International Journal of Electrical and Computer Engineering (IJECE)
Vol. 15, No. 1, February 2025, pp. 89~98
ISSN: 2088-8708, DOI: 10.11591/ijece.v15i1.pp89-98

Development of an internet of things based smart cold storage with inventory monitoring system

Suganya Angappan[1], Aarthi Nataraj[1], Loganathan Navaneetha Krishnan[2], Anbarasu Palanisamy[3]
[1]Department of Electrical and Electronics Engineering, Dr. Mahalingam College of Engineering and Technology, Pollachi, India
[2]Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India
[3]Department of Electrical and Electronics Engineering, Sri Eshwar College of Engineering, Coimbatore, India

Article Info

Article history:

Received Apr 10, 2024
Revised Aug 28, 2024
Accepted Oct 1, 2024

Keywords:

Cold container observer
Hotness inquiry
Internet of things
Real time intelligent monitoring and notification system
Superiority figuring

ABSTRACT

Consuming fresh drupes, vegetables can help lower a chance of developing several chronic diseases. Unfortunately, the post-harvest life cycle's storage stage is where fruits and vegetables (FVs) lose the most of all the food that is produced annually. A failure to recognize important ambient environmental conditions when using cold storage seems to be the main causes of this elevated loss rate. The current monitoring systems for cold storage are only able to measure warmth and moistness and ignoring further crucial acceptable surrounding factors of radiance and gas quantity. Serious matter gets handled in order to lower the system's harm degree. The real time intelligent monitoring and notification system (RT-IMNS) for icy container is described briefly in the paper. It employs a device management platform (IoT)-enabled technique to continuously monitor hotness, comparative moisture, brightness, fume quantity and alert staff when dangerous thresholds are reached.

Corresponding Author:

Anbarasu Palanisamy
Department of Electrical and Electronics Engineering, Sri Eshwar College of Engineering
Kinathukadavu block, Coimbatore District, Tamil Nadu 641202, India
Email: anbarasu.p@sece.ac.in

1. INTRODUCTION

According to food and agriculture organization (FAO), food loss is projected like 1.3 bn tone for 12 months, or 33% of total generation. The need for food is always rising and by 2050 it may be 150% to 170% higher than it is today. Additionally, the World Health Organization (WHO) estimates that inadequate intake of fruits and vegetables (FVs) contributes to almost 1.7 million deaths annually worldwide.

In comparison to every nutritious, such as flesh of an animal (20%), crops yielding (20%), dairy (20%), and grain (30%), fish and sea food have a higher loss rate (35%) than FVs (45%). The gerund of FVs, which will continues even after received and stay until they are overripe or begin to rot, is often thought to be slowed down by low temperatures in cold storage [1]. Although there are other important environmental factors to reduce the worth of FVs container part besides heat and relative moistness, such as gas concentrations (CO_2, O_2, C_2H_4) [2], [3], light intensity [4], [5] and dust.

The existing cold storage in underdeveloped nations ignores all these environmental factors, rejecting warmth and moistness, that results in a high rate of FV loss. In light of this, In order to dilute the drawbacks on perishable FVs in freezer container, intellectual observation on crucial social factors like hot, moisture level, carbon dioxide, including luminous level is required [6]. There are several unique techniques in the field of cold storage system that includes optimization algorithms [7], novel intelligent monitoring system, and intelligent cooling system using design changes in induction motor [8].

Cool depository is a useful tactic to preserve the calibre of perishable goods from manufacture to consumption [9]. Here, minimizing the drop of putrefiable goods namely FVs, sensitive persons is our top priority. We monitor environmental factors within cold storage in real time in view of executing it. This study describes an internet of things (IoT) supported instantaneous intelligent surveillance and alerting system for several environmental parameters, including correlative moistness, illumination velocity, ambient temperature, and gas agglomeration in frosty environments [10], [11].

Figure 1 depicts how real time intelligent monitoring and notification system (RT-IMNS) functions in the FV supply chain. Following cultivation, FVs are transported right away. They are first kept in cold storage, where goods may be kept for a short or long time, before being sent to a grocery store, where consumers pick them up. The suggested method uses an RT-IMNS sensor device installed in cold storage to measure environmental factors in real time. These values are sent to a cloud database via ESP-WROOM-32, where they will be kept. Using the RT-IMNS Android app, staff members may keep an eye on these environmental factors and verify the condition of commodities anticipated by prediction models at any time, from any location. Unlike previous procedures, cold storage does not need staff to be physically present. Because the encircling conditions in cool depository are automatically monitored in instantaneous, taking timely action has become easier.

