B. TECH. PROJECT REPORT

On

Design & Development of a Model of Smart Vending Machine

BY

Shubham Kumar Mishra
Ugrah Narayan Pathak

DISCIPLINE OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY INDORE
December 2017

Design & Development of a Model of Smart Vending Machine

A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degrees

of
BACHELOR OF TECHNOLOGY
in
MECHANICAL ENGINEERING

Submitted by:
Shubham Kumar Mishra
Ugrah Narayan Pathak

Guided by:
Dr. Santhakumar Mohan

INDIAN INSTITUTE OF TECHNOLOGY INDORE

CANDIDATE'S DECLARATION

We hereby declare that the project entitled **"Design & Development of a Model of Smart Vending Machine"** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in 'Mechanical Engineering' completed under the supervision of **Dr. Santhakumar Mohan(Associate professor, Mechanical Engineering),** IIT Indore is an authentic work.

Further, we declare that we have not submitted this work for the award of any other degree elsewhere.

Signature and name of the students with date

CERTIFICATE by BTP Guide(s)

It is certified that the above statement made by the students is correct to the best of our knowledge.

Signature of BTP Guides with dates and their designation

Preface

This report on “Design & Development of a Model of Smart Vending Machine" is prepared under the guidance of Dr. Santhakumar Mohan.

Through this report, we have tried to give a detailed and comprehensive method for design and institution of smart & affordable vending machine.

We have tried to the best of our abilities and knowledge to explain the content in a lucid manner. We have also added graphs and figures to make it more illustrative.

Shubham Kumar Mishra
Ugrah Narayan Pathak
B.Tech. IV Year
Discipline of Mechanical Engineering
IIT Indore

Acknowledgements

We wish to thank **Dr. Santhakumar Mohan** for his kind support and valuable guidance. This work has been done in framework of the IIT Indore project. We would like to Acknowledge PhD scholar **Mr. Jayant K Mohanta,** Centre for Robotics and Control and Central Workshop of IIT Indore for providing their sincere cooperation and guidance to carry out this research.

It is their help and support, due to which we became able to complete the design and technical report. Without their support this report would not have been possible.

Shubham Kumar Mishra
Ugrah Narayan Pathak
B.Tech. IV Year
Discipline of Mechanical Engineering
IIT Indore

Abstract

Vending machine is a device that dispenses goods upon receiving money. Success of vending machine is attributed to the fact that it does not require any operator. In developed countries where labor cost is high, vending machine is very popular. But, high cost of ownership and availability of low waged labor in developing countries like India, China, Pakistan, and Sri Lanka has deterred the application of vending machines. Recent time have seen a drastic increase in product with smartness incorporated. Circulation of Smart Vending machine is very low even in developed countries, despite its advantages.

This project aims to solve two main problems a) High cost of vending machine. b) Lack of smartness in modern day vending machine. Implementation of the existing technology is expensive and unaffordable. Application of state of art **Planar Parallel Manipulator** in vending machine reduces motor horde to just 5 Nos. which thereby shall undercut the overall cost of production. It incorporates distinctive smart features like remote inventory management and communication through smartphones.

Table of Contents

List of Figures

Chapter 1

Introduction

1.1 Introduction:

A **vending machine** is an automated machine that provides items such as snacks, beverages to consumers after money is paid to the machine. It is very popular in countries like Japan and USA. It is usually found at school, college, gas station, railway station, metro stop, Airport. It is generally deployed where opening shop is not profitable. Common vending machine includes Snack vending machine, change machine, beverage machine, stamp vending machine and ticket vending machine. Other specialized vending machine includes automobile vending machine, book vending machine, pizza vending machine and French fry vending machine.

