Cashless Vending Machine

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Abstract

This research paper presents the work done to design and fabricate a prototype of a cashless vending machine in Bhutan. The integration of GSM (Global System for Mobile Communications) technology and bank account QR (Quick Response) code scanning into the vending machine's payment system for transactions using local payment applications is the approach taken for enabling a cashless payment system. A straightforward but efficient logic for the vending machine has been developed by integrating and testing a variety of hardware. There is one raspberry pi and touchscreen to be used as a user interface to select the product. When the selection is completed it sends the command to the Arduino uno which will determine whether to send the command to Arduino mega after checking the message received by the GSM module. If the Phone ID and message content matches as specified in the code, then it will transmit the command to mega. The Arduino Mega will turn the motor according to the command from raspberry pi once command is received from Arduino uno. There has been hands-on experience in designing and constructing a customized vending machine solution and it was possible to do this because of the availability of FABLAB CST in the college to get the final prototype.

Key Words: *Vending machine, Arduino uno, GSM, Arduino mega, Raspberry pi, Cashless payment.*

1. INTRODUCTION

Vending machines are automated devices designed to dispense a variety of products including snacks, beverages, lottery tickets, and more. Their primary function is to save time and minimize human effort. One of their key benefits is their flexibility in terms of operating hours (Ratnasri & Sharmilan, 2021).

Using vending machines for the purpose of selling products started only in 1888 as a desperate measure by one chewing gum company that was unable to sustain. For this chewing gum company, the vending machine tactic worked very well and became so popular that they even started calling their product the "penny-candy". After their success many other companies started showing interest and have now advanced to where it is today (Britannica, 2024).

The popularity of vending machines has increased due to the shift towards digital payment methods, such as mobile apps, and the increasing preference for digital or cheques over traditional cash (Sibanda et al., 2020).

In Bhutan, automatic vending machines are relatively rare but can be advantageous for businesses due to their low supervision requirements, high efficiency, minimal space usage, easy maintenance and operation, and mobile functionality. This paper aims to explain the design and development of a prototype of a cashless snack vending machine for the Bhutanese community, offering a range of features and capabilities tailored to enhance user experience.

The vending machine prototype will offer smooth mobile payment options, allowing transactions using smartphones, and a user-friendly touchscreen interface for intuitive navigation and engagement.

However, there are several challenges faced by vending machines in Bhutan. First, there is a lack of compatibility with local payment apps and currency, which can hinder the development of the vending machine sector. Second, there are no experts in the vending machine industry in Bhutan, which limits the growth of the industry.

To overcome these challenges, new entrants must understand the design, functionality, and integration of vending machines with local payment infrastructure. The aim and objectives of this paper includes fabricating an operational vending machine that supports Bhutanese mobile payment apps by scanning QR codes, developing circuit design, electronic payment system, and compatibility with local payment apps, procuring materials, conducting circuit connections, coding hardware, constructing the working vending machine, and assembling it.