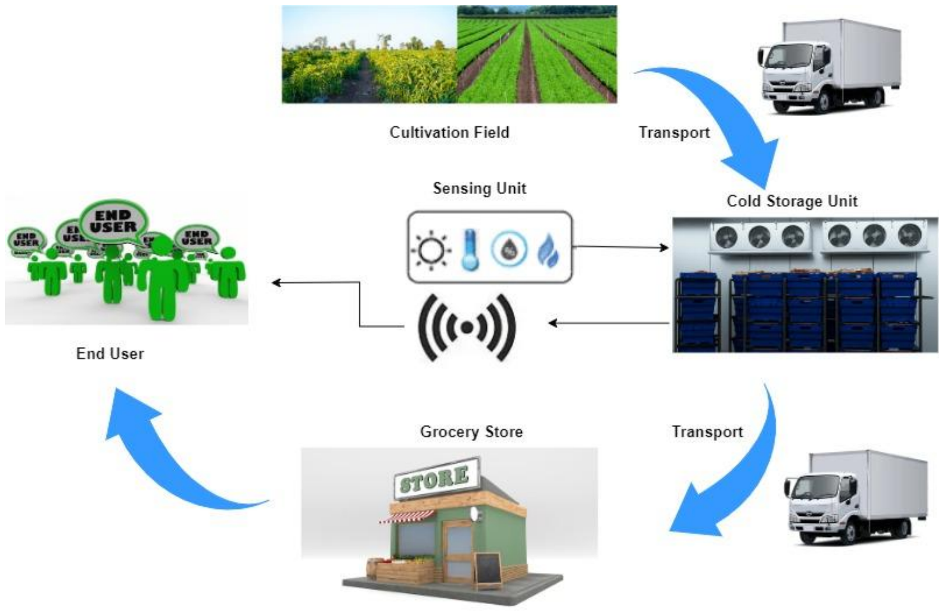


Figure 1. RT-IMNS food supply chain

2. PROPOSED SYSTEM

2.1. Objective of the proposed system

The internet of things is among the most effective technologies for managing, regulating, and intensify supply chain performance [12]. The device helps to trace the place of the product, while the wireless sensors help to regulate environmental factors like temperature and humidity, according to the authors who demonstrated an interface for consuming the IoT to surveil and control a warehouse [13]–[15]. Temperature accuracy class, which categorizes temperature recording systems, is one of the standards that a monitoring system must satisfy [16]. The suggested approach is utilized to lower the perishable goods' rate of loss in the cold storage area. Utilizing ambient condition monitoring sensors, output devices, also an embedded controller with wireless local area network (WLAN) effectiveness, data may be accessed from the cloud at any time and uploaded to a Google Spread Sheet.

2.2. Block diagram of RT-IMNS

The research methodology is provided in the Figure 2. The methodology explains the research design, repeatable research processes, and data summarization and analysis techniques. The ESP8266 is a cost-effective Wi-Fi microcontroller for IoT applications. The block diagram of RT-IMNS illustrates the information flow among various sensors like MQ-135 for air quality, DHT-11 for temperature and humidity, light-dependent resistor (LDR) for light intensity. The collected analog signals are converted into digital signals in data acquisition unit. This data is processed in microcontroller for decision making based on predefined threshold values. Furthermore, these data are stored in data base for historical analysis and allow user interface to visualize data and to send alerts to end users.

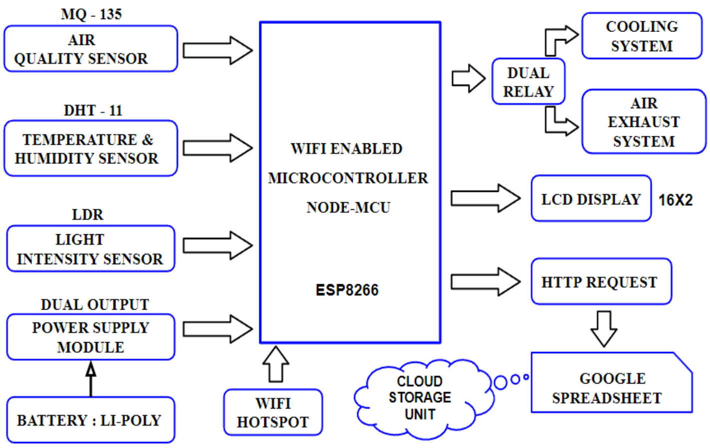


Figure 2. Block representation of the proposed RT-IMNS

2.3. Circuit diagram of proposed RT-IMNS system

The circuit diagram of the suggested method is depicted in the Figure 3. The circuit diagram comprises of various components and the data collected from various sensors are processed in the microcontroller, which serve as the central processing unit. For remote monitoring and control, Wi-Fi module is used to communicate with a user interface. In addition to that, alert mechanism is provided in terms of liquid crystal display (LCD) display to alert user when predefined threshold limits are met. This interconnected system enables real time monitoring to users.

