EIWMS: Enhanced Intelligent Warehouse Monitoring Systems 4.0

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Abstract
The development of a new digitized industrial methodology named asIndustry 4.0 has a positive influence on the performance of the supply chain.Traditional Warehouse Management System(WMS) became inefficient and inappropriate to meet the increasing market requirements nowadays. Hence there arises a need for effective management of warehouses. The emergence of multipurpose sensors on the Internet of Things (IoT), over the last decades, has been investigated to build innovative devices with versatile applications in different fields of technology, especially in the food industry.The field of fruits and vegetables environmental monitoring is very challenging due to its promising capability.We propose the cost-effective micro-system named as Enhanced Intelligent WMS (EIWMS), to improve the remote monitoring capabilities of decentralized management of warehouses in a dynamic environment.Our system is composed of temperature,humidity RFID, and gas sensors, that provide the essential information needed for assessing the quality factor of the eatable things. This information is transmitted to a Blynk cloud wirelessly by providing an interface with which the user could track the changes in the product quality periodically. EIWMS provides a user-friendly application to visualize and analyze sensor data for an efficient and low-cost monitoring system. Tested results prove that the functional performanceof the system is entirely balanced and can meet the design needs in real-time data collection and remote access. A unique method is proposed by EIWMS for collecting the data from environment that eliminates the need of wires or manual labor.
Keywords: Industry 4.0, EIWMS, remote monitoring,multi-sensor data collection,Blynk app.

Introduction

Human history hascome across a series of industrial revolutions that made huge turning points in the economy. At present, Industry 4.0 makes the era of the fourth industrial revolution. The development of a new digitized industrial methodology named as Industry 4.0 has a positive influence on the performance of the supply chain.The fundamental part of supply chain is the presence of warehouse. A well developed Warehouse Management System(WMS) provides cost reduction and customer satisfaction. Therefore, it is essentialto manage warehouses effectively and allocate their resources productively. WMS has been developed for monitoring, tracking, and controlling the warehouse operations in a potential manner. Due to the ever-growing needs and changes in the market, systems with traditional methodologies have become less efficient and inappropriatefor current market requirements, which results in the outburst of new technologies. Therefore, it is essential to createa smartwarehouse. Smart warehousing refers to intelligent networking, mobility, the flexibility of logistic operations and their interoperability, integration with customers and suppliers, and in the adoption of modern commercial enterprise models. Internet of Things (IoT) is an assuredand most suitable technology that can be used in the context.
In this paper, we recommended EIWMS: Enhanced Intelligent Warehouse Monitoring Systems 4.0. The is a smart model for fruits and vegetable warehouse monitoring based on the IoT that comprises many interconnected technologies to exchange information. Fruits and vegetable warehouse is completely temperature adjustable and which requires monitoring and maintain temperature to prevent goods deterioration or dehumidifying. The cold room is a part of our warehouse, and it provides a better way to protect products in extreme temperature conditions.EIWMS track and create a virtual copy of the real-world industry processes. Hence it helps to aware us about the actualposition of each industry process and make appropriate decisions

on a concurrent basis,mainly in fruits and vegetables. This leads to a great improvement in efficiency factors oftime, energy, and accuracy while cost, human error, and human effort will be considerably reduced. Although EIWMS creates a revolution in contemporary warehouses, it makesit easier to merge the Cyber-Physical System (CPS) methodologies into smart warehouses for Industry 4.0. Fig 1. shows the EIWMS architecture.

