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Design of Portable IoT based Grocery Tracking System via Wi-Fi Module for Home Automation

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Abstract – *As technology is developing everyone and everything is coming closer and are being connected. IoT is a great example of this, with versatile machines being connected from computing devices, objects, digital machines, mechanical systems to providing unique identifiers, and its ability of data transfer over the network without any human or computer interaction. Technology inclining towards this field, this paper concentrates on the design of a weighing scale for live grocery tracking, interconnected using the Wi-Fi module to encourage home automation. The use of IoT in this field reduces the inconveniences of tracking the exhausted, the leftover commodities or making a list to go shopping etc. Since the device is connected over Wi-Fi, the application developed for the mobile devices helps you keep track of the activities with enhanced features of calculating expenditure on the groceries and the rate of exhaustion of the available resources and the auto-generated list of required items. The use of machine learning algorithms in the backend of the android application helps in notifying the time for which the particular commodity is going to get exhausted and automatically orders it.*

Key Words: Internet of Things, MQTT Protocol, Cloud Computing, Real-Time Clock

1. INTRODUCTION

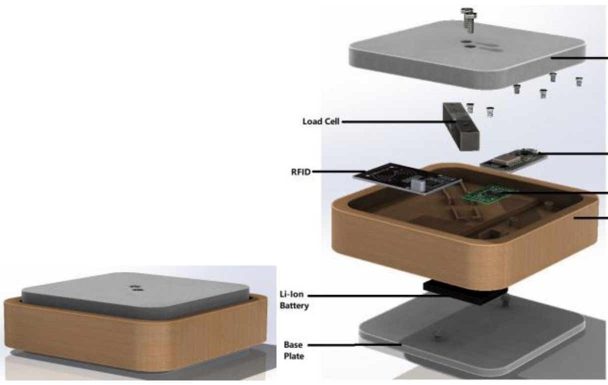
Buying groceries is an integral part of every household. The most general way to do this is to make a list and go to the local vendors for shopping or using the available applications to order it online. In both cases, we still go through the trouble of creating a list and cross-checking it at least 2 to 3 times to confirm it. This process is highly inefficient, sometimes leading to overspending on already available resources or forgetting to add a product to the list. In recent times, with such busy schedules, people opt for easily available or majorly automated processes.

So, using an IoT based weighing scale will help in proper tracking of groceries for households and help in restocking of the items on the shelf. The android application will help in a proper connection between the supply and the demand by giving prior notifications about the commodities that are in higher demand this will help the retailers to stock the right amount of commodities and this will also help the online retailers to provide the accurate delivery of the items in less amount of time. The proposed hardware also has automatic detection of any commodity placed on it using the RFID reader. As the detection is taking place the load cell calculates the weight of the product placed on it and signals are generated proportional to the weight being placed. Once the data of both weight and RFID tag is collected, the esp8266 module sends this via the home Wi-Fi network directly to the Cloud Server. After it has sent the first batch of data the module goes into sleep mode allowing it to conserve power until the next movement on the load cell is detected.

2. PROPOSED SYSTEM

2.1 Mechanical Design

The basic requirements of the model for the domestic application were: to be small-scaled and with high load-bearing capacity. The designing and prototyping were performed keeping these facts in mind. Figure 1(a) represents the collapsed view and figure 1(b) represents the exploded view of the scale designed in SolidWorks. There are 3 major parts of the design, the Top plate, the main body, and the bottom plate, averaging to a length and width of 140mm and height of 42.7mm. The amount of internal moving parts has been reduced and the model uses only bolted fixtures or snap-fit sliding locks. The product for the testing purpose was manufactured using Poly-lactic acid (PLA), but the actual product was built with PET for the top and bottom plates and wood for the main body.

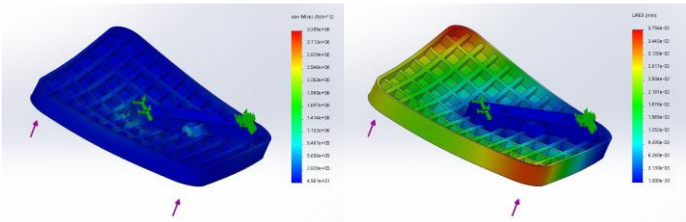


1(a) 1(b)

Fig -1: Mechanical Design 1(a) Compact View 1(b) Exploded view with labeled parts

2.1.1 Top Plate

The top plate is the part that comes in direct contact with the weight to be tested. It has 2 slots for the bolts that attach the top plate to the load cell. All the measured force is made to be distributed on the top plate which is in no contact with the rest of the body, hence the force gets concentrated on the load cell specifically. Being exposed to the large load, the load-bearing capacity of the top plate has been increased by fabricating it with 3mm internal wall thickness, forming a rectangular honeycomb structure as shown in fig 2. The simulation was studied with an applied force of 20N. The stress varied from 4.561e+01N/m2 to 3.395e+06N/m2 and was well within the acceptable range whereas the total displacement of the top plate varied from 1e-30mm to 3.756e-02 mm, making it almost a negligible amount.