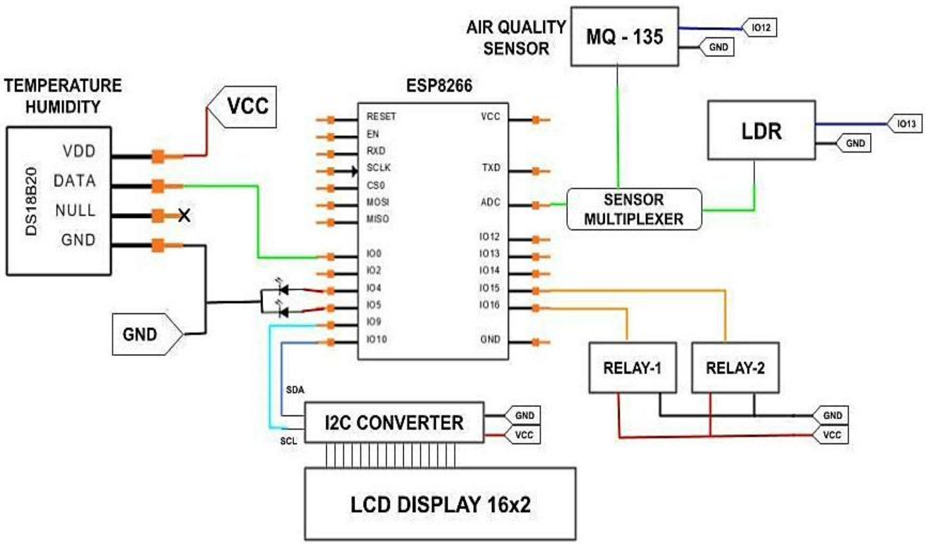


Figure 3. Circuit diagram of the proposed RT-IMNS system

2.4. Flow diagram of proposed RT-IMNS system

The flowchart representation of the invented scheme is depicted in Figure 4. There are two main blocks in the depicted Figure 4. The censoring with controlling block and the algorithmic block with database storage and display.

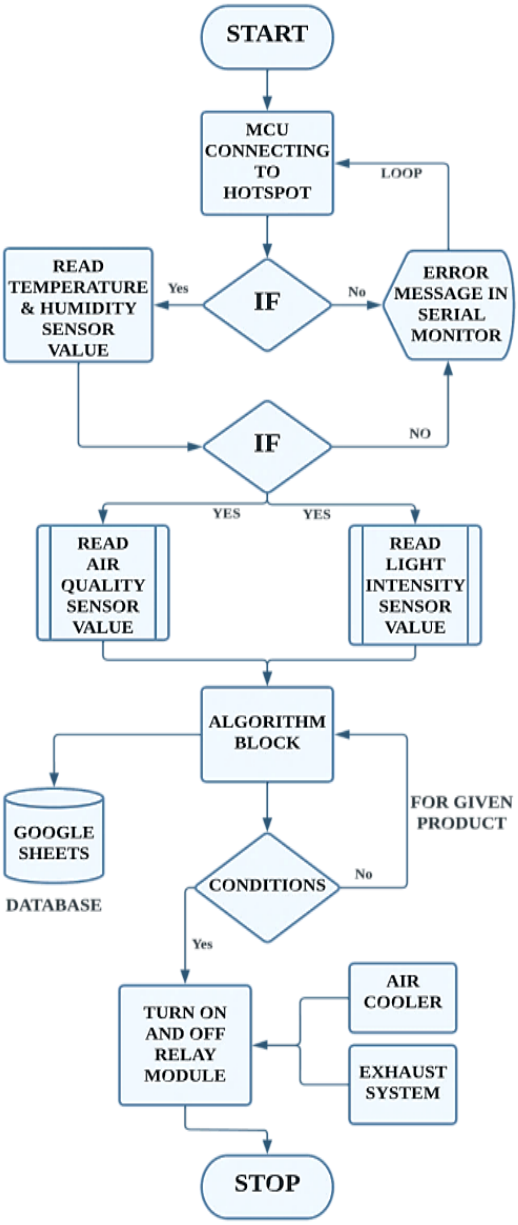


Figure 4. Flowchart of the proposed RT-IMNS system

3. RESEARCH METHOD

3.1. Monitoring unit

Two units, a monitoring unit and a controlling unit, make up the processing system. All sensor data is gathered by the monitoring unit, which then uploads the numbers to Google Sheets every three seconds in a variety of formats, including Microsoft Excel, open document, PDF, comma separated numbers, and tab separated values. The values are processed to provide a final status on the product quality and environmental factors for cold storage as: excellent, moderate, or poor.

3.2. Controlling unit

The controlling unit plays a vital role in processing the several data collected from various sensors. The control unit gathers all the data and sends it to the algorithm block, which is a set of instructions that, depending on the product type, conducts activities like turning on and off the exhaust system and the air-cooling system. This is done to regulate the ambient conditions in the storage unit for the specific products. In addition, feedback mechanism is incorporated in the system for better performance based on user inputs or change in environmental aspects.

