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Automated Systems for Smart Agriculture

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***Abstract*- The abundant availability of food is extremely essential for human existence on this planet, thus making agriculture a mandatory practice throughout the world. Within two decades, a severe complication of food will arise. Hence, the advancement and progress of agriculture is essential. With the help of trending technologies like IoT, the environmental factors that affect the crops are easily monitored, and decisions are taken based on them so that crop monitoring is done remotely, which is a magnificent IoT application. Today, agriculture in the world is partially automated, and farmers mostly rely on traditional methods because of which they suffer from scarcity of rainfall and dearth of water. A plethora of techniques exist that provide automation of agricultural activities and hence increase their efficiency so that better crop output is obtained. The automation of agriculture enables reduction in human involvement. The main purpose of this review paper is to present an overview of various techniques adopted in automated agriculture systems which save the farmers' time, money and power. This paper also extracts key features of existing automated agriculture systems based on their advantages and disadvantages. This paper will assist in the development of a system which will overcome the drawbacks of existing automated agriculture systems.**

Index Terms- Agriculture, Irrigation, Sensors, IoT, ZigBee

I. INTRODUCTION

Agriculture has been one of the most important things for the life of humans for centuries. It is the primary source of plant (food grains) and animal products. Also, it plays an essential role in the economic growth of a nation by providing abundant opportunities to people. World's population is reaching towards 7.7 billion [1], and the population is constantly escalating with time. Advancements in the field of agriculture are crucial for the economic and prosperous growth of a nation. However, even today, traditional methods of farming are adopted by many farmers, which result in a low yield of harvest. With the increase in automation of various agricultural processes, improvement in the yield is observed. This implies that the use and application of modern science and advanced technology in the agricultural field are necessary for improving crop yield.

Only monitoring the environmental factors is not sufficient to improve the yield of the crops. Crop productivity is dependent on environmental factors as well as other factors such as an attack of pests, insects, birds, and wild animals. There is also a risk of theft during the stage of harvesting. Farmers face storage issues even after the crop is harvested. Therefore, developing a system which will handle all these parameters that affect the productivity of a crop in all the stages of cultivation, harvest, and post-harvest storage has become necessary. This paper studies the technologies and methods applied in existing automated agricultural systems. The performance of the system is studied by discussing the advantages and disadvantages. Integration of key features of each system leads to a complete solution for the automation of agricultural activities. Section 2 describes the evolution and usage of different technologies which have huge application in the agricultural automation sector. The further section discusses the different existing automated systems.

II. TECHNOLOGIES USED IN AGRICULTURE

Agriculture has always been a manual task since the beginning. With the development of agriculture through various agricultural revolutions, and with the emergence of digital technologies, the Food and Agriculture Organization has referred to this change as a 'Digital Agriculture Revolution' or the fourth agricultural revolution. Digital Agriculture encompasses various technologies from sensors to Digital Platforms and communications to AI and ML. In recent times, wireless sensors and wireless sensor networks are used in various scientific domains due to the availability of smaller sized devices. These reductions in sizes have been possible because of the advancement in engineering technologies. Intel Corporation, in cooperation with Intel Research Berkeley Labs, has studied the deployment of a sensor network in a vineyard [2][3]. The R&D team of Accenture Technology Labs has carried out similar work in a field test in Pickberry Vineyard [4]. [5] gives an overview of the modern development of wireless sensor technologies and standards for wireless communications as applied to wireless sensors. Hybrid wireless sensor networks are used [6] to reduce intensive human involvement required in current agriculture systems. [7] introduces ZigBee technology architecture and design of ZigBee nodes which collect important environmental parameters such as the temperature, humidity, and illustration in real-time and then convey the data to the monitoring centre.

WSN's based on ZigBee is a promising technology, as shown in a survey [8]. Image processing is one of the technologies that is proving to be useful. [9] presents a survey on different Image Processing techniques that assist the farmers as well as researchers to improve various agricultural processes like monitoring plant growth, weed/crop identification, fruit defect identification and disease identification. To gather information on large areas of farms, the farmers require to visit them frequently. Remote sensing is used to provide an accurate picture of agricultural sectors of large areas, thereby reducing the frequency of visits. [10] summarizes various existing remote sensing applications and its development in terms of regional as well as global applications for agriculture.

