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Monitoring Grain Silos Instantly with IoT Based Control System

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Abstract: The need of preserving variable products' amount and quality the best and the longest time aroused the need of storage. Especially cereals can be stored long times without losing their quality under favorable conditions. These favorable conditions can be provided with silos for cereals. The products stored in silos to be used in times of need, must be protected well and durable. Yet, humidity and temperature like factors can make silos unsafe. With the development of technology, especially the concept of Internet of Things, silos can be monitored in real-time and kept under control. Regular silos can be turned into smart silos thanks to systems created via Internet of Things. In this study, the humidity and temperature values of the cereals in a silo created as a prototype, measured with an IoT based real-time system and data gathered were monitored instantly via a web-based software. Hence, without the need of much manpower, cereals could be kept under favorable temperature and humidity levels.

Keywords: IoT, Silo, Sensor, Real-time Communication, Node MCU

Introduction

Since the need of usage through whole year grains, which are staple food since the transition to settled life of humanity and has still great importance contemporarily, must be stored and preserved. Grain storages (silos) are used for this purpose (Yaldıran, 2018). Silos are convenient for grains to be stored long times without decaying. Stored items can be processed easily because of silos' loaders and dischargers. Preservation of the yields which are harvested with toil has utmost importance for continuity of agriculture, thus silos are needed every time. Silos are generally built from reinforced concrete, stainless steel or galvanized iron sheets (Dalmış, 2018). Below are the silos in Figure 1.

Silos can be in various types for different products. For grains, generally tower silos are used. In order to preserve the products stored in the silos without losing any of their qualifications for a long time their atmosphere, that is the values like humidity and temperature of the silos, should be under control at all times. In any case where the relative humidity of storage is higher than 65%, because of the hygroscopic (moisture sensitive) feature of grains, the water content of the grain kernels is monitored to rise over 14% and a speed up in deterioration rate is detected (Baykara, 2018).

Due to the importance of the storage, there have been significant studies carried out in recent years. Özel (2007) conducted a thesis study about the design of steel silos which has different characteristics and widely used in our country as in the world. Satuk (2011), in his study measured the temperature and humidity values of the grains

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stored in the silos with an electronic circuit and kept the temperature and humidity values of the grains convenient via a desktop computer software. Mısır (2015), created a receptor network with Control Area Network (CAN) communication protocol in order to monitor silo control systems. Baykara (2018) in his study designed a new Grain Control System for grain bagging systems.

Figure 1. Silos

In this designed system humidity and temperature values, which are important parameters in safe grain storage instead of CO2 rates, can be obtained automatically via wireless censor nodes and these data can be saved to database of the system for later monitoring and interpretation with a user interface instantly. Gupta (2018), has designed a smart medicine storage system which allows real time monitoring by using Internet of Things (IoT). Kumar (2019), has designed an irrigation system which allows real time monitoring by using IoT. In this study; on the basis of humidity and temperature problem in silos, it is aimed to develop an IoT based prototype system to monitor the silos by keeping them under control in real time web platform.

Material and Method

Embedded architecture and NodeMCU micro controller with Wi-Fi module are used for the IoT based generated system. Temperature values of the silo's inside is gathered with DS18B20 temperature sensor. The humidity values of the silo's inside is gathered with DHT 11 temperature and humidity sensor. The materials used are like this:

NodeMCU

It has a modular structure with Wi-Fi feature installed on it. Since it can be programmed, we can develop Internet of Things applications with low cost. It has analog input, PWM output, and digital input/output units and can provide communication assistance. Pin connection structure belonging to NodeMCU micro controller is shown in Figure 2.

