INVENTORY (WAREHOUSE) STOCK MANAGEMENT SYSTEM PROBLEM AND SOLUTION ANALYSIS

A PROJECT REPORT

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ABSTRACT

In the intricate web of modern supply chains, efficient Inventory Warehouse Management Systems (IWMS) play a pivotal role in ensuring streamlined operations. This thesis undertakes a comprehensive exploration of the challenges encountered in inventory management within warehouses, with a keen focus on the problems of understocking and overstocking. It examines the potential of leveraging the Internet of Things (IoT) in forecasting to address these issues, providing an in-depth analysis of the impact and efficacy of IoT-driven solutions.

The initial sections of the thesis lay the groundwork by elucidating the historical evolution of inventory management, emphasizing the pivotal transition from manual methodologies to sophisticated Warehouse Management Systems (WMS). Core principles of inventory management are explored, encompassing the classification of inventory types and the overarching objectives of an effective IWMS.

The research delves into the nuanced challenges associated with understocking, dissecting its causes such as ineffective demand forecasting and lead time challenges. Consequences are elucidated, emphasizing the adverse effects on customer satisfaction and revenue. The counterpart, overstocking, is scrutinized in terms of poor demand forecasting and bulk ordering practices, revealing implications on holding costs, obsolescence, and overall warehouse efficiency.

A substantial segment of the thesis is dedicated to evaluating the transformative potential of the Internet of Things in the realm of inventory management. It dissects how IoT can revolutionize forecasting accuracy by enabling real-time data acquisition and analysis. The integration of IoT sensors, RFID technology, and connectivity tools is explored, providing a theoretical framework and practical insights into their application within IWMS.

Case studies are presented to exemplify instances where organizations successfully integrated IoT-driven solutions to rectify understocking and overstocking challenges. The analysis not only demonstrates the efficacy of IoT in addressing these issues but also underscores the tangible benefits, including enhanced visibility, reduced errors, and improved overall warehouse efficiency.

The research expands its scope to the domain of demand forecasting, exploring how IoT technologies can augment traditional statistical methods. The thesis delves into the application of IoT in demand sensing, predictive analytics, and collaborative forecasting, showcasing the potential of a more dynamic and responsive forecasting paradigm.

In tandem with the exploration of IoT-driven solutions, the thesis identifies and elaborates on best practices in inventory management. This includes the adoption of Just-in-Time (JIT) strategies,

Vendor-Managed Inventory (VMI), and cross-docking practices. Through case studies, the effectiveness of these strategies is highlighted, providing a holistic view of how technology and best practices can synergize for optimal results.

The challenges and future trends in inventory management are critically examined, culminating in a discussion on the role of IoT in shaping the future of warehouse management systems. The thesis concludes with a synthesis of key findings, offering recommendations for practitioners, industry stakeholders, and avenues for future research.

In essence, this thesis not only underscores the criticality of addressing understocking and overstocking challenges in inventory warehouse management but also highlights the transformative potential of the Internet of Things in revolutionizing forecasting accuracy and enhancing overall warehouse efficiency. Through a judicious blend of theoretical insights and practical case studies, this research contributes to the evolving discourse on the integration of IoT in modern supply chain management.

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SYMBOLS		
ABBREVIATIONS	**IoT**	Internet of Things
	IoE	Internet of Everything
	SoC	System on a Chip
	MCU	Microcontroller Unit
	API	Application Programming Interface
	SDK	Software Development Kit
	SSID	Service Set Identifier
	WPA/WPA2	Area Under Curve
	RFID	Radio-Frequency Identification
	JSON	JavaScript Object Notation
	HTTP	Hypertext Transfer Protocol
NOMENCLATURE		
	1. NodeMCU	An open-source firmware and development kit based on the ESP8266 WiFi module, simplifying IoT project development.
	2. ESP8266	A low-cost Wi-Fi module with a full TCP/IP stack and microcontroller capabilities, commonly used in IoT applications.
	3. ThingSpeak	An IoT platform that enables the collection, analysis, and visualization of data from IoT devices, with support for MATLAB analytics.
	4. IFTTT	Stands for "If This Then That." A web-based service that allows the creation of applets to automate tasks and integrate various online services and devices.
	5. Ultrasonic Sensor	A device that uses ultrasonic waves to measure the distance to an object by emitting pulses and calculating the time it takes for them to bounce back.

CHAPTERS

✓ Chapter 1: INTRODUCTION

In the dynamic landscape of modern commerce, where global markets interconnect seamlessly and consumer expectations evolve rapidly, the efficient management of inventory within warehouses stands as a critical determinant of organizational success. An intricate dance between supply and demand, inventory management is a linchpin that orchestrates the delicate balance between ensuring product availability and minimizing costs. This thesis embarks on a comprehensive exploration into the challenges embedded in Inventory Warehouse Management Systems (IWMS), with a specific focus on the persistent dilemmas of understocking and overstocking. At the core of this investigation lies the transformative potential of the Internet of Things (IoT) in forecasting—a technological beacon guiding organizations toward intelligent solutions for mitigating these challenges and propelling warehouse management into a new era of efficiency and adaptability.

Background

The historical evolution of inventory management is marked by a gradual shift from manual, labor-intensive methodologies to the sophisticated, technology-driven Warehouse Management Systems (WMS) that characterize the modern era. The initial section of this thesis provides a comprehensive overview of the evolution of inventory management, highlighting the pivotal milestones and paradigm shifts that have shaped its trajectory. Understanding this historical context is crucial to contextualize the contemporary challenges faced by organizations in efficiently managing their inventory within warehouses.

Objectives of the Thesis

The primary objective of this thesis is to conduct a comprehensive analysis of the challenges posed by understocking and overstocking within Inventory Warehouse Management Systems. Moreover, the research aims to evaluate the transformative potential of the Internet of Things in forecasting to address these challenges effectively. Through an exploration of real-world case studies, theoretical frameworks, and technological applications, the thesis seeks to provide valuable insights for practitioners, scholars, and industry stakeholders.