2. METHODOLOGY

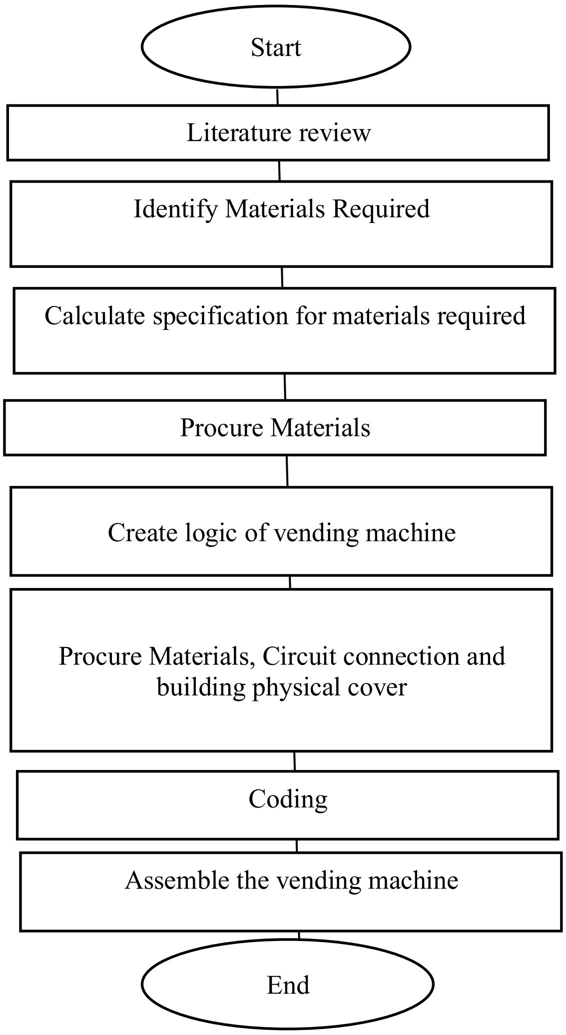

Fig.1: *Methodology*

3. LITERATURE REVIEW

Sultan et al. (2019) has discussed using a GSM architecture to remotely monitor and control energy meters, establishing bi-directional communication lines between the energy meter, service provider, and customer. SMS messaging was used for informing the users about their energy usage. They also enabled a billing mechanism; the smart meter could disconnect the power supply upon exhaustion and reconnect only when it received an SMS from the service provider with the instruction to reconnect (Ratnasri & Sharmilan, 2021).

In another paper by Yusof et al. (2018), they proposed a Smart Energy Meter system that utilizes GSM technology to receive messages, support consumers to remotely monitor their energy usage, and receive warnings through SMS from the GSM module. The Arduino Uno was used as the main controller for delivering data from the energy meter to the GSM module (Yusof et al., 2018).

The integration of GSM and Arduino Uno microcontrollers was a promising approach for remote controlling motors for VMs (Arduino®, n.d.).

4. SYSTEM OVERVIEW

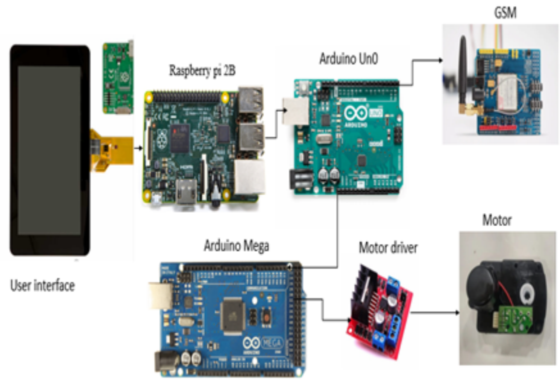

Fig.2: *Hardware connection*

The Arduino Uno acts as the main brain for interfacing with the Raspberry Pi 2B, the GSM SIM900 module, and the Arduino Mega. In this chapter it will show connections between these devices with reference to the Arduino Uno and their functions.

The Raspberry Pi 2B (Cox, 2014) and Arduino Uno are connected using a USB wire. The Raspberry Pi is also connected to a 7-inch touch screen so that users can interact with the VM to convey what they would like to have. Tkinter-based GUI program is used to design the user interface for product selection. There are five items available for selection in the GUI for the users to choose from, and after a selection is made, a serial USB connection transmits data to the Arduino Uno about the product chosen by the user. The Raspberry pi and the touchscreen is also responsible for displaying the QR code for payment so, once a choice is made, the screen shows the QR code for payment for the next thirty seconds before returning to the beginning.

The GSM SIM900 module is connected to the Arduino Uno using the RX (pin 7) and TX (pin 8) pins and configured using the Software Serial library. The GSM module is used mainly for payment verification through SMS. After a command from Raspberry pi 2B is received and stored by the Arduino Uno, the Arduino uno will monitor the SMS received by the GSM module and once it is received it will compare the message to see if it is from a specific phone number and has a specific message. In the case that we do receive the message we were expecting from the specified phone number, the command will be forwarded the Arduino Mega (Tola et al., 2013).

The Arduino Mega (Louis, 2016) is connected to the Arduino Uno through the I2C connection and we use the SDA and SCL pins for this connection. The Arduino Mega acts as the slave while the Arduino Uno acts as the master, so the Uno will be able to send commands to the Mega. The Arduino Mega is used to control the 5 motors that are responsible for dispensing the products and the motors are connected to the motors through a motor driver. As mentioned above the Arduino Uno will forward the command after the payment is verified while the Arduino Mega will be monitoring for the command from Arduino uno. Once the command is received it will activate a motor based on the selection made by the user.

