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Zigbee Based Advanced Food Storage Yards with Automated Control

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Abstract: India is the world's largest production of milk and second largest production of fruit, vegetables and food grains and also one of the biggest waters in the world. Nearly INR 440 billion worth fruits, vegetables and grains are wasted every year. The biggest contributors to the wastage are the lack of refrigerated transport and adequate high quality cold storage yard facilities for food manufacturers and retailers. Food wastage has become more common in southern and western regions of India due to tropical and humidity climatic conditions. This paper proposes an integrated system for constant monitoring and controlling of environmental factors like temperature, humidity and turbidity in food storage yards using ZigBee technology. The food product chosen includes grains, wheat, rava and milk. The automated image processing system identifies the type of stored food and ZigBee sensors transfer the environmental parameters to control centre. The received values are compared with threshold values and issues commands accordingly using microcontroller based system. The automated aeration system incorporated as a part of control strategy mainta ins the temperature and moisture content within threshold limits thus ensuring food security. The biggest challenge of feeding India's billion plus population is not really about agriculture and food production improvements but getting the food produced to the people.

Key words: pH · Wireless sensor networks · ZigBee · Aeration control · MP Lab · Image processing

INTRODUCTION

In the world today we produce enough food to feed everyone but 1 in 7 are facing starvation. 1 in 3 kilograms of food produced goes to wastage. India wastes about Rs44000 crores worth food every year. In India 23 million tons of wheat(enough to feed atleast 70 million people)are being wasted due to improper infrastructural facilities. 70% of welfare agencies are experiencing an increase in number of people seeking food. 90% of welfare agencies don't have enough food to meet out the demand. The environmental factors like temperature, pH, humidity and light greatly influence the storage of food grains. Also, the factors like time and purpose of storage, type of storage, preventive insecticide treatments and storage practices account for the food storage losses. During storage both qualitative and quantitative losses occur due to insect pests, mold growth, rodents, rats, fungi, micro organisms and subsequent production of mycotoxins in storage. The occurrence and number of stored food insect pests are directly related to the climatic and geographical conditions. The multiplication rates of almost all the species of insects is very high and may destroy up to 10 to15% of food grains and deteriorate the rest with undesirable odor and flavors. Hence, monitoring and control of the environmental factors at the food storage depots like FCI is very much essential. Traditional ware house monitoring systems have the disadvantages of using large temperature cables. The effect of light illumination also plays a vital role in the storage of food. Apart from food grains, there are other food products like cereals, wheat, rava, maida etc which needs to be stored safely [1]. Wireless sensor networks play a significant role in monitoring and control of remote applications like grain storage silos. Here, an integrated system has been proposed to remotely monitor and control the pH, temperature, humidity and light of different food products viz. milk, grains, wheat, rava and maida using ZigBee sensor networks. The ZigBee mesh net workng technology has been used to collect environmental data from different sensor nodes inside the storage bins and monitored [1]. In the proposed system, images of food product are captured using a camera and then image analysis is done on various images of the food items.

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The statistical parameters like mean, standard deviation, skewness and kurtosis are measured and the image of food is identified based on the mean value of the image. Depending on the range mean values of images and the address of the ZigBee module, the environmental conditions are maintained for the respective food product [1]. An automated aeration control strategy is used to provide aeration inside the bin to maintain the environmental conditions within limits thus ensuring food security

Environmental Factors Influencing Insect Infestation: The environmental conditions and infrastructure facilities of the food storage warehouses/depots are two important factors which greatly influence the stored food quality and insect infestation. Among the two, the environmental factors like temperature, moisture content, relative humidity and even lighting conditions have a major impact on the quality of stored food products in large depots. The proposed integrated system includes four major food products viz., rice, wheat, rava and maida and milk.

The mass and heat transfer occurs at times when there is considerable difference between inside and outside bin temperatures. For example, if the inside bin temperature is normal and outside bin temperature is so cool, then moisture migration takes place from near the walls of the bin towards the center. Real time monitoring and control of these mentioned factors prevent fungi and microbial growth, insect infestation and deterioration of food grains to a great extent. The table given below provides the moisture content thresholds to be maintained for the different food products [2].