3.3. Hardware components of the system

3.3.1. Microcontroller-ESP8266

A cheap, simple, small, and low-powered Wi-Fi module that can have both the message queuing telemetry transport (MQTT) and serial protocols is the espressif system ESP8266 as depicted in Figure 5, also known as the ESP8266 wireless transceiver. It connects the IoT-based control (IoT-BC) peripherals to the cloud platform and the internet [17], [18]. The ESP8266 hosts applications, which launch instantly from the flash. The optimized utilization of memory is supported by the integrated high-speed cache. The compact form removes the need for large printed circuit boards (PCBs).

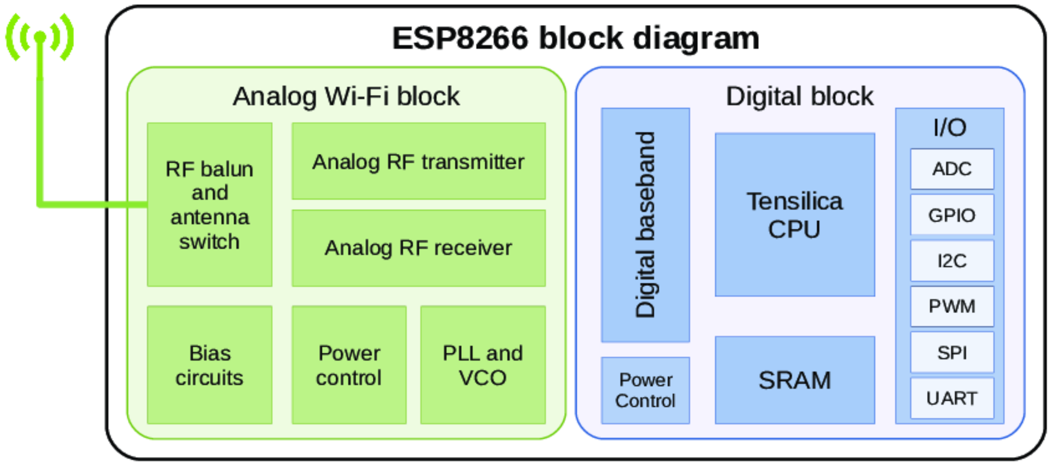


Figure 5. Block diagram of ESP8266

3.3.2. Temperature and humidity sensor

DHT11 is a standard sensing equipment to determine the heat and humid level. Self-supervision level of the cool depository and handling must be improved for further reinforcement, and the performance expenses must be significantly reduced, if we proceed to move the refrigerator industry toward a shielded, regulated, atmospheric defense, fuel-efficient, appropriate behavior, and plain form of development [19], [20]. The sensor transmits temperature and humidity data serially and includes an 8-bit microprocessor and negative temperature coefficient (NTC) for heatness quantification. It is plain to bind the sensor to different microcontrollers because it has been fully calibrated. The sensor has a 2 °C and 2% accuracy and can measure heat from zero degree to fifty degree Celsius and humid levels from twenty percentages to 80% [21]. The mentioned sensing equipment is made up of a storage element for identifying humidity and a resistance thermometer for calculating heat shown in Figure 6. Amongst the 2 electrodes of the humid detector capacitor, there is a non-conducting medium to hold moisture. The R rate decreases as the heat rises because this sensing element utilizes a NTC resistance thermometer to measure heat. R rises for a small change in heat [22]. The DHT11's specifications are listed below.

– Working voltage: 3.50 to 5.75 V
– Working current: 0.3 mA (measuring) 60 µA (standby)
– Output: serial data
– Working temperature: 0 °C to 55 °C
– Humidity range: 10% to 85%
– Resolution: 16-bit
– Accuracy: ±2 °C for temperature and ±2% for humidity

3.3.3. LI sensor – LDR module

By detecting the ecstatic vitality which prevails in the extremely constrained set of periodic cycles that are commonly denoted to be illuminous, also this range of periodic cycle which starts from IR till visible extended till UV, the above device generates O/P sign to specify the strength of illuminous is shown in Figure 7. LDR module changes its resistance based the light intensity that falls on it, making the system to act on variations in lighting. This module contributes in energy conservation and also in security aspects.

3.3.4. Air quality sensor – MQ135

The MQ-135 as shown in Figure 8 is an air quality sensor (C_6H_6), and CO_2 [23]. This one from the MQ family features both a D/A O/P port. If the level of prementioned chemicals shoots up above the prescribed rate, the D port reacts immediately. This rate will change by implementing variable resistance. An analog voltage is produced by the analog output pin and can be used to calculate the concentrations of atmospheric gases.

The module depicted in Figure 9 locates dangerous pollutants in the air in residences and businesses. Tin dioxide (SnO_2), which makes up the conductivity of the sensor unit's gas sensor layer, which is less than that of unpolluted hair, rises in response to air pollution. A tiny potentiometer built inside the air quality sensor enables the user to adjust the load resistance of the sensor circuit. A 5 V power source powers the air quality sensor. It must be heated up in order to produce trustworthy results.