Structure of the Thesis

The subsequent sections of this thesis will delve into a thorough literature review, examining the historical evolution of inventory management, the challenges posed by understocking and overstocking, and the significance of forecasting. The research will then transition to an in-depth analysis of the transformative role of IoT in mitigating these challenges. Case studies will be presented to illustrate successful implementations of IoT-driven solutions. The thesis will conclude with a synthesis of key findings, recommendations for practitioners, and avenues for future research.

In essence, this introduction sets the stage for a profound exploration into the intricate realm of Inventory Warehouse Management Systems, unraveling the challenges, and illuminating the potential of IoT-driven forecasting solutions in reshaping the future of warehouse efficiency and supply chain resilience.

✓ Chapter 2: LITERATURE REVIEW

1. **Historical Evolution of Inventory Management Systems:**
The roots of inventory management can be traced back to the early days of commerce when manual methods were employed to track and control stock levels. Over time, the advent of technology ushered in a paradigm shift, evolving inventory management into sophisticated Warehouse Management Systems (WMS). Historically, the primary goal was to maintain adequate stock levels, but the complexities of modern supply chains demand a more nuanced and technologically driven approach.

2. **Significance of Inventory Management in Modern Businesses:**
Effective inventory management is recognized as a strategic imperative for contemporary businesses. It extends beyond the logistical sphere, influencing financial performance, customer satisfaction, and competitive positioning. Organizations strive to strike a balance between meeting customer demands, minimizing holding costs, and optimizing the flow of goods through the supply chain. The strategic significance of inventory management is underscored by its direct impact on overall operational efficiency and profitability.

3. **Challenges in Inventory Management: Understocking and Overstocking:**
Two perennial challenges, understocking, and overstocking persistently plague inventory management systems. Understocking occurs when inventory levels fall below customer demand, leading to missed sales opportunities and dissatisfied customers. On the contrary, overstocking involves accumulating excess inventory, leading to increased holding costs and the risk of obsolescence. These challenges are multifaceted, rooted in ineffective demand forecasting, lead time variability, and the dynamic nature of market conditions.

4. **Demand Forecasting in Inventory Management:**
The accuracy of demand forecasting emerges as a linchpin in addressing understocking and overstocking challenges. Traditional methods, such as time series analysis and regression modeling, have been the stalwarts of demand forecasting. However, the rapid pace of market changes demands a more agile and responsive approach. This sets the stage for exploring the transformative potential of the Internet of Things (IoT) in enhancing demand forecasting accuracy.

5. **The Internet of Things (IoT) in Inventory Management:**
IoT represents a revolutionary force in the field of inventory management. The interconnected network of devices embedded with sensors, RFID technology, and real-time data capabilities offers a new frontier for enhancing visibility and responsiveness within warehouse environments. IoT facilitates the continuous monitoring of inventory levels, tracking product movement, and collecting real-time data on factors influencing demand. This real-time connectivity enables organizations to move beyond traditional forecasting limitations and adapt swiftly to dynamic market conditions.

6. **IoT-Driven Solutions for Understocking and Overstocking:**
Numerous case studies exemplify how organizations leverage IoT-driven solutions to address understocking and overstocking challenges. Real-time monitoring of inventory levels allows for proactive decision-making, ensuring that stockouts are minimized, and excess inventory is mitigated. The integration of IoT with advanced analytics enables organizations to refine demand forecasting models continuously. As a result, IoT not only serves as a tool for mitigating current challenges but also as a catalyst for ongoing improvement and optimization.

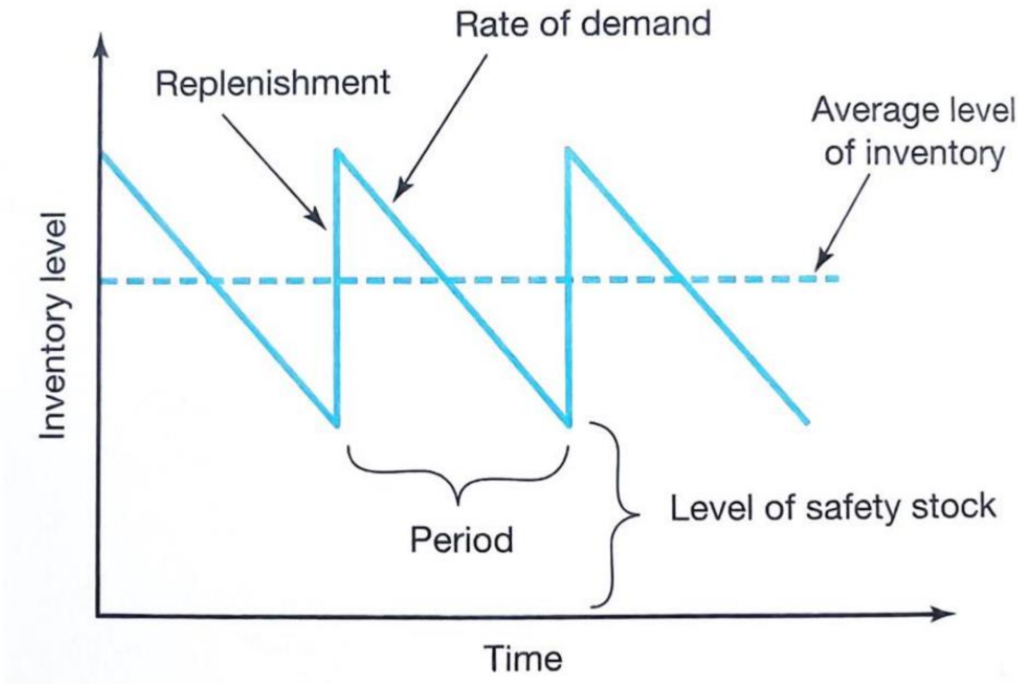
7. **Comparative Analysis of Forecasting Techniques:**
The literature review includes a comparative analysis of traditional and IoT-driven forecasting techniques. While traditional methods have their merits, the limitations become apparent in volatile

and rapidly changing markets. IoT-driven forecasting, with its ability to gather and analyze real-time data, presents a more accurate and adaptive approach. The review aims to provide insights into the strengths and weaknesses of each method, guiding practitioners in selecting the most suitable approach for their specific contexts.

