Smart Dispensing of Ingredients Using VL53LOX and Piezoelectric Polymer Sensor

K. R. Prakash, V. Guruprasad, and K. S. Nithin

1 Introduction

The food materials are preliminarily categorized based on daily requirements for a house of 4–6 members. This includes rice, dal, and food grains such as rava, broken wheat and seeds, etc., are considered as high-volume consumables. Other items such as mustard seeds, chili powder, salt and sugar, etc., are considered as low-volume requirement. Figure 1 explains the working of smart inventory. A set of standard containers are designed to meet the high- and low-volume requirements, keeping in mind, the volumes of containers are so designed using standard regular shape such as circular, square and rectangular of different dimensions to store raw material at their respective position [1]. The container will be provided with a cap, and a bottom plate on which it sits exactly. VL53LOX sensor is mounted on the cap. VL53LOX sensor is very small in size and can be fitted very easily to any size of the cap. At the bottom, a plate with piezoelectric polymer sensor along with circuit consisting Arduino nano board will log the values from both the sensors and push those values to cloud. An AI engine with a web application will display the physical container in a virtual platform showing filling status.

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S. K. Natarajan et al. (eds.), *Recent Advances in Manufacturing, Automation, Design and Energy Technologies*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-16-4222-7_49

Fig. 1 Working diagram of smart inventory

1.1 Objectives

1. The first and foremost objective of this project is to raise the level of the automation that is currently employed in the existing system.
2. Integration of sensors data for accurate analysis.
3. A system for automatically maintaining inventory status of dry/liquid items with self-calibration/correction ability.
4. This project designed to provide self-learning techniques AI for smart containers.

1.2 Scope of the Project

The smart container will have combination of sensors mainly VL53LOX nano sensors with robust electronics, which is mounted on the cap side and piezoelectric polymer gasket which acts as sensor to indicate resistance change when the volume is dispensed and is embedded to bottom of container. However, in this project, implementing smart container concept for few numbers of the containers for a particular dispensing application has been achieved mainly for an automatic cooking machine where the ingredients are dispensed according a set program. These kinds of smart containers are developed and integrated with a display device and a mobile application where user can monitor live updates on inventory, quantity dispensed, minimum level, and maximum level.

1.3 Design of Machine and Container

The project aimed at selecting regular shape container as it is easy to predict the exact volume changes during the dispensing of the ingredients. To suit the machine, cylindrical jars were preferred in the project. However, it is possible with any standard regular shape containers and even non regular containers can be used by initially calibrating it. Based on the geometry of the container, a program calculates the volume.

$$A = \pi * r^2 \quad (1)$$

$$V_1 = \pi * r^2 * h_1 \quad (2)$$

$$V_2 = A * (h_1 - h_2) \quad (3)$$

‘r’ is radius of the container.
‘A’ is area of the container.
‘V_1’ inside full volume of empty container.
‘V_2’ is the volume occupied by the material inside.
‘h_1’ inside height of empty container.
‘h_2’ is the depth of remaining material from top edge (Data from the sensor).

Similarly, by giving basic dimensions to the software allows direct display of the volume and weight. However, during the trails, it is observed that there is an error in measurement mainly when solid ingredients are used in the container and dispensed. As our machine needed accurate dispensing with minimum error, the containers were modified and fitted with a sensor made by piezoelectric polymer material as a base which gives resistance change with respect to volume stored in the container. By clubbing these two data, dispensing errors were minimized. The author has already published paper [1], and recently, the machine was modified and built in different layers with circular profile to house different components used for cooking ingredients in smart cooking machine which comprises of four layers. Layer 1 contains machine base, heating element, vessel and vessel clamping device. Layer 2 contains layer split, exhaust assembly, thadka assembly and cube vegetables dispenser assembly. Layer 3 contains ingredients transfer system. Layer 4 has ingredients container, spices container and liquid dispensing containers. Different types of containers were used based on the application with the provision for mounting sensor and routing wire for example as shown in Figs. 2 and 3. Provision for mounting sensors on to the containers is made during the design stage in the container cap. 1. Machine chassis, 2. Controlled heating device, 3. Tadka heating vessel, 4. Stirrer assembly, 5. Exhort, 6. Veggies containers, 7. Ingredients transfer line, 8. Spicy box, 9. Main ingredients containers, 10. Layer height adjustment, 11. Cooking vessel, 12. Cooking vessel position lock, 13. Layer spilt, 14. Base heating element mount.

