

Embedded Systems & IoT for Smarter and Efficient Food Supply Chains

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ABSTRACT: Food is the essential need of human beings. Hence, production and effective distribution of food crops in order to meet the entire human demand is an important task. This concept aims at transforming the traditional food supply chains to smart chains. Internet of Things in combination with embedded system technologies can make the conventional FSCs smart and efficient. The proposed system focus on the technological advancement of primary crop handling and distribution centre, named Storage and Treatment Unit (STU). STU involves autonomous washing, drying and treatment of crops with bio-pesticides. This unit also takes care of monitoring the storage conditions of crops. Also, the required quantity of crops is automatically loaded into the containers for transportation. IoT module enables the remote monitoring of STU using a website. Several STUs can be monitored from a single control station and it is also possible to give emergency commands from this control room to the system. The proposed system is purely an embedded based system which uses a mechanical structure controlled by combination of number of motors, RFID tagging, IoT module, a set of sensors and related devices.

KEYWORDS: Internet of Things, RFID, STU, Food Supply Chains.

I. INTRODUCTION

Food is the most basic need for all living things and it is necessary to satisfy the needs of a growing population. Growth in population and modernization reduced the size of farm fields. Now, the challenge is to meet the growing demand from available farm fields. This can only be achieved by increasing the efficiency of production and using appropriate crop handling and distribution mechanisms. In India, farmers usually follow traditional systems for farming. The farming systems are based on the climatic and geographic conditions of the area. Major challenges in agriculture industry include insufficient human resources, time consuming processes, reduced ground water table, increase in expenditure and fluctuations in climatic conditions. Here comes the importance of technology towards agriculture. Progressive research works in this area can introduce technological advancements to reduce the challenges in agricultural sector [1].

The objective of this project work is to find smart solutions for the challenges in the processes of conventional food supply chains. Here, some phases of the food supply chains are selected to make it smarter and efficient by applying available technologies. This system proposes an autonomous concept in the FSC which reduces human intervention and increases the efficiency and enhances food safety. This can be done by designing an embedded system which incorporates Internet of Things (IoT) and related available technologies [1]. The use of technology can automate each phase of the food supply chains to find solutions for several challenges faced during the progress of each phase. Here, the Storage & Treatment phase of freshly harvested crops is taken into consideration. The proposed system uses a mechanical structure controlled by combination of number of motors, RFID technology and a set of sensors and related devices along with the concept of Internet of Things.

The Storage and Treatment Unit (STU) performs automatic washing, drying and bio-pesticide treatment of freshly harvested crops. This unit is implemented at the Handling and processing centre where the freshly harvested crops are handled first. This initial phase of treatment is followed by storage of crops until it is supposed to be transported. The

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proposed system automates the monitoring of the storage room conditions using a set of sensors. It also powers appropriate devices such as exhaust fans, incandescent lamps, etc., if any monitored parameters vary from the previously defined range. Hence the storage room environment can be kept ideal. Keeping the storage conditions intact is necessary to reduce the damage and thereby wastage of crops. It also enhances food safety. RFID (Radio-frequency identification) tagging helps the automatic loading of required amount of crops to the containers for transporting to various destinations. Using the concept of IoT, more than one such FSCs can be monitored and controlled from a single place.

Paper is organized as follows. Section II discuss about the related works in this area. The schematic diagram of mechanical structure used is given in Section III. Section IV describes methodology which includes an overview of the proposed system, schematic diagram of the system and block diagram of STU with detailed description. Section V presents experimental results showing results of hardware and software implementations. Finally, Section VI presents conclusion.

II. RELATED WORK

The objective of the project work is to implement a system which automates some parts of the food supply chains and to make the system smarter to improve the efficiency and control the expenditure. It requires careful selection of available technologies to establish and develop the concept for implementing the objective. The use of Internet of Things and emerging technologies is considered here for the design and implementation of the proposed idea. A study to find expected outcomes and possible challenges is important for the successful completion of the project work. It requires careful study of the related works in the area to collect useful information which can be applied to implement the proposed idea. The key information and findings obtained from the study of related works in the field is discussed here.

RevathiNukala et al. [1], discusses about the idea of incorporating Internet of Things (IoTs) technologies along with conventional food supply chains. Author provides a review of state-of-the-art technologies and strategies that constitutes the IoT and how that applies to 'Farm to Fork'. The paper presents the research trends and challenges in the food supply chain industry, mainly focusing on products such as meat, fruits & vegetables.