The first coin-based vending machines were introduced in London, England in the year 1880 that dispensed postcard. The machine was invented by Percival Everitt in 1883 and soon became a widespread feature at railway stations and post offices, dispensing envelopes, postcards, and notepaper. In 1893, Stollwerck, a German chocolate manufacturer, was selling its chocolate in 15,000 vending machines. It set up separate companies in various territories to manufacture vending machines to sell not just chocolate, but cigarettes, matches, chewing gum and soap products. Its first manufacturing plant in America was setup by a gum company in 1888. Slowly and steadily it was started to be used in other parts of the world. Currently, vending machine have changed to smart vending machine. They have included credit and debit card payment, refrigeration facility, touch display and a wide range of interactive technology.

Today USA and Japan are top two companies in number of vending machine. According to market research by Frost & Sullivan, global shipments of smart vending machines are forecasted

to reach around 2 million units by 2018, and further to 3.6 million units by 2020 with penetration rate of 20.3 percent.

1.2 Motivation:

Despite being a very useful product vending machine is not popular in developing countries like India, Bangladesh, Pakistan, Sri-Lanka etc. Primary reason for it is its cost. A typical vending machine is sold around INR 200,000 which is very high for countries like India where the low labor cost is very low. This has limited its scope to metropolitan cities. A large part of cost is constituted by motors used in it. Average number of motors used in a snack vending machine is 40 which costs around INR 40,000. Thus reducing the number of motors is one of best way to reduce cost of vending machine. They are bulky and their bulk increases the transportation cost, thus increasing overall cost of production. A lot of time consumer does not have coin with them. Therefore they are unable to purchase through vending machine. It can easily be solved by integration of smart payment method like payment through RFID card. People usually do not get consumable with high demand. Most of the time they are out of stock and owners of vending machine have not idea of it. This results due to poor inventory management. Despite having many smart features, modern vending machine do not provide any option of advance booking or paying for any other person. Also, currently they do not direct person to a nearby vending machine in case some goods or change is not available.

1.3 Objective:

1. Reducing the number of actuators
2. Reducing weight of the model
3. Reducing cost of production
4. Providing alternate mode of payment
5. Enabling inventory management

Chapter 2

Proposed Architecture

The proposed design works on linear motion system in 3 perpendicular direction and a rotary system to rotate the coil. Design uses only 5 motors to operate snack vending machine. Removing all the motors and making one motor to reach and rotate all the coils is purpose of this design. Reduction of actuator (objective) is achieved by replacing all the motor with a planar parallel mechanism. This mechanism allows us to move end-effector at any point in vertical plane (YZ plane). Whole process of dispensing a good occurs in four steps. First, motion along Z-direction is done by motor 1 and motor 2 (Fig. 1). Then, motor 3 moves end-effector in direction of Y-axis. Combination of these motion shifts end-effector along engaging line with snack containing coils. Then, a forward motion (with the help of motor 4) along X-direction engages actuator (motor 5) with coil through couplers. Motor 5, then, rotates the coil and dispenses the goods. Stepper motors are used as actuator to induce all the motion in the system. The dispensing system described above comprises of four fundamental steps-

STEP 1 (Motion along Z-axis)

Translation in vertical direction (along Z-axis, Fig 1) is obtained by converting rotary motion of stepper motor into linear motion with the help of Threaded rod-Nut pair (Fig 2).