4.1 Circuit Connection and Required Components

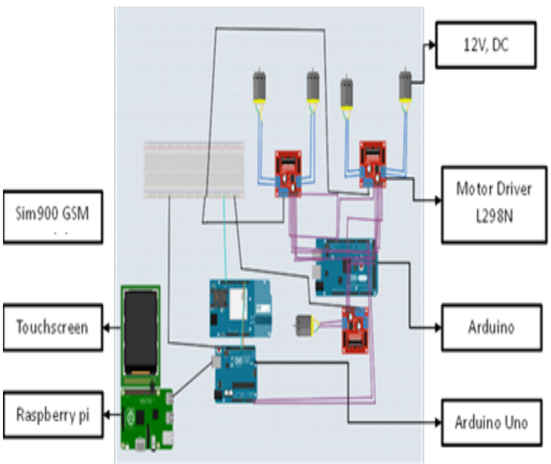

Fig.3: *Circuit Connection*

This designed prototype is using two microcontrollers, one microprocessor, one GSM module and three motor drivers to control five motors.

- Arduino uno
- Arduino Mega 2560
- Raspberry pi 2B
- GSM sim900 module
- L298N motor driver
- 12V DC motor
- 7-inch touchscreen display
- 12V DC fan

4.2 Power and energy calculation

Energy = Total Power ×time
Assuming the VD is powered on for 24 hours:
Energy= 161.5W×24hrs

=3885.6 Wh/day or 3.8856 kWh/ day

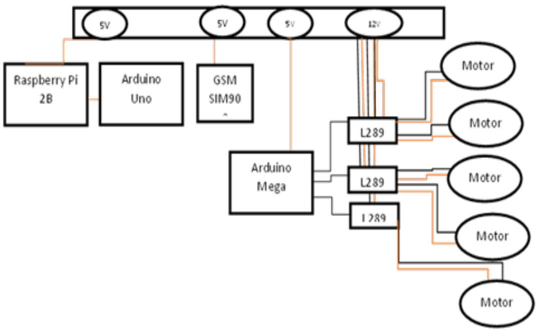

Fig.4:. *Power supply for the components*

Table 1: *Power required by each component*

Sl. no	Component	Maximum power required (Watts)	Qty	Total
1	Motor	3.8	5	19
2	Motor driver	25	3	75
3	GSM sim900	13.5	1	13.5
4	Arduino Uno	10	1	5.5
5	Arduino Mega	5.5	1	2
6	Raspberry pi 2B	2	1	10
7	DC fan	3.6	2	7.2
8	LED light strip	17.6/m	2 m	35.2
	Total power required			161.9