Ji-chun Zhao et al. [2], proposes a system which uses Internet of Things technologies for remote monitoring of the agricultural environments especially greenhouses. This uses a combination of WSN (Wireless Sensor Networks) technology and IoT technologies. Here, this system uses temperature, humidity and soil moisture sensors for monitoring the environment inside the greenhouse.

Vladimir Todorovic et al. [3], proposes the usage of RFID tags for tracking and monitoring of shipped perishable goods. The idea is to employ the RFID technology in conjunction with integrated sensors to build the system.

Qidi Zhao et al. [4] proposes an intelligent system for monitoring and controlling of the grain condition. In this, the grain environment Information such as temperature, humidity, and CO₂ concentration is collected and stored by Multi-sensors.

Hua Xianzhe et al. [5] proposed a system for controlling the internal temperature and humidity in an engine room. That system takes parameters from inside and outside of the engine room. It uses fuzzy algorithm to evaluate the read parameters to control the working of related equipments such as fans and air conditions as required.

III. MECHANICAL STRUCTURE OF THE SYSTEM

The main part of the proposed system is the mechanical structure of Storage and Treatment Unit. Fig. 1 shows the mechanical structure of STU. The major parts of this mechanical structure include a washing container and conveyor belt. The conveyor and washing container are fixed on a platform as shown in the figure.

The washing container consists of inlet valve (For filling water in to the container), Outlet valve (For draining the waste water from the container after washing). The base of the washing container is free to turn in both directions (Tilting). During washing, washing container tilts in both directions to facilitate washing and during loading, the washing container bends towards the conveyor to facilitate loading. The drying fan and bio-pesticide sprinkler is fixed above the

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conveyor to dry out and treat the washed crops during loading. The conveyor belt is followed by a lower platform to place transporting container (Loading Terminal). The crops passing through the conveyor falls on the transporting container. The RFID reader near the Loading Terminal reads the tags and facilitate loading of required quantity.

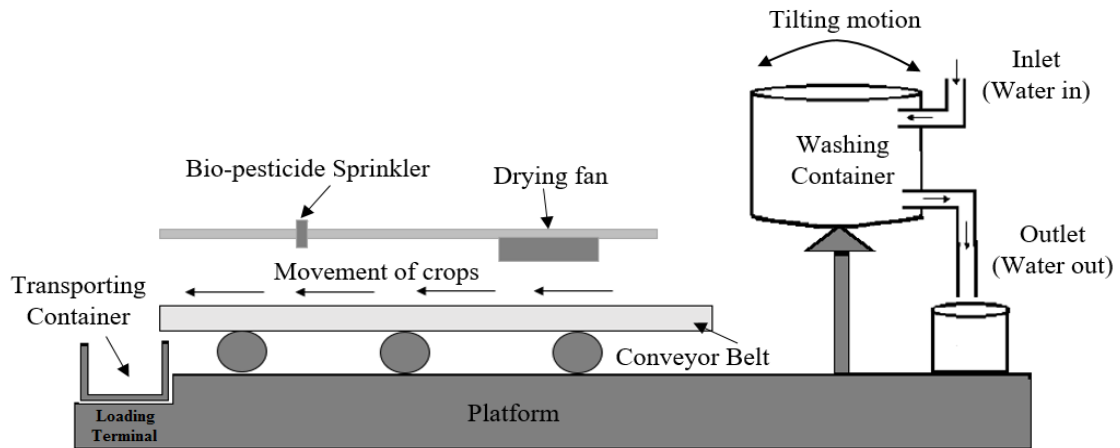


Fig. 1 Mechanical structure of the system

IV. METHODOLOGY

The proposed system focus on the storage, treatment, distribution and monitoring of the harvested crops at its primary handling centre. Fig.2 shows the schematic diagram of the proposed system. The heart of the system is named as Storage and Treatment Unit. STU involves autonomous washing, drying and treatment of crops with bio-pesticides. This unit also takes care of monitoring the storage conditions of crops. Also, the required quantity of crops is automatically loaded into the containers for transportation. IoT modules enables the remote monitoring of STU using a website. Several STUs can be monitored at a time from a single control station and it is also possible to give emergency commands from this control room to stop or reset the working of an entire system or peripheral devices according to the requirement. The proposed system is purely embedded based which uses a mechanical structure controlled by combination of number of motors, RFID system, IoT module, a set of sensors and related devices.