The feature of IOT, which is an augmentation of internet connectivity into physical devices and everyday objects, has

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evolved largely into the sector of agriculture. The connected objects interact with each other and are controlled remotely over the internet. [11] presents an IoT based monitoring system that monitors the environmental parameters and provides vital information to the farmer, thereby maximizing the yield of the crop. Aerial images and IoT combined is applied to systems and make them smart and scalable by using aerial mapping sensors and HD cameras [12]. In the field of agriculture, smart automation and IOT is used to perform different activities like weeding, spraying, moisture sensing, etc which is based on a real-time data. Intelligent drones or robots can be created to perform the mentioned activities. [13]. Greenhouse monitoring is made easy by the integration of IoT with Wireless sensor network, ensuring the smooth operation of the greenhouse, making it convenient to monitor large scale Greenhouses [14] remotely.

The Internet of Things is starting to transform our world, but it is generating an enormous amount of data, which in turn puts tremendous stress on the infrastructure. Cloud Computing plays a significant part in connecting the devices. CC and IoT go hand in hand as IoT generates a massive amount of data, and CC provides a path for that data to reach its destination. IoT and CC play a remarkable role in the agricultural sector and are used to comprehend different technologies, build a sustainable smart agriculture system, and promote research in the field of application of IoT in agriculture [15][16]. Cloud computing is used to maintain records related to product performance, quality and security information in the logistics process, and also to find out growth of a plant by using pattern identification technology and maintaining data related to fertilization and disease prevention [17][18].

FarmBeats is an IoT platform for agriculture which is highly available [19]. For providing low-cost and long-range technology, high bandwidth sensors are deployed which use TV White Space (TVWS). To provide a guarantee that all the services are available, a weather aware base station which can be solar powered and an intelligent gateway has been used. With the help of new path planning algorithms, the battery life of a drone can be extended. The system has been utilized in two farms and the farmers are using it for animal monitoring, storage monitoring, and precision agriculture.

III. LITERATURE SURVEY

The main purpose of [20] is to give an overview of remote monitoring and control systems with the technologies used and their probable benefits. An ingenious remote-controlled embedded system for irrigation based on GSM/Bluetooth is discussed in the paper. The system fixes the time of irrigation corresponding to the reading from temperature and humidity sensors and the crop type, and is able to automatically irrigate the field. The far end and the designed system exchange information via SMS. Figure 1 shows the block diagram of the system discussed in paper. The system contains a Bluetooth module which is assembled with the microcontroller chip. When the user is within the defined field of few meters to the designated system, then it uses Bluetooth for communication, so the SMS charges are eliminated. The system notifies the end users about several situations and scenarios like the electricity status, dry running motor status, rise in temperature, the soil moisture and smoke by Bluetooth or via SMS on GSM network. The system becomes more cost-effective by replacing SMS network with a WIFI module which will help to eliminate SMS charges.

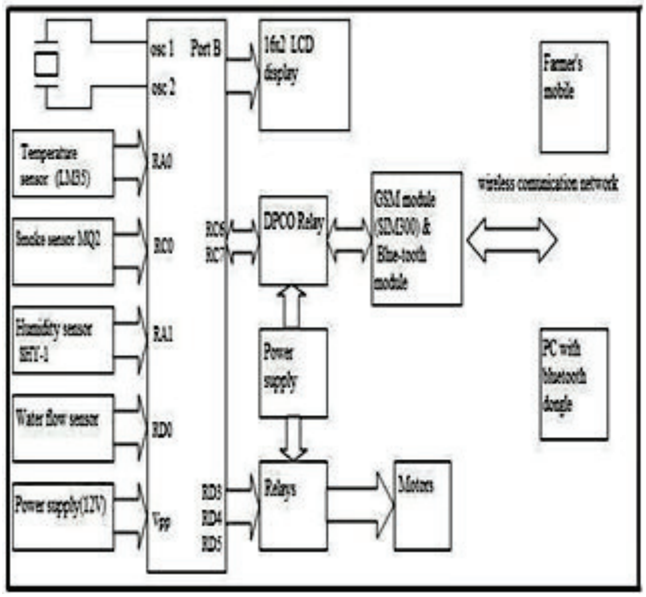

Fig. 1. Block Diagram of System [20]

The microcontroller ATMEGA328P on Arduino Uno platform has been used in the system [21]. The system also includes Internet of Things for making it possible for farmers to remotely observe the scenario of sprinklers installed in the field with the use of values measured by sensors. This makes the work of farmers much comfortable because they are able to focus on some more significant agricultural activities. The system is an amalgamation of various hardware and software elements. The hardware comprises of an embedded system, and the software consists of a webpage that is modelled by using PHP. The webpage comprises of a online-hosted database in which the values measured by sensors are updated using the hardware.