5. LOGICAL FRAMEWORK

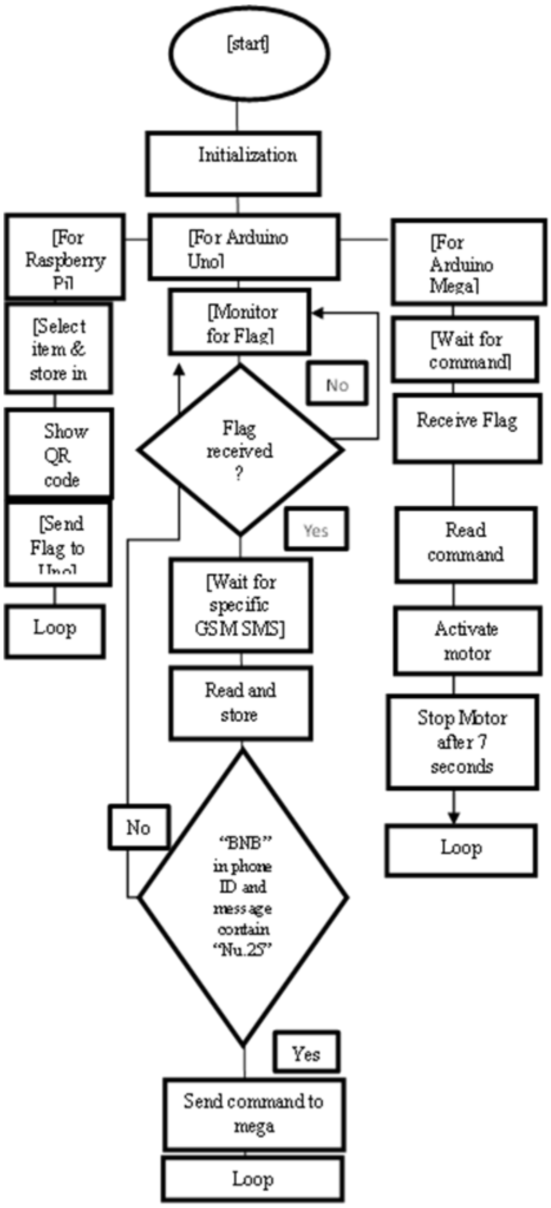

Fig.5. *Flowchart of the vending machine prototype*

6. EXPERIMENT FOR MOTOR SPEED CONTROL

6.1 PWM and motor control experiment

The aim of this experiment was to determine the optimum PWM for controlling speed of the 12V dc motor we were using for the conveyor belt. We are using Arduino uno to generate the PWM signals and an H- bridge motor driver (L298N) to ensure proper power supply for motors and for reversing the rotation direction of the motor.
The circuit involves connecting a voltmeter in parallel and an ammeter in series. The code is uploaded to the Arduino IDE, and the motor is turned on for 30 seconds. The PWM value is modified in the code, and the code is uploaded to the Arduino UNO (Priyanka & Mariyammal, 2018).

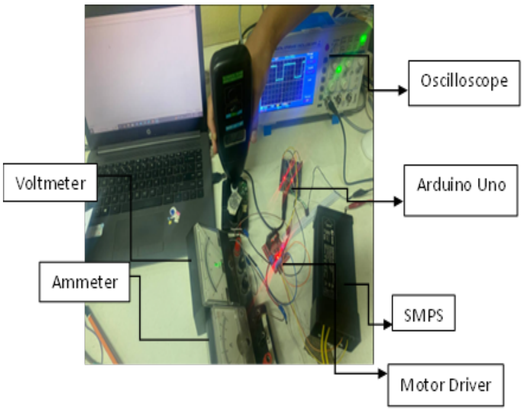

Fig.6. Circuit diagram for experiment 1

For every PWM setting, measurements of current, voltage, and speed are noted down. The following formula is used to determine power consumption and torque:

Power= Current * Voltage

Torque= Power/Speed.

Characteristic graphs are plotted for both clockwise and counterclockwise directions as shown. We can change the direction by switching the IN1 and IN2 connection.

6.2 Observation

Fig.7: *PWM settings*

Table 1: *Readings in clockwise direction*

Clockwise direction					
PWM	Current (A)	Voltage (V)	Speed (RPM)	Power (Watt)	Torque
90	0.15	1	0	0.15	0
100	0.1	5.5	9.8	0.55	0.056122
110	0.1	6	10.2	0.6	0.058824
120	0.1	6.25	11.5	0.625	0.054348
130	0.1	6.5	12.3	0.65	0.052846
140	0.1	7	12.7	0.7	0.055118
150	0.1	7.25	13	0.725	0.055769
160	0.1	7.5	13.6	0.75	0.055147

170	0.1	7.75	13.9	0.775	0.055755
180	0.1	8	14.3	0.8	0.055944
190	0.1	8.25	14.9	0.825	0.055369
200	0.1	8.5	15.2	0.85	0.055921
210	0.1	8.75	15.7	0.875	0.055732
220	0.1	9	16.2	0.9	0.055556
230	0.1	9.25	16.5	0.925	0.056061
240	0.1	9.5	16.9	0.95	0.056213
250	0.1	9.75	17	0.975	0.057353
255	0.1	10	18.2	1	0.054945