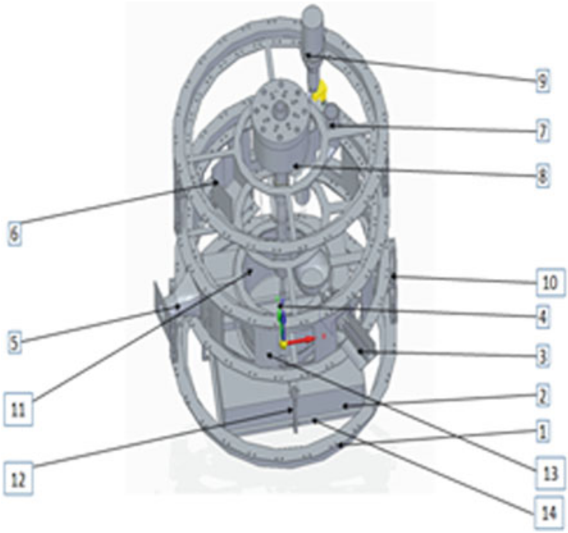

Fig. 2 Components of cooking machine

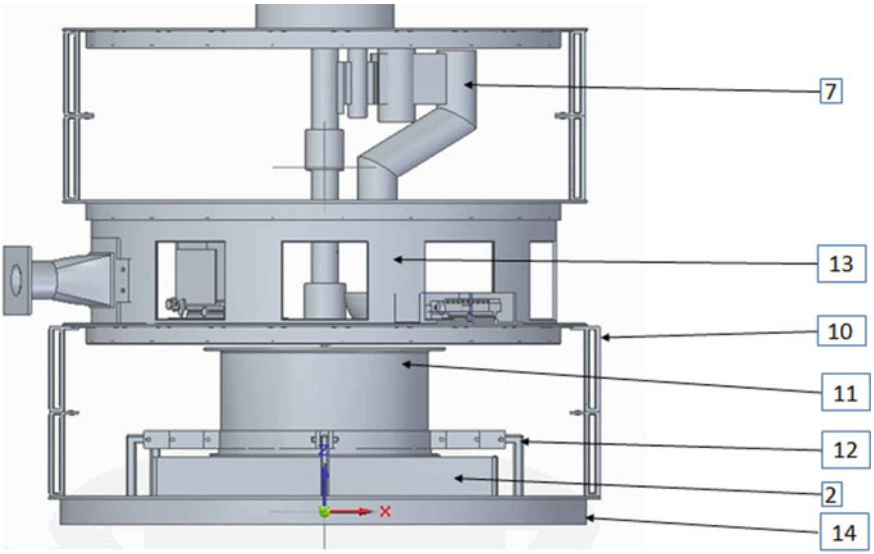

Fig. 3 Different layers of smart cooking machine

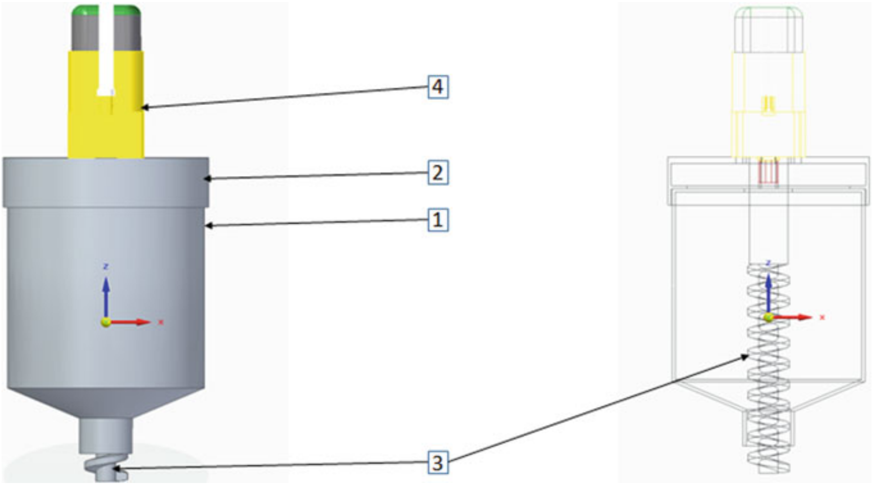

Fig. 4 Container

Design of the container is shown in Fig. 4. 1. Containers 2. Motor holders 3. Screw rod mechanism 4. Geared DC motor.

Screw rod mechanism used will remain in the machine, whereas the containers can be separated and stored elsewhere without disturbing the ingredient contents inside (can be refrigerated and dish-washable). Spice container assembly will get opened only when positioned in respective location of the machine with proper locking mechanism which includes a Poke-Yoke system.