8. **Best Practices in Inventory Management:**
   The literature survey delves into best practices in inventory management, exploring methodologies such as Just-in-Time (JIT), Vendor-Managed Inventory (VMI), and cross-docking. Understanding these best practices is essential for contextualizing how IoT can complement and enhance existing strategies. The goal is to identify synergies between proven methodologies and emerging technologies to achieve optimal results in warehouse efficiency.

9. **Challenges and Future Trends in IoT-Driven Inventory Management:**
   Acknowledging the transformative potential of IoT in inventory management, the literature review addresses the challenges associated with its implementation. Security concerns, data privacy, and integration complexities are among the hurdles that organizations must navigate. Furthermore, the review anticipates future trends in IoT-driven inventory management, offering a glimpse into how emerging technologies such as blockchain, artificial intelligence, and machine learning may further shape the landscape.

10. **Conclusion of the literature review:**
    Acknowledging the transformative potential of IoT in inventory management, the literature review addresses the challenges associated with its implementation. Security concerns, data privacy, and integration complexities are among the hurdles that organizations must navigate. Furthermore, the review anticipates future trends in IoT-driven inventory management, offering a glimpse into how emerging technologies such as blockchain, artificial intelligence, and machine learning may further shape the landscape.



✓ Chapter 3: THEORY, METHODOLOGY, MATERIALS & METHOD

The methodology adopted for the design and implementation of the IoT-integrated inventory tracking and supply chain optimization system is structured to ensure a systematic approach, incorporating pervasive computing principles. The following sections outline the key steps undertaken to conceptualize, develop, and deploy the system.

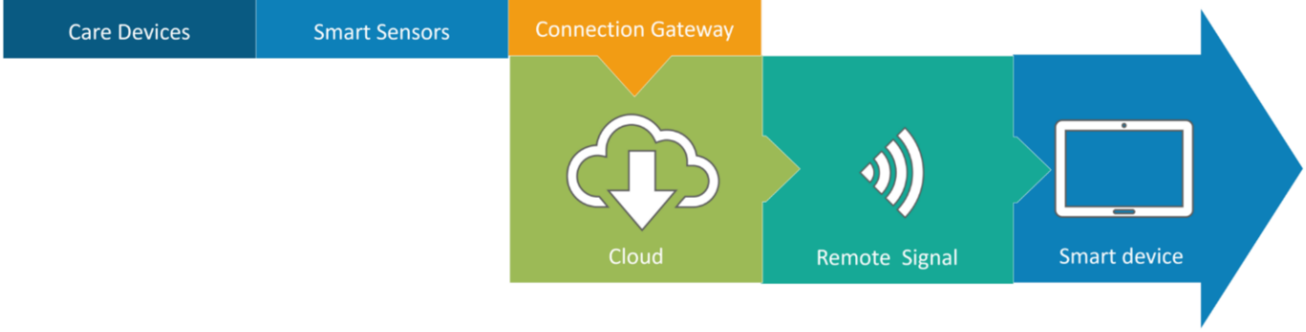
IoT Sensor Selection and Integration

1) Sensor Identification

a. Identified and selected IoT sensors suitable for data collection, including RFID, barcode scanners, and environmental sensors.
b. Considered the compatibility of IoT devices with the pervasive computing infrastructure.

2) Integration Plan

a. Developed a detailed plan for the integration of selected IoT sensors into the existing inventory storage infrastructure.
b. Addressed considerations such as connectivity, power supply, and data transmission protocols.



Working of IOT enables care devices.

PROBLEM STATEMENT:

Understocking in a food inventory management system leads to insufficient stock levels, causing potential disruptions in supply chains and customer dissatisfaction due to unmet demand. It can result in lost sales opportunities and negatively impact the reputation of the business. On the other hand, overstocking poses challenges such as increased holding costs, potential wastage of perishable goods, and the risk of obsolescence. This can strain financial resources and hinder efficient inventory turnover. Balancing the delicate equilibrium between understocking and overstocking is crucial for maintaining operational efficiency, meeting customer demand, and optimizing financial resources in the food industry.

So we're creating a smart inventory system using the Internet of Things (IoT). With this system, you can keep track of your inventory remotely from your home or office. In simple terms, it's a high-tech way to manage and monitor your inventory efficiently, making your life easier.

PROPOSED SYSTEM

we are going to make an IoT enabled inventory management system using an Ultrasonic Sensor, NodeMCU ESP8266, and ThingSpeak cloud platform. In this system Ultrasonic sensor is used to count the number of products stored in a rack, ThingSpeak is used for live monitoring of data, and IFTTT is used to send a mail whenever the products count goes below the user-defined criteria.

The switch is used to turn off or on the energy in a specific region manually. The ESP8266 Node MCU is a programmable IoT kit. Unlike the ESP- 01
ESP8266, which only has the IOT functionality, it has both the IOT and programming features

Figure Node MCU ESP8266 Obviously, wire will be used to connect the components.

NodeMCU (Wi-Fi Module) - NodeMCU is a Wi-Fi SoC (System on chip) produced by Espressif systems. It is based on the ESP8266 – 12E Wi-Fi SoC module. It is a highly integrated chip design to provide full internet connectivity in a small package. It can be programmed directly through a USB port using the Arduino IDE. By simple programming, we can establish a Wi-Fi connection and define input/output pins according to our needs, turning into a web server and a lot more. NodeMCU is a Wi-Fi equivalent of ethernet module. It combines the features of a Wi-Fi access point and station plus microcontroller. These features make the NodeMCU extremely powerful tool for Wi-Fi networking. It can be used as an access point and/or station, host a web server or connect to the internet to fetch or upload data.

Figure Jumper Wire

We are using a breadboard to connect the components because it does not require soldering and is also reusable.

