a change in humidity, the change in moisture levels of the substrate causes the resistance of the circuit to change. For the temperature, it consists of a thermistor, a resistor that changes circuit resistance with a change in temperature. The change in resistance in the circuit alters the current flow, which is processed by a pre-installed IC to find the temperature and humidity.

For countable items like ice-cream, an " interrupted laser counter" system is installed. This consists of a laser beam that is projected on an LDR sensor. If any item passes through this channel (interrupting laser flow), the count is increased by one. Figure 8. shows the proposed conveyor system installed with the interrupted laser counter system. The laser beam is interrupted by the item moving with the belt and the count is increased by one.

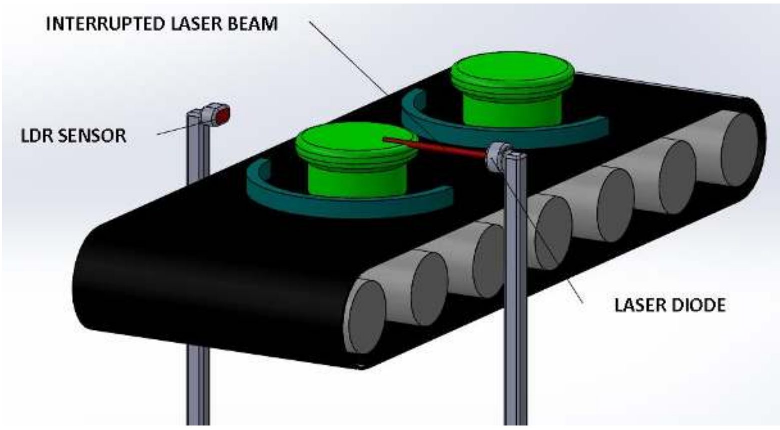

Figure 8. Conveyor System with interrupted laser counter system.

4.3 Layout

Figure 9. shows that in feeding the big crowds of food halls, each item is served by an individual server. In the proposed layout, a single vending machine can be used with only one operator being required for all the maintenance tasks. Though, depending on the menu for different days, the number of operators and machines required may be subject to increase.

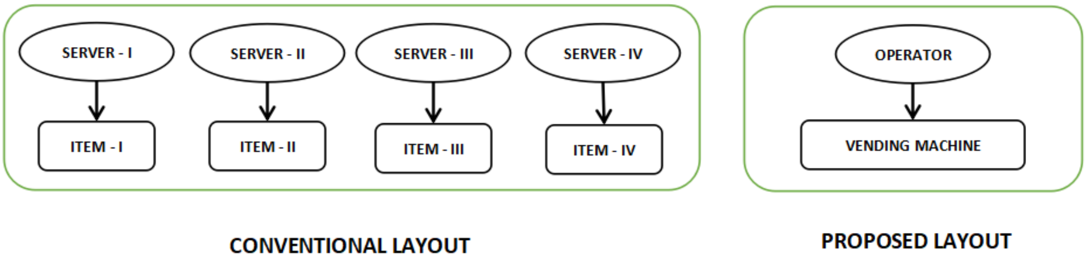

Figure 9. Layout of Conventional System against Vending Machine-Based System.

The proposed machine runs on a sophisticated framework with an intelligent system comprising technologies like Machine Learning and The Internet of Things (IoT). It uses an energy-efficient Microcontroller Web structure using solar power which is one of the most feasible forms of

IOP Conf. Series: Earth and Environmental Science **573** (2020) 012041 doi:10.1088/1755-1315/573/1/012041

renewable energy among urban as well as rural dwellers. The customer interface enabled with the Voice Recognition System (VRS) creates an interactive ordering system and eliminates all sorts of contact between people. The two options of payment and RFID provide businesses and other corporations with the flexibility to use the machines in various scenarios, moving it to various places and catering to larger populations. The machine requires minimal human workforce and the installed real-time monitoring system helps the operator as well as the supervisors to keep track of all machine operations from remote locations.

The authors have come up with the discussed framework with due consideration for all the associated aspects of the machine's functioning. The scope of such automated systems, the different areas where these can be used, the rising trend of the concept of green building, and the ongoing development of renewable energy technologies have come as the prime source of motivation and work is underway for the practical implementation of the discussed idea.