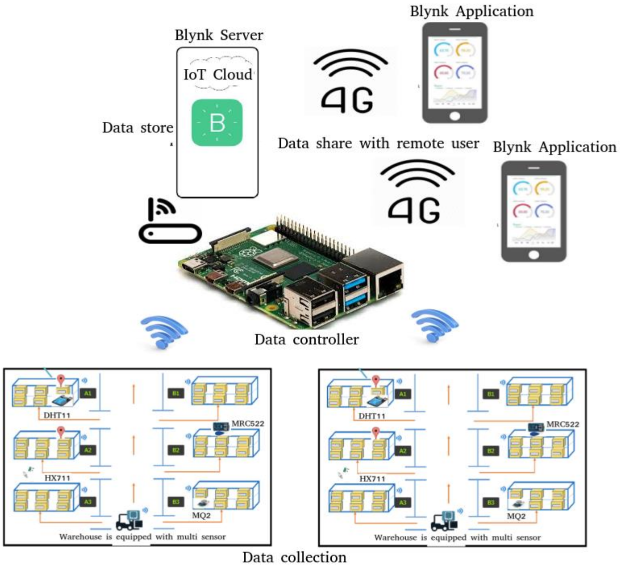


Fig 1. EIWMS architecture in fruits and vegetables warehouse.

The EIWMS is designed to track and control the warehouse environment with the help of various factors such as temperature, humidity, low stock indicator,RFID,and smoke detection that serve as indicators in examining the environment prevailing inside the warehouse. Thus, making the user manage the warehouse economically and effectively. EIWMS is a suitable model to monitor and organize the small and medium scale warehouses in Industry 4.0.

2. Related Works

In past decades, computing systems have shown enormous growth in a wide range ofhuman activity sectors. Nowadays, IoT has become an integral part ofthe novel inventions.IoT encompasses numerous objects which operate either wireless or cabled manner. It has unique addressing schemes that interact and collaborate with other objects, providing new services and applications. In this section, various research ideas were surveyed.

2.1 Warehouse Management System(WMS)

Nee (2009) analyzed the effect of WMS on business performanceby adoptingwireless barcodes and Management Information Systems (MIS). WMS assisted incost reduction, inventory investment reduction, upgrading the management efficiency, creating a flexibleprocess. It also speeds up the entire process, thereby reducing the delivery time and thus increasing customer satisfaction,which in turn improves competitiveness. Utomo and Sahuri (2016) helped small enterprises bydeveloping a web service-based system to enhancewarehouse management.The concept of this system is the usage of Short Message Service (SMS) totransferdetailsof the stock to the mobile phone.It eases the decision-making processby providingexact data and removes the need for manual intervention. Adiono et al. (2017) suggested agoods locator systemconstructed upon RFID tags fixed to the items.It also includes details about the items. It finds thepurchased item’s location by reading the distance of the particular item with the help ofRFID readers. Bluetooth technology is used to link the reader to a WMS installed smartphone. This entire setup updates inventory detailsinstantaneously, thereby decreasing the time tofind the purchased items,enhances the productivity of the WMS, and results in speedy delivery. Oner et al. (2017) selected a wool yarn industry for performing a wide variety of tasks by proposing an RFID-based information structure. The various tasks are monitoring the progress of work, computing and tracking inventories, choosing, receiving, and dispatching of semi-processed products. Acost-effective analysis for the above-mentioned system is performed that decreased the needed workforce by 20% and reduced the lost work-in-progress(WIP) rate. It therefore,reduced costs and upgraded the functional performance of the wool yarn industry. Wei et al.(2015) presented the usage of the barcode management application in the operational design of the WMS for a pharmaceutical enterprise. Itmanages inventories effectively, reduces workforce costs, and supports decision making with respect to data warehouses. Qin et al. (2017) proposed a modelassessing the problem of inaccurate inventory using RFID. The bullwhip effect arises out of distorted informationthrough the supply chain that createsan inaccurate inventory problem. This effect enlarges the stocking and insufficiency costs. The authors concluded that using RFID in the downstream is more advantageous and provides effectiveness in comparison with using it in the upstream stages.