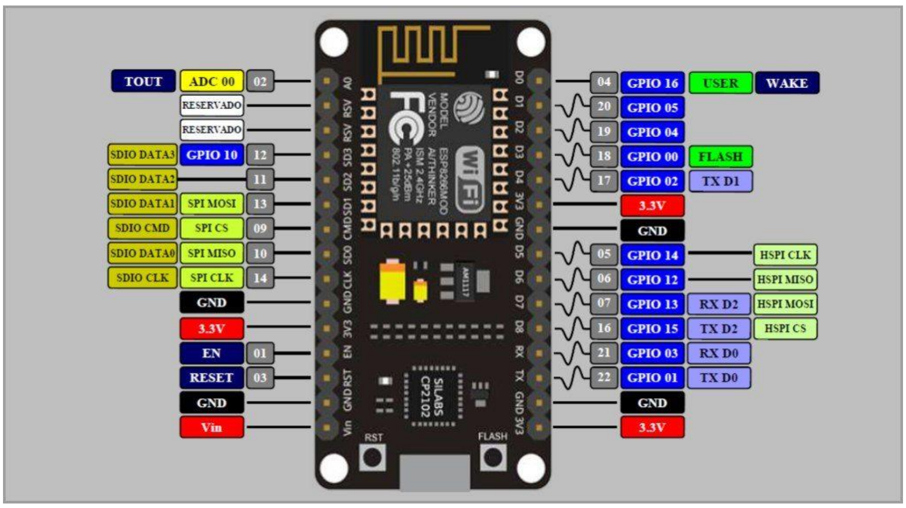

Figure 2. NodeMCU

NodeMCU, is a widely used IoT controller with an internal Wi-Fi module. It contains a 32-bit RISC Tensilica LX106 micro controller working at 160 MHz. To program the NodeMCU Arduino IDE compiler is used with C++ programming. In Table 1 is shown the technical features of the controller.

Table 1. NodeMCU technical features

Features	Value
MCU	32 bit Tensilica L106
CPU Frekans	80/160 MHz
Input/Output	13xDIO
ADC Pin	1x10 bit (1V)
Working Voltage	3.0 - 3.6 V
Working Current	12-200 mA
Program Memory	4MB
WiFi	IEEE 802.11 b/g/n
Sleep Mode Current	<10uA
Standby Mode Current	<10mA

DHT 11 Temperature and Humidity Sensor

In this study, in order to measure the humidity level of silo's inside a DHT 11 temperature and humidity sensor is used. This sensor is shown in Figure 3 and its technical features are shown in Table 2.

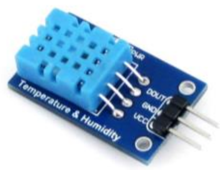

Figure 3. DHT 11 Sensor

Table 2. DHT 11 Technical features

Output Type:	Digital Signal.
Current Voltage:	3V ~ 5.5V (Tipik: 5V)
Working Current (mA):	0.5 ~ 2.5.
Temperature Sensing Range (°C)	0 ~ +50.
Humidity Detection Range (%RH):	20 ~ 90.
Sensor Temperature Sensitivity:	±2 °C.

DS18B20 Temperature Sensor

It uses 1 wire interface and communicates with Micro controller on a single line. Each sensor has a unique 64 bit serial code which was generated during the fabrication in ROM memory. Thanks to this code multiple sensors can communicate on a single line. In Figure 4 is shown DS18B20 sensor and in Table 3 its technical features are shown.

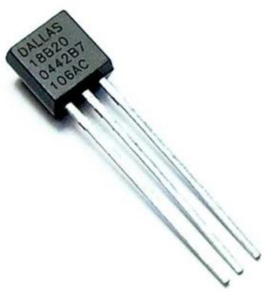

Figure 4. DS18B20 Sensor

Table 3. DS18B20 technical features

Working Voltage:	3V ~ 5.5V
Temperature Sensing Range (°C)	-55 ~ +125
Sensor Temperature Sensitivity:	±0.5 °C.

Application

Silos are the safest storage areas yet, their control is troublesome. Especially in a filled silo, to control the lower level products technology is needed (Mondal, 2018). The pioneer problems of silos are humidity and temperature. Humidity under no control can cause a series of problems which goes all the way to the decaying (Dizlek, 2012). Likewise, the temperature problem can cause especially the bug problem. In order to solve these temperature and humidity problems a prototype is generated. This generated prototype is designed as four layers as hardware, gathering the sensor data and wireless communication with the program part developed with C++, Web host and user interface. Design layers are shown in Figure 5.