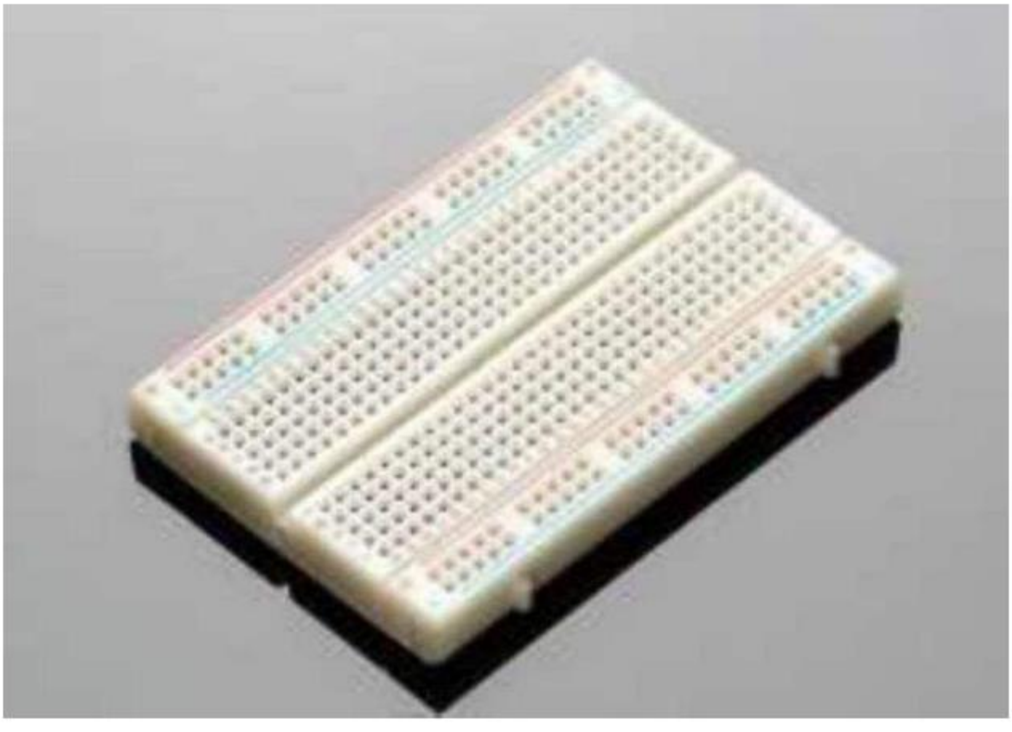


Figure Breadboard

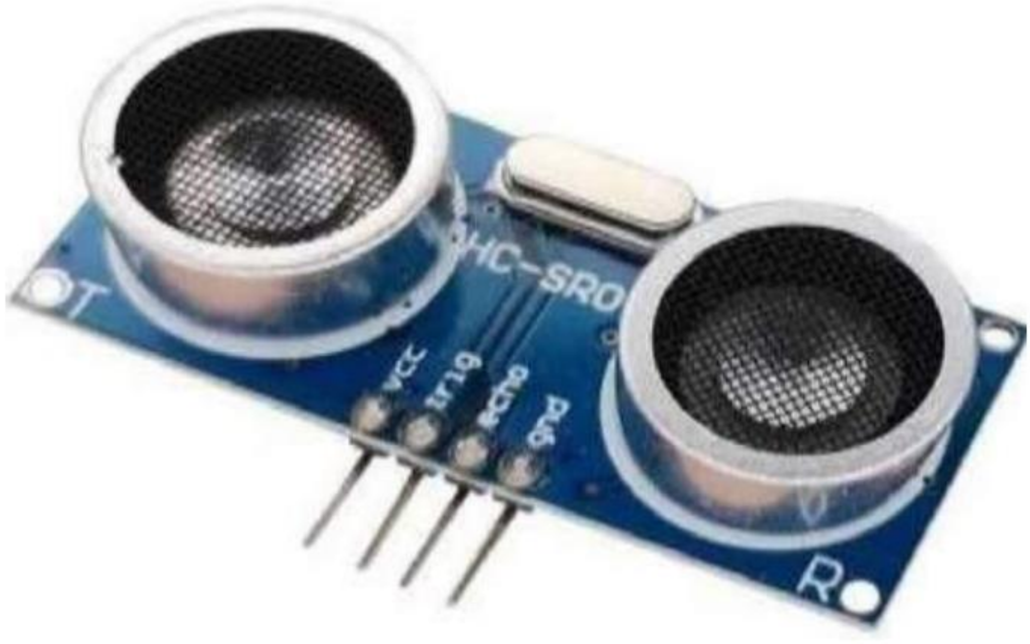


Fig Ultrasonic Sensor

Ultrasonic Sensor -
The ultrasonic transducer utilized is the HC-SR04, which has a transmitter and a receiver and runs on 5 V. There are three input pins and one output pin on the sensor. The echo is the output, and it's connected to the Raspberry Pi through a logic shifter. Two of the remaining three inputs are 5 V and GND. The trigger is the other input, which does not require a level shifter to connect to the Raspberry Pi. The voltage at the output pin drops to zero when a trigger pulse of adequate width (about 10us) is applied to the transducer's trigger pin.

The ultrasonic sensor is a multi-use sensor with four pins. It can be used to avoid obstacles and Ultrasonic sensors use ultrasonic waves to measure
distance. It makes a noise.

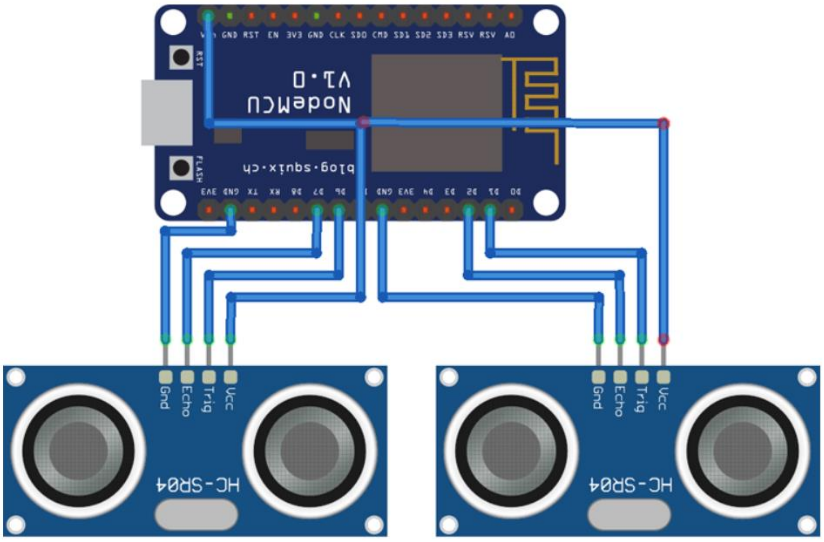
It sends out an ultrasonic pulse and receives the reflected wave from the target. The following formula can be used to calculate the distance:

Distance D = 1/2 × T × C Where T= Time and C= Speed

Where T denotes time and C denotes speed. The concept is to utilize an ultrasonic sensor to measure the distance between it and the stacked boxes. If
we know the width of one box, we can guess how many boxes are currently stacked in a row based on this distance value.