2.2 Monitoring as a Service

Han and Zhu (2017) examined the existing problems regarding thelogistics of warehousing systems and devised methods forthe betterment of the entire warehouse system. The authors created a warehouse management information system throughthe optimization design of logistics. It improves the enterprise efficiency, strengthens the coordination among all departments, decreases labor size, solves the material confusion problem, and also cost-effective. Patil et al. (2018) deployed Software-as-a-Service (SaaS) to develop a dynamic web application system. It delivers a cloud-centeredimplementation of WMS.It helped in reducing manual intervention and made the software to process that helped the user to access data effortlessly and fast. The proposed system alsomakes the work more accurate, increases visibility, captures real-time data. The main outcome of this system is the graphical representation of purchase order, product stocks, stock in and out.Pane et al. (2018) used Arduino Uno microcontroller to implement an RFID system in WMS and inferred that it offered several advantages; promoted the warehouse labor work, controlled operations effectively, geared up to work processes, declined error rate, improved warehouse productivity and streamlined the work processes. Woźniakowski et al. (2018) analyzed the dissimilarity betweenWMSs systems and ERPand concluded that the integration of ERP with WMS supports each other, and givesmuch profit to the enterprise. Mao et al. (2018) proposed an effectivearchitecture of smart WMS built witha cloud model using both RFID and GPS.To solve the cloud's scheduling problem, a hybrid genetic approach with bee colony optimization is also proposed.Real-time data is also provided useful in choosing better scheduling and decision making.

2.3 IoT implementation in supply chains and warehousing

From the beginning, researchers have been surveying theprobability of adopting IoT in multiple fields. Some research worksdealt withthe utilization of IoT in the Supply Chain Management (SCM) field. Yan et al. (2016) designed an IoT model in the agricultural supply chain domain that uses RFID to overcome the issues of incomplete information and bullwhip effect. For inquiring the static and dynamic information, two distinctmethods of inquiry are used that improve supply chain efficiency,genuineness, and quality of the products. These factorsassist the operators to track, trace, and examine products irrespective of time and process stages. Qu et al. (2016) framed a real-time production logistics in a synchronized environment with IoT system.It integrated cloud manufacturing with IoT infrastructure to confront the dynamics in production logistics tasks. This production logistics serves as the most suitable solution to plan unattainability resulting from execution dynamics. It also provides a wayto combine IoT and cloud manufacturing. Lee et al. (2018) suggesteda combination of computational intelligence methods with the fuzzy logicto choose the appropriate method for choosing the process in an IoT-based WMS with updated data analytical environment. This system enhances several factors, such as order fulfillment,shipping method, inventory tracking, and the entire functionality of the warehouse. Tejesh and Roy (2017) created an inventory controlling system withIoT and free to use hardware; it tracks, monitors, and collects the data from stockroomand details about a specific product.Li and

Li (2017) presentedthe ability of an IoT cloud in improving the SCM performance, with specific concern to Supply Chain Innovation (SCI). The authors illustrated the performance improvement of all the supply chain partners by integrating data between resources, processes, and activities.

2.4 Intelligent micro-system in WMS

Thousands of people are influenced byfood poisoning on a yearly basis. Toxicated food should be noticed and cleared early to protect from fatal health issues.Food poisoning arises out of consuming products with microorganisms like pathogenic bacteria, parasites, viruses. It also results from the presence of artificial or general toxins like poisonous mushrooms. The contaminated food emits poisonous vapors that can be sensed using gas sensors McCabe-Sellers et al., (2014).The consumer can communicate with the food company and their communication is improved by a smart micro-system. It helps in achieving the quality and durability,thereby reducing wastage of food; Affordability and reliability of food play a key role in smart food packaging during production- consuming process and while assuring the health. Different types of vapors emitted from the contaminated food can be sensed by a collection of gas sensors Del Nobile et al., (2019).

3.Components of IoT Infrastructure

The main objective of this research is to create and analyze the usefulness of an IoT-based EIWMS with a less-volume, extremely efficient warehouse monitoring of fruits and vegetables.