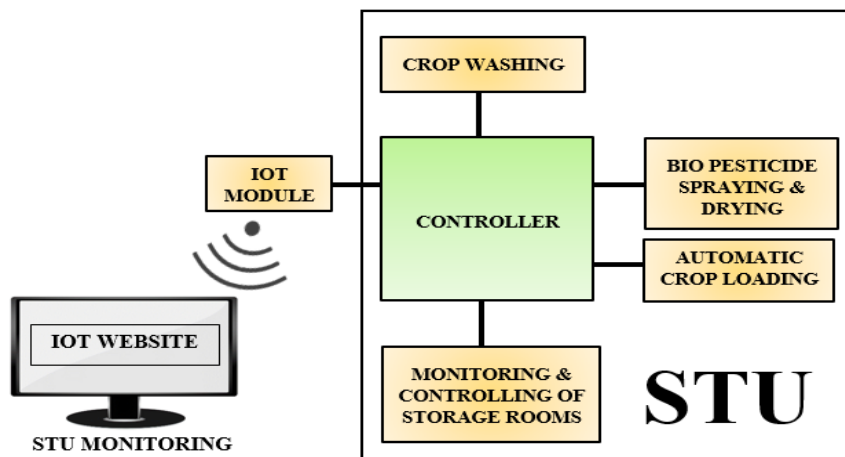


Fig. 2 Schematic diagram of the system

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The proposed system automates the crop handling works and maintains the ideal storage conditions for crops. It also communicates with the website to update its current status with it. Hence, it is possible for a distant monitoring of the work and conditions of the unit. It is possible for a single person to monitor the status of a number of STUs that are thousands of kilometres apart. Along with distant monitoring, it is also possible to give reset or stop commands to STUs remotely in case of emergency by using virtual control switches. The system works throughout when powered ON and it carries out washing of crops until a container for loading arrives. The block diagram of the STU is shown in Fig. 3. It consists of a crop treatment section and a storage condition monitoring system, both communicate with the controlling system. LCD is used to display the working status of the STU.

