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IoT based system for monitoing food products

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Abstract

Today, customers want to be sure about the quality and safety of food products they buy, and for this reason monitoring of food products during their lifecycle becomes an important task. To a large extent, the quality and safety of food products are affected by the conditions of storage and transport, such as temperature and humidity, as well as oxygen, nitrogen and carbon dioxide concentrations in the air. In this paper, we describe an implemented system that enables the collection of parameters of interest throughout the lifecycle of the product (so-called "from field to table"). Access to collected data can be made by food business buyers in order to ensure the quality and safety of food products, as well as manufacturers, sellers and participants in product storage and transport, in order to improve the quality and safety of products.

Key words: *Agriculture, Cloud, IoT, Product tracking*

1. INTRODUCTION

The quality of food products, both farmed and others that are used in human nutrition, are of great importance to humen. If the products are not produced in an adequate manner or if they are stored and transported inappropriately, this may have a significant impact on the price, quality and correctness of food products. On the other hand, if we would have information about the conditions in which the food product was located throughout the lifecycle, from production to table, we could give relatively high reliability information about the expected condition of the product. These parameters mostly relate to fresh agricultural food products.

Parameters that significantly affect the quality of agricultural food products are: temperature and relative air humidity, the concentrations of oxygen and carbon dioxide in the air and vibration during transport. In order to monitor and record all parameters of importance, IoT based system has been developed in order to monitor and record the parameters of agricultural food products throughout the process of picking/harvesting, storing, transporting, processing and selling the product. Product information is available through a developed web service. Information can be presented to the end user via the appropriate application. The end user or customer can thus have accurate product information and verify that the product has been manufactured, stored, transported and processed in an appropriate manner.

The IoT system has found its application in almost every segment of humen life. The term Internet of Things (IoT) refers to interconnected devices that have their own intelligence (integrated FW) and have direct or indirect Internet access [1]. In most cases, IoT devices are devices such as RFID (Radio Frequency Identifiers) readers and tags, various sensors, actuators, mobile phones, personal computers that communicate with each other and share data to achieve a common goal [2]. IoT has an impact on almost every aspect of human activities: health [3, 4], home automation [5, 6], transport [7-9], smart cities [10-12], industry [13, 14].

A particularly important aspect of ICT (Information and Communication Technologies) is agriculture. The most important part of ICT in agriculture is the use of IoT, where it is most often used to monitor the parameters during the production and processing of agricultural products, smart agriculture. ICT is used in agriculture to increase the yield and quality of its products [15-18], and consumers get accurate inforamtion about the product.

2. PROPOSED SOLUTION

For the purpose of monitoring the micro-climate conditions of agricultural food products, it was necessary to develop a system that would enable clear identification of the agricultural food product unit and the importing the unit into the information system. After the product is imported into the system, it is necessary to monitor the condition of the product through the complete lifecycle of the product "from field to table". In order to enable monitoring, it is necessary to set appropriate IoT elements with necessary sensors in adequate places during all phases of the lifecycle of an agricultural food product.

As one of the possible solutions for the system for monitoring and collecting data about agricultural food products, was based in Raspberry Pi computer together with microcontroller sensor board. Proposed solution turned to be most economical and most effective for further research. The microcontroller sensor board should collect data with a minimum of six sensors. It is planned that three sensors measure both temperarature and humidity, while the remaining three measure the temperature of the products. After a successful measurement, the values from the sensors are transferred via Bluetooth communication from microcontroller sensor board to a Raspberry Pi computer.

The data collection system should send the measured micro-climate data to the appropriate web service, if the internet connection is available. If for some reason the Internet connection is not available, the measured parameters are stored locally in the sqlite database at Raspberry Pi itself. When the internet connection becomes available, unsent data is resent, and synchronized with database in cloud. Synchronization is done in only one direction, from sensors to cloud. In the event that an internet connection is not available throughout the entire measurement period, the data can be downloaded in .csv format, using a portable memory (USB flash or SD card memory) and then processed, analyzed or manually sent to the web service.