3.1 EIWMS architecture

Researchers have proposed different architectures. Four layers are present inEIWMS; the devices layer forms the first layer that uses the sensors for acquiring information from physical objects, which constitutethe physical world in the digital world and actuators that modify the environment to therequired state. The Interface layer located next to devices layer is incharge of data pre-processing and data uploading by using several methodologies such as data science,Wireless Sensor Networks (WSNs), communication networks,network infrastructures, and communication protocols. The computation layer lies below interface layer,which serves like a connector between the application layer and the interface layer. The computational power is provided in the form of a cloud to monitor and control the flow of data. Enabling the users to access sensor data,receivea notification, and visualize the performance with the help of mobile applications is performed by the application layer.

3.1.1 Devices layer

Devices layer is composed of 4 sensors viz., temperature sensor (DHT11), RFID (RC522), Humidity sensor(DHT11), Load sensor (HX711), and Gas sensor (MQ2). These sensors are connected to the Pi microcontroller thathelps in sending the actual parameter values to the computing layer.

A. Temperature sensor

DHT11 is a Digitized tempertaureSensor withtwo sensors moulded together as one sensor module for sensingvalues of humidity and temperature. An 8-bit Microcontroller,a Resistive-type Humidity Sensor,an NTC (Negative Temperature Coefficient) Temperature Sensor are the various components inside the sensor. It is used to change the analog signals and produce outputs in digitised format.A temperature sensor is generally a thermocouple measuring the temperature via an electrical signal. Two dissimilar metals are used to make a thermocouple that generatesan electrical voltage which is directly proportional to changes in temperature.

The temperature T and measurable quantities such as pressure and volume where Thermal contact of A is used for temperature, where p_A and p_B are measured pressure after equilibrium has been reached.

$$\frac{P_A}{P_B} = \frac{T_A}{T_B} \quad (1)$$

An arbitrary reference point is used as per (2) for numerical representation.

$$T_A = 273.16\ (\frac{P_A}{P_{ref}}) \quad (2)$$

Celsius is calculated by (3)

$$T_k - 273.15 \text{ degrees Celsius} \quad (3)$$

B. Humidity sensor

A humidity sensor measures both air temperature and moisture. Therefore it is used to sense,compute, and relay the information aboutair's relative humidity. The relative humidity is stated as the ratio of actual moisture in the air to the maximummoisture at a given temperature.

C. RFID

Radio-**F**requency **I**dentification (**RFID**) utilizes the radio waves to scan and acquire information stored in a tag fixed to a particular object. A tag can be scanned from a long distance and does not need to be within direct line-of-sight of the reader to be tracked.The **RFID reader collects**the tracking information about the individual objects from an RFID tag. The radio waves are used to transmit the data from the tag to a reader. A **passive tag** is an RFID tag,not havinga battery, and the reader supplies the needed power. The coiled antenna present inside the tag creates a magnetic field ,when encountering a passive RFID tag comes with radio waves from the reader,. The tag energizes the circuits by drawing power from the magnetic field.

The below equation determines antenna Inductance

$$L_{ant} = K_1 x \mu_0 x\ N^2 x \frac{d}{1+K2\ x\ p} \quad (4)$$

D. Load sensor HX711

This microchip is specifically formed for amplifying the signals from load cells. The amplified signalsare reported to another microcontroller. The load cells are fixed into this board.The board reports the measured values of load cells to the Pi. Hence the load sensor reads the information from the Load Cell, amplifies the signals and then sends it to the Pi for processing

E. Gas sensor MQ4

The Grove - Gas Sensor(MQ4) module detects the gas discharge in-home and commercial areas. It senses the gases like H2, LPG, CO, CH4, Alcohol, Smoke, or Propane. Because of its high reactivity and rapid response time, the values can be measured promptly. The potentiometer regulates the sensor's reactivity.

