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An Internet of Things (IoT)-based smart irrigation and crop suggestion platform for enhanced precision agriculture

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Abstract

The country's agriculture sector operating autonomously within the overall economic system. India is the world's number two producer of agricultural goods. Farmers primarily focus on crop rotation, irrigation, and fertilization. Modern technological advancements have rendered farmers completely powerless when it comes to attaining optimal agricultural yields under the present weather conditions. Maximizing agricultural output via the integration of cutting-edge technological solutions must take precedence. Agricultural productivity is enhanced with the usage of the Internet of Things (IoT) as it allows for improved prediction of crop production and other factors that contribute to high yield. Soil temperature, pH, and water level are three of the many factors that influence how crops should be spaced out for maximum harvest. To help farmers who use the Internet of Things (IoT) for precision agriculture increase their crop output, this study proposes a smart irrigation system and an agriculture cultivation recommender. By analyzing water content throughout the several phases of plant development and integrating the IoT applications into agriculture, the module optimizes the water level for future irrigation decision-making, ensuring optimal crop growth and water stability in precision agriculture. Using the suggested method to keep tabs on massive agricultural areas yields good results. This method is useful for anticipating irrigation needs using a variety of sensor metrics, which in turn assists with irrigation planning. Soil moisture, soil temperature, and humidity are the characteristics used for prediction. The experimental findings presented here provide credence to the idea of smart irrigation, which may increase agricultural yields while decreasing water use.

Subject Classification: *68xx.*

Keywords: *Agricultural Internet of Things (IoT), Precision, Smart Irrigation, Decision-making.*

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1. Introduction

"Agriculture," meaning the method of cultivating plants, requires little movement on the part of humans. Products from the agricultural sector include food, raw materials, fibres, and items with a distinct economic impact on the nation.

When it comes to crop rotation, irrigation, and fertilisation rank front and foremost among agricultural concerns. Farmers have been using genetic engineering to improve their crops since the dawn of humanity. Finding crops with desirable traits, such resistance to pests or drought, is an important part of this process. Water shortage is exacerbated by the growing urban population. Land deterioration and improper irrigation are two examples of the environmental difficulties that exacerbate problems in the agricultural sector[1][2].Weather, temperature, and precipitation patterns are all impacted by climate change, which in turn impacts farming. Agriculture is now seen as a productive activity by industry. Making as much money as possible is the primary goal of most businesses in the agricultural sector. Over the last ten years, farmers have begun to use soil features as a tool to better understand the seasonal changes that affect their cultivated fields and to choose crops. Nevertheless, when it came to large-scale farming in particular, the inadequacy of suitable technology rendered this knowledge utilization ineffective in terms of targeting and optimizing agricultural inputs.[3] There will be a greater need for food in the future, since several agricultural studies predict that the global population will grow by 9.8 billion by 2050. Regarding the mentioned matter, experts in the field have pioneered the use of "Precision Agriculture" technology to improve farming practices in response to pressing environmental concerns. The fundamental goal of this study is to develop a novel agricultural decision-making system that may increase productivity while decreasing farmer intervention. Every farmer must carry out the specific tasks outlined in the field manual, including planting, weeding, watering, fertilizing, and harvesting. It takes more time and water to complete this operation, and it requires a lot of physical effort.[4] At each stage of the agricultural cycle, the method entails a number of decisions meant to boost crop yields. By continually measuring soil moisture, humidity, temperature, and pH, as well as other supporting duties, precision agriculture increases crop production while decreasing water resources used for cultivation. A large portion of the industrialized world's precision agriculture is dependent on the internet of things. The need of irrigation management is particularly highlighted in regions with few freshwater resources. The purpose of watering plants is to provide them with-it enough water to meet their water requirements.[5] In order to estimate production by moisture or commercial yield, by evapotranspiration, or by irrigation water (IW), one may use the Water Production Function (WPF). In order to determine the appropriate irrigation doses, it is necessary to first assess the water needs. The quantity of water that may be used by the crop depends on many factors, including the soil's texture, the amount of precipitation, the timing of irrigations, the crop's development stage, and the soil's water content. Irrigating large regions, typically between 3.5 and 65 hectares, is often reserved for center pivot irrigation because to the expenditures involved. The Internet is very important in today's world.[6]