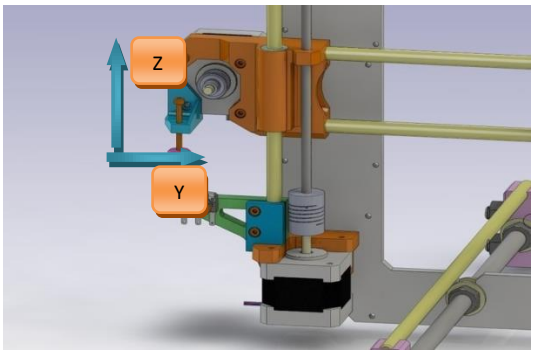


Fig. 1 Translation in vertical direction

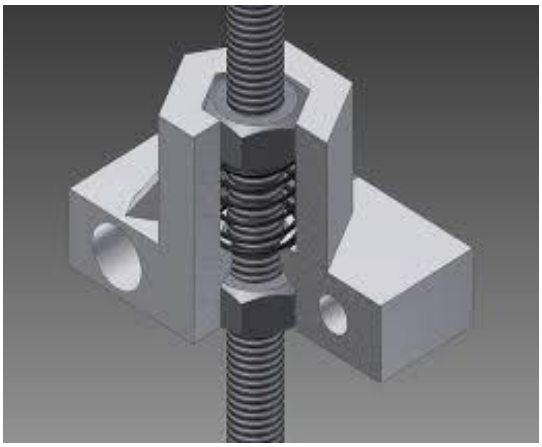


Fig. 2 Threaded Rod and Nut pair

Two stepper motor (motor 1 and motor 2) turn threaded rod which translates end-effector along Z-axis. A linear guide consisting of linear bearing is provided for smooth motion and stability. When bottom stepper (motor 1 and motor 2) motors rotate in counter-clockwise direction, rest of the three motors (including motor which will rotate coil) moves in upward direction (Fig 3, Fig 4). Rotation of bottom motors in clockwise direction will move end-effector in negative Z-direction.

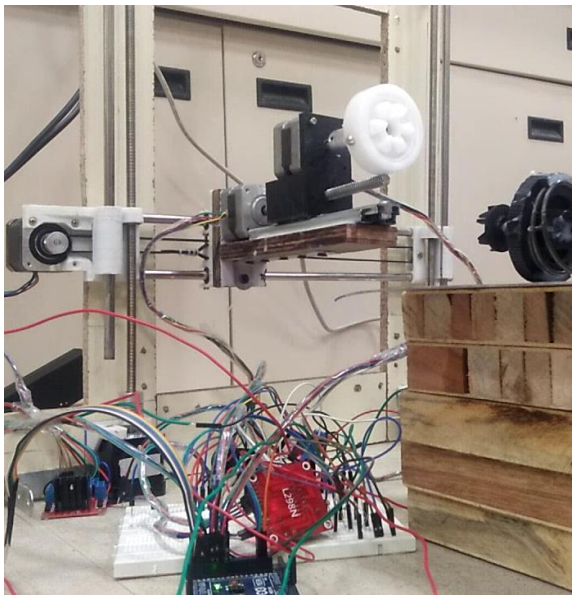


Fig. 3: Initial setup for reaching the target point

This step, places motor 5 in the horizontal line of coupler attached with coil.

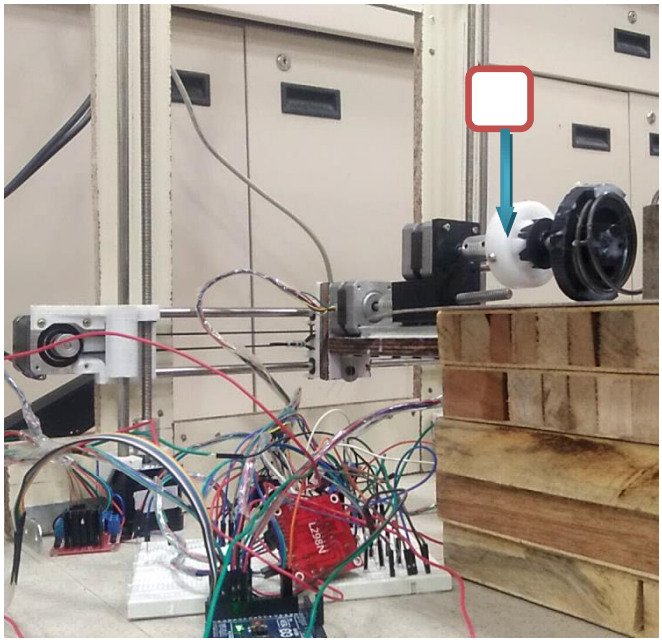


Fig. 4: Final position of the coupled with the coupler

STEP 2 (Motion along Y-axis)