Table 1: Moisture content levels for different foods

S.No	Food Product	Max Moisture content in %
1.	Rice	12.2-13.8
2.	Wheat	12.8-13.9
3	Rava	11.1-13
4	Maida	10.5-13

Table 2: PH content for Milk

S.No	Food Product	Allowable PH range
1.	Milk	6.4-6.8

The moisture content to be maintained also varies depending on the time of storage. The values specified above have been mentioned with respect to long storage periods. The temperature is an important parameter which influences the moisture holding capacity of air. If the temperature is high then moisture holding capacity of air increases, leading to increasing levels of moisture content. Hence, a proper choice of temperature level is made. The lighting conditions are also playing a role in increasing the infestation levels of food. The reproduction of various insects depend on the lighting levels inside the bin. An optimum illumination level between 50 lux and 90 lux is maintained to prevent increase in infestation. Hence, by having the environmental conditions within the allowable limits, the food grains are controlled & prevented from damage.

System Architecture: The proposed architecture for monitoring and controlling of the grain storage divided into two parts (1) Hardware component, (2) Software component. The hardware part placed in granary with data acquisition models and software part located in control room from where administrator can generate controlling action.

Block Digram

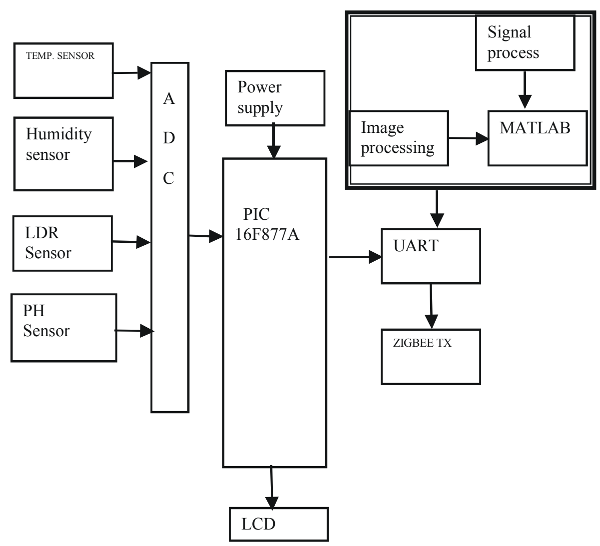


Fig. 2.1: Transmitter Section

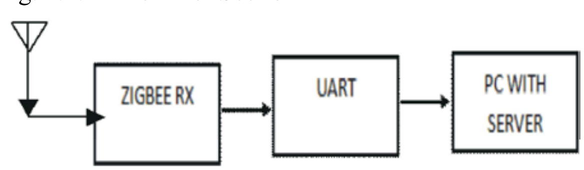


Fig. 2.2: Receiver Section

The various environmental factors like temperature, moisture content,light and pH values are sensed by employing various sensors.The Automated image processing is performed using MATLAB software for identifying the food item.The PIC microcontroller identifies whether the sensor values are within the optimal range for a particular food item if not it issues automated command pulses to the aeration control unit which modifies the temperature automatically [2]. The UART transfers the processed data via Zigbee Network to PC for future references.

Hardware Implementation:

PIC 16F877A: The PIC16F887 is one of the latest products from *Microchip*.It features all the components which modern microcontrollers normally have. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as: the control of different processes in industry, machine control devices, measurement of different values etc. Some of its main features are listed below.

RISC Architecture:

Only 35 instructions to learn
All single-cycle instructions except branches

Operating Frequency 0-20 MHz

Precision Internal Oscillator:

Factory calibrated
Software selectable frequency range of 8MHz to 31KHz

Power Supply Voltage 2.0-5.5V:

Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz) 50nA (stand-by mode)

Power-Saving Sleep Mode

Brown-out Reset (BOR) with software control option

35 input/output pins

can be reprogrammed up to 100.000 times

***In-Circuit Serial Programming* Option:**

Chip can be programmed even embedded in the target device

256 bytes EEPROM Memory:

Data can be written more than 1.000 High current source/sink for direct LED drive software and individually programmable *pull-up* resistor
Interrupt-on-Change pin

8K ROM Memory in FLASH Technology:

Chip.000 times

368 bytes RAM memory

A/D converter:

14-channels
10-bit resolution

3 independent timers/counters

Watch-dog timer

Analogue comparator module with

Two analogue comparators
Fixed voltage reference (0.6V)
Programmable on-chip voltage reference