3. IMPLEMENTED SOLUTION

The implemented solution consists of a central unit made up of a Raspberry Pi 3 model B + computer with peripheral devices, microcontroller sensor board with sensors and a web service for accessing the web database.

3.1 Central unit

The central unit is a Raspberry Pi 3 model B + computer. The computer was built around Broadcom BCM2837 SoC (System on Chip) and is shown in Fig. 1. This computer has a quad ARM Cortex-A53 processor with a maximum clock speed of 1200 MHz. The computer has 1GB LPDDR RAM, running at 900 MHz. Part of the RAM is shared with the GPU (Graphics Processing Unit). The GPU is Broadcom VideoCore IV. The computer has four USB 2.0 ports, which are connected to a single portable USB hub on the board, one port is used for Ethernet connection.

For connecting with display devices, Raspberry PI uses HDMI and TRRS connectors. Raspberry PI also has an Ethernet port, for wired connectivity, Rasbperry PI has the capability of wireless communication over 2.4 GHz 802.11n. Also, the computer has Bluetooth 4.1 classic and Bluetooth Low Energy wireless communication. It owns a 40-pin GPIO heder, which simultaneously uses serial communication (SPI, I2C and UART) and additional digital inputs and outputs. In addition, it has a 3.5mm analog audio-video port, Camera Serial Interface (CSI) and Display Serial Interface (DSI). The microSD memory card is used for storing data.

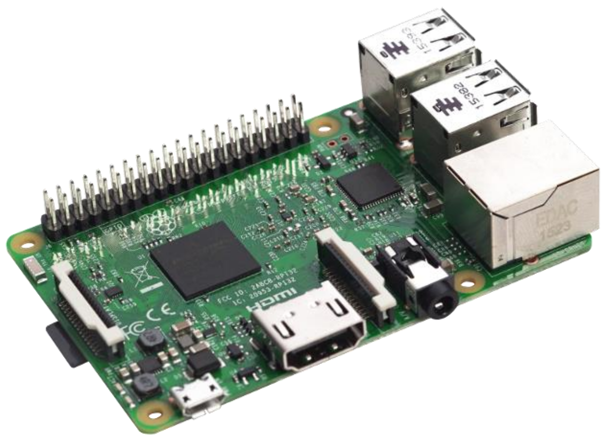


Figure 1. Raspberry Pi 3 computer

On Raspberry Pi 3, is installed Microsoft Windows 10 IoT operating system. An application that communicates with the microcontroller sensor board and the local (and cloud) database, was developed using Microsoft Visual Studio 2015 in C# language, using the .NET 4.5 framework. The Windows 10 IoT platform was selected to take advantage of the .NET framework and know-how in C#.

For the storage of data locally on the Rasberry Pi computer, the SQLite database was used. SQLite is a database that does not need a server, so called serverless database. The SQLite database proved to be the ideal solution for limited resource systems and ebedded systems, due to low requirements. The application’s algorithm is shown in Fig. 2.

3.2 Sensor unit

The main task of the sensor unit is to periodically measures relevant data through connected sensors and sends them to the Raspberry Pi 3 computer. In addition to the measurement, it is necessary to convert the measured values to the appropriate standard units and to perform diagnostic of the sensor status. After diagnostics, the read values from all sensors are sent via Bluetooth communication to the central unit.

Sensor unit is controlled by Atmel Atmega32 microcontroller, to which sensors are connected. It is possible to connect two sensor types, analog and digital, to the sensor unit. Values from analog sensors are read through the A/D converter on the microcontroller itself and the value with digital sensors is read through digtal communication (I2C, 1-wire and SPI). The measurement range is defined for each of the analog sensors and if the measured value outside of the range, the corresponding error for the given sensor is sent. For digtal sensors the same principle applies, which is the extent of measurement. In addition, some digital sensors offer the possibility of sensor's auto-diagnostics. The following sensors were used for the experiment:

- Temperature and humidity of the air
- Temperature of the products.