Circuit Diagram

The complete circuit diagram for IoT Inventory System is shown below. It is pretty simple as we only need to connect two ultrasonic sensors with our ESP NodeMCU board.



The Vcc and GND pin of both ultrasonic sensors are connected with Vin and GND pin of NodeMCU. While the trig and echo pins of the first ultrasonic sensor is connected with D1 and D2 and trig and echo pin of the second ultrasonic sensor is connected with D6 and D7 pins respectively. The complete set-up will be powered by the micro-USB port of Node-MCU through a USB cable. I made the connections using connector wires, and it looked like something below

The ultrasonic sensor is a 4-pin multi-use sensor. It can be used as an obstacle avoider and distance calculator. Ultrasonic sensors measure distance by using ultrasonic waves. It emits an ultrasonic wave and receives the wave reflected from the target. The distance can be calculated with the following formula:

Distance D = 1/2 × T × C

Where T= Time and C= Speed

The idea is to use the ultrasonic sensor to measure the distance between the sensor and the boxes that are stack. Based on this value of distance we can predict how much box is currently stacked in a row if we know the width of one box. My project arrangement was something like this.

ThingSpeak Setup

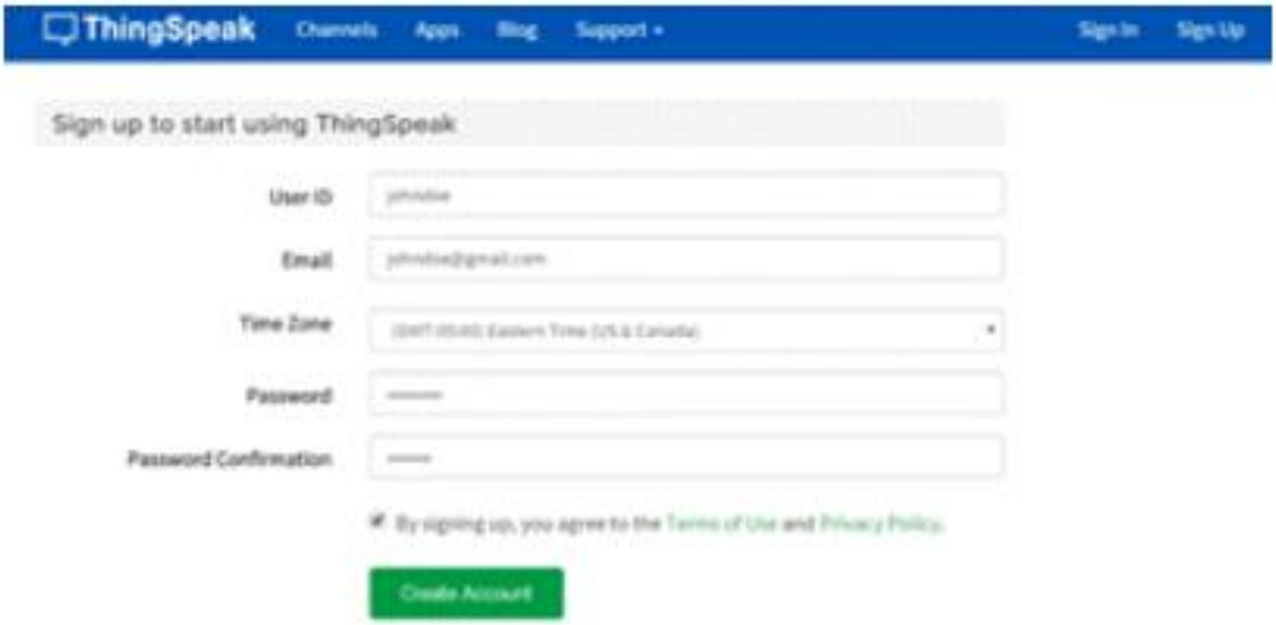
ThingSpeak is an open data IoT Analytics platform that allows you to aggregate, visualize, and analyze live data in the cloud. You can control your devices using ThingSpeak, you can send data to ThingSpeak from your devices, and even you can create instant visualizations of live data, and send alerts using web services like Twitter and ThingHTTP.

Step 1: Sign up

To send data to Thingspeak, a Thingspeak account is required. To do so navigate to Thingspeak website

[https://thingspeak.com/.](https://thingspeak.com/)

