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A Decentralised Smart Fertigation and Irrigation System

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Abstract

The extreme climate conditions of recent times and the ever-increasing population pose a great risk to food production. To curb these unfavourable conditions, it is necessary to look for ways to improve the processes involved in food production. Efficient data collection and farm automation are those ways to achieve this. The system proposed here incorporates smart sensors and blockchain into farm fertigation and irrigation processes. Smart sensors sense changes in quantities such as soil moisture and leaf transmittance process these changes via an embedded microprocessor unit and trigger the system based on pre-defined parameters. The blockchain serves as a decentralised database to store sensor data immutably and help the farmer monitor farm resource inputs and make informed decisions that improve farm yield. The outcome of this project will be permission-less farm data that can be accessed by any farmer at any time without needing any authorization.

Keywords: Microprocessor, smart sensors, fertigation, server, blockchain.

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Introduction

Data collection is crucial to almost any marketing strategy to improve productivity and sustainability. “Without data, one is said to be marketing blindly, merely hoping to reach target consumers”(Rickman, 2021). With growing technology, fierce competition among businesses, increasing population, unfavourable climate conditions and farmland depletion, the importance of increasing food production cannot be overemphasized. Hence, the need for efficient collection, storage and use of data.

Farm collect data (such as water cycles, fertilizer requirements, soil moisture, rainfall pattern, equipment usage etc.,) and the result of this action from different commercial farms in the U.S shows that the data gotten influences farmers' decisions making which often yields positive results because of data-informed decisions (Thompson *et al.*, 2021). Data collected from these smart farms are normally stored in a centralised system. The problem with this centralised storage is that any failure of this storage will result in the total loss of the data and also the data can be manipulated by the central admin for some dubious reasons.

Data in centralised systems have a central authority. This authority may tend to have their interest in mind while handling collected data. This gives them the power to manipulate the data in order to make decisions that favours their agendas.

The use of smart systems for collecting data and a decentralised system for storing the collected data in the farm process will facilitate timely and correct data collection along with data transparency and immutability.

The proposed system aims to automate the fertigation and irrigation process in farmland while keeping data records captured by the automation system on a decentralised database to help farmers make informed decisions and more accurate forecasts and assists the research process.

The contributions of this work are as follows:

- Identify previous related works and their drawbacks.
- Describe the Proposed system:
    - Describe the Smart Sensor component.
    - Describe the decentralised database.
- Highlight the benefits of the proposed system.

Traditional agriculture has undergone many drastically positive changes, and one of them is the introduction of high-cut technologies such as Global Positioning System (GPS), Internet of Things (IoT), Cloud Computing, Big Data, Global, and Artificial Intelligence etc., into agriculture and this is termed smart farming (Corinne, 2022). Information like humidity, air and soil temperature, light, and soil moisture, is data that can be gotten from Agricultural sites using special sensors (Anjum& Reddy, 2013). This information/data can be studied using an AI algorithm when aggregated and stored in a central cloud-based system.

Smart farming, a software-managed and sensor-monitored farming has been a management concept focused that will provide the agricultural industry with the infrastructure to leverage advanced technology that is; big data, the cloud and IoT- for tracking. Monitoring and analysing operation. All these are ways to minimize human efforts and maximize the usage of available scarce resources. With the availability of data gotten through pests and disease monitoring and other risk factors, analytics can be performed on these data so that the right materials for production can be put in place; and also different equipment used for implementation can be assembled as needed to work on dimming, ventilation and temperature control including other actions needed to get smart control for the budding agricultural space. Lin, Shen, Zhang, & Chai (2018) stated that in a wider meaning, smart agriculture includes but is not limited to e-commerce in agriculture, agricultural information services, food traceability (supply chain) and anti-counterfeiting.

Different techniques, technologies and applications for smart agriculture and food safety are discussed as follows:

Nayyar & Puri (2016), proposed an "IoT Based Smart Sensor Agriculture Stick for Live Temperature and Moisture Monitoring System." The system proposed here made use of Arduino, Wi-Fi Communication Module, Cloud Computing and Solar Technologies. The system was powered via solar technology. The charge for the solar battery powered the temperature sensor, the soil moisture sensor and the Arduino mega. The sensor readings were inputted into the Arduino mega for processing and the data was communicated to the users' device via the Wi-Fi communication module. The system proposed here only measured and monitored data relating to soil moisture and temperature. No external system was triggered from the obtained data.