3.1.2 Interface layer

The Raspberry Pi is a cost-optimizigmini-computer that executes Linux with the help of GPIO (general purpose input/output) pins. These pins provide anuser the control of electronic components for physical enumeration and traverse the Internet of Things (IoT).Its low cost and portability allow researchers to promote research projects. The EIWMS uses the Pi as a controller to collect and organize the data from the lower layer to the upper layers.

3.1.3 Blynk cloud

Blynk cloud is a private cloud designed especially for IoT based applications such as eHealth,smart city, Agriculture,smart meter,weather monitoring, and much more. It candisplay, store, and visualize sensor datato perform many operations by controlling the hardware remotely.

The three major components of Blynk Cloud:

•**Blynk App** – Provides various functionalities to develop extraordinary interfaces for your application using user-chosen widgets.

•**Blynk Server -** The smartphone and hardware can communicate only with the help of the Blynk server. The user executes runprivate Blynk serverlocally. It is capable of handling thousands of devices and can easily be launched in a Raspberry Pi because of its open-source availability.

•**Blynk Libraries** –It possesses multiple functions for various well-known hardware platforms that enable communication between server and process to carry out the incoming and outgoing commands.

3.1.4 Application layer

It provides the interface to the computation layer, which the user visualize. Many typical applications are used today in an internetwork environment, such as web browsers,mobile applications. EIWMS enables the users to monitor the warehouse activities through the inbuilt mobile app launched by Blynk private cloud.

3.2 Implementation of EIWMS in Warehousing

The various parameters related to warehouse environmentslike temperature, weight,humidity,RFID, and gas sensors collected data are sent to the Interface layer ofthe EIWMS monitoring system. The efficient monitoring and event handling system consist of the four-layers in EIWMS. The captured data from the sensors are uploaded to the Blynk, which tracks and maintains the record of changes in the atmospheric parameters of the warehouse. The app shows the values sensed by the sensors. The uploaded data has a delay of 20s. It is because for processing the data values and incoming data, the controller has a waiting time of 10s,and the Blynk needs another 10s, respectively. The processed data can now be used to perform either statistical or visual analysis purposes in real-time and decide whether to give a notification to the user about the current issues. The EIWMS is constructed upon IoT technology, a semi-automated system in our paradigm, with the following capabilities such as Temperature, Humidity, RFID, weight, and gas identification.

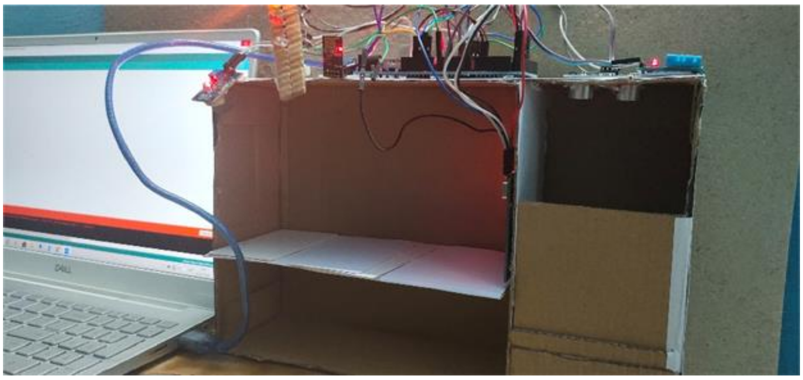


Fig 2 . EIWMS design model

The warehouse managers can get notifications and alerts from EIWMS continuously depends on the warehouse status. The gas sensor will give the notification depends on ethylene ppm.

4. Theoritical framework of IoT implementation in a warehouse

This section deals with the performance evaluation of the proposed system for examining the various selected parameters in fruit and vegetable warehouse—the results obtained with a cold container placed in the warehouse for 7 days.