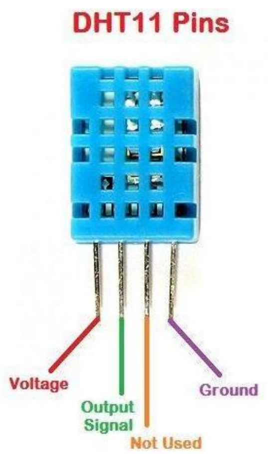


Figure 6. Representation of DHT11

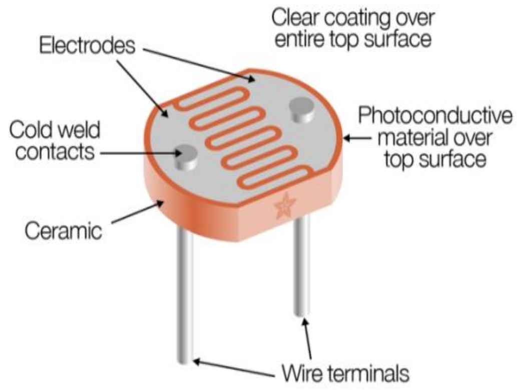


Figure 7. LDR sensor

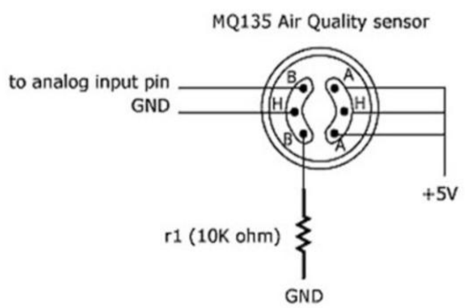
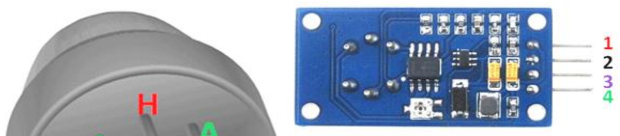


Figure 8. MQ-135



Pin No.	Pin Name
1	Vcc(+5V)
2	Ground
3	Digital Out
4	Analog out

Figure 9. Representation of air quality sensor

4. RESULTS AND DISCUSSION

Implementing an IoT-based module yields substantial benefits in terms of operational efficiency, product quality assurance, and regulatory compliance. Stakeholders can use IoT technology to optimize cold storage management methods, cut costs, and improve overall business resilience in the face of changing market demands and environmental problems. To deduct the deprivation of putrefiable items in cool depository, we exhibited an intelligent system for instantaneous surveillance and alerting using an IoT-enabled method. This system automatically monitored the temperature of the inside and exterior atmospheres, as well as the internal RH, CO_2, C_2H_4, and ambient light intensity level and alerts users to unsafe environmental parameter thresholds such as hotness, parallel moistness, gas level, and illumination level. In addition, the table will display presented data such as temperature, gas level, and humidity. It worked on both the design and the LCD screen. The temperature ranges from 40 °F to 120 °F, the moisture level ranges from 10% to 100%, the gas level differ from CO_2 from 0 to 5,000 ppm and Lithium from 100 to 5,000 ppm/Lum and the light intensity ranges from 162 to 171. The gathered data is displayed in Table 1.

Table 1. Database output I

Temperature (F)	Humidity (%)	Light Intensity
42	82	162
42	82	172
45	81.5	186
45	82	186
45	82	170
45	85	170
44	85	170
41	86	169
53	90	169
51	90	169
40	92	168
40	80	168
60	85	170
62	85	169
58	82	170
78	25	169
80	23	171
68	38	170
70	35	171
58	70	169

Performance evaluation predicts that the suggested strategy will help prevent the loss of perishable FVs. Additionally, our suggested method allows for instantaneous surveillance via an Android application remotely all time. Additionally, suggested RT-IMNS creates and notifies staff members of potentially hazardous environmental parameter limitations so they can take the appropriate action in a timely manner. However, current monitoring methods are limited to measuring temperature and do not allow for real-time monitoring via an Android app.

Furthermore, there is no way to alert staff members when appropriate action needs to be taken in the existing methods. As depicted in Figure 10, the first graphical user interface that displays when the user launches the RT-IMNS app pulls instantaneous surrounding factors from the RT-IMNS directory. Based on read values, the prediction model determines whether the commodity's state is good, unsatisfactory, or frightening when the user presses the status button. The user receives an automated alert for urgent action when conditions become frightening or unacceptable. On the RT-IMNS app, users may also view a graph of measured environmental data like temperature, humidity, CO2 concentration, and light intensity as depicted in the Figure 11.