Patil, Tama, Park, & Rhee (2017) proposed a template for "Blockchain-Based Secure Smart Green House Farming." This system model is made up of four groups: Smart Green House (SGH), an Overlay Network, Cloud Storage, and an End User. The SGH is equipped with many IoT sensors (humidity, light, water level, and CO_2 sensors), actuators (fan, heater, sprinkler and LED lights) and a private blockchain that is centrally controlled by the owner. The Overlay networks are nodes that exist in the SGH to provide a means consensus can be reached among the nodes in order to determine the validity of blocks that are to be added to the blockchain. Cloud Storage provides the storage database needed by a professional when the SGH require technical guidance. The End User refers to the owner, so, the user can remotely control and manage the SGH via smart devices.

Lin, *et al*., (2017) also proposed a "Blockchain-based ICT e-agriculture model for use at the local and regional scale." The data is first backed up locally and then appended to the blockchain when the blockchain provider node creates the block. The system distributes the water quality data across the blockchain so that no single node can have access to the data in its entirety. A query system is implemented to allow the provider node to cross-reference the blockchain data with the backed-up data. Each node possesses a water quality API to facilitate the system operation. This ICT e-agriculture system equipped with a blockchain infrastructure ensures the immutability of data and a way to spatially and temporally trace recent and past agricultural data as agricultural products go from their production sources to the user.

Cambra, Sendra, Lloret, & Garcia (2017) proposed a low-cost irrigation system using a smart IoT communication system. The irrigation system makes use of real-time data and parameters gotten from the field to make informed decisions. The index vegetation, gotten using aerial images, the field parameters and irrigation events, like flow level, pressure level or wind speed, are periodically sampled and data are processed in a smart cloud service.

An irrigation system that describes every possible sensor, actuator and microcontrollers using a fuzzy logic computational algorithm for IoT smart irrigation system was proposed by Kokkonis, Kontogiannis, & Tomtsis, (2017). This irrigation system uses sensors interspersed all over the farm to monitor air temperature, humidity, and soil moisture. The measured data from these sensors are fed into the microcontroller that applies a fuzzy computational algorithm and decides whether to open a servo valve or not. Likewise, all of the data collected are transmitted to the cloud for statistical information and processing.

Zhao, Lin, & Miao, 2017, designed a smart irrigation system which can be remotely controlled via a mobile app. The communication module used in this system is LoRa which receives data from the field, processes it and activates a solenoid valve if need requires. The irrigation node sends data to the cloud through LoRa gateways wirelessly. Their experiment resulted in a reliable transmission distance and energy consumption.

"Smart Irrigation Analysis" is an irrigation system designed by Kinjal, Patel, & Bhatt, (2018). It provides remote monitoring and analysis of irrigation in a field. The system receives real-time data from sensing and analysing of moisture content of the soil in the field. The system uses ESP8266 Microcontroller with a built-in Wi-Fi module for the analysis and afterwards, sends these data to the cloud. Data from the cloud is analyzed and irrigation related graph report for future use for the farmer is made to make the decision about which crop is to be sown.

A system primarily focusing on the food supply chain to tackle food safety issues by replacing manual recordings and verification of food supply data was proposed by Lin, Shen, Zhang, & Chai (2018) in their paper titled "Blockchain and IoT based Food Traceability for Smart Agriculture." The architecture of the system is made up of a new IoT system and the traditional Enterprise Resource Planning (ERP) legacy system. A smartphone serves as a node in this blockchain system for the various users (Farm companies, farming processing plants, plantation companies, planting processing plants, logistics companies and food retail storefronts as well as the customers) to access the information stored in the chain. The main part of the entire architecture which can aid to establish a trusted, self-organized, open and ecological smart agriculture application system is a virtual Trusted Trade Blockchain Network Cloud Platform (TTBNCP).

Methodology

The proposed system comprises four essential modules: the Smart Sensor, the Server, the End User device, and the Irrigation/Fertigation system. The smart sensor triggers an electric relay (based on pre-defined parameters) which in turn activates the irrigation or/and fertigation system. The data readings of the smart sensor are also captured on the decentralised database (the blockchain) so as to enable the farm owner to analyse, manage, and calibrate the entire system to accurately accommodate future changes that may arise due to environmental change and optimise farm inputs with respect to farm outputs.