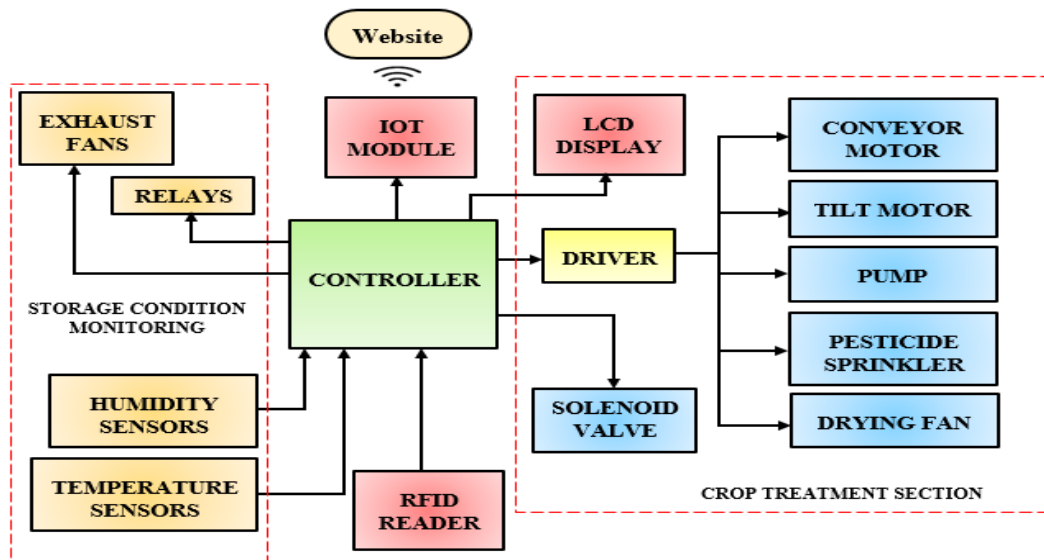


Fig. 3 Block diagram of STU

1. **Washing of crops:** Washing of crops refers to the removal of mud, especially in the case of root crops. This autonomous task is achieved by controlling the working of motors and solenoid valve. There is a purifier container to which the crops for cleaning is loaded. The water for cleaning the crops is filled into the container through the inlet valve using a water pump. After filling the water, the purifier container is tilted in forward and backward direction to make the impurities settle at the bottom of the container. Tilting of purifier container is achieved by using a DC motor that rotates in both directions. This tilt motor itself can be used to unload the crops from the purifier container to the conveyor by tilting the purifier towards conveyor. The outlet is connected to a solenoid valve which can be closed and opened automatically as per requirement. After washing the crops, the solenoid valve is made open to dry out the impure water with sediments from the container. This process is continued till containers for transportation arrives. Noises due to power fluctuations and other external interactions can affect the proper alignment of the washing container. This situation is avoided by the use of limit switch. A limit switch is provided at one end of the washing container to maintain the proper alignment of the container during the progress of working. While washing, this status is indicated on the LCD screen by displaying 'washing...' on the screen.
2. **Drying and Bio-pesticide spraying:** Drying of the washed crops is carried out by the use of fans during the loading process. The drying fan is fixed just above the conveyor. Drying fan is turned ON during the loading process. While loading, the crops pass through the conveyor to reach the container. When the crops pass as a thin layer below the drying fan, they get dried. Once the loading process is completed, the drying fan is turned OFF along with the conveyor belt. Bio-pesticide spraying is also carried out during the loading process. Bio-

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pesticide is kept in a container with a motor to pump the bio-pesticide on the crops. One of a pipe is connected to the motor pump inside the pesticide container and the other end connected with a nozzle is fixed above the conveyor. The motor pump is turned ON during the loading process. When the crops pass below the tube, they get sprayed with the bio-pesticide over them. The motor pump is turned OFF along with the conveyor after the termination of the loading process.

- Automatic loading of required quantities:** Different destinations require unique quantities of crops as per the market demand at different places. Once the containers for transportation to different destinations arrive, it must be loaded only with the required quantity. This is achieved with the help of RFID tags. Unique RFID tags are provided to each container. The RFID tags in each containers stores information related to the quantity required. As the container comes close to the Loading Terminal, RFID reader reads the code inside the tag and gives commands to the controller accordingly. According to the tag code the loading process is carried out. Once loading process is initiated, the conveyor starts running. Then the washing container tilts towards the conveyor to deliver the crops into the conveyor. The time duration of the purifier container at tilted position for unloading the crops into the conveyor decides the quantity loaded. This time period varies according to the read RFID codes. The conveyor belt starts running before the loading action of the washing container to avoid the generation of a heap of crops on the conveyor. Similarly, the conveyor stops only after a small delay from the return of washing container after completing the loading procedure. This ensures that all the crops loaded from the washing container reach transportation container. Drying and bio-pesticide spraying processes are carried out during the loading process. The destinations for transport are named as Destination1, Destination2, etc. Each destination is provided with a unique tag which gives information regarding the quantity required for that particular destination. While loading, the name of the destination to which loading is in progress is displayed on the LCD screen as '*Loading... Product to Destination X... RFID No: XXXXXXXXXXXXX*'. The name of the destination to which the product has been loaded is displayed on the monitoring website.
- Monitoring & controlling of storage conditions:** The quality of crops is highly influenced by the storage conditions which should be strictly monitored and controlled. The proposed system takes care of the monitoring and controlling of storage room environment with the help of sensors and related devices. Here, the temperature and humidity of the storage rooms are measured. If the temperature and the humidity vary beyond previously set limits, the controller turns ON appropriate devices such as exhaust fan to maintain the storage room conditions ideal for preventing the stored crops from damaging. The storage conditions for various crops are different. Hence, it is important to maintain the storage condition which is specific to that stored crop. Here, two different storage conditions (S1 & S2) are implemented enough to store two different varieties of crops or two groups of crops with unique storage conditions. When the value of monitoring parameters of each storage room goes beyond its corresponding predefined values, the system powers ON exhaust fan and a relay for S1 and one relay for S2. Relays can be connected to any device such as air conditioners enough to control the parameters to be maintained within the set parameters. The storage conditioning process works throughout when the system is powered ON. The values of measured environment parameters corresponding to each storage room are displayed on the LCD screen and monitoring website at regular intervals.
- Remote monitoring and controlling of STU using IoT:** The monitored environmental parameter values (Temperature and humidity readings) of the storage rooms are displayed on the monitoring website in the format "*S1_Temp:xx, Hum:xx.xx, S2_Temp:xx*" where 'S1' and 'S2' denotes storage1 and storage2 respectively. Eg: "*S1_Temp:32, Hum:70.00, S2_Temp:35*". If loading is in progress, the name of the destination to which the current loading action is performed (Destination1, Destination2, etc.) is indicated on the website as "*Product_to_dest.x loaded*". Eg: "*Product_to_dest.2_loaded*". Along with these, the date and time of each update are also available which helps to measure and monitor the workflow and efficiency of the system.