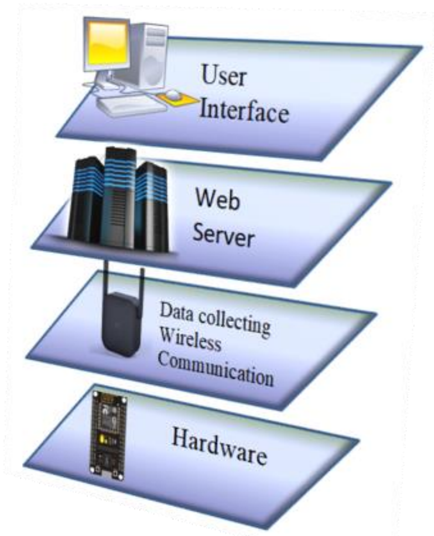

Figure 5. Design layers

The methodology followed to control humidity and temperature in the generated prototype is shown in Figure 6.

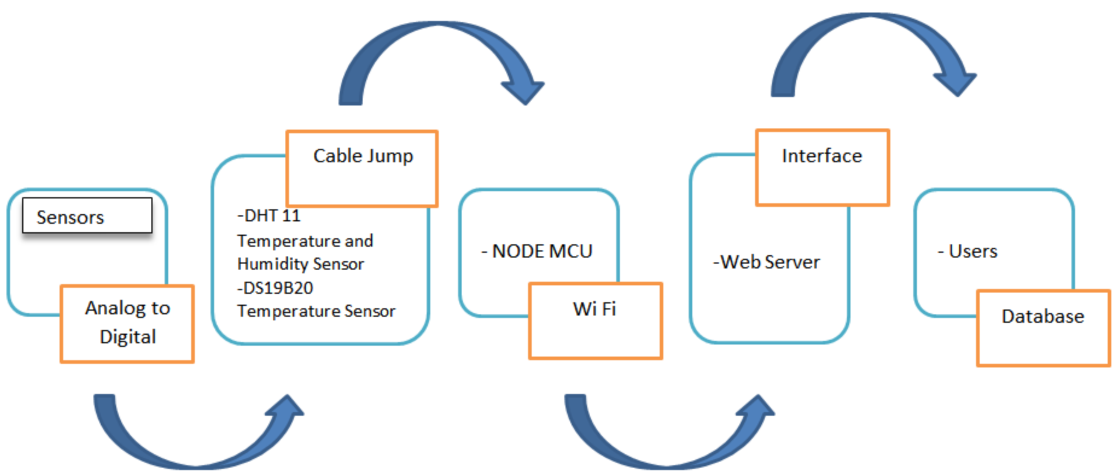

Figure 6. System methodology

Block diagram of IoT based prototype system developed in the framework of determined methodology is shown in Figure 7.

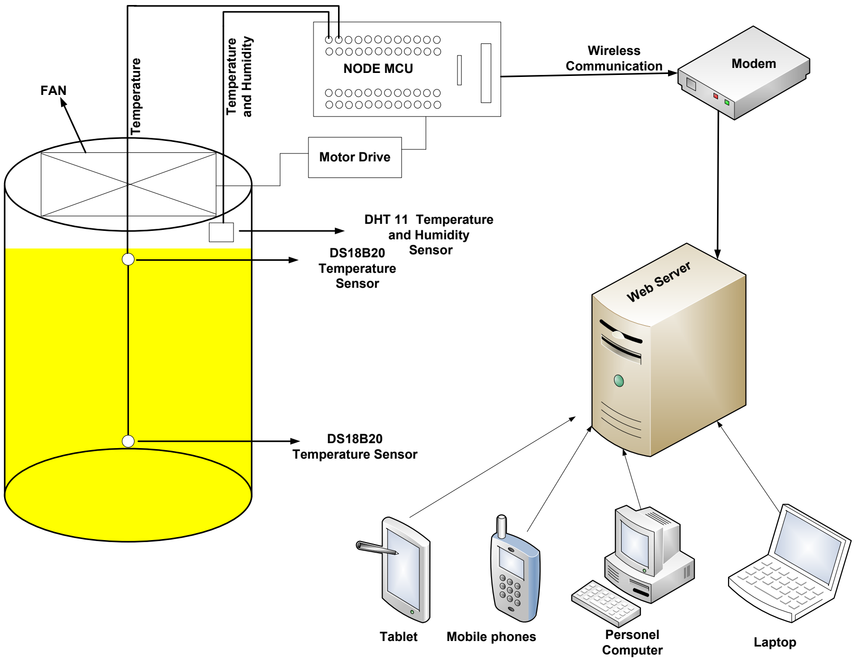

Figure 7. Block diagram of IoT based prototype system

Flow diagram to follow in order to solve the problem in generated prototype is shown in Figure 8.