Translation along horizontal Y-axis is done by converting rotary motion of stepper motion into linear motion with the help of timing belt. (Fig 5, Fig 6) A belt drive consists of a timing belt with teeth, a toothed pulley which is attached to the motor, and a carriage attached to the belt. When the motor turns, it turns the pulley. The teeth on the pulley interface with the teeth on the timing belt so that when the motor rotates the pulley, the timing belt is pulled in the direction it needs to go. A carriage is attached to the belt such that it moves back and forth with the belt.

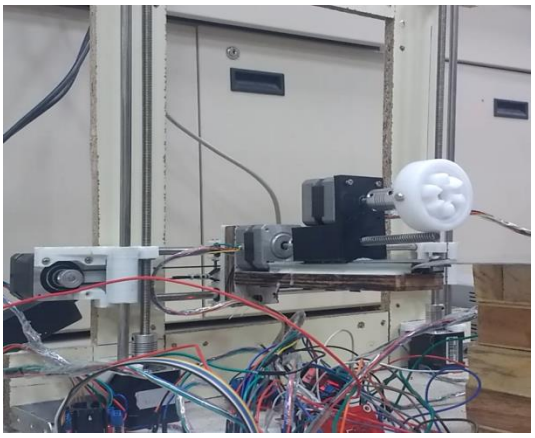


Fig 5.Operataion of X-axis motion initial position

This step places the motor 5 along the line of center of the coil.

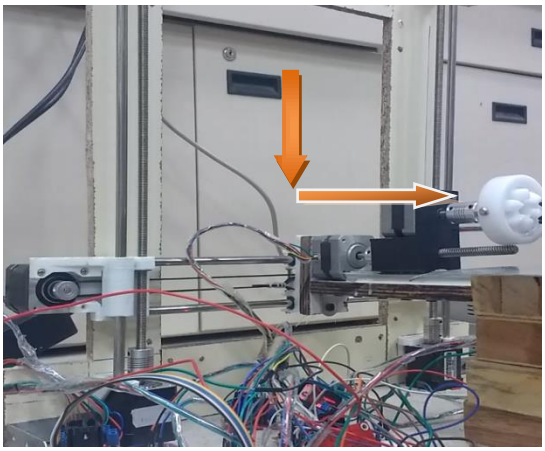


Fig 6.Operataion of X-axis motion final position

STEP 3 (Motion along X-axis)

Translation along horizontal X-axis is obtained by using lead screw with the help of motor 4. “Ball Bearing Drawer Slide” has been used for smooth motion of end-effector. Platform mounted on the Ball bearing slide contains the motor for rotating coil. Rotation of lead screw provides linear motion to the platform and motor. Motion in positive X-direction engages the coupler attached with motor and coupler attached with coil and similarly motion in negative X-direction disengages the couplers.

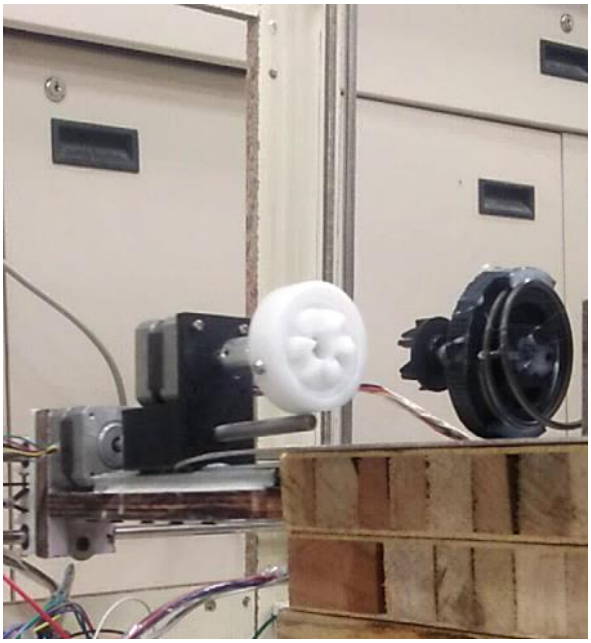


Fig 7. Disengaged Couplers

This step engages motor 5 with coil (Fig 8).