***Table 2:** Readings for anticlockwise direction*

Anit-clockwise direction					
PWM	Current (A)	Voltage (V)	Speed (RPM)	Power (Watt)	Torque
90	0.15	1	0	0.15	0
100	0.15	1.5	0	0.225	0
110	0.15	5.5	9.2	0.825	0.089674
120	0.15	6	10.3	0.9	0.087379
130	0.15	6.25	11.6	0.9375	0.080819
140	0.15	7	12.2	1.05	0.086066
150	0.15	7.25	12.9	1.0875	0.084302
160	0.15	7.5	13.4	1.125	0.083955
170	0.15	7.75	13.9	1.1625	0.083633
180	0.15	8	14.7	1.2	0.081633
190	0.15	8.25	15	1.2375	0.0825
200	0.15	8.5	15.6	1.275	0.081731
210	0.15	8.75	16	1.3125	0.082031
220	0.15	9	16.1	1.35	0.083851
230	0.15	9.25	16.2	1.3875	0.085648
240	0.15	9.5	16.4	1.425	0.08689
250	0.15	9.75	16.7	1.4625	0.087575
255	0.15	10	17.3	1.5	0.086705
255	0.1	10	18.2	1	0.054945

6.3 Characteristic graphs

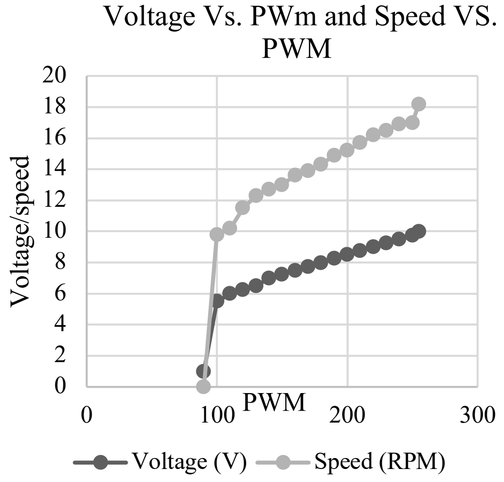

***Fig. 8:** Graph for clockwise direction*

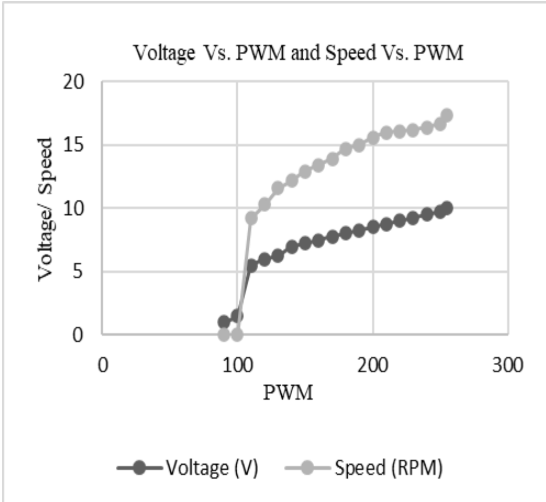

***Fig.9:** Graph for anticlockwise direction*

6.4 Discussion

This experiment compared the functioning of a DC motor driving a conveyor belt in clockwise and anticlockwise direction. The results showed that increasing the PWM value leads to a rise in motor speed and voltage, indicating a clear relationship between PWM duty cycle and motor performance. Power consumption increased with increase in PWM signal level, and it was noticeable that more power was consumed in the anticlockwise direction. Through this experiment, we were able to determine that the optimum choice while using this particular 12V DC motor to run a conveyor belt was best to rotate it in clockwise direction with a PWM signal at 255.

7. FABRICATION OF VENDING

MACHINE

7.1 Dispensing mechanism

The conveyor system is a mechanical mechanism that is used in vending machines to dispense products to customers. The design of the system aims at providing optimal item delivery where there are no frequent breakdowns as this undermines the flow of products and how efficiently the product is rolled out without frequent jam (Abbas, 2021). This is realized through the implementation of conveyors which enable the vending convenience since it reduces the amount of time taken and little need for repairs.