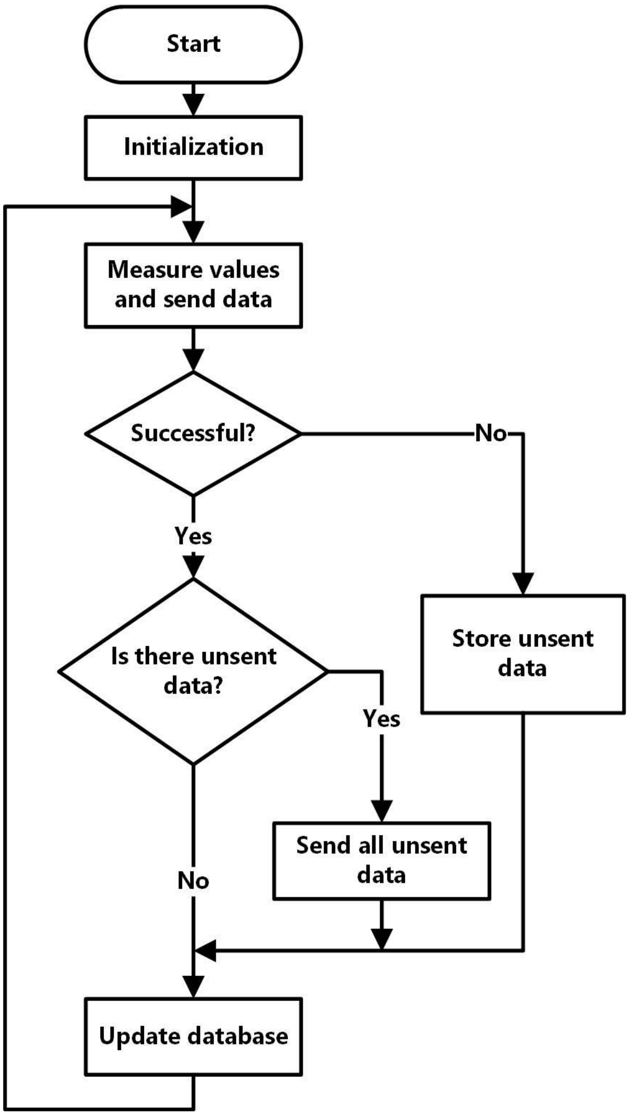


Figure 2. Application's algorithm

Analog sensors were used to measure the temperature of the product. Digital sensors were used to measure the temperature and humidity of the air.

After the measurement and diagnostics of the sensor, the sensor board unit sends the data to the central unit in the following format:

FE A.A | B.B | C.C | D.D | E.E | F.F | G.G | H.H | I.I | I | J | K | L | M | N | O | P | R FF

Where are:

FE – start of message;

A.A – air temperature 1;

B.B – air humidity 1;

C.C – air temperature 2;

D.D – air humidity 2;

E.E – air temperature 3;

F.F – air humidity 3;

G.G – temperature of the product 1;

H.H – temperature of the product 2;

I.I – temperature of the product 3;

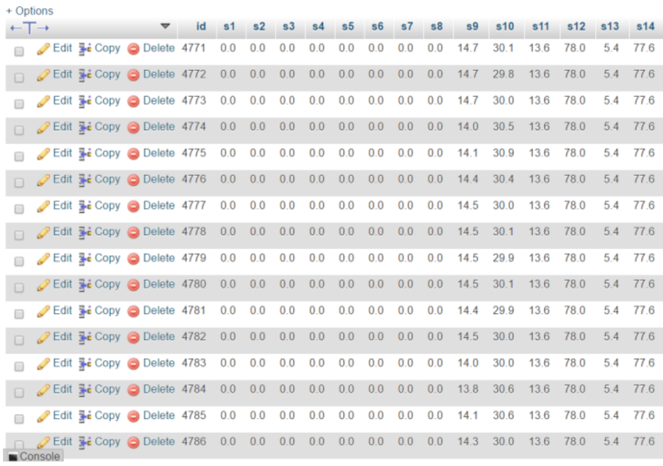
I, J, K, L, M, N, O, P i R – the status of the appropriate sensors (0 - if everything is correct and if the value is different from zero there was an error);

FF – end of message.