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V. EXPERIMENTAL RESULTS

The hardware of the system is composed of a mechanical structure interfaced with circuitry. Crops are added to the washing container manually. Fig. 4 shows the image of the hardware prototype. The system takes a few seconds to initialize when the power is turned ON. After initialization, the system starts working and begins washing process. This can be considered as the idle working state of the STU. The tilting action of the washing container during the washing process removes mud and dirt from crops. Storage room monitoring and controlling will be carried out simultaneously independent of the working state of STU.

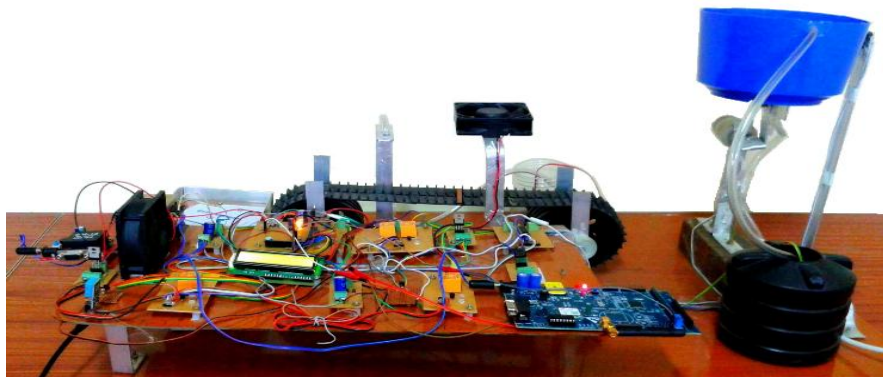


Fig. 4 Image of hardware prototype

Distant monitoring of STU's (Storage and Treatment Unit's) working status and storage room conditions is achieved by the help of IoT module. The websites provided with the product give user interface. The websites provided with the product are Monitoring website and Control website. Monitoring web page displays the transmitted data from the system, whereas the control web page allows limited control commands to be transmitted to the system. Fig. 5 (a) shows the web page for viewing the updates of the status of the system. The data along with date and time is displayed on the web page. The user can clear the data log if required. Fig. 5 (b) shows the control page for giving a few commands to the system. Here, the first virtual switch is linked to the input of one storage room relay via IoT module and it can be turned ON and OFF manually from anywhere in the world with the help of control page. The Web link for monitoring website is "<http://www.iotclouddata.com/project/505/iot16view.php>" and the Web link for control page is "<http://www.iotclouddata.com/project/505/controlview1.php>".

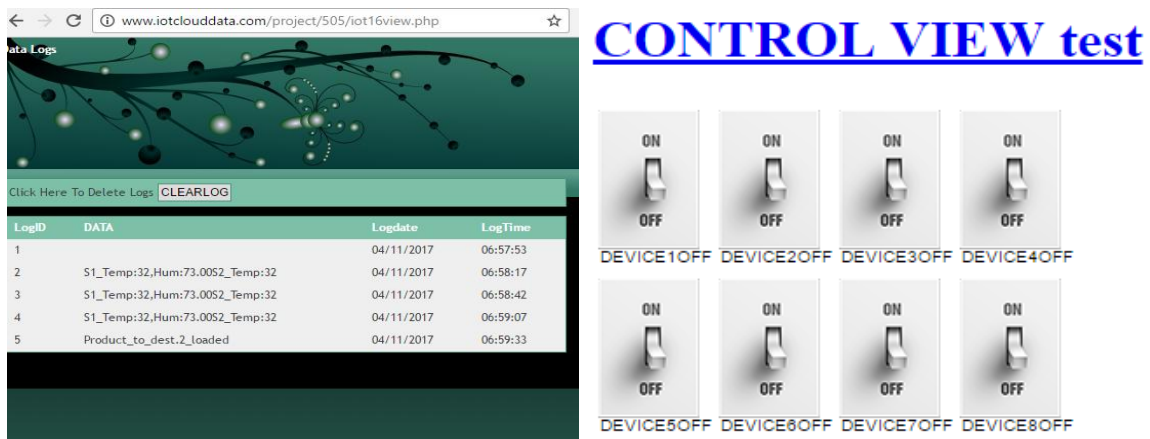


Fig. 5. Website images (a) Webpage for remote monitoring of STU (b) Webpage for remote controlling of STU