2(a) 2(b)

Fig -2: Simulated result of Top Plate Rectangular honeycomb structure for 20N load
2(a) Stress 2(b) Displacement

2.1.2 Main Body

The central part of the design is the main body which consists of the load cell sensor, the ADC chip, RFID, the Wi-Fi module, and battery. The main body is made of wood, making it quite sturdy for weight balance. There are internal channels in the body that helps the interconnections of circuits & travels throughout the body. The placements of individual electronic parts have dedicated positions, snap-fit for load cell, bolting for RFID, ADC, and Wi-Fi module, and an empty slot for the Li-ion battery.

2.1.3 Base Plate

The bottom-most part of the design is the base plate. It has 2 protruded column-like structures that are responsible for easy sliding into the main body and then get fixed. This sliding mechanism is provided for locking the battery in position, easy attachment, and removal of the Li-ion battery.

3(a) 3(b)

Fig -3: 3(a) Lower part of the main body with sliding holes
3(b) Single column of base plate used for locking

2.2 Electronic Components

The electronic system consists of 4 major components. Basic features, working and the connections are described below.

2.2.1 Load Cell Sensor

The sensor converts the mechanical force applied on it into a low power analog electrical signal that can be measured to determine the weight of the commodity. The load cell is fitted under the top plate that will give weight readings to the centrally connected esp8266 Wi-Fi module. The load cell used has an acceptable limit of 20 Kg.

2.2.2 HX1711 24-bit ADC Module

The HX1711 module is a 24 bit Analog to Digital Converter (ADC) chip that comes in with an integrated pre-amplifier. Since the output signals generated by the load cell is in millivolts with the analog format, the module amplifies and converts these signals to standard digital format for proper readings for the microcontroller (esp8266 chip).

2.2.3 RFID Sensor

Each Tag contains a unique serial number of data embedded into it that is transferred via radio waves to the reader. The working of the RFID is similar to bar codes but has an advantage of range and it does not need to necessarily be in line-of-sight to a reader. The RFID tag must be within the range of an RFID reader, which ranges from 5 to 10 cm, in order to be read. To identify items placed in the sections of the self, even if misplaced an RFID reader is used to gather information from an RFID tag attached at the bottom of the container. This allows the technology to be a proper fit for the hardware and to ease the user's process by eliminating the detection of items manually.

2.2.4 ESP8266 Wi-Fi Module

The ESP8266 Wi-Fi Module is a self-contained microchip. It can hence give access to a wireless network from any microcontroller. It helps in seamless communication between the hardware and the cloud servers. The user only has to input the network credentials through the app. This module consistently pushes data and consumes very low power thereby making it a perfect fit for the device.

There are 3 major types of sleep modes available on the MCU, No-sleep for normal mode, not at all efficient, keeps the microcontroller awake, Modem-sleep for generally the default mode added onto the board, decent in conserving power, can only be enabled if the MCU is connected to an access point, Light-sleep mode to mimics the same function as Modem-sleep with the exception of keeping the CPU idle and shutting down the system clock and Deep-sleep for allowing serious control over power-saving and shuts down everything except the System Real Time Clock (RTC). Wakes itself up during every x microseconds and goes back to sleep. Among the available modes, the hardware will be using the deep-sleep mode by consuming the least amount of power and resources hence extending battery life.