4.1 EIWMS Blynk app notification

The proposed EIWMS notification screens are shown in Fig 3 to 6. It is integrated with a blynk private cloud for easy and secure remote monitoring. In Fig 3. four widget icons are used, namely rack weight, temperature, humidity, RFID moved, and Ethylene level. By using rack weight notification, the manager can identify the low stock level in the warehouse environment. The temperature and humidity icons are used to gain current environmental weather conditions. RFID is used to predict the fast-moving and total bagged items is in the container.Ethylene level indicates the fruits and vegetable conditions to the manager.

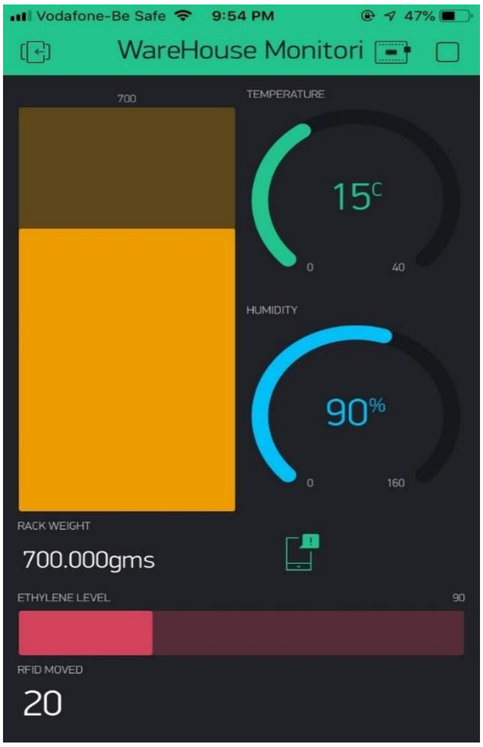


Fig 3. Proposed bylnk mobile application

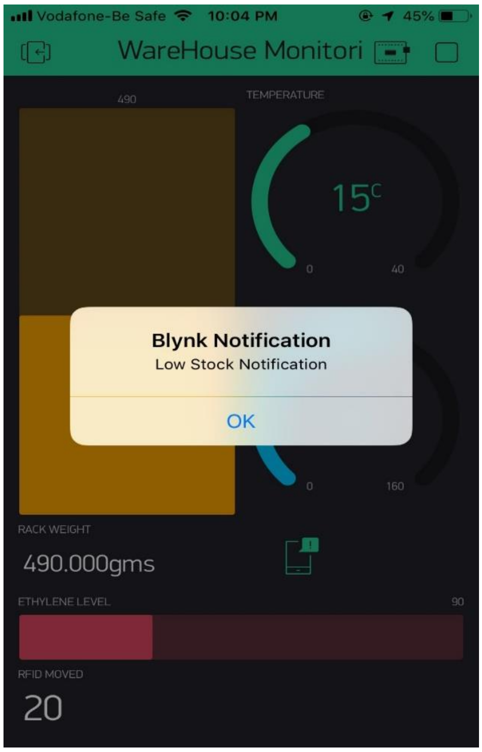


Fig 4. Low Stock Notification

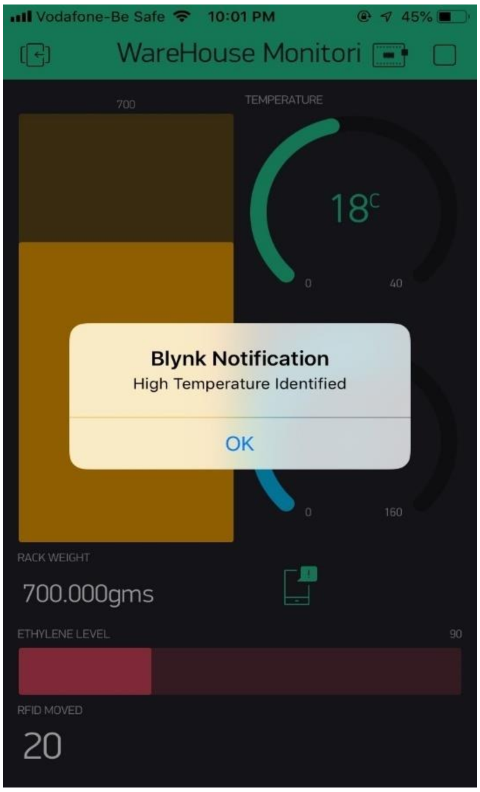


Fig 5. Temperature Notification

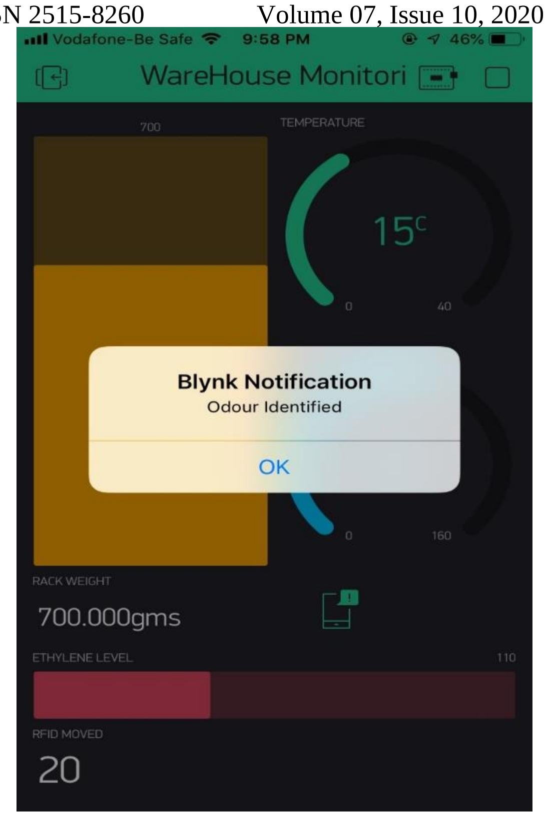
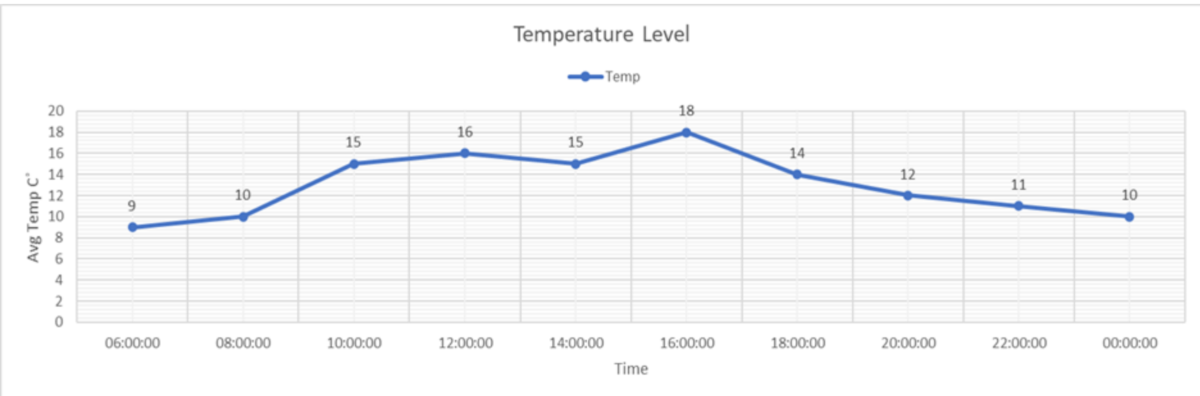


