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Smart agriculture: IoT based precise and productive farming approach

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ABSTRACT

Internet of Things (IoT) is a new technology that gained great attention from researchers since it becomes an important technology that promises a smart human being life. It allows human to communicate between objects, machines and everything. IoT represents a system which consists of things in the real world and sensors attached to combine these things, connected to the Internet either wired or wireless network structure. The main aim of this study is to provide a literature focus on the researchers working with IoT in the agricultural field.

Keywords— *Cyber-physical systems, Evapotranspiration, FarmBeats, FMIS, Precision agriculture, Wireless Sensors Network*

1. INTRODUCTION

In Indian, 70% population has agriculture as their main occupation. Many types of research are happening in the field of agriculture. IoT is a network of physical devices, home appliances or any other items embedded with electronics, software, sensors, actuators and connectivity which enable these objects to connect and exchange the data. The key elements involved in the IoT [1] are identification, sensing, communication, services and semantics. The identification element matches the services with the demand. The sensing element obtains the information from various objects within the network then sends back the sensed data to the cloud or to the database. The communication element interlinks the heterogeneous objects for providing the specific smart services. The computation elements are the processing units of the IoT. India's economic growth depends on Agriculture. The productivity of traditional farming is very much dependent on the climate.

2. SMART AGRICULTURE

Nowadays there is a vast enhancement in technologies, different tools and techniques are available in the agriculture sector. To improve efficiency, productivity, global market and to reduce human intervention, time and cost there is a need to divert towards new a technology. Vinayak N. Malavade and Pooja K. Akulwar [2] says that IoT is the network of devices to transfer the information without human involvement. For gaining high productivity, IoT works in synergy with agriculture to obtain smart farming. The main advantages of using IoT in enhancing farming are as follows:

1. With the help of sensors, water management can be done efficiently using IoT, so no wastage of water.
2. IoT helps continuous land monitoring so that precautions can be taken at an early stage.
3. Farming efficiency improved by reducing manual work, time and increases productivity.
4. By observing the growth of the crop, crop monitoring can be done easily.
5. PH level, the Moisture content of soil can be identified easily so that farmer can sow seeds according to soil level. That is soil management.
6. Plant diseases can be recognized with the help of Sensors and RFID chips. The reader receives EPC (information) from RFID tags and is shared across the internet. From a remote place this information can be accessed by farmer or scientist and take necessary actions, automatically crops can be protected from coming diseases.
7. Sale of the crop will be increased in the global market. A farmer can easily connect to the global market without restriction of any geographical area.

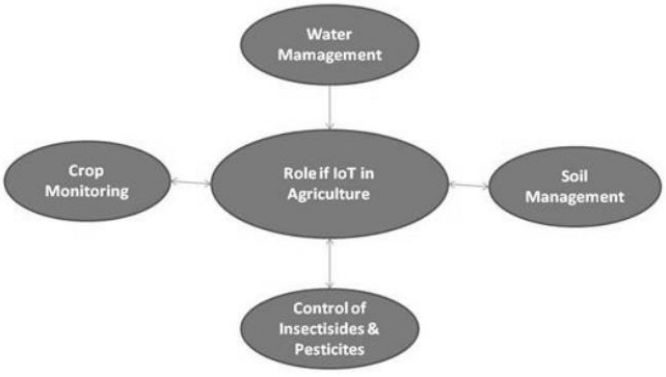

Fig. 1: Role of IoT in Agriculture

Finally, they concluded that Farming will play a vital role in the next few years in the country. Thus there is a need for smart farming and it will be possible using IoT.

C.N. Verdouw [3] did a review on the Internet of Things (IoT) in agriculture and food, provides an overview of existing applications, enabling technologies and main challenges ahead. His review shows that IoT in agriculture and food is very much dominated by Asian scientists, especially from China. In other continents, the concept of IoT was up to recently mainly adopted by non-agricultural scientists. The food supply chains are addressed most frequently in the application area, followed by arable farming. The literature reviewed focuses on monitoring and sensing, while remote control and actuation are much less addressed. The findings indicate that IoT is still in its infancy in the agriculture and food domains. Applications are often fragmentary, lack seamless integration and especially more advanced solutions are in an experimental stage of development. To overcome this situation, important challenges include (i) integration of existing IoT solutions by open IoT architectures, platforms and standards, (ii) upscaling the usage of interoperable IoT technologies beyond early adopters especially by the simplification of existing solutions and make it more affordable for end users, and (iii) further improvement of IoT technologies to ensure a broad usability in the diversity of the agrifood domain.