It is common practice in agricultural regions to use the proposed method for Internet of Things (IoT) field monitoring. A wide variety of agricultural parameters may be studied with the use of sensors that are based on wireless sensor network technology. For this example, we use the proposed system to collect soil data, which we then store in the cloud. The term "Internet of Things" (IoT) refers to the integration of computing and electrical engineering with more conventional farming practices. Specialised hardware, software, and IT services allow us to do this. Soil water content, ambient temperature and other relevant data may be retrieved in real-time using this approach.[7] The system uses the data to provide crop market prices, irrigation schedules, soil management recommendations, and harvest timing recommendations to farmers. Conversely, there are several possible areas of specialization within the vast field of agriculture. The system delves into the role of the internet of things (IoT) in watering plants. There are one billion interconnected gadgets that make up the Internet of Things (IoT) that can detect, gather, and transfer data amongst themselves without any help from a person [1]. Various fields, such as logistics, health care monitoring, and building automation,

The implementation of the Internet of Things has far-reaching consequences for many industries, including transportation, smart cities, infrastructure, the grid, the home, retail, agriculture, and farming [2]. Internet of Things (IoT) applications in Smart Agriculture are introduced in this work. After a thorough overview of the IoT's foundational ideas, this chapter delves into an examination of Wireless Sensor Networks (WSNs) and associated protocols, as well as Smart Agriculture that Makes Use of WSNs and the Internet of Things (IoT)[8].

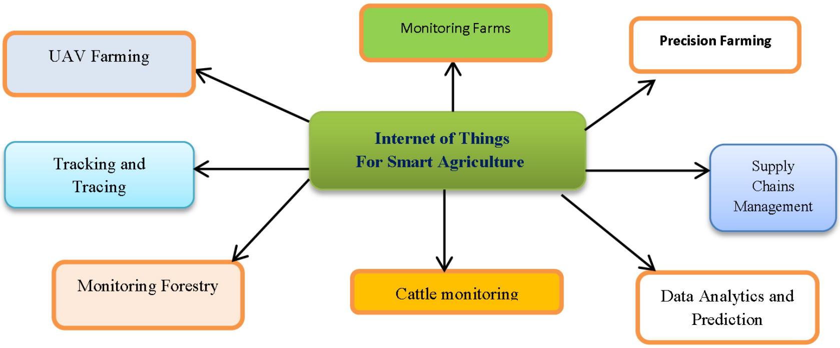

Figure 1

An illustration of IoT applications for smart agriculture

Figure 1 illustrate the IoT applications for smart agriculture. Using IoTs prompts large-scale or enormous information to provide essential data. As a result, several tests have tried to turn this knowledge into valuable data and learning. The system was designed for social events by a WSN to investigate plant-related sensor information to provide atmospheric power, treatment, water system, and bugs [5]. WSN's information was used by the system to find learning through data mining. Given remote sensors and field level identification, this review centered on leaf spot disease monitoring the relationship between yielding climatic conditions [6]. A classifier was able to detect the ailment. Given distributed computing, another beneficial Internet-based observation method for IoTs is proposed. After aggregating enough information from an agrarian IoTs method, it was shown that the use of enormous information analysis in agribusiness was advanced by showing substantial useful prerequisites. Only a few studies have used knowledge mining to extract valuable data and learning so this present work would undermine IoT's information [9].