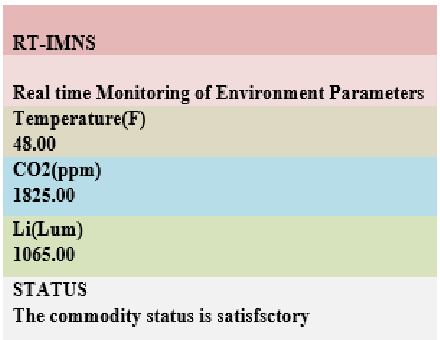


Figure 10. Details of monitored values in App

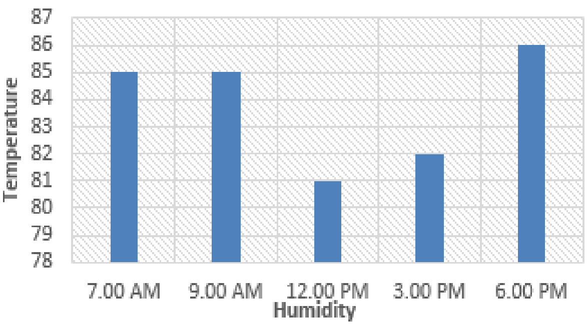


Figure 11. Graphical depiction in App

The objective of the suggested instantaneous surveillance cum notifying module is to rank the commodity's position into three batches: good, satisfactory, or worrying. From analysis, it was found that to ban tinned commodities from rotting, dilating, clearance ought to be chill and arid. The allowed hotness scale is between 50 °F and 59 °F, Ripe fresh fruits and vegetables should be kept in storage between 35 °F and 40 °F [24]. The best temperature to preserve bananas is at 55 °F; oranges, 39 °F to 41 °F; apples, 30 °F to 39 °F [25]; mangos, 50 °F to 55 °F; and papayas, 45 °F. This can also be extended for other commodities. The suggested module has been executed in hardware and the same has been depicted in the Figure 12.

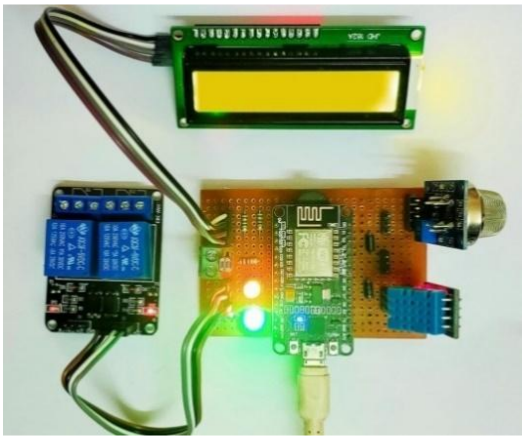


Figure 12. Hardware representation of the proposed system

5. CONCLUSION

Aside from temperature and relative humidity, present strategies prohibit instantaneous surveillance of several surrounding factors. Moreover, not a single method exists to alert personnel, the instantaneous condition of commodities in cool depository over time. Now, an instantaneous surveillance and communicating module in accordance with an IoT supported method and aiding in beating the depriving of putrefiable commodities in cool depository. The suggested system efficiently monitors the ambient environmental conditions, thereby lowering the high loss rate. It monitors the temperature, relative humidity, light, and fume quantity to inform the entire system when there is a threat. Finally, the creation of an intelligent module in accordance with IoT in smart cool depository system with new surveillance indicates a vital forge ahead in the management of perishable goods. Through seamlessly integrating hardware, software, and data analytics, this revolutionary system assures ideal storage conditions, improves inventory visibility, and reduces the risks associated with temperature changes and stock shortages. The system's ability to modify ambient conditions using wireless sensors and real-time parameter monitoring will make it indispensable in the warehouse industry. Workers in the warehouse can accurately monitor temperature, humidity, and gas configuration due to the product's dependability and quickness, allowing them to take precautions and keep food safe. Using a wireless network can help you save space, money, and power. Monitoring several elements remotely allows for more efficient utilization of the labor and increases product quality. Because of the huge increase in demand for cold storage services, occupational safety for warehouse employees is becoming increasingly important. To ensure occupational health and safety in cold storage facilities, comprehensive occupational safety management with real-time information sharing and integration is required. Worker safety can be ensured by providing appropriate alarms and real-time situational visualization. By implementing this approach, productivity and performance at work can be improved.

REFERENCES

[1] R. Torres-Sánchez, M. T. Martínez-Zafra, N. Castillejo, A. Guillamón-Frutos, and F. Artés-Hernández, “Real-time monitoring system for shelf-life estimation of fruit and vegetables,” *Sensors*, vol. 20, no. 7, Mar. 2020, doi: 10.3390/s20071860.

[2] D. El-Rayes, “Effect of carbon dioxide-enriched atmosphere during cold storage on limiting antioxidant losses and maintaining quality of ‘Barhy’date fruits,” *Journal of King Abdulaziz University-Meteorology, Environment and Arid Land Agriculture Sciences*, vol. 20, no. 1, pp. 3–22, 2009, doi: 10.4197/met.20-1.1.