In India, one-third of the nation's capital comes from farming. In the development of the country, issues concerning agriculture have been always hindering. Smart agriculture by modernizing the current traditional methods of agriculture is the only solution to this problem. Nikesh Gondchawar and Dr R. S. Kawitkar [4], in their project, aims at making agriculture smart using automation and IoT technologies. Smart GPS based remote controlled robot to perform tasks like weeding, spraying, moisture sensing, bird and animal scaring, keeping vigilance, etc are the highlighting features of this project. Smart irrigation with smart control and intelligent decision making based on accurate real-time field data is the second one and finally smart warehouse management which includes temperature maintenance, humidity maintenance and theft detection in the warehouse. Using any remote smart device or computer connected to the Internet, these operations will be controlling and the operations will be performed by interfacing sensors, Wi-Fi or ZigBee modules, actuators with micro-controller and camera, raspberry pi. Implementation of such systems in the field will definitely help.

For ages, agriculture is the primary occupation in our country. But due to the migration of people from rural to urban, there is a hindrance in agriculture. Smart agriculture techniques using IoT is the only solution to this problem. Dr N. Suma [5], includes various features like GPS based remote controlled monitoring, moisture & temperature sensing, intruders scaring, security, leaf wetness and proper irrigation facilities in their project. It makes use of wireless sensor networks for noting the soil properties and environmental factors continuously. This is achieved by deploying various sensor nodes at different locations on the farm. Using any remote device or internet services, these parameters are controlled and the operations are performed by interfacing sensors, Wi-Fi, a camera with a microcontroller.

3. CROP MONITORING SYSTEM

Zhao Liqiang [6], proposed an agricultural application of wireless sensor network, main work is to implement two types of nodes and building a sensor network. Data process unit, radio module, sensor control matrix, data storage flash, power supply unit, analogue interfaces and extended digital interfaces are constituted by the hardware platform. TinyOS which is composed of system kernel, device drivers and applications are software system. The energy-saving algorithm is implemented in the software system. The monitoring network adopts two networking protocols. Collection Tree Protocol is a tree-based collection protocol which collects the data generated in the network into a base station. The dissemination is the complementary operation to the collection. The dissemination protocol is to reliably deliver a piece of control and synchronization instructions to every node in the network. Finally, the experimental results show that the monitoring system is feasible for applications in precision agriculture.

4. PRECISION AGRICULTURE

Farmers use an unavoidable decision-support system to optimize water use. In this context, indeed, the real-time supervision of microclimatic conditions are the only way to know the water needs of a culture. Wireless sensor networks play an important role with the advent of the Internet of things and the generalization of the use of the web in the community of the farmers. It will be judicious to make supervision possible through web services. The IoT cloud represents platforms which allow creating web services suitable for the objects integrated on the Internet. Fough Ali Karim [7] presented the alert system for the control of water stress of plants using IOT technology. In the first part of the project described the steps of the creation the decision support system intended to an agricultural community in order to be able to estimate the quantities of water required. For irrigation management, the farmer will get benefit from a dashboard software in the form of a graph, to monitor in real time the variations of the soil conditions and on the other hand a process of notification by SMS transmitted by the application when a critical level is reached to avoid water stress. This application can be improved is to make it very sophisticated one envisages the integration of the method of evapotranspiration to calculate the water requirement of a plant per day in our system of decision support.

The agriculture sector is evolving with the advent of information and communication technology. Efforts are being made to enhance productivity and reduce losses by using the state of art technologies and equipment. Most farmers are unaware of the technology and latest practices, many expert systems have been developed in the world to facilitate the farmers. These expert systems rely on the base of stored knowledge. Raheela Shahzadi [8] propose an expert system based on the Internet of Things (IoT) that will use the input data collected in real time. Which help to take proactive and preventive actions to minimize the losses due to diseases and insects/pests.

According to Ciprian-Radu RAD [9], there is an intense shift from advanced mechatronic systems to Cyber-Physical Systems (CPS). In the field of precision agriculture, CPS play an important role and it is expected to improve productivity in order to feed the world and prevent starvation. In order to expedite and accelerate the realization of CPS in the precision agriculture field, it is necessary to develop methods, tools, hardware and software components based upon Transdisciplinary approach, along with validation of the principles through prototypes and test beds. Ciprian-Radu RAD presented precision agricultural management integrated system architecture for monitoring vegetation condition of potato crop based on CPS architecture and design technologies. This system allows farmers to follow the evolution of certain parameters of interest and take appropriate decisions in order to increase agricultural productivity. Implementing such a system is not an easy task and requires knowledge of potato crop,

management strategies, processing and visualization of information technologies, etc. in order to be viable in practice.