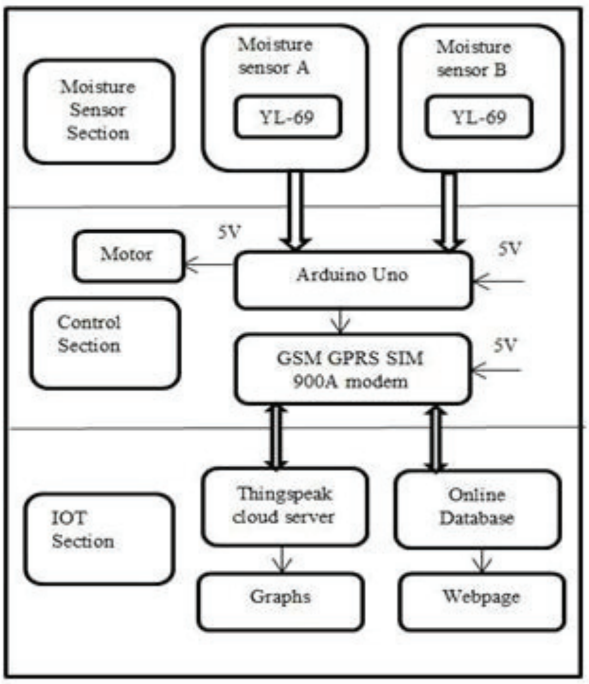

Fig. 2. Overall engineering design of system [21]

Figure 2 illustrates the general engineering design of the system. Control over water sprinkler is accomplished by fixing a threshold value; if measured value goes below the threshold value then irrigation should be initiated. When the moisture content detected by the sensors is below the threshold value, the sprinklers are switched on and the field is irrigated till the soil is completely moist. The threshold values are dependent on the soil type used. Data collected by sensors is also sent to a THINGSPEAK channel to access graphs. ThingSpeak is an open-source data platform which aids you to collect, store, analyse, visualize, and act on data from sensors or actuators, such as Arduino. The system does not deal with water management in drought conditions and is not very useful at places facing water scarcity.

A cost-effective system for agriculture farm monitoring is designed which periodically measures the moisture contents of the soil of plants and alerts the farmer if the moisture goes low, via email or a SMS [22]. The architecture of the system is illustrated in Figure. 3. In the system, node MCU board which is like a client uses the Message Queuing Telemetry Transport (MQTT) protocol to broadcast the values collected by sensors into Losant Message Broker.

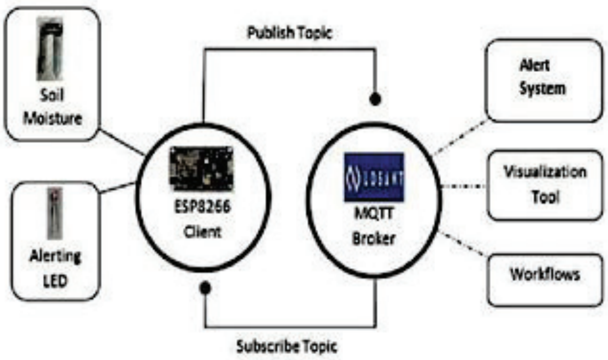

Fig. 3. Block Diagram of Soil Monitoring System [22]

Losant is an easy and very capable cloud platform for IOT and the advancement of the subsequent generation. It provides a real-time visualization of data measured by sensors and it is possible to work upon from any location. The position of the field is immaterial. A definite JSON-based payload should be adhered to in order to figure out the messages of losant. The broadcasted data will accordingly get saved in the losant and make it accessible in the losant platform visualization tool.