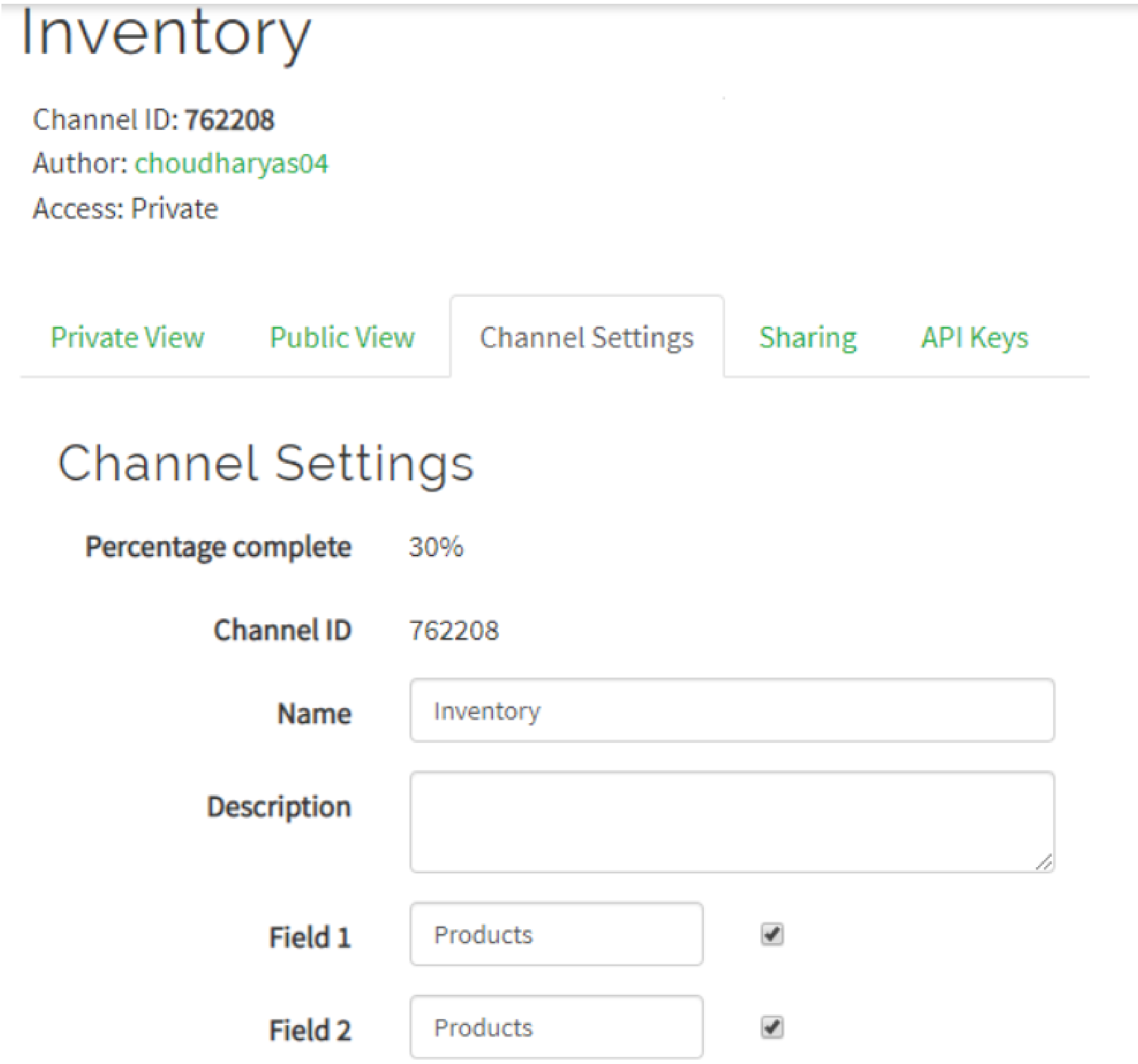
Click on the ‘Sign up’ option in the top right corner and fill out the required details



After this verify your E-mail id and click on continue.

Step 2: Create a Channel for Your Data

Now as you are logged in your account, create a new channel by clicking "New Channel" button.



After clicking on "New Channel," enter the Name and Description of the data you want to upload on this channel. For example, I named it as "Inventory." Enter the name of your data in Field1 and Field2. If you want to use more than two Field, you can check the box next to Field option and enter the name and description of your data.

After that, click on save channel button to save your details. ThingSpeak usually shows data in Graph format, but you can add some widgets in your channel. To add a widget, click on the 'Add Widgets' option and choose the widget you want to use. In this project, I am using the 'Numeric Display' widget.

Step 3: API Key

To send data to ThingSpeak, we need a unique API key, which we will use later in our code to send values from ESP8266 to ThingSpeak. Click on "API Keys" button to get your unique API key for uploading sensor data. Now copy your "Write API Key." We will use this API key in our code.

Inventory

Channel ID: **762208**
Author: choudharyas04
Access: Private

Private View | Public View | Channel Settings | Sharing | API Keys

Write API Key

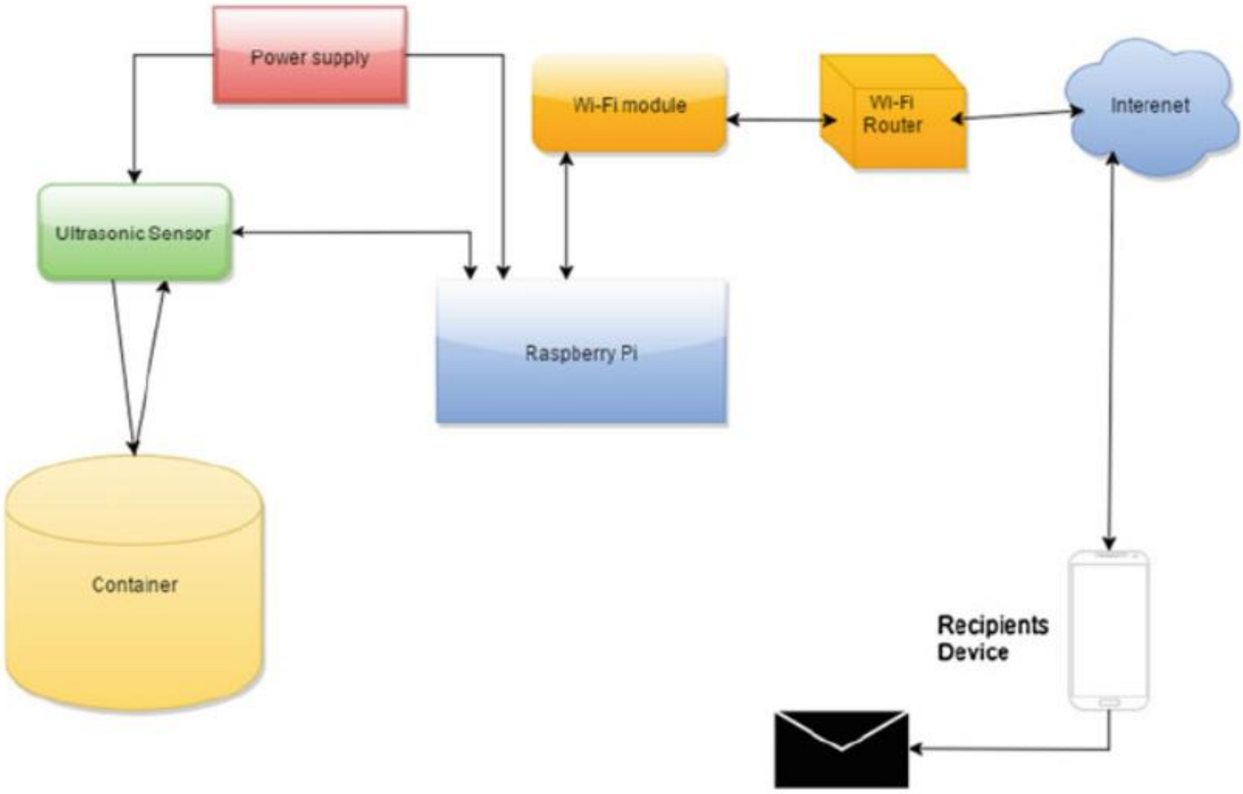
Key [redacted]