1.4 VL53LOX Sensor

Due to compactness required, VL53LOX sensor was finally used which gives the distance in millimetre. Figure 5 shows the schematic representation of VL53LOX sensor. This VL53LOX sensor is very small in size and provides longer-ranging distance measurement [3]. It has higher immunity to ambient light and better robustness, and uses the flight sense technology for the precise measurement. The pulses of IR laser light are emitted from the emitter and reaches the nearest object then it reflects back to the detector, so it can be considered as a tiny, self-contained lidar system. The TOF (time of flight) measurement enables to accurately determine the absolute distance from the target without the object's reflectance greatly influencing the measurement.

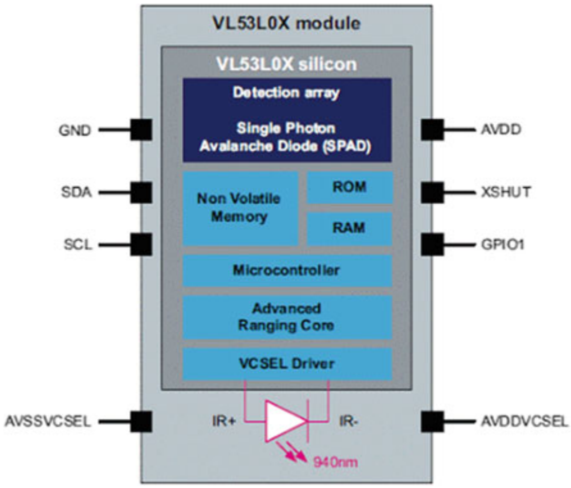

Fig. 5 Schematic diagram of VL53LOX sensor

1.5 Piezoelectric Polymer Sensor

The piezoelectric polymer sensor in our experiment is sensitive to the change in volume or change in the weight. This change is interpreted as resistance change by the piezoelectric polymer sensor. The sensor is a thin layer made up of piezoelectric polymer material. The advantages of using polymers in sensors are their high surface to volume ratio, response time, cost-effective and sensitivity [4, 5]. The sensor is placed on the bottom of the container further this sensor is placed on the fixture as shown in Fig. 6. Copper terminal embedded to the piezoelectric polymer is connected to the controller to acquire continuous data. When the level of the ingredients is varied the corresponding height change is given by the VL53LOX sensor and the corresponding volume change is given by piezoelectric polymer sensor. Both these sensors act as closed loop system to dispense the required quantity of ingredients.

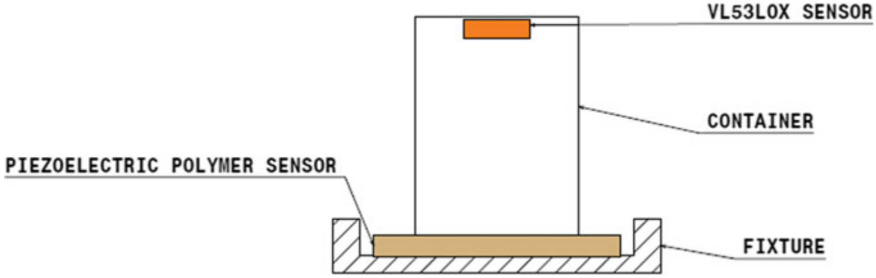

Fig. 6 Setup of the container with sensors

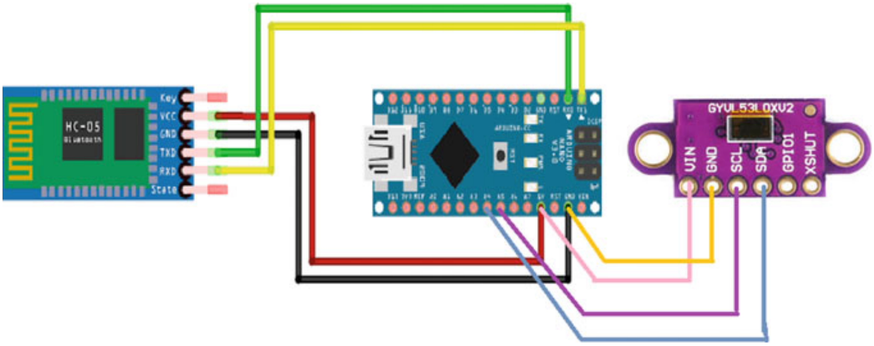

Fig. 7 Circuit diagram of VL53LOX model

1.6 Arduino Nano Module

Arduino nano is small, compatible and flexible. It is based on ATmega328p/ATmega168. The operating voltage of nano is 5 V, and the input voltage is 7–12 V. There are 14 digital pins, 8 analog pins, 2 reset pins and 6 power pins. Since the size of the microcontroller is smaller, it can be used in the applications where the size of the electronic components is of great concern.