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The proposed system implements two storage rooms with different conditioning parameter levels. Table 1 describes the threshold levels in these storage rooms for the monitored parameters and the corresponding conditioning action followed when any parameter values vary across the threshold. Here, Storage room-1 (S1) monitors both humidity and temperature while Storage room-2 (S2) concentrates only on the temperature levels. Relay of S1 (Relay 1) is interfaced with IoT module and can be controlled manually by a distant operator using the Control web page. Once the virtual control switch (In control page) has turned ON, the relay-1 enters manual mode and turns ON independent of monitored parameter threshold. After entering manual mode, it has to be manually turned OFF to exit from this mode to follow commands based on monitored parameter values from the controller.

Table 1 Storage room conditioning

Storage room	Monitored parameter	Control action
Storage Room 1 (S1)	Temperature $\leq 40^{\circ}$	Relay 1 - OFF
	Temperature $> 40^{\circ}$	Relay 1 - ON
	Humidity ≤ 60	Exhaust fan - OFF
	Humidity > 60	Exhaust fan - ON
	IoT Control switch - ON	Relay 1 - ON (Enters manual mode)
	IoT Control Switch - OFF	Relay 1 - OFF (Exits manual mode)
Storage Room 2 (S2)	Temperature $\leq 60^{\circ}$	Relay 2 - OFF
	Temperature $> 60^{\circ}$	Relay 2 - ON

VI. CONCLUSION

In the perspective of human beings, satisfying the need for food is achieved by a chain of processes as a result of group coordination and organization. In FSCs, inefficiency of organization results in wastage and loss. Automating and controlling of these processes with the help of available technologies helps to tackle the issues up to an extent. This project proposes a system which makes use of the Internet of Things and sensor technologies with an embedded system.

The proposed system intends to automate some of the processes in the food supply chains. This reduces human intervention and increases the efficiency of the food supply system. It also enables distant monitoring of tasks. In this project, the storage, treatment and loading of freshly harvested crops is automated with the help of available technologies. The crops are automatically washed, dried and are treated with bio-pesticide. The crops are automatically loaded to transporting containers in required quantities. The crops are stored in conditioned storage rooms in which the storage conditions corresponding to the stored crop is strictly monitored and controlled. By the use of IoT technology, working status of STU and the Storage room conditions can be monitored in real time from anywhere with the help of a website. The storage room relay can be turned ON and OFF manually by using the control website from anywhere around the world. With the implementation of this system the duration and expenditure of all these processes can be considerably reduced.

The proposed system is the first step towards autonomous FSCs. Handling of all varieties of crops and efficient automatic tracking, updating of data regarding stock availability as well as requirement at each destination becomes the real challenges which have to overcome. Enhancing food safety has much more importance, since lack of which affects

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health. Both scarcity and wastage that occurs simultaneously in most cases can be eliminated by efficient planning and organization. The concept of Internet of Things has a wide range for finding solutions for the challenges in current scenario and also for making further advancements.

REFERENCES

- [1] Nukala, Krishna Panduru, Andrew Shields, Daniel Riordan, Pat Doody, Joseph Walsh, "Internet of Things: A review from 'Farm to Fork'", in IEEE, 978-1-5090-3409-3, 2016.
- [2] Ji-chun Zhao, Jun-feng Zhang, Yu Feng, and Jian-xinGuo, "The study and application of the IOT technology in agriculture", in IEEE, pp. 462-465, 2010.
- [3] Vladimir Todorovica, Marius Neagb, Milovan Lazarevica, "On the Usage of RFID Tags for Tracking and Monitoring of Shipped Perishable Goods", 24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013.
- [4] Qidi Zhao, Yanju Liu, Yang Yu, Jianhui Song, Guang Zhou, "Intelligent system for monitoring and controlling of the Grain condition based on ARM9", in IEEE, 978-1-4799-3708-0/14, 2014.
- [5] Hua Xianzhe, "Room temperature and humidity monitoring and energy-saving system", in IEEE, 978-1-4244-9718-8/11, 2011.