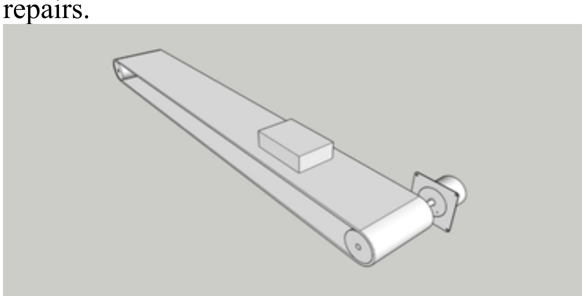

Fig.10: *Designed conveyor belt*

Calculation for specification
No of product: 5 Number
Each product mass: 0.5 Kg
Length of conveyor= 42 cm
Width of conveyor =18 cm
No. of product: 5 Nos.
Each product mass: 0.1 Kg
Total Load on Conveyor = 100 x 5
= 0.5 kg
Mass of the Belt
Belt (Cotton 7018)
Area Density = 216 g/m2
=0.216 kg/m2
Mass of the belt = total area x unit density
Area of belt = 2 x length of belt x width of belt
= 2 x 0.42 x 0.18
= 0.1512 m2
Mass of belt = 0.1512 x 0.216
=0.03266 kg
Total load on conveyor = (0.5+ 0.03266) kg
= 0.5326 kg
Coefficient of friction= 0.2
Speed of the conveyor belt
Desired speed= 0.75398m/min
Linear speed= in meter/s
Cycle time: seconds
Speed = 0.012 m/s
Power
Power = Work/time
= (force × displacement)/time
= force x velocity
Force
Frictional force= friction coefficient x normal force (m x g)
= 0.2 x 0.5326 x 9.81
= 1.04496 N
Power of each conveyor belt system
Power = 1.04496 x 0.012 m/s
= 0.01254 Nm/s
Power = 0.01254 watt
1 HP= 746 watt
Safety factor = 1.5
Therefore, power= 0.01254 x 1.5
= 0.01881 watt

Circumference of the roller = 3.14 x diameter of the roller
= 3.14 x 0.012
= 0.0377 m
1 revolution = 0.0377 m
1m = 1/0.0377
Since the desired speed is 0.75398 m/min and to find the RPM of the motor,
0.7536 m = 1/0.0377 x 0.7536
= 20 RPM
Torque
Torque = (Power)/ (angular speed)
Now, to find the angular speed,
Angular speed= RPM X2π/60
= 20 x 2π/60
= 2.0944 rad/s
Torque = (Power)/ (angular speed)
= 0.01881/2.0944
= 0.00898 Nm

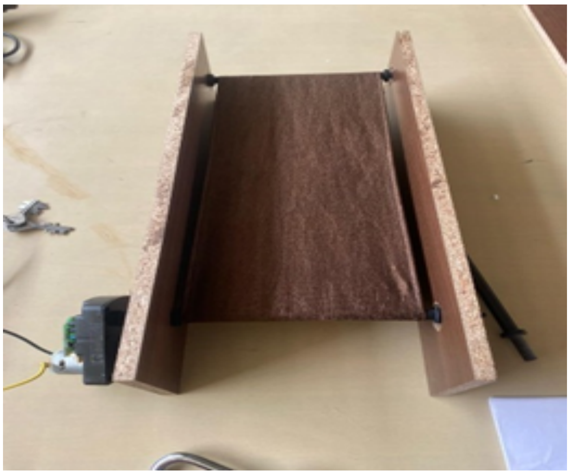

Fig.11: *Prototype conveyor belt*

7.2 Design and calculation Outer casing

In designing the outer casing of the vending machine, we had considered the number of items to be stored and the number of compartments to include, as well as size of the conveyor. We also made sure that there is sufficient space for the connection as well as the dispensing section to allow easy connection and movement of the dispensing mechanisms.

We decided to include five compartments, each measuring 28 cm, based on the size of the products and the conveyor. After incorporating all these considerations, we arrived at the following dimensions for the vending machine: a height of 1.71 meters, a length of 1 meter, and a width of 30 cm.

After considering the size and dimension of all the items and components that need to be fit in the design of the vending machine, looking at the 2D design of the vending machine, we designed the 3D using a software called Fusion 360. After the 2D and 3D designing of the vending machine, we used the facilities from the FabLAB in our college for cutting and assembling the outer casing of the vending machine. The figures below show the 3D overview of the vending machine in Fusion 360.