2. Review of Studies On The Application Of The Internet Of Things (IoT)

Wei Zhao U et al, [1] Autonomous agriculture technologies may solve the personnel shortage that is limiting farmer production. Most autonomous agriculture systems will use automated navigation and mapping. Mesh-SLAM and the Internet of Things are used to create a ground-level navigation and mapping system that can create a 3D farm map on both the cloud and edge sides. Layer one, a ground-based robot vehicle subsystem, employs a monocular camera to capture frames. Layer two, an edge node layer, processes and sends picture features. Layer three, a cloud layer, manages everything and executes deep computing. These three tiers distinguish this system. This method lowers feature data and rebuilds the features map using scalable units and filtering. Cloud computing enables deep computing and extensive customising. Using dynamically allocated computational resources to edges, the system could manage larger fields and more sophisticated settings. First, Mesh-SLAM outperforms in mapping and localization accuracy, precision, and yield prediction error at one centimetre. Second, the Internet of Things (IoT) architecture is scalable and flexible, making it easy to add or delete functional modules or sensors, making the system modularizable.

Syeda Iqra Hassan et al [2] researches to describe the several control strategies used by agricultural automation. Methods such as the IoT, aerial photography, machine learning, AI, thermal imaging, hyper spectral imaging, near-infrared (NIR), and multispectral cameras are all part of these plans. Many agricultural issues, such as plant diseases, pesticide control, weed management, irrigation, and water management, may be efficiently addressed by various control and automated systems. Increases in both crop yields and soil fertility have been documented as results of automated farming systems using sophisticated management strategies

According to Ahmad F. Subahi et al [3] IoT technology in greenhouse farming may reduce the direct impact of extreme weather. This paper presents an IoT-based greenhouse temperature control system. Excellent scalability. One purpose of this technology is to monitor the greenhouse and alter the temperature to save energy without reducing productivity. Using a Petri Nets (PN) model, we can track greenhouse conditions and estimate the appropriate reference temperature. This data is sent to a temperature-regulating block. This data will be examined to estimate crop growth, energy use, and production. Model transformations and model-driven architecture are used to organise various sorts of unstructured raw data in a consistent and technology-agnostic manner. Many IoT gadgets will supply this data.

Muhammad Ayaz et al [4] Current agriculture is more data-driven, rigorous, and smart than previous generations, contrary to popular opinion. The Internet of Things (IoT) changed “smart agriculture” from qualitative to quantitative methodologies, among other disciplines. These revolutionary advances, which are upending agricultural systems, present new opportunities and many challenges. This article discusses agricultural potential and difficulties from wireless sensors and the IoT. IoT devices and communication protocols for farming wireless sensors are examined in detail.The study also examines UAVs' potential for crop monitoring and agricultural productivity optimisation. We exhibit cutting-edge agricultural IoT architectures and systems when relevant. In conclusion, this comprehensive study identifies research bottlenecks and existing and future agricultural IoT trends.

Hong Li et.al. [5] Understanding IOT perception layer sensors required investigation. The IoT needs to identify and categorise physical objects. Smart manufacturing, agriculture, transportation, and environmental preservation employ sensor data. Merging MS and PAN images in multi-sensor image fusion for object identification, classification, and detection is tested. Traditional injection model-based spectral weight calculation aggregates MS images. Because objects have differing spectral sensitivity, MS photos disregard local information and misrepresent spectra. We recommend IFIOT-based multi-sensor image fusion to retain MS image spectrum data. This approach detects small homogeneous zones using super pixel segmentation. The studies demonstrate that IFIOT protects spectrum information while achieving excellent fusion outcomes.

3. IoT-based Smart Irrigation and Fertilization Framework

Conceptual framework is the most crucial aspect of building an architecture for any research study, as it acts as a foundation for the development of the research's various components. Developing a framework helps the researcher in arriving at a specific position for or against a phenomenon. Various phases within a conceptual framework integrate towards lucrative functioning of the framework. In context of the proposed study, two aspects, i.e., water and fertilizers are of paramount importance[13].The presence of water is a basic necessity for the functioning of all forms of life that exist on earth. Excessive distribution of water is pernicious for crops and for the environment. When the crop is not properly irrigated, the tips and edges of the leaf get dry and change their color from green to brown. Gradually, with the passage of time, the leaves of the plant die. On the other hand, when water is distributed in excess within the fields, it often results in water-logging. Due to this phenomenon, the process of germination gets initiated, i.e., roots either don't grow properly or the standing crops get destroyed. In addition to it, the amount of salt on the surface soil also enhances [11]. Similarly, fertilizer also holds an important aspect within agricultural domain. Mineral fertilizers are mainly used as supplements which are quickly absorbed by soil for crop's proper growth. Excessive usage of fertilizers is harmful to