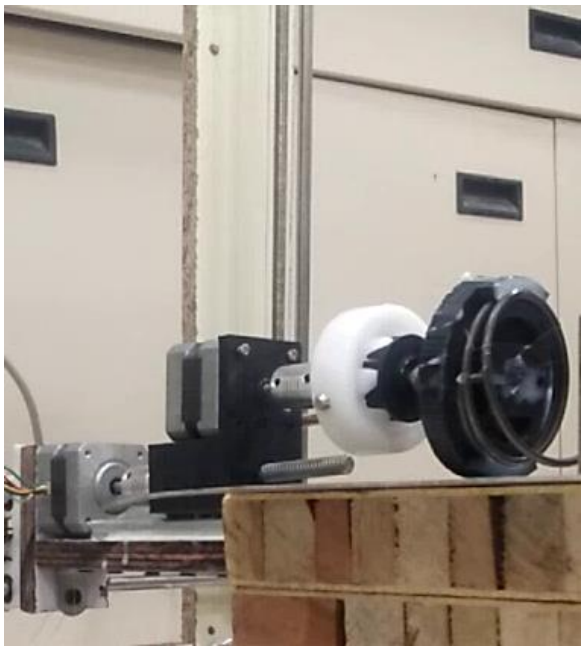


Fig 8:Engaged Couplers

STEP 4 (Rotation of Coil)

Rotating motor 5, one rotation in counter-clockwise direction, rotates coil by 360 degree and dispenses the good.

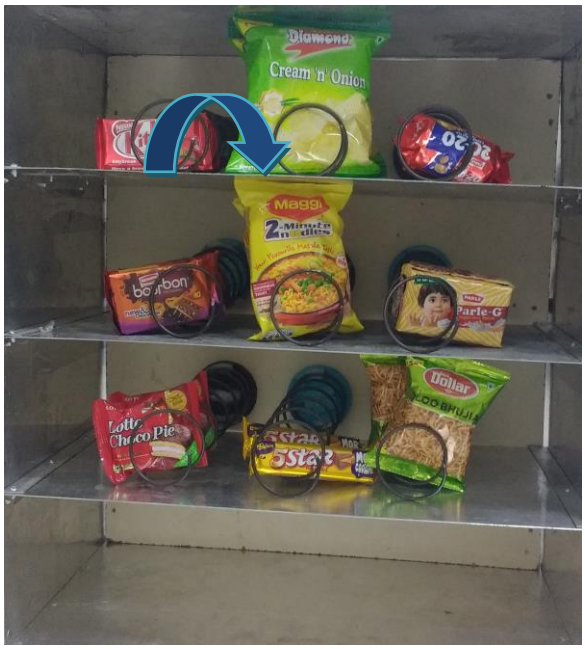


Fig 9. Coil Rotates and Item is Dispensed

Chapter 3

Mechanical Design and Sensor Fusion

This section describes the methodology involved in integration of telematics into mechanical device and their operation-

3.1 Mechanical Design:

3.1.1 Components

- Stepper Motor:

Rated V/I: 2.8V/1.68A

Torque: 4.4 Kgcm

Step Angle- 1.8 Degree

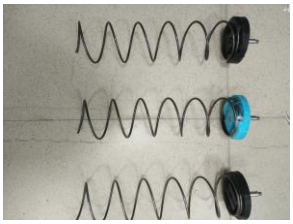
- Lead Screw:

Length: 400mm

Pitch: 5mm

Max Load- 60N

- Coils:



Length: 280mm

Pitch: 50mm

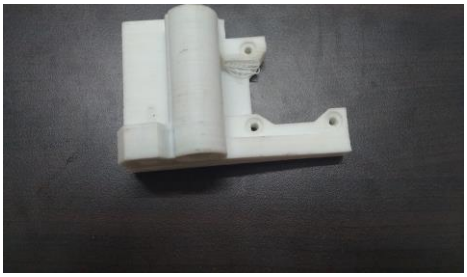
Diameter (outer): 62mm

- Coupler:

Designed & 3-D Printed Coupler:

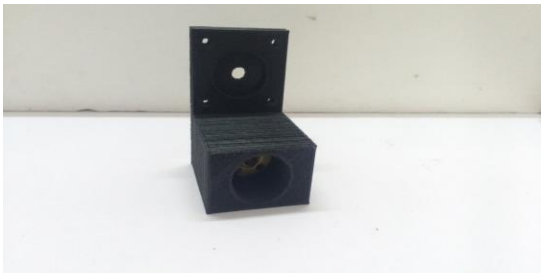
Outer Dia: 72mm

- 3-D Printed Mountings:



- Drawer Slider Platform:

Slider for Reciprocation



3-D Printed Traveler

- Belt & Pulleys:

- Toothed Belt
- Pulley to drive
- Puley Dia- 20mm

- Coil Matrix:

3.1.2 Operation:

Mechanism employed in the vending machine is a Planar Parallel Manipulator that has the efficacy to dart at any point in a given plane based on input commands. As described above, it comprises of five stepper motors to perform the operation. The system utilizes Lead-screw mechanism and belt drive to maneuver the position of the end-effector over a plane. End-effector moves forward on a sliding platform, with the help of lead-screw driven by motor, by a certain distance to clutch with coupler rigidly attached to the coil. Thus, the coupled coil rotates by 360 degrees and dispenses the desired item.

All these five stepper motors can be controlled by micro-controllers and the operation can be mechanized and items can be dispensed by just a couple of input commands. Rows of Ultrasonic proximity sensors are installed in each compartment corresponding to every coil to count the number of goods, keep a track and assist in inventory management.

Chapter 4

Control System & Sensor Fusion

In this section integration of controllers and communication devices with the mechanical drivers are discussed in details-

4.1 Control System:

Components:

1. Arduino-MEGA 2560:

Input Rating: 5V

SRAM: 8kb

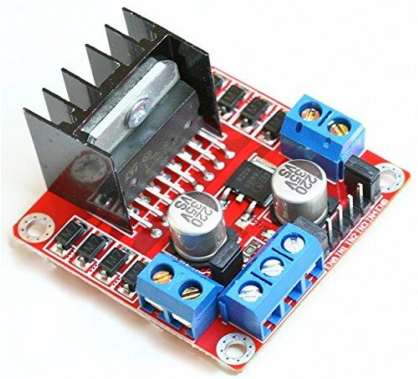
Flash: 256kb

2. Power Supply:

Input: 220V AC

Output Voltage: 12V DC

3. Motor Drivers:



L298N Driver

Output V: 5V-46V

Imax (drawn): 2A

4. Ultrasonic Proximity Sensor:

HC-SR04

Range- 2cm-400cm
Power Rating- 5V

5. RFID Device (Radio Frequency Identification):

RFID RC522

Operating Frequency: 13MHz

6. Bluetooth Module:

HC-05 TTL Module

Operating Frequency: 2.4GHz

Op Voltage: 1.8-3.6V

7. GSM Module:

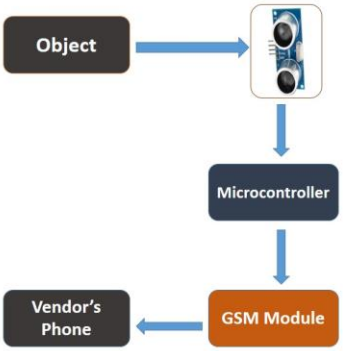
SIM900 GSM Module

Quad-Band: 850/ 900/ 1800/ 1900 MHz

4.2 Schematics of Communication & Operation:

1. Ultrasonic Sensor

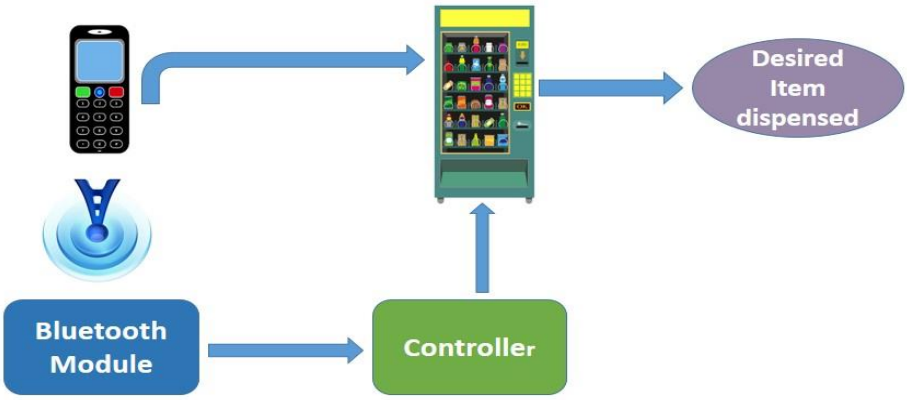
Proximity sensor recognizes if second last item is dispensed, sends signals to the microcontroller which after processing activates the GSM Module. A notification is sent to the owner's phone via GSM module.



2. RFID Device (Radio Frequency Identification):

When the card having an identification number is hovered over the RFID module it sends a signal to the Arduino-Controller which processes it, reads the database and performs the output as follows-

3. Bluetooth Module:



Communication between the smartphone and vending machine can be established via Bluetooth module. Once the phone is connected items from the vending machine can be dispensed by an application and payment can be done by Offline wallets in users phone. This replaces conventional system in machine by a smart dispensing system.

Chapter 5:

Conclusion

Here the vending machine proposed with an idea of reducing the number of actuator requirement and make it compatible for the purpose of smart vending. That is to enable the vending machine to connect to internet and provide meaningful communication among the devices in order to make the service more effective. The first objective was to use a parallel manipulator setup with use of 4 motors and complete the vending task that is to dispense the object ordered by the user. For this purpose a parallel manipulator having two extra degree of freedom at the end effector is fabricated. Then vending operations are validated using the experiment. Engaging and disengaging of the coupling mechanism is also processed and verified by real time experiments. Further, configuring the device with the infrared card reader is tested and suitable material dispense system is tested by changing cards pertaining to the users. Similarly, Bluetooth module is also tested and with smart phone and found suitable to be used as payment medium to get goods from the machine.

References

[1] Melissa A. Matthews, Tanya M. Horacek, Vending machine assessment methodology. A systematic review. Appetite, Volume 90, 1 July 2015, Pages 176-186

[2] André S.P.H. Navarro, Carlos M.F. Monteiro, Carlos B. Cardeira, A Mobile Robot Vending Machine for Beaches Based on Consumers' Preferences and Multivariate Methods. Procedia - Social and Behavioral Sciences, Volume 175, 12 February 2015, Pages 122-129

[3] A. Wood, S. Peterson, D. Sowa, Development and Testing of Healthy Choices Vending Machines, Journal of the Academy of Nutrition and Dietetics, Volume 116, Issue 9, Supplement, September 2016, Page a14

[4] L.W.M. Verhoef, Decision making of vending machine users, Applied Ergonomics, Volume 19, Issue 2, June 1988, Pages 103-109

[5] Andrew C Gross, The information vending machine, Business Horizons, Volume 31, Issue 1, January–February 1988, Pages 24-33