Fig.12: *3D design in SolidWorks*

Fig.13: *Casing of the vending machine*

7.3 Payment System

To ensure that payment is processed after picking the product, we found a fairly simple method to do that after conducting thorough research. In Bhutan, there is a transition from cash to mobile payment apps, the most popular of which is mBOB and mPay. To ensure that payment has been made, banks have made it so that users receive an SMS on their mobile phone when they get credited with some amount using a QR code of their account, and they must link a phone number to the account to receive the payment confirmation message.

The most reliable Bank that gave that confirmation message each time while receiving payment using the QR code was BNB.

BNB is used for this research, and the bank account is linked with the number "+97577710715" so every time a payment is made, a message as shown below is received:.

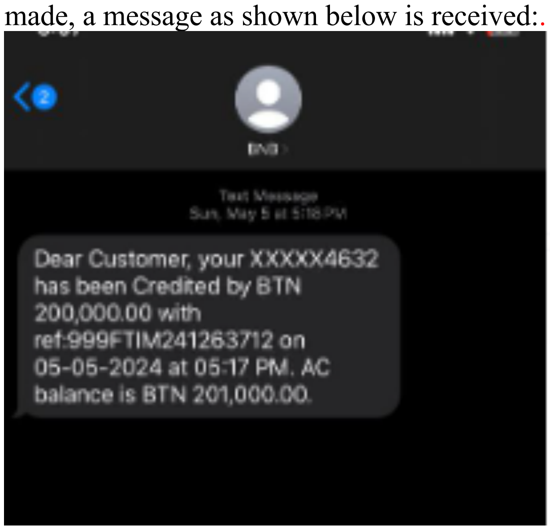

Fig.14: *Message from BNB after transaction using BNB*

Fig.15. Integration of payment systema

The GSM module will receive every message from the sim card and the Arduino uno reads and filters all the message each time to search if it is from a specified number and message.

Note: Any payment app that can pay using scanning the QR code is compatible with this designed VM.

8. CONCLUSION

The key objective of this paper was to fabricate vending machines with a specific focus on the incorporation of the cashless-payment system. The adoption of local means of payments including mobile payment such as mBOB and mPay will ensure that the customers have a secure and direct way of paying for the products to be bought from the vending machine without use of physical cash. Not only does it enhance the convenience of transactions, which is a goal of this paper, but it also helps with putting people of Bhutan in a better position of being able to utilize simple financial services.

Through this paper, it was possible to create a functional vending machine that can dispense different types of snacks. This involved the integration of sturdy hardware, such as microcontrollers, microprocessor and communication modules, to guarantee reliability and flawless performance in practical settings.

Centralizing the modification and enhancement of the vending machines' cashless payment technology would greatly assist in the modernization of the machines' transactional capacity in Bhutan. With the help of the existing payment system, and collaborations with local banks, there is a possibility to offer consumers to

Fig.16. Prototype

buy the products they need using a phone from an automated machine.

9. RECOMMENDATION AND FUTURE SCOPE

- The system that has been designed and executed for this project is functional, but this is just a stepping stone and it could be improved.
- From our research, we have found that the payment system could be more reliable if it was an IoT based system.
- Creating a payment gateway could be done by partnering up with the banks in Bhutan and RMA.
- Improvements could also be made into the aesthetics of the vending machine. As of now our VM looks basic and for attracting the interest of users, the aesthetics play a very important role.
- The next very important improvement that the current prototype needs is ensuring continuous power supply and creating a protective circuit for the fragile components, such as the Raspberry pi, which is very sensitive to overvoltage and undervoltage.
- Purchasing a minimum of one spare for every component is advised to avoid project delays caused by having to place a new order if a component gets damaged.
- Purchasing materials for projects based on prototypes can be particularly difficult and time-consuming because it can be difficult to find a reliable supplier at an affordable rate. If the college or department had a designated dealer for the prototype materials, it would be advantageous for the students. This dealer could not only help students obtain their materials more quickly, but it would also make it simpler to record how the funds were allocated and used.
- Finding and purchasing components with the right specifications is advised, especially for the voltage and power specifications, as some components are quite delicate and prone to damage easily.

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