The recent situation of reducing water tables, shrinking of rivers and lakes and unstable environmental conditions calls for an urgent need for efficient water utilization. This is handled by installing various sensors (temperature, soil moisture) placed at pre-defined positions for crop monitoring. An algorithm is explained [23] which contains predefined temperature and soil moisture threshold values. This algorithm is programmed on a microcontroller-based gateway and is responsible to manage the amount of water required for irrigation. The system is powered with photovoltaic cells. A duplex communication link is established which enables programming of data interpretation and irrigation scheduling via a web page. The use of photovoltaic panels makes the system highly power-efficient.

A distributed wireless sensor network based remote sensing and irrigation control system is developed [24] that focuses on real-time in-field sensing, adaptive irrigation and managing a precision irrigation system specific to a location to optimize yield with minimum water. The features of the construction of the mentioned system has been mentioned using relevant software [24]. Figure 4 represents the conceptual system layout.

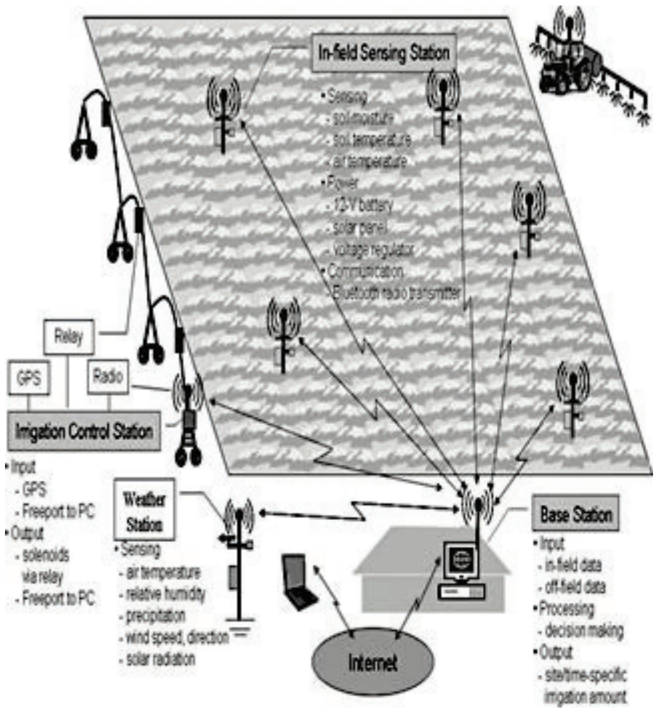

Fig. 4. Conceptual system layout of distributed in-field WSN [24]

The entire system is constructed by deploying five sensor nodes on the field. Global positioning system (GPS) is used by these nodes to transmit the data collected from the field to the base station. The irrigation is managed at the base station with the help of this data and a database that is already connected to the system. The system proposes a reliable, inexpensive wireless application for remote controlling of precision irrigation.

The lifetime of monitoring apparatus like sensors depends on various environmental factors. [25] presents a hierarchical WSN which uses a probabilistic communication protocol. This protocol helps in achieving a very low duty cycle and increases the functioning period of the soil monitoring system. Sensors are installed beneath the soil. These sensors communicate with the relay nodes using an effective communication protocol that provides a low duty cycle. Microcontroller, universal asynchronous receiver and transmitter (UART) interface and sensors are used to develop the system while the data is processed by sampling, buffering and transmitting the data hourly.

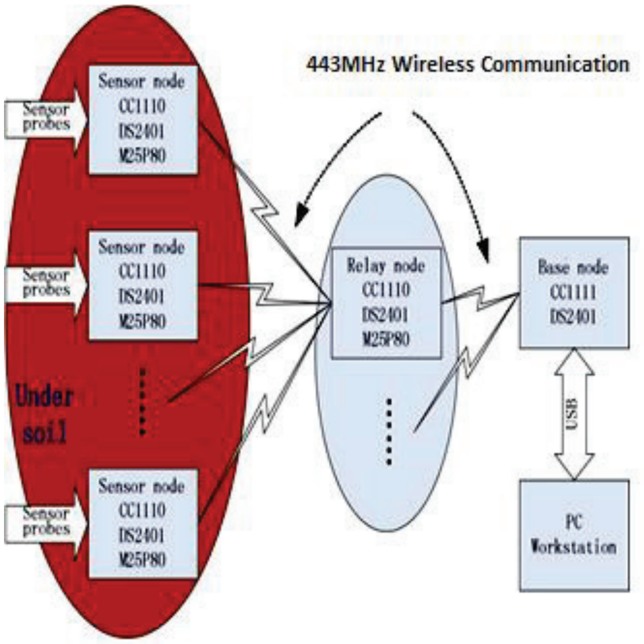

Fig. 5. Structural diagram of the soil measuring WSN [25]