[3] M. M. Blanke and R. Shekarriz, “Gold nanoparticles and sensor technology for sensitive ethylene detection,” *Acta Horticulturae*, vol. 934, pp. 255–262, 2012, doi: 10.17660/ActaHortic.2012.934.31.

[4] L. Manzocco, B. Quarta, and A. Dri, “Polyphenoloxidase inactivation by light exposure in model systems and apple derivatives,” *Innovative Food Science and Emerging Technologies*, vol. 10, no. 4, pp. 506–511, 2009, doi: 10.1016/j.ifset.2009.02.004.

[5] S. Noichinda, K. Bodhipadma, C. Mahamontri, T. Narongruk, and S. Ketsa, “Light during storage prevents loss of ascorbic acid, and increases glucose and fructose levels in Chinese kale (*Brassica oleracea var. alboglabra*),” *Postharvest Biology and Technology*, vol. 44, no. 3, pp. 312–315, 2007, doi: 10.1016/j.postharvbio.2006.12.006.

[6] Y. P. Tsang, K. L. Choy, C. H. Wu, G. T. S. Ho, H. Y. Lam, and P. S. Koo, “An IoT-based cargo monitoring system for enhancing operational effectiveness under a cold chain environment,” *International Journal of Engineering Business Management*, vol. 9, 2017, doi: 10.1177/1847979017749063.

[7] H. Afreen and I. S. Bajwa, “An IoT-based real-time intelligent monitoring and notification system of cold storage,” *IEEE Access*, vol. 9, pp. 38236–38253, 2021, doi: 10.1109/ACCESS.2021.3056672.

[8] E. Gogou, G. Katsaros, E. Derens, G. Alvarez, and P. S. Taoukis, “Cold chain database development and application as a tool for the cold chain management and food quality evaluation,” *International Journal of Refrigeration*, vol. 52, pp. 109–121, 2015, doi: 10.1016/j.ijrefrig.2015.01.019.

[9] M. Dora, J. Wesana, X. Gellynck, N. Seth, B. Dey, and H. De Steur, "Importance of sustainable operations in food loss: evidence from the Belgian food processing industry," *Annals of Operations Research*, vol. 290, no. 1–2, pp. 47–72, Jul. 2020, doi: 10.1007/s10479-019-03134-0.

[10] B. Sarmah and G. Aruna, "Detection of food quality and quantity at cold storage using IoT," in *2020 International Conference on Wireless Communications, Signal Processing and Networking, WiSPNET 2020*, 2020, pp. 200–203, doi: 10.1109/WiSPNET48689.2020.9198348.

[11] S. G. Srivatsa, K. R. M. Bharadwaj, S. L. Alamuri, M. M. C. Shanif, and H. S. Shreenidhi, "Smart cold storage and inventory monitoring system," in *2021 6th International Conference on Recent Trends on Electronics, Information, Communication and Technology, RTEICT 2021*, pp. 485–488, 2021, doi: 10.1109/RTEICT52294.2021.9573939.

[12] M. Eden, V. Raab, J. Kreyenschmidt, T. Hafliason, G. Olafsdóttir, and S. G. Bogason, "Continuous temperature monitoring along the chilled food supply chain," *Food Chain Integrity: A Holistic Approach to Food Traceability, Safety, Quality and Authenticity*, pp. 115–129, 2011, doi: 10.1016/B978-0-85709-068-3.50008-1.

[13] A. Ali, M. T. M. Muhammad, K. Sijam, and Y. Siddiqui, "Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya L.*) fruit during cold storage," *Food Chemistry*, vol. 124, no. 2, pp. 620–626, 2011, doi: 10.1016/j.foodchem.2010.06.085.

[14] H. Hromic *et al.*, "Real time analysis of sensor data for the internet of things by means of clustering and event processing," in *IEEE International Conference on Communications*, vol. 2015-Septe, pp. 685–691, 2015, doi: 10.1109/ICC.2015.7248401.

[15] Y. Omura, A. Mallik, and N. Matsuo, "MOS devices for low-voltage and low-energy applications," *MOS Devices for Low-Voltage and Low-Energy Applications*, pp. 1–465, 2016, doi: 10.1002/9781119107361.

[16] P. J. Sousa, P. Abreu, and M. R. Quintas, "Modular system for cold storage monitoring," *International Journal of Online Engineering*, vol. 12, no. 4, pp. 46–48, 2016, doi: 10.3991/ijoe.v12i04.5127.

[17] M. Mohammed, K. Riad, and N. Alqahtani, "Design of a smart IoT-based control system for remotely managing cold storage facilities," *Sensors*, vol. 22, no. 13, Jun. 2022, doi: 10.3390/s22134680.