Generate New Write API Key

✓ Chapter 4: RESULTS, ANALYSIS & DISCUSSIONS

The experimental model was made according to the circuit diagram and the results were as expected. The home appliances could be remotely switched over Wi-Fi network. Both the switch mode and the voice mode control methodologies were successfully achieved. The Blynk application was also successful in displaying the status of every application.

WORKING



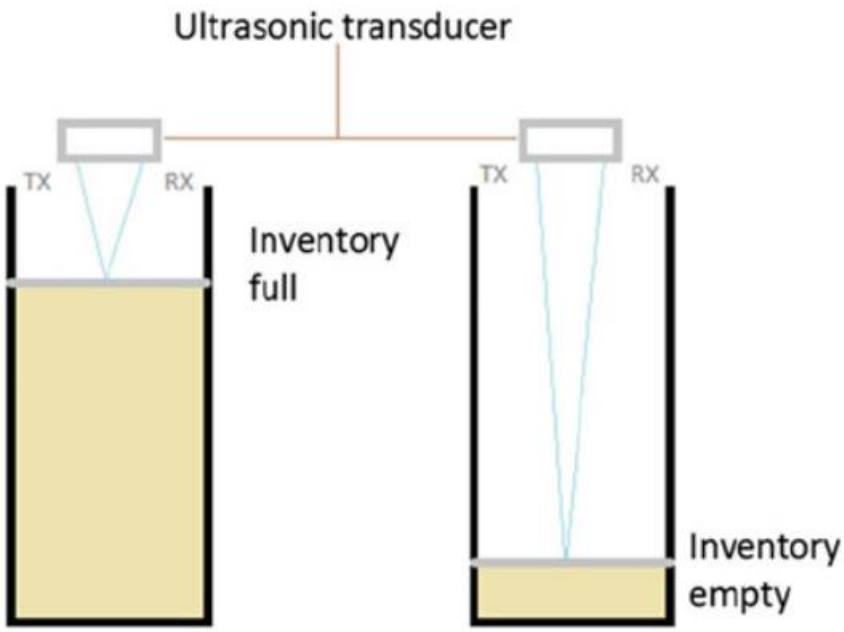
Functional block diagram of the proposed design (Fig 1)

Result:

1. Number of boxes can be seen through sensors to be accessed.
2. Removing the boxes and checking value is being rewritten.
3. Removing some of boxes to check the other output
4. Check value once again.
5. Getting e-mail through IFTT

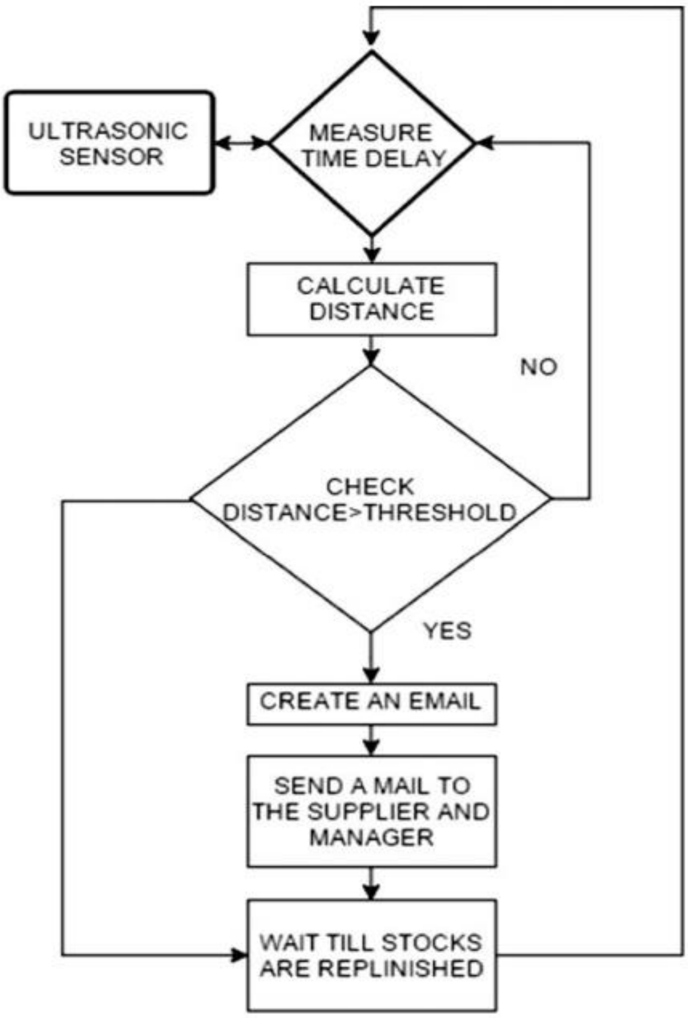
packaging stage. By establishing a shared inventory for vivid departments of the enterprise, it allowed them to timely and efficiently maintain and control their inventory [7,8]. While measuring inventory, there are several measuring sensors that are available in the market, such as a NodeMCU, Arduino UNO, Raspberry PI, load cell etc