TABLE I. NODE FUNCTIONS [25]

Node Type	Data Collection	Storage	Identification	Radio	USB
Sensor	Ĝ	Ĝ	Ĝ	Ĝ	
Relay		Ĝ	Ĝ	Ĝ	
Base			Ĝ	Ĝ	Ĝ

The system is a layered design consisting of three node blocks as shown in Figure 5: sensor nodes, relay nodes, and a base node. Nodes are categorized into three groups in accordance with their functionality. Table I enlists the functions of each node category. The system turns out to be expensive and stationing of sensors beneath the soil leads to the attenuation of radio frequency (RF) signals.

The system developed is based on Bluetooth for monitoring agricultural parameters like temperature using a microcontroller that works identical to a smart weather station [26]. The system is an inexpensive wireless result which is used for monitoring of agricultural factors in real-time. However, limited communication range and limited connectivity are some disadvantages. It requires configuration of Bluetooth with android mobile for continuous monitoring.

A smart sensing platform based on ZigBee is used for monitoring environmental factors like temperature, relative humidity, pressure, and sunlight by using a microcontroller that works identical to a smart weather station [27]. The survey is done with respect to features like the benefit of economical equipment, precise and accurate sensors, and high data rate. Figure 6 shows the system block diagram.

The Microcontroller is interfaced with various sensors, which are capable of showing analog voltage signals. The obtained signals are collected and converted into the corresponding values. These values are then sent through ZigBee to a base station. The base station saves the obtained data onto an Access Database. The ZigBee module has the capacity to provide a wide range of data rate, low operating voltage, and also reduces the current consumption of the circuit. This system works only on mesh network so that each and every node communicates with each other and also sends data to the main station. The platform works for 24 hours, and real-time data is observed on GUI based application in PC. The system provides a user-convenient interface. However, it can be extended to other networks in the future.

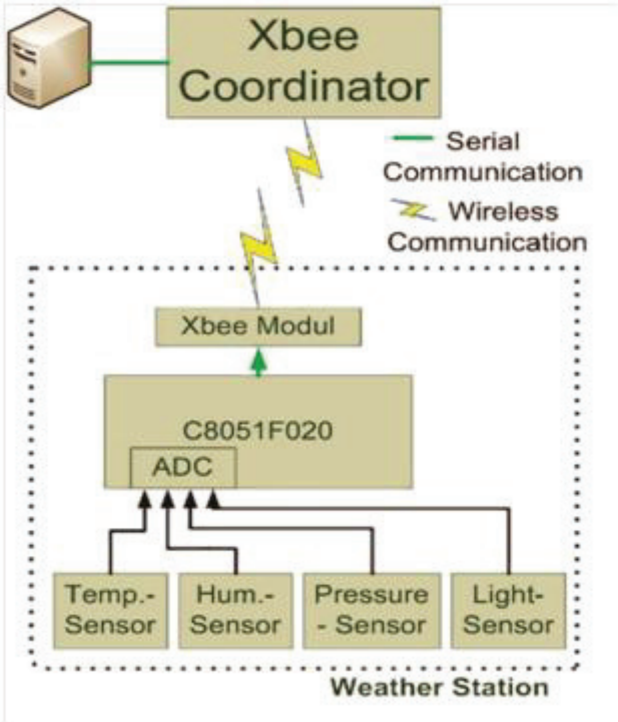

Fig. 6. Block diagram of developed system [27]

A smart wireless sensor network for agriculture based on Wi-Fi is explained by considering measuring parameters such as temperature, humidity, pressure, light intensity, soil moisture, and water level [28]. The goals of the system are to construct a smart wireless sensor network for farming, implementing it to acquire data to PC, which is connected to a network from various sensor nodes. This system provides transmitting and logging data into the cloud. It reduces the setup difficulty. The use of wireless media reduces the expenses and labour of integrating wiring and enhances the resilience and portability of the system.