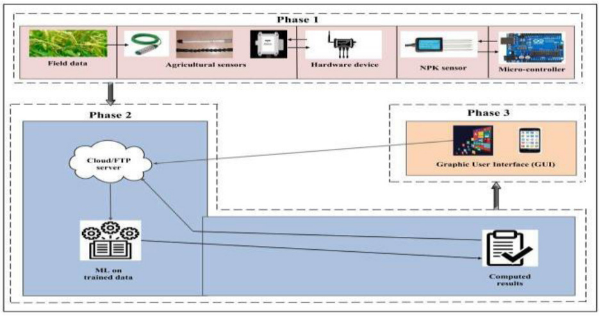

Figure 2

Proposed framework for Minimal Distribution of Water & Fertilization based System

both crops and the environment alike excessive water distribution. It often results in chemical burns to crops, enhances air pollution, and acidification of soil's surface resulting in mineral depletion of the soil. Hence, it becomes necessary to first evaluate the precise requirement for both the aspects before their distribution within the fields.

4. Overview of IoT-based Smart irrigation and fertilization framework for the proposed system

The most effective method is to use a structured framework approach, which not only explains how the framework is designed to function as a whole but also lets both the developer and the user enhance specific modules within it . A system called the Minimization Distribution of Water and Fertilisation based Technology has been suggested as a means to achieve the goal of optimising the distribution of fertiliser and water usage in the fields. Figure 2 shows a visual depiction of the suggested framework. There are three distinct parts to the proposed framework. There is an unique purpose and major impact at each stage. Each stage's internal functioning has been described in full below.Level One: Sensor Network and Data Acquisition

Step 1 of the proposed framework focuses on agricultural sensor deployment in the fields to gather readings on multiple variables such as Soil moisture (Sm), Soil temperature (St), Atmospheric pressure (Ap), Humidity (H), and Luminosity (L) and Volumetric-water-Content (VWC). In order to record the aforementioned characteristics, agricultural sensors were attached to two separate hardware devices: the Libelium's Waspmote Plug and Sense device and the Arduino Uno . Additionally, in order for the hardware device to be able to record measurements on multiple parameters, two separate codes were uploaded to both devices. This allowed the related device or devices to periodically create signals in order to record data on distinct parameters.

Step 2: The Computing and Storage Layer The second and most noticeable stage of the suggested structure is this. Data collected in the previous step is used as input here. The second phase begins with storing the data collected by Libelium's Waspmote Plug and Sense device on a cloud server. Data pre-processing is the second stage after storage. It was necessary to pre-process the data by identifying missing and duplicated values before it could be sent on to the integrated ML approach [18]. Before doing any calculations, the ML method divides the data into two sets: one for training and one for testing. The computed results were sent back to the server in the cloud for archival and reference purposes. Furthermore, these findings are also communicated to the third stage of the suggested design.

Srep 3: User Interface via Menus The suggested structure has reached its third and final stage. This layer's primary function is to display the final calculated results to the end-user using a graphical user interface. The interface also includes a feature that allows you to check live farm statistics as data is being captured. This graphical user interface worked with both mobile and online browsers. The findings may be seen on both mobile devices and laptops. It allowed the user to take practical and timely action in the context of farming techniques based on the calculation results. On top of that, you could access the collected data using the GUI interface.

5. IoT-based automatic water relay mechanism for irrigation

Several studies suggest that agriculture needs water. Over- and under-irrigation damage crops and soil. Recent thorough research has reached similar results. Only remotely-controlled actuators allow smart irrigation. Overall, it saves water waste and costs. To enhance field water distribution, we created and deployed an IoT-based automated water-valve control system. Low-power wide-area networking radios power wireless sensors and actuators. Farmers may remotely control field watering using the proposed device. All three test beds assessed the hypothesised mechanism. The test bed included a sensor node, gateway, server app, and mobile interface. Figure 3 depicts the IoT irrigation water relay concept.