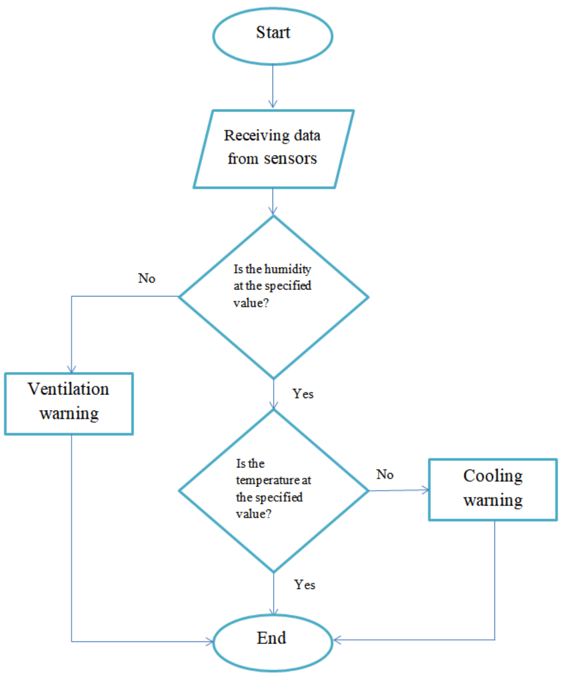

Figure 8. Flow diagram

As shown in Figure 8, temperature and humidity sensors are installed inside of the prototype silo generated in hardware layer and the data from these sensors are transferred to NodeMCU used as sensor node IoT. At the second layer the temperature and humidity data gathered are transferred to a host computer with the help of wireless technology. At the third layer an infrastructure is created to reach the data from a Web host including mobile platforms. At the last layer thanks to a web based interface software, users are ensured to monitor the data. After the system installation, the temperature and humidity values are interfered in to test the ability to monitor authentic data from computer. These data is saved at the database at the same time. This system is shown in Figure 9.

Figure 9. Created system

The stages of the system shown on Figure 9 are like below:

Hardware: A prototype tower type silo, which is especially used for grains, is created by using aluminum material (Duysak, 2020). One DHT 11 temperature and humidity sensor is installed in the middle part of the silo in order to measure humidity. Two DS18B20 temperature sensor are installed at the middle and lower part of the silo. According to pin table the power and input/output cables from sensors are connected to NodeMCU IoT. Sensor data is gathered with C++ code

Communication: Wi-Fi module integrated with NodeMCU is used for communication. The Wi-Fi module is ensured to communicate with monitoring computer.

Web Host: A Php Web host is used on a local computer.

Interface Program: A web based interface program is written so that a user can see the data from silos. The written program is ensured to be reachable from a computer with internet connection. In this created interface the data from sensors are replenished in every 30 minutes (Alanso, 2020, Rehena, 2018). The interface program is shown in Figure 10 below.

Figure 10. Monitoring program

Data Control: Sensor data is ensured to reach the web page created after filling the silo with grain. To change the temperature value the setting is heated. To change the humidity value on the other hand, a vapor device is used. In a room, in different periods of various parts of a day the humidity and temperature values are measured with the created system inside the silo in ten minutes intervals. The following three days the humidity and temperature inside the silo is interfered in and again in ten minutes intervals system has measured the data. Whether the values are changing or not is controlled via interface. When the temperature and humidity levels rise the user interface has given warnings of risky and dangerous product. The integrated fan of the system is checked to see if it becomes active to cool down or ventilate.

Results and Discussion

On the basis of the most significant problem of silos, temperature and humidity problems, a prototype is constructed to control the humidity and temperature of the silo. Some values are determined as benchmarks and the product is classified as secure, risky and in danger according to these values. For humidity, relative humidity values are determined for secure grain between 42-48%, for risky grain between 82-85%, for in danger grain 92-99% (Baykara, 2018). For temperature control, the values for secure grains is below 18 ^{o} C and for risky grains it is above 18 ^{o} C (Erbaş, 2013). The results of the measurements in determined periods for four days in total is shown in Table 4.