Agriculture products depend on different environmental factors and climatic conditions such as temperature, relative humidity, soil moisture, pH of the soil, light intensity, etc. [11]. Small fluctuations in the values of any of these factors lead to issues like irregular growth of plants, diseases, etc. which mostly result in decreasing the productivity. The block diagram of the system depicted in Figure. 7 comprises of various kinds of sensing units like temperature sensor, soil moisture sensor, and relative humidity sensor.

These parameters are the most important for agricultural production. For measurement of such parameters, the microcontroller is used, and digital data is transmitted to the cloud through esp8266, which acts as an internet gateway. The esp8266 module for wireless communication uses UART which is a serial protocol. The monitoring systems like Personal Digital Assistant (PDA), Computer, etc. use a webpage for observation of graphical variation of environmental parameters.

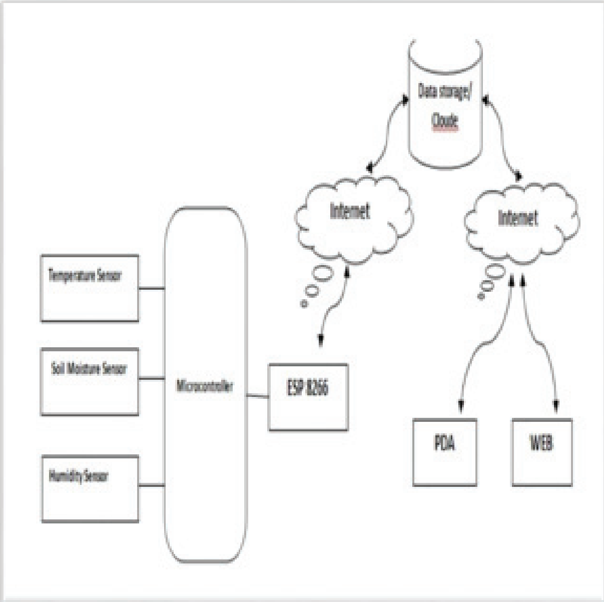

Fig. 7. Basic block diagram of system. [11]

IV. DISCUSSION

The adoption of digital technologies in agriculture is increasing at a rapid pace. The reason for this is that digital technologies bring tremendous value for business and individuals. Several challenges arise when it comes to the process of digitizing agriculture. The systems that are discussed in the Literature Survey use a variety of technologies ranging from WSN's to IoT and Cloud Computing. Each technology has its own set of standards, and these standards are vital for devices to communicate with each other. When the devices are not able to conform to the standards, problems tend to arise. Before IoT came into existence, technologies like WSN's and ZigBee were used that operated on stored or pre-recorded data. Today, the sensors send a massive amount of data, and this data needs to be handled on the spot via real-time systems where IoT, Cloud Computing, and Big data come into the picture. As discussed, some systems used wired technologies, whereas most of the systems today depend on wireless media as the cost of wiring is high for large farms. The equipment deployed at the farm is under a high risk of damage as it is exposed to various environmental factors such as extreme temperatures, high- speed winds, solar radiation, and rain. These factors are capable of damaging the electronic circuits. The equipment deployed at the farm needs to have high reliability and must stay active for long periods. Besides, replacing batteries on a largescale open field is very difficult. Therefore, circuits consuming less power are necessary so that the batteries are replaced less often. Also, considering alternative power sources that cause less pollution will make the system more environment-friendly. When a system is cost-effective, the performance and accuracy are compromised, whereas highly efficient systems are not affordable to the farmers. Many of the smart agriculture systems discussed consider factors such as temperature, humidity, and soil moisture, pH of soil. However, the unpredictability in the climatic conditions in the recent years demands a system to make decisions based on current and probable climatic conditions. Hence an improved system considering all the above factors and adopting all possible improvements will be able to provide for a complete solution for a fully functional automated agriculture system.

V. CONCLUSION

The automated agriculture systems for farming provide benefits to farmers in farming. These systems help the farmer to monitor the crop field remotely and save his time, money, and energy. Today, there are countless systems present which use different techniques for automation and communication. However, these systems are not full-fledged and lack in many aspects. This paper has thrown a review on different features, advantages, and disadvantages of existing systems. There is scope of improvement in existing systems and hopefully this paper will be useful in constructing an improved automated agriculture system free from most of the drawbacks in the existing systems.

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