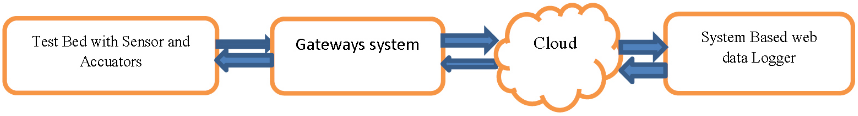

Figure 3

Conceptual working of IoT-based automatic water relay mechanism for irrigation

The traditional agricultural industry and associated businesses are ill-equipped to meet the demands of modern farming in terms of efficiency, quality, and production. To forecast the best possible yields and harvests in a given area, it is necessary to update methodologies. The use of data and IT over a certain time frame may accomplish this. The latest developments in precision agriculture are being studied in relation to affordable, dependable satellites (pictures, location), mobile appliances, and high-speed Internet. The internet of things has several applications in the agricultural sector, one of which is precision agriculture.In this method, many crop metrics are monitored using electronic devices that are connected wirelessly. Soil moisture, air humidity, and ambient temperature are all supplied. To turn the water pump on and off when needed or wanted, the model must also follow user instructions.

Sensors for diesel engines: The widespread usage of tractors equipped with generators in farming results in a high demand for petrol. There is a lot of diesel fuel theft. An instantaneous readout of the diesel his team has used and the remaining amount should be shown to the farmer once a vehicle’s fuel tank is empty.Weather prediction sensors can be useful for farmers while they are planting seeds, watering crops, or harvesting crops. It would be great if weather sensors could automatically notify farmers in their native language.

6. Smart Diary Management Using IoT

Farms that raise cattle also make use of Internet of Things (IoT) technologies. Internet of Things (IoT) sensors attached to cows and read by farmers’ cellphones or tablets make it easy to locate cows and identify serious problems with animal welfare, such as rumination and lameness. Internet of Things (IoT) cows will be the new standard as more and more farmers equip their livestock with IoT devices, transforming them into what is colloquially known as linked cows, intelligent cows, or the Internet of Things. By enhancing the production of water, electricity, nutrition, and other resources while also conserving animal welfare, the Internet of Things concept may be useful in cow farming and ranching. In addition, it allows farmers to keep tabs on each animal's life cycle, sort cows into different groups, generate reports, and arrange data . A farmer would spend twenty to thirty minutes, four or five times a day, in the stables checking on the cows to see if any of them are in heat, a sign of estrus. Because of the Internet of Things, these issues are no longer as pressing. Cows that have Internet of Things (IoT) sensor tags attached to their ears, necks, or legs may have their daily activity and general health monitored in real-time, every hour. Hence, the detection rate of the IoT solution might be as high as 95%, compared to 55 to 70% for traditional approaches. A variety of data will be collected at the smart cow farm by means of animal sensors as well as other adjacent sensors. Animal status monitoring, automatic equipment control, and user choice suggestions are all made possible by data.

Conclusion

The agriculture industry has found it easier to apply current technological solutions to long-standing challenges with the help of the Internet of Things. We were able to close the gap between output quantity and quality as a result of this. Evaluation of data A plethora of tools allows for rapid intervention with little plant harm. These devices are recorded for later use or for use in real-time measurement. Supermarkets see the effects of increased production speeds during the busiest season of the year as a result of a simplified approach and better execution of business processes. Farmers and ranchers may be able to collect expressive data using Internet of Things applications in agriculture. The Internet of Things (IoT) has the potential to help both big and small landowners by making their industrial operations more attractive and sustainable with the use of smart knowledge. This article delves into the many possible applications of the Internet of Things (IoT) in agriculture and how farmers might use it to expand their businesses. The article explores the possible job opportunities presented by the IoT.

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