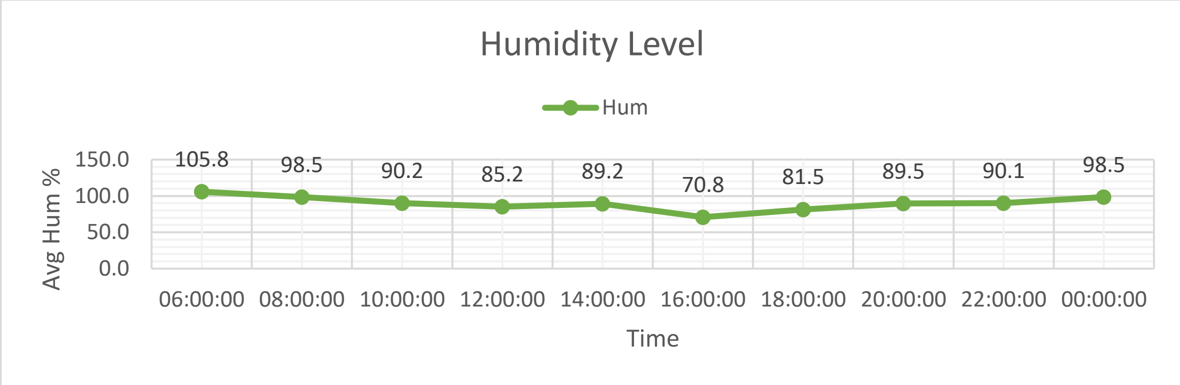
Fig 6. Odour Notification

4.2 EIWMS Performance evaluation

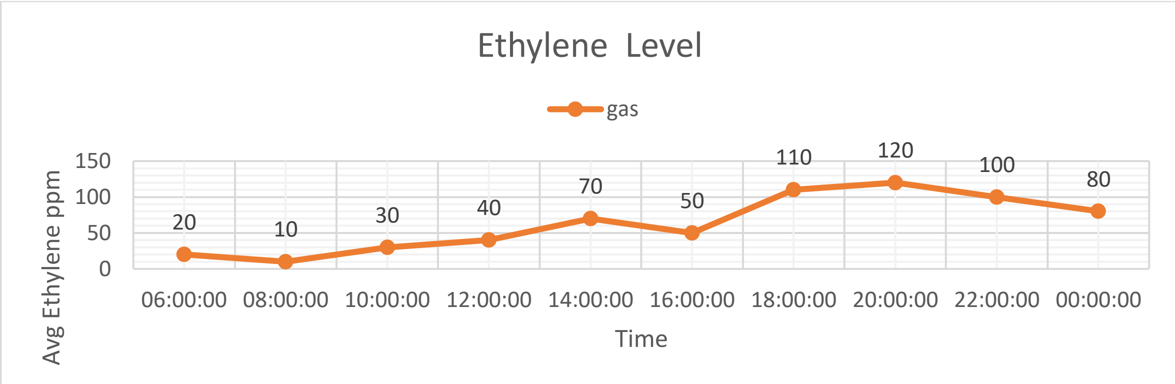
The following figures show the average evolution of the temperature sensor reading. The experiment was conducted in a container with an ambient temperature of 10 ◦ C and relative air moisture of 95 %



During the noon sessions, a significant variation of the temperature and humidity can be observed.



The following figure shows the ethylene level during the entire test period. It is observed that when the level increases above 100 ppm the vegetable and fruit is getting spoiled.



5. Conclusion

The reference parameters measured in the empty container appeared constant to a greater extent. We chose to test the cauliflower as it is available everywhere and prone to storage conditions. Then the behavior of cauliflower is analyzed for 18 hrs at container temperature. The results showed that the cauliflower's emissions strongly influenced the low-cost MQ4 gas sensors. The respiration rate in cauliflower decreased moderately due tothe depletion of oxygen, andthe reduction of its metabolic activities in the graph. The major compound detected from the cauliflower emissions is ethylene.

In this study, it was showed that temperature, humidity,RFID, and gas sensors are used in EIWMS, which can be implemented in the fruits and vegetable warehouse monitoring. The proposed EIWMS was validated successfully with the help of advanced sensor technology. It improved the effectiveness of warehouse management and reduced the error rate remarkably based onthe Internet and cloud computing technologies. Further, it can be enlarged with large scale environments.

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