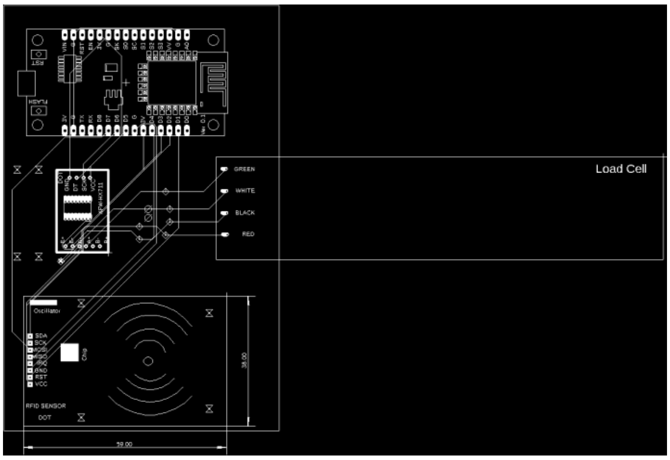


Fig -4: Diagram of on System board Connections with selected components

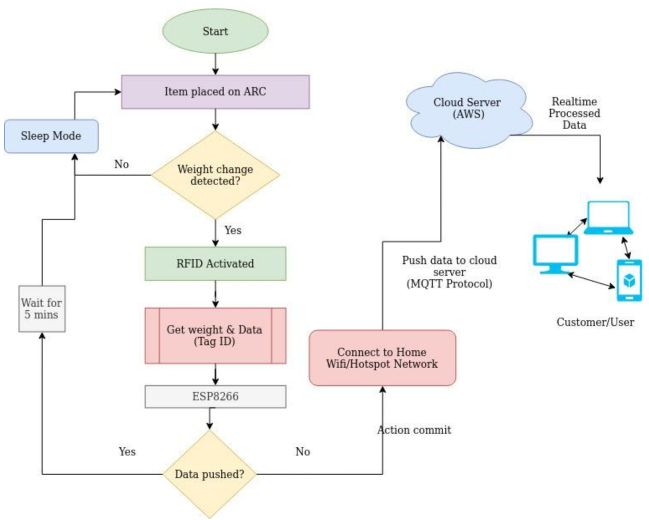


Fig -4: Hardware Action Flow

3. CALIBRATION

Calibrating any device before using it is an integral part improve the accuracy of the device. Converting the measured mv/V output from the load cell to the measured force:

MF : Measured Force A : Expected output
B : Offset RO : Rated output

$$MF = A * \text{Measured mV/V} + B$$

It's important to decide what unit the measured force in - grams, kilograms, pounds, etc. The load cell has a preset output of 1.0±0.15mv/v which corresponds to the sensor's capacity of 20kg.To find the value A:

$$\text{Capacity} = A * RO$$
$$A = \text{Capacity} / RO$$
$$A = 20 / 1.0A = 20$$

The offset varies for each load cell; hence it needs to be calculated to avoid incorrect readings. Measure the output of the load cell with no force on it and note the mv/V output measured by the Wheatstone Bridge Phidget.

$$\text{Offset} = 0 - 20 * \text{Measured Output}$$

- Tare Mode: Allows the reset and proper calibration while rebooting the microcontroller for the first time. The mode works by allowing the placement of a defined weighted object over the load cell and then saving the sensitivity change with the defined value into the EEPROM (Electrically Erasable Programmable Read-Only Memory).

4. CONNECTIVITY

4.1 Overview of MQTT Protocol IoT

Protocols being a crucial part of the structural integrity & security for any IoT system need to be chosen carefully according to requirements and hardware specifications. Message Queuing Telemetry Transport (MQTT) is the most widely adopted and used protocol best suited for lightweight messaging and communications between Low Power consumption (LOC) devices. It allows many to many communications with a middleman called the MQTT Broker between the publisher and subscriber. Each hardware piece is considered a Publisher while the client is the Subscriber. The publisher publishes data regarding a certain Topic/Topics while the Subscriber gets the data only related to the Topic he subscribed to.

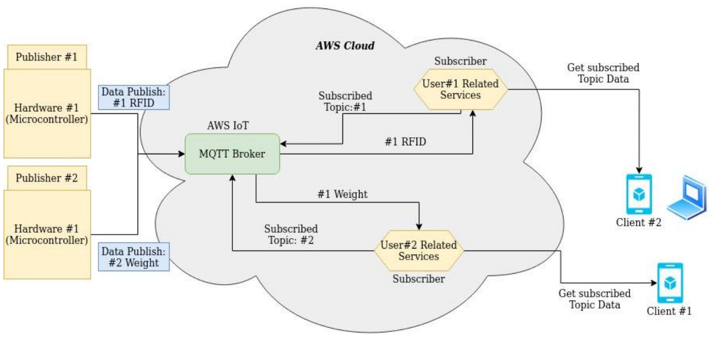


Fig -5: MQTT Pub-Sub Architecture

4.2 Cloud Server

The Server runs on a base set of different Machine Learning algorithms and services that track and Segregate the received data from each hardware. The cloud service provided here is the Amazon Web Services (AWS) platform which gives the freedom of processing data using different services provided by the platform.

- AWS IoT: The majority of the Pub-Sub communications from the hardware and services regarding the receiving data is handled by AWS IoT. Communications are done via MQTT over TLS (Transport Layer Security) in the system.