[18] T. Lu and Z. Liu, "Temperature control system of cold storage," in *2015 International Conference on Electromechanical Control Technology and Transportation*, 2015, pp. 1–6, doi: 10.2991/icectt-15.2015.1.

[19] M. S. S. Mitkari, "A survey paper on cold storage monitoring system using IoT," *International Journal for Research in Applied Science and Engineering Technology*, vol. 8, no. 12, pp. 642–645, 2020, doi: 10.22214/ijraset.2020.32582.

[20] A. Popa *et al.*, "An intelligent IoT-based food quality monitoring approach using low-cost sensors," *Symmetry*, vol. 11, no. 3, 2019, doi: 10.3390/sym11030374.

[21] N. Loganathan, A. Selvanayakam, P. Anbarasu, and T. Logeswaran, "IoT-based energy meter monitoring system for sustainable development," *Journal of Environmental Protection and Ecology*, vol. 25, no. 1, pp. 182–191, 2024.

[22] N. Aarthi, P. Anbarasu, D. Nagarajan, A. Sajitha Banu, and M. Vinosh, "Genetic based fuzzy logic control of SEDC motor," in *2023 International Conference on Computer Communication and Informatics, ICCCI 2023*, pp. 1–6, 2023, doi: 10.1109/ICCCI56745.2023.10128371.

[23] A. Selvanayakam, A. C. Varishnee, S. Deepika, and N. Hemalatha, "LLC resonant converter with modified gain model and semi active structure rectifier," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 12, pp. 1162–1166, 2018.

[24] N. M. Chinenye, S. I. Manuwa, O. J. Olukunle, and I. B. Oluwalana, "Development of an active evaporative cooling system for short-term storage of fruits and vegetable in a tropical climate," *Agricultural Engineering International: CIGR Journal*, vol. 15, no. 4, pp. 307–313, 2013.

[25] K. Tu, B. Nicolaï, and J. De Baerdemaeker, "Effects of relative humidity on apple quality under simulated shelf temperature storage," *Scientia Horticulturae*, vol. 85, no. 3, pp. 217–229, 2000, doi: 10.1016/S0304-4238(99)00148-X.

BIOGRAPHIES OF AUTHORS

Suganya Angappan received her B.E., degree in electrical and electronics engineering from Pavendhar Bharathidasan College of Engineering and Technology, Tamilnadu in 2011 and M.E., degree in power systems from Vivekanandha College of Engineering for Women, Tamil Nadu in 2014. She holds a Ph.D. from Anna University Chennai. Currently, she is working as assistant professor in the Department of Electrical and Electronics Engineering at Dr. Mahalingam College of Engineering and Technology, Pollachi. Her current research interest includes power quality enhancement, FACTS devices. She has a 1 year of industrial experience and a total of 7 years of academic experience. She can be contacted at email: suganya116@drmcet.ac.in.

Aarthi Nataraj received her B.E., degree in electrical and electronics engineering from PA College of Engineering and Technology, Tamil Nadu in 2013 and M.E., degree in power electronics and drives from Sri Eshwar College of Engineering, Coimbatore, Tamil Nadu in 2015. Pursuing her Ph.D. from Anna University Chennai. Currently, she is working as assistant professor in the Department of Electrical and Electronics Engineering at Dr. Mahalingam College of Engineering and Technology, Pollachi. Her current research interest includes power electronic converters for renewable energy sources. She has a total of 5 years of academic experience. She can be contacted at email: aarthin@drmcet.ac.in.

Loganathan Navaneetha Krishnan received her B.E., degree in electrical and electronics engineering from Regional Centre of Anna University Coimbatore in the year 2012, completed masters in power systems engineering from K S Rangasamy College of Technology, Tiruchengode in 2015, and completed Ph.D. in electrical engineering from Anna University, Chennai in 2023. He is currently working as assistant professor in the Department of Electrical and Electronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore. His area of specialization is energy management system, intelligent controllers in renewable energy systems and smart grid. He has a teaching experience of 9 Years. He can be contacted at email: logukirsh@gmail.com.

Anbarasu Palanisamy received his B.E., degree in electrical and electronics engineering from V.S.B Engineering College, Tamil Nadu in 2009 and M.E., degree in power electronics and drives from Anna University Regional Campus Coimbatore, Tamil Nadu in 2013. Completed Ph.D. from Anna University Chennai in 2024. Currently, he is working as assistant professor (Selection Grade) in the Department of Electrical and Electronics Engineering at Sri Eshwar College of Engineering, Coimbatore. His current research interests are power electronics for renewable energy sources, evolutionary algorithms, and electric vehicle. He is life member of the Indian Society for Technical Education (ISTE), System Society of India (SSI), International Association of Engineers (IAENG). He has 2 years of industrial experience and 12 years of academic and research experiences. He has completed 4 Government of India funded projects and 1 CSIR project. He holds one Indian design patent. He can be contacted at email: anbarasu.p@sece.ac.in.