1.7 Arduino Bluetooth Module

The Arduino Bluetooth module is used to send the data from microcontroller to the android device. Here, we are using HC-05 Bluetooth module. It is a serial Bluetooth module for Arduino and other microcontrollers. The range is less than 100 m. This module can either work as master or slave. And also, it can be easily interfaced with laptops and smart phones. Figures 7 and 8 show circuit connection of VL53LOX to microcontroller and Bluetooth module.

2 Result and Discussion

Table 1 shows the reading of sensors with respect to the weight of ingredients in the container. The container is filled with item and cap is closed and is placed on the auto cook machine, piezo sensor will start showing the resistance value corresponding to the weight of ingredient stored, also the current level inside the container is detected using VL53LOX sensor using time of flight concept. The data fetching is done by Bluetooth modules, and it calculates the distance process the information to arrive at weight of ingredient. Now, the dispenser will start dispensing material using screw

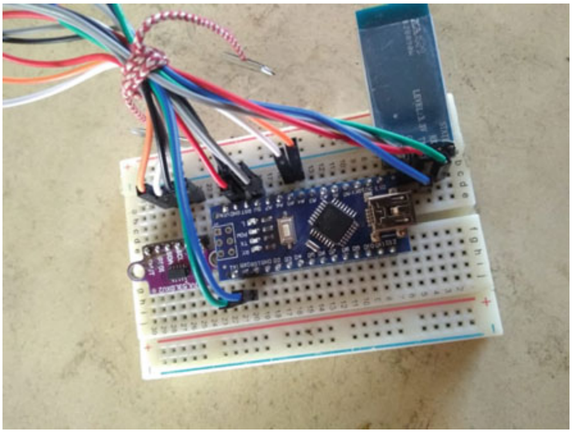

Fig. 8 Connecting VL53LOX to microcontroller and Bluetooth module

Table 1 Sensor readings

VL53LOX sensor reading (mm)	Weight of ingredient in container (kg)	Piezoelectric polymer sensor reading (kΩ)
205–210	0.892	11.4
220–224	1.206	9.6
225–230	1.300	8.8
192–197	1.508	6.6
180–185	1.553	6.5
170–175	1.613	6.1
173–175	1.708	5.6
160–165	1.909	4.3
155–160	2.127	4.1
145–150	2.338	3.6
135–140	2.451	3.2
70–75	2.6615	2.1

type feeder mechanism as per the program resulting in change of the height values and resistance values. Taking the new values of both sensor data, AI module will display the net amount of material dispensed from the container. In that way, it can also take commands for serves based on number of persons to whom the food is to be prepared. As the machine is under patenting process and one of the major innovations is on dispensing technology, the paper focuses on only on the basic methodology. In the trails , some amount of ingredients has been dispensed randomly from the container. For particular quantity of ingredients dispensed, the remaining weight is calculated. Simultaneously, the height of ingredient level from top of the cap is given by VL53LOX sensor, and the value of resistance for current weight of ingredient is taken from piezoelectric polymer sensor. However, the accuracy level is proved at 97%.

3 Scope for Improvement

The smart inventory proposed will have containers with artificial intelligence elements built in it to indicate the levels of the necessary stock and can communicate between the server/user by graphical interface or to a mobile phone. However, in this project, implementing smart container concept for few numbers of containers for a particular dispensing application has been done. In future, item storage can be replaced with smart containers with integration to display devices to deploy it in a mobile application where monitoring and live updates on inventory is possible. The project uses Bluetooth module HC-05 for the simplicity. Further, Wi-Fi module or RF master-slave device can be used for long range. The concept can be extended to warehouses, hotels, restaurants and other areas where monitoring may help to avoid the wastage of materials. Also, this can be a tool for kitchen inventory management.

4 Conclusion

The auto cooking machine with smart containers integrated with VL53LOX sensor and a polymer sensor for individual containers proved to be a good system to dispense the ingredients to the process as the two sensors data are fused the system will be a reliable and accurate and is suitable for small capacity machines used, the same may be used in medium scale industries, groceries shop and also in kitchen inventory. Because of its miniature size, it can be integrated in very less space. The containers periodically "wake up" and communicate to a base station regarding their inventory status and dispensed quantities, and the fill status is automatically updated using the same sensor [2]. By implementing AI, the container will be smart and self-learning over a period of time.

Acknowledgements This project was supported by KCTU Government of Karnataka. A part of the patent project—6018/CHE/2014.

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