PWM output steering control

Enhanced USART module

Supports RS-485, RS-232 and LIN2.0
Auto-Baud Detect

Master Synchronous Serial Port (MSSP)

supports SPI and I2C mode

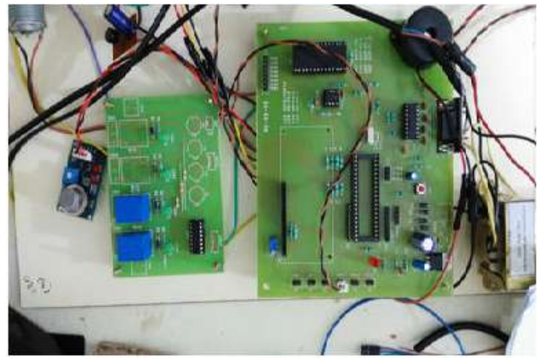
Hardware Design: In India, the food grains are being packed in sacks and stored at warehouses. The Cover and Plinth (CAP) storage has been used which is not a safe method of storage. Such poor infrastructure facilities are contributing to grain storage losses. When food grains are stored in large silos in a controlled atmosphere, the losses can be reduced and stopped completely at a stage. The silo bins are generally made out of concrete or galvanized steel. Here, the prototype silo bins have been designed with

a height of 30cm and diameter 20cm made of galvanized steel. The ZigBee sensor network is designed with the end device forming the sensing unit, router and coordinator at the monitoring end connected to the PC. The LM35 temperature sensor and humidity sensor HR202 is used to measure the temperature and moisture content of the food grains. Both, temperature and humidity sensors are resistance based and hence voltage divider circuits are used. The system at the remote end consists of individual storage bins for different food products like rice, wheat, rava and maida. The storage bins are also located at different places. The end devices are those ZigBee sensor nodes which consist of the sensors to measure the atmospheric grain temperature, moisture content and light illumination inside the storage bin [1]. The routers are those ZigBee nodes used at various levels to increase the strength of the sensor signal from end device ZigBee nodes. The sensor data signals from the end device are sent to the monitoring end coordinator node through the router nodes [3].

The system at the monitoring end consists of the coordinator node (otherwise meant as Gateway sensor node) which collects sensor data from various nodes at the remote bins. These datum at the coordinator node are transferred to the PC through the UART to USB interface [4]. The lighting condition to be maintained inside the bin is very much necessary. The reproduction of different insect species is greatly influenced by the varying lighting conditions. The optimum lighting to be maintained inside the food storage bin is between 50 lux and 90 lux. For the considered prototype system, with the total area of cylinder bin to be 0.25m2 (diameter-20cm and height 30cm), the lumen output is calculated to be nearly 12.5 lumens. The ZigBee analog pins are configured to directly accept the sensor data. The conversion of voltage level from 5v to 1.2v is required, since the maximum pin voltage of ZigBee is 1.2volts. This is done by using a 50K potentiometer across the sensor voltage output. The ZigBee series 2 module consists of a 10-bit ADC, hence each of the analog pins can read in a range from 0 to 1023 values of sensor data. The step size is considered to be 1.172mV [5].

The ZigBee modules are powered by a 9volt battery with the help of LM1117 to tap a voltage of 3.3volts. The three analog pins of ZigBee are configured to connect to the temperature, humidity and the light sensor [2]. The sampling rate at which the data needs to be sent is also configured at the end device. The sensor data received at the other end is being monitored using Visual Basic software.

Application Framework: The user interface is developed using the MPLAB softtware. The tab control is provided for monitoring the temperature, humidity and lighting conditions for different food products viz rice grains, wheat, rava and maida. First,the image analysis is done to identify the food product based on the statistical parameters like mean and standard deviation. The image is identified by checking for the meanof the image within a specified range.



Then, the address match is done to check for the correct address of the ZigBee module. Once, both the conditions are satisfied, it checks if optimum environmental conditions for that particular food product are maintained.. If the sensed environmental parameters are out of specified range, then control of those parameters within limits is necessary. If the system environmental factors shows high temperature then automatically moisture holding capacity of air increases as a result of which the insect infestation occurs. On the other hand, if the temperature is very low, the moisture migration takes place, which leads to formation of mould and fungi at certain spots. Thus, to maintain the environmental conditions a control algorithm is implemented to pass hot and cold air depending on the condition [5].

RESULTS AND CONCLUSION

The main objective of this paper is to design a prototype to control the environmental parameters of a grain storage chamber so that the life span of food products can be enhanced. The parameters considered here are temperature and humidity of the chamber [5]. The last 6 bytes (excluding the stop bit) of ZigBee data contains the data information of temperature, humidity and light level. These bytes are separated into three to get the three sensor parameters mentioned above. These data are then converted to get the ADC reading. The ADC reading is used in the respective formulas to get the actual values of temperature in °C, relative humidity and moisture content in % and light intensity in lux. The indicators are being used as shown to indicate if any of the three environmental factors are exceeding the threshold limits. Thus, this integrated system is used to combinely monitor the environmental conditions like temperature, moisture content and lighting levels of the food products viz. rice, wheat, rava and maida at a station far away from the remote food depots using wireless sensor networks [4].

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