In our design, we strive to improve the performance, yet maintain the simplicity ofthe system. Here, we use the power of IOT to simplify and make it efficient by eliminating any unnecessary human interference and automating the entire network responsible for inventory management. The dividing line between the pre-existing design and the proposed design is the use of dedicated hardware for Inventory management. The other ingenious idea incorporated in our design that sets it apart is the effective utilization of the ultrasound transducer to measure the inventory. Since our design has a dedicated hardware, it can run on batteries. This is effective when the system is installed in industries that do not depend mainly on electric power for its operation. In the presented design, an ultrasonic transducer is implemented to measure the stocks available. The design is generalized as shown in Fig. 1. There is no need for modification for change in inventory type. The same transducer can be used to manage both solid and liquid stocks with no changes. This is achieved using the ultrasonic transducer. The transducer is used to measure the time taken for a pulse to travel from the top of the container to the surface of the filled container and return back. This time is used to determine the distance from the top of the container to the surface of the inventory. By assuming two values, i.e., ax and threshold, where max is the distance for full inventory and the threshold is the distance for acceptable minimum inventory. It is clear that max < threshold, since the distance increases with decrease in stocks. The threshold value to be so chosen that the industry should be capable of functioning till the new goods arrive. The stock measurement occurs as shown in Fig. 2. The heart of the system is a Raspberry Pi, which is used for two purposes. First, it is interfaced to the ultrasonic sensor to determine the time (Fig. 3)

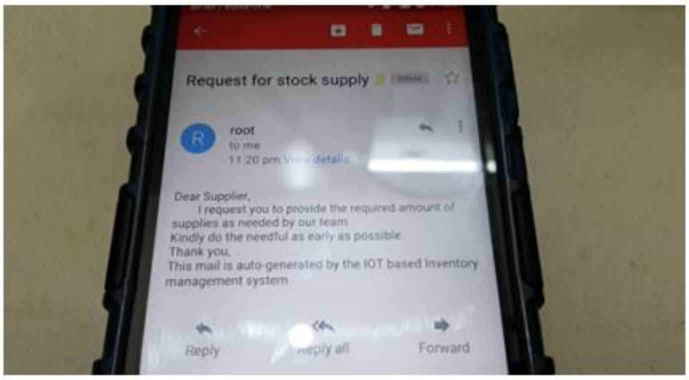


Ultrasonic distance measurement (Fig 2)

Second, the system is connected to the Internet through an LAN cable or using a suitable wireless Wi-Fi module. Figure 1shows the system connected to the net-work via Wi-Fi. The presented design lets that the system sends an e-mail to the supplier as well the company's inventory manager. The inventory management based on IOT eliminates any human interaction with the system, thereby automating it with high efficiency. As we can see, when the stocks reach the threshold value determined in the first stage, the system sends a mail directly to the supplier with the required number of stocks as shown in Fig. 4. It also alerts the inventory manager by sending him a mail about the new order. Using the multitasking ability of the Raspberry Pi, we run two programs necessary for our design. First, the code required for measuring the distance and sending the mail is executed. Second, a Web server is installed and made to run in the background to host a Web page. The Web page contains information, regarding the inventory and whether new stocks are added. This is achieved by installing Apache Web server on the Raspberry Pi. The Apache Web server runs on boot, thereby one can access the Web page by entering the local IP address of the raspberry Pi in their browser. The IP address of the Raspberry PI can be made static, so as to fix the Web page address, else every time, the Raspberry Pi boots the IP address changes. The distance is calculated every 10 min and compared with the threshold value to decide whether to generate a mail or not. After the mail is sent, the system waits until the inventory crosses the threshold value. This is necessary, because the system would continuously send a mail every 10 min if not.



Flow chart of the proposed design (Fig 3)



A typical mail received by the supplier from the system (Fig 4)

SL NO	Component	Quantity
1	NodeMCU ESP8266	1
2	Ultrasonic Sensor	1
3	Breadboard	1
4	Jumper Wires	10-15
5	Arduino Uno	1 (if required)
6	Raspberry pi	1 (if required)

Component listing

✓ Chapter 5: CONCLUSSION, FUTURE SCOPE & LIMITATION

❖ Conclusion:

The cost-effectiveness of this system is obvious. We simplified the system by using other ultrasonic sensors' Vcc and GND pins are linked to the Vin and GND pins of the NodeMCU. The first ultrasonic sensor's trig and echo pins are linked to D1 and D2, respectively. The second ultrasonic sensor's D2 and trig and echo pins are connected to D6 and D7 pins. Respectively. The entire setup will be fueled via Node-micro-USB MCU's connector. Through the use of a USB cable Calculate for distance. Ultrasonic sensors to measure the stocks, which can be utilized for both solid and liquid stocks. It is simpler and easier to mount the ultrasonic sensor because it must be positioned on the top of the container.

As can be seen, the system sends a mail to the provider directly, reducing the need for human intervention. Errors. Because the threshold amount was established in such a way, the stockpiles are sufficient for operation till the New Year. Stocks arrives, the system is self-sufficient and there are no supply shortages. Inventory Because of its low cost, ease of installation, and efficient design, it can be advantageous. It has been deployed in hospitals, small-scale companies, and large-scale industries.

It is simpler and easier to mount. As the user can clearly see the real-time value of the product container, it is easy to track our product items. The threshold value is chosen so that product stocks are sufficient for use until the new stocks arrive. Because of the low cost, effective design and easy implementation, it can be implemented to support the smart home initiative and become an essential prototype.

❖ Future scope:

In this proposed system we had created only one Nodemcu prototype. Multiple Nodemcu prototype can also be created in a similar way to identify differently product items in the kitchen. Also, a database using SQL can be created to have a past record of product items. Furthermore, an application platform can also be created to integrate all the things which include live tracking of multiple product items, database to see a past record of product items and if the product items are running out of stock, one-touch button is provided in the application to contact nearer product vendor by sending SMS of scarce product items.

APPENDICES

➢ **HARDWARE:**

- CPU – i7 11^{th} Gen.
- GPU – Nvidia RTX 3050 (4GB)
- RAM – 16GB (DDR 4)
- OS – WINDOWS 11
- NodeMCU ESP8266
- Ultrasonic Sensor
- Breadboard
- Jumper Wires
- Arduino Uno
- Raspberry pi

➢ **SOFTWARE:**

- Arduino IDE
- ThingSpeak (https://thingspeak.com)
- IFTTT
- Blynk application

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