5. CLOUD COMPUTING

Fan TongKe [10] says IoT is closely related to cloud computing in a way that IoT obtains powerful computing tools through cloud computing and cloud computing finds the best practising channel based on IoT. Agricultural information cloud is constructed based on cloud computing and smart agriculture is constructed with a combination of IoT and RFID. Hardware resources in agricultural information network are integrated into the resource pool by using vitalization technology, achieving a dynamic distribution of resource and balance of load, significantly improve the efficiency of resource use. A large amount of data are obtained by using radio frequency identification, wireless communication, automatic control, information sensing techniques of IoT are handled with agricultural information cloud, truly realizing smart agriculture.

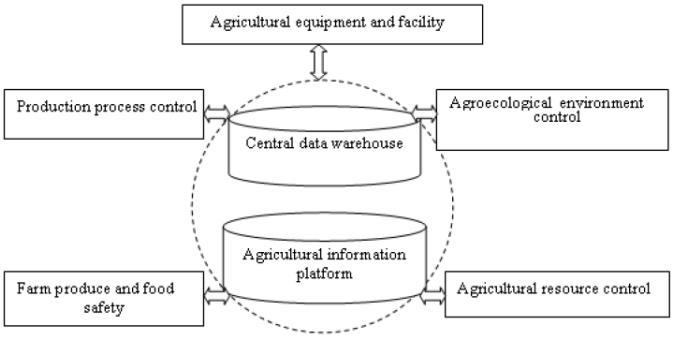

Fig. 2: Control architecture of smart agriculture based on cloud computing and IOT

The control architecture of smart agriculture based on cloud computing and IOT is shown in Figure 2. This data center consists of control platform and database, and the platform further consists of such subsystems as agro-ecological environment control, agricultural resource control, production process control, farm produce and food safety, agricultural equipment and facility. The data center is a set of complex facilities. It includes not only computer systems and other facilities go with it (like communication and memory system), but also redundant data communication links, environment control facility, monitor facility and various kinds of security devices. Data center architecture based on a cloud network is shown in figure 3.

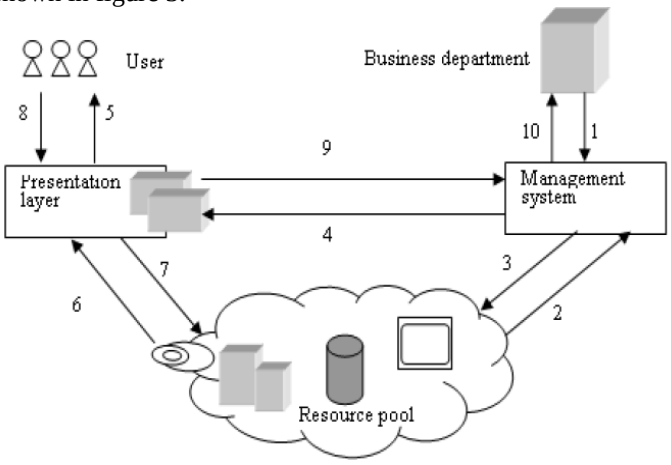

Fig. 3: Data centre architecture based on a cloud network

Agraj Aher [11] is trying to digitalize the agricultural field using the mobile application because Cloud-based IoT services are getting popular. The main task is to collect data from multiple locations on a farm. This data will be available to the farmers via the cloud service. This data can be accessed through a mobile application. Not only providing data graphically, but the mobile app will also provide numerous services beneficial for the farmers. This is a remote monitoring system for agricultural industry combined with some farmer friendly applications. The main aim is to collect the readings from multiple nodes and help the farmers handle various operations wirelessly providing a smart agricultural field for smart farmers.

Ojas Savale [12] says IoT, the idea of getting real-world objects connected with each other, will change the way users organize, obtain and consume information radically. IoT enables various applications such as crop growth monitoring and selection, irrigation decision support, etc in Digital Agriculture domain. The Wireless Sensors Network (WSN) are widely used to build decision support systems. These systems overcome many problems in the real world. Precision Agriculture (PA) is one of the most interesting fields having an increasing need for decision support systems. Through sensor networks, agriculture can be connected to the IoT, which allows creating connections among agronomists, farmers and crops regardless of their geographical differences. With the help of this approach which can provide real-time information about the lands and crops that will help farmers make the right decisions. The major advantage is the implementation of WSN in Precision Agriculture (PA) will optimize the usage of water fertilizers while maximizing the yield of the crops and also will help in analyzing the weather conditions of the field.