- DynamoDB: Received real-time data is stored into the NoSQL database (DynamoDB) and recorded for other services to act on. The data tables contain the Hardware MAC Address, IP Address, RFID Data, Weight Data, and Token ID of the hardware.

- Sagemaker: The Machine learning algorithms in Sagemaker use Linear Regression models and data from them to give Analytical on the usage of the item over the given tenure.

- Lambda Function: The function acts as a trigger to periodically execute actions like data processing in the server.

- Relational Database Service: The RDS is a SQL (Structured Query Language) Database that takes care of the storage of Structured static data like user account information into the cloud for selective use or access by other services.

- Simple Storage Service (S3): Data that is not required for hot access is separated and stored onto the S3 Bucket to minimize load on other services. Take note that bulky data is also stored in this as well.

- App/Web Server: The App and Web server take care of connecting to the app as well as the web portals for users to log in from.

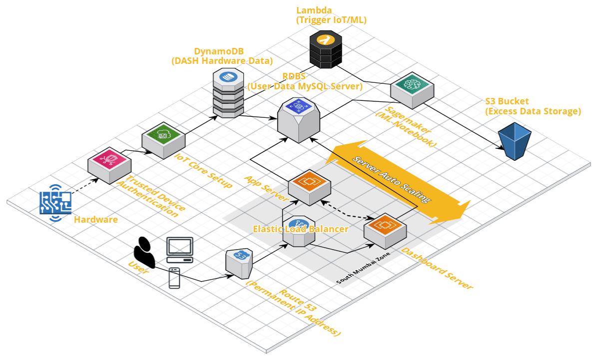


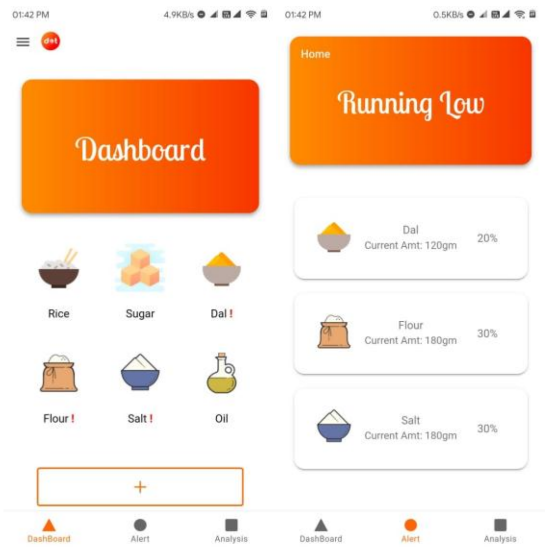
Fig -6: Cloud Server Internal data processing Architecture

4.3 Android App Development

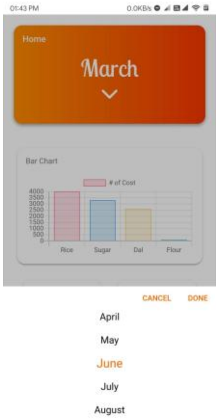
To make tracking simple an android app is also an important feature to let users access the inventory and manage the System. As shown in Fig 7, all the screens are of the data preprocessed and served to the user via the app.

The App consists of mainly 3 Sections:

- Dashboard - The section displays real-time data and information about all the hardware connected to the client's account.
- Alerts - This section contains a real-time list of all items that are running below the threshold limit and needs a refill.
- Analysis - This section displays all the analytics regarding the consumption rate to expenditure recorded by the system of the particular item.



7(a) 7(b)



7(c)

Fig -7: Application Interface
7(a) Dashboard 7(b) Alerts 7(c) Analysis

5. CONCLUSIONS

This paper presents the integration of a weight sensor-based smart tracking system into the existing consumer shelves that can be used to track groceries. This weight detection is possible using a cantilever load cell and it is interconnected using the concept of IoT. The advantage of using a load cell and ESP8266, there is precise tracking of weight and seamless communication between the android application and the hardware system. The prototype hardware design was successfully manufactured and tested for various conditions. The scale is designed to bear a maximum load of 20kg. With the small size of the weighing scale, it is quite efficient, takes less space and has high weight-bearing capacity. The Android application works successfully in displaying weight data as well as other parameters using DynamoDB as a backend for the access of users. The usage of machine learning algorithms in the backend helps in the tracking of the consumption pattern of a particular grocery commodity and helps in automatic notification and order of the commodity. This technology can further be used in diverse avenues, and hence would make it easier for people to be updated to the available resources.

Fig -2: The prototype was tested and verified

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