All measured values are sent as a series of bytes in hexadecimal format via bluetooth communication.

3.3 WEB SERVICE

The web service was developed using php and MySQL database. Access to the MySQL database goes through the REST service. The service implements all standard operations over a database called CRUD (Create Read Update Delete). The appearance of MySQL database and the corresponding table in the phpMyAdmin panel is shown in Fig. 3.



+ Options

	id	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14
Edit Copy Delete	4771	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	30.1	13.6	78.0	5.4	77.6
Edit Copy Delete	4772	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	29.8	13.6	78.0	5.4	77.6
Edit Copy Delete	4773	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	30.0	13.6	78.0	5.4	77.6
Edit Copy Delete	4774	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	30.5	13.6	78.0	5.4	77.6
Edit Copy Delete	4775	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	30.9	13.6	78.0	5.4	77.6
Edit Copy Delete	4776	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	30.4	13.6	78.0	5.4	77.6
Edit Copy Delete	4777	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	30.0	13.6	78.0	5.4	77.6
Edit Copy Delete	4778	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	30.1	13.6	78.0	5.4	77.6
Edit Copy Delete	4779	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	29.9	13.6	78.0	5.4	77.6
Edit Copy Delete	4780	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	30.1	13.6	78.0	5.4	77.6
Edit Copy Delete	4781	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	29.9	13.6	78.0	5.4	77.6
Edit Copy Delete	4782	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	30.0	13.6	78.0	5.4	77.6
Edit Copy Delete	4783	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	30.0	13.6	78.0	5.4	77.6
Edit Copy Delete	4784	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	30.6	13.6	78.0	5.4	77.6
Edit Copy Delete	4785	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	30.6	13.6	78.0	5.4	77.6
Edit Copy Delete	4786	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	30.0	13.6	78.0	5.4	77.6

Console

Figure 3. Appearance of a web database in phpMyAdmin

REST service accepts and returns JSON (Java Script Object Notation) objects. The database is implemented for experiment purposes as one table, where columns are: column ID, then measured data from the sensor and at the end of the measurement time. Data in the database can be inserted as individual measurement or as a set of individual measurements (bulk inserts). Also, data from the database can be taken as a single record (individual measurement), it is possible to download the entire table or as measurements within a given period of time. REST service allows pagination in case the service needs to return a large number of records. When returning a large number of pages, the service provides information about the number of records per page, the total number of records and the current page index.

4. CONCLUSION

In this paper, we described a system for collecting parameters on food products using Internet of Things technologies. The described solution has shown that the system can be successfully used to collect data about the micro-climate in which the food products are located and that the data is available for further research.

Collected data is available for analysis by agricultural producers, buyers, sellers, scientific institutions and state authorities. By analyzing it, it can be determined whether the food production is treated in an appropriate way, or whether the product is treated according to the defined set of rules. Also, places in the lifecycle of the product where the product is not stored or transported in an appropriate manner can be identified. By solving problematic locations in the supply chain, it is possible to provide a quality product for the end user, which can be sold at the same or higher price.

For the future work, it is planned to redesign sensor unit with sensors for measuring the concentration of oxygen and carbon dioxide in the air. Also, it is planned to connect the accelerometer and the gyroscope to the sensor unit, which will measure the vibrations during the transport of the product. In addition, a wireless network between the central unit and multiple sensor units will be provided. Further plans envisage that each sensor unit has its own unique identification number, which will keep the appropriate measurements in a modified database on the server. In addition, product tracking is planned with RFID or 2D bar code and with that it will be known at any time where the current product is in the supply chain, how much time it spent and under what conditions during each link in the supply chain.

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