6. DATA-DRIVEN AGRICULTURE

Data-driven techniques help boost agricultural productivity by increasing yields, reducing losses and cutting down input costs. However, these techniques have seen sparse adoption owing to high costs of manual data collection, limited connectivity solutions. In the paper, Deepak Vasisht [13] present FarmBeats, an end-to-end IoT platform for agriculture that enables seamless data collection from various sensors, cameras and drones. The design of FarmBeats's system that explicitly accounts for weather-related power and Internet outages has enabled six month long deployments in two US farms. Finally concluded that FarmBeats is a low-cost, highly available IoT platform for agriculture. It supports high bandwidth sensors using TVWS, which is a low-cost, long-range technology. FarmBeats uses a weather-aware solar-powered IoT base station and an intelligent Gateway that ensures that services are available in the Cloud and offline. It also incorporates new path-planning algorithms that extend drone battery life. The entire system is deployed in two farms, and the farmers are already using it for three applications: precision agriculture, animal monitoring, and storage monitoring.

7. SMART SENSORS AGRICULTURE STICK

IoT technology brought revolution to each and every field of common man's life by making everything smart and intelligent. IoT makes a self-configuring network. The development of Intelligent Smart Farming IoT based devices is day by day turning the face of agriculture production by not only enhancing it but also making it cost-effective and reducing wastage. Anand Nayyar's [14] proposed a Novel Smart IoT based Agriculture Stick assisting farmers in getting Live Data (Temperature, Soil Moisture) for efficient environmental monitoring which will enable them to do smart farming, increase their overall yield and quality of products. The Agriculture stick is integrated with Arduino Technology, Breadboard mixed with various sensors and live data feed can

be obtained online from Thingsspeak.com. The product is tested on Live Agriculture Fields giving high accuracy of over 98% in data feeds.

Table 1: The growth of IoT based adoption in Agriculture sector from 2000 to 2016 and Forecasts of the year 2035-2050

Year	Data Analysis
2000	525 Million Farms connected to IoT
2016	540 Million Farms till Date are connected to IoT
2035	780 Million Farms would be connected to IoT

8. PRODUCTION SUPPLY CHAIN MANAGEMENT

Xiaohui Wang [15] introduces the related technologies of the internet of things and tries to build a model of Agricultural Means of Production Supply Chain based on it. Which analyzes the function and utility of the internet of things applying on the agricultural means of the production supply chain. This article describes the trends and prospects that the technology of the internet of things in Agricultural Means of Production Supply Chain. How to improve the agricultural supply chain operation efficiency and competitiveness is the key to problem-solving. Application of IoT in the agricultural supply chain helps to improve the agricultural supply chain information technology level, so that the operating efficiency of the supply chain of agricultural products is improved by enhancing whole supply chain integration. In the fierce global competition environment, our country agriculture highlights low level of industrialization, the low-value chain level, low management level, low level of information. In order to solve the above problem, the application of new technology is a feasible method, the applications of the Internet of things technology to the agricultural products supply chain, in order to improve the operation efficiency of the supply chain of agricultural products, promote the development of agriculture in our country. There are many factors affecting the adoption of agricultural products supply chain of IoTs. There is still a long run for the internet of things to enter into the practical stage of the agricultural supply chain. There are also many problems for IoT to solve, which include how to reduce costs, carry on the R&D of core technology, develop industry standards, protect privacy and so on. But IoT based on RFID technology has been integrated into all aspects of supply chain management and it will have a significant impact on the development of supply chain management.