Table 4. Results

Day	Period (Hour)	Average Temperature Value	Temperature Status	Average Moisture Value	Humidity Status	Warning	Explanation
Day 1	Periyod 1 (06.00-14.00)	21,5	Normal	43	Normal	Risky Product	Room Conditions
	Period 2 (14.00-22.00)	23	Normal	45	Normal	Risky Product	
	Period 3 (22.00-06.00)	20	Normal	44	Normal	Risky Product	
Day 2	Period 1 (08.00-09.00)	28	Risky	45	Normal	Risky Product	Temperature Increased.
	Period 2 (09.00-10.00)	18	Normal	45	Normal	Safe Product	Fan Enabled.
	Period 3 (21.00-22.00)	26	Risky	44	Normal	Risky Product	Temperature Increased.
	Period 4 (22.00-23.00)	18	Normal	44	Normal	Safe Product	Fan Enabled.
Day 3	Period 1 (08.00-09.00)	17	Normal	85	Risky	Risky Product	Humidity Increased.
	Period 2 (09.00-10.00)	17	Normal	50	Normal	Safe Product	Fan Enabled.
	Period 3 (21.00-22.00)	18	Normal	93	Risky	Risky Product	Humidity Increased.
	Period 4 (22.00-23.00)	18	Normal	55	Normal	Safe Product	Fan Enabled.
Day 4	Period 1 (06.00-14.00)	28	Risky	85	Risky	Risky Product	Temperature and Humidity Increased.
	Period 2 (14.00-22.00)	18	Normal	55	Normal	Safe Product	Fan Enabled.
	Periyod 3 (22.00-06.00)	32	Risky	95	Risky	Risky Product	Temperature and Humidity Increased.
	Period 4 (22.00-23.00)	18	Normal	50	Normal	Safe Product	Fan Enabled.

As seen on Table 4 the first day measurement wan in normal room conditions and both temperature and humidity classified as risky. The following three days humidity and temperature are interfered in and as a result of increase in temperature and humidity, the fan was activated to cool down and ventilate.

The written interface also generates weekly average graphic of temperature and humidity values. The example generated weekly average temperature and humidity value change graphic is shown in Figure 11.

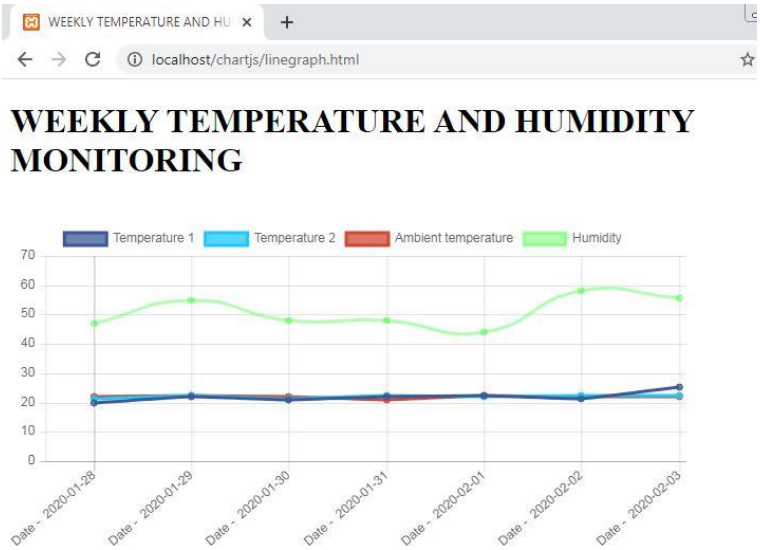

Figure 11. Weekly average temperature and humidity values

Conclusion

In order to keep the temperature and humidity which are the most significant problems of silos under control, a system IoT based, low cost and constantly monitor-able even from portable internet connected devices, is designed. With the created system, it was aimed to prevent human errors and it was ensured that more accurate and reliable results could be obtained.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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