5. Conclusion

As vending machines have already been popularized in countries such as Japan, the USA, and the UK, growing health concerns and the global spread of diseases such as COVID-19 has made them a necessity rather than a luxury. With work underway on the development of a working physical model, the voice-enabled vending machine design incites interest in various fields of business, technology, and academia. The Microcontroller Web system provides the users with high customizability wherein one can use any additional setup as per her or his requirement. Adding to the existing framework, with more powerful microcontrollers, better knowledge of Machine Learning, and the development of solar technology along with other forms of renewable energy, it can be used in even more complex environments with longer life for multiple elaborate tasks that allow classification and feature extraction. The system can be improved by connecting Raspberry Pi to the internet, creating its server for multiple payment options including card payment and digital wallet transactions. For healthcare applications, deep learning algorithms for detecting face masks and ensuring social distancing can be used. The discussed example of the food dispenser system shows how the VRS can find use in various unconventional fields. Its versatile systems increase process efficiency and reduce human intervention, all with high levels of hygiene and user-satisfaction, the very motive of a Green Building Environment. The machine can offer multiple functionalities with minimal space and resource utilization. Hence, depending upon the requirement, such systems can be customized to be used in several places like residential buildings, offices, malls, streets, airports, and hospitals.

References

[1] Lee J, Davari H, Singh J and Pandhare V 2018 Industrial Artificial Intelligence for Industry 4.0-based manufacturing systems *Mfg. Letters* **(18)** pp 20–23

[2] S. Kamble S, Gunasekaran A and A Gawankar S 2018 Sustainable Industry 4.0 framework A systematic literature review identifying the current trends and future perspectives *Process Safety and Environmental Protection* **(117)** pp 408–425

[3] Pratap Singh R, Javaid M, Haleem A and Suman R 2020 Internet of things (IoT) applications to fight against COVID-19 Pandemic, Diabetes & Metabolic Syndrome *Clinical Research & Reviews* **(14)** pp 521-524

[4] Wang M, Zhang G, Zhang C, Zhang J and Li C 2013 An IoT Based Appliance Control System for Smart Homes *Fourth International Conf. on Intelligent Control and Information Processing (ICICIP)*

[5] Hwan Lee D 2003 Consumers' Experiences, Opinions, Attitudes, Satisfaction, Dissatisfaction, and Complaining Behavior with Vending Machines *J. of Consumer Satisfaction, Dissatisfaction and Complaining Behavior* **16**

[6] Pereira A, Villanueva-Rey, Vence X, T Moreira M and Feijoo G 2018 Fresh milk supply through vending machines: Consumption patterns and associated environmental impacts*Sustainable Production and Consumption* **15** pp 119-130

[7] Obadia Y, Feroni I, Perrin V, Vlahov D and Moatti 1999 JP Syringe vending machines for injection drug users: an experiment in Marseille, France *Am J. Public Health* **89(12)** pp 1852-1854

[8] M. Philbin M, Mantsios A, Lozada A, Case P, A. Pollini R, Alvelais J, A. Latkin C, Magis-Rodriguez C and A. Strathdee S 2009 Exploring stakeholder perceptions of acceptability and feasibility of needle exchange programmes, syringe vending machines and safer injection facilities in Tijuana, Mexico*Int. J. of Drug Policy* **20** pp 329-335

[9] Han-Markey T L, Wang L, Schlotterbeck A, A Jackson E, Gurm R, Leidal A and Eagle K 2010 A public school district’s vending machine policy and changes over a 4-year period: Implementation of a national wellness policy *Public Health* **126** pp 335-337

[10] Rosi A, Zerbini C, Pellegrini N, Scazzina F, Brighenti F and Lugli G 2017 How to improve food choices through vending machines: the importance of healthy food availability and consumers’ awareness *Food Quality and Preference*

[11] Cheng Lin F, Wen Yu H, Hao Hsu C and Chun Weng T 2011 Recommendation system for localized products in vending machines *Expert Systems with Applications* **(38)** pp 9129-9138

[12] Blough, C. G. (1956) Checking vending machine inventories. *J. of Accountancy (pre-1986)* **102(2)** pp 72–74

[13] Durani H, Sheth M, Vaghasia M and Kotech S 2018 *Proceedings of the 2nd International Conference on Inventive Communication and Computational Technologies (ICICCT 2018)*

[14] Singh Parihar P, Pande K, Sanjana P, Sarkar T and G Kanimozhi 2020 Smart Residential Multi-Level Plantation System *Inter. J. of Adv. Science and Tech.* **29(06)** pp 5135 - 5146