9. FIELD AUTOMATION

The agriculture sector in India is diminishing day by day which affects the production capacity of the ecosystem. There is an exigent need to solve the problem in the domain to restore vibrancy and put it back on higher growth. Mohanraj I [16] proposed an e-Agriculture Application based on the framework consisting of KM-Knowledge base and monitoring modules. To make profitable decisions, farmers need information throughout the entire farming cycle. The required information is scattered in various places which include real-time information such as market prices and current production level stats along with available primary crop knowledge. A knowledge dataflow model is constructed connecting various scattered sources to the crop structures. The world around is getting automated replacing manual procedures with the advancement of technology, since it is energy efficient and engross minimal manpower. Mohanraj explained the advantages of having ICT in the Indian agricultural sector, which shows the path for rural farmers to replace some of the conventional techniques. Monitoring modules are demonstrated using various sensors for which inputs are fed from the Knowledgebase. A prototype mechanism is carried out using TI CC3200 Launchpad interconnected sensors modules with other necessary electronic devices. A comparative study is made between the developed system and existing systems. And the system overcomes with limitations of traditional agricultural procedures by utilizing water resource efficiency and also reducing labour cost. Farmers need help during different stages of crop growth and guidance should be given at the right time. Farmers are suffering a lot economically, socially and politically. Various challenges in the agricultural domain are identified and architecture was framed meeting the above-mentioned challenges. The knowledgebase is structured with various crop details which speak about knowledge acquisition, flow, various input like market availability, geospatial data, and weather prediction. Monitoring contains modules like remainder, monitoring plant growth in various stages, irrigation planner, crop profit calculator, calamity check, problem identifier. Evapotranspiration method is used to calculate water need of a plant per day with devised algorithm's help. A comparative study was made between various applications available with the current developed system taking various aspects into account like a knowledge base, monitoring modules, efficiency and reliability.

Remote monitoring of mobile machine requires radio technology, Internet technology, protocols and applications. Mobile cellular networks provide both radio and communication for Internet services while the protocols for IoT are under development. In industrial automation, the protocol used for connecting machine automation to production process control is OPC (Open Platform Communications). The latest version of this technology is OPC Unified Architecture (OPC UA). Timo Oks [17] did a study on suitable technology for agricultural machinery telemetry application. The presented case is a combine harvester with a yield monitoring system. This technology consists both the server side system in the combine and the client for remote monitoring. The results include the measured latencies of the system. The detected end-to-end latency over Internet connection was less than 250 ms, which is sufficient for most telemetry applications in agriculture. Standards are required for Internet-of-Things devices. Mr. Oks consider OPC UA as one potential technology for that purpose as it fulfils the general requirements of safe and secure communication, thanks to the origins in industrial automation. Also explained the use of the technology to access the parameters of the combine harvester remotely. The protocol implementation was done using commercial SDK's of Unified Automation. The server implementation requires remarkably more effort, as it requires designing an information model, for instance. The client is much more straightforward to implement. Accessing data of a combine harvester is easy if all data is directly available in CAN bus. In this case, the combine harvester, yield monitoring system and the positioning device were separate from each other and the first stage was to multiplex this data into a single CAN bus. Based on the latency test, the latency of the subscription is less than 200 ms when both the server and the client are located in the same region. The sample rate of most signals in CAN bus of the combine harvester is either 200 ms or 1000 ms, so this latency is considered sufficient even if the maximum frequency is desired. However, the sample rate of 200 ms over the Internet is rare in any telemetry system, in the commercial telemetry systems designed for agricultural machinery, a typical sample rate is 10 or 15 seconds. In case TCP/IP connection is transferred large distances, like across continents, the network

latency will be remarkably more significant compared with the intrinsic latency.

According to Dimitris S. Paraforos [18], agricultural production management is entering into a new era where every day farmer's decisions are supported by highly sophisticated Farm Management Information Systems (FMISs). Latter have evolved from simple record keeping software into complex systems that can manipulate large amounts of data and provide decision support capabilities. The development of FMIS, which utilizes new technologies, such as those which were introduced by the European initiative Future Internet Public-Private Partnership Program (FI-PPP). The developed application focused on individual farmers or farmer cooperatives, who wish to perform precision agriculture via the usage of mobile devices and modern technology. The main focus is to perform farm financial analysis based on all farm transactions but also estimating profitability based on fixed values that farmer imports. The application proved to be capable of performing a profitability analysis based on the recorded cost transaction but also based on the performed tasks and standard values given by the user.

10. CONCLUSION

In the upcoming years, Farming will play a vital role in our country. Almost 70% of Indian population is having their main income from farming. Many farmers are not aware of modern technologies but still use the traditional methods of farming. This will result in low yielding of crops and fruits. The focus of this paper was mainly to improve the quality in Agricultural fields using advanced modern technologies. Smart farming can be enhanced with the help of IoT. It works in different domains of farming to improve crop monitoring, time efficiency, soil management, water management, control of pesticides and insecticides etc. These technologies can minimize human efforts, simplifies techniques of farming and help to gain smart farming. Along with these features, smart farming helps to grow the market for a farmer with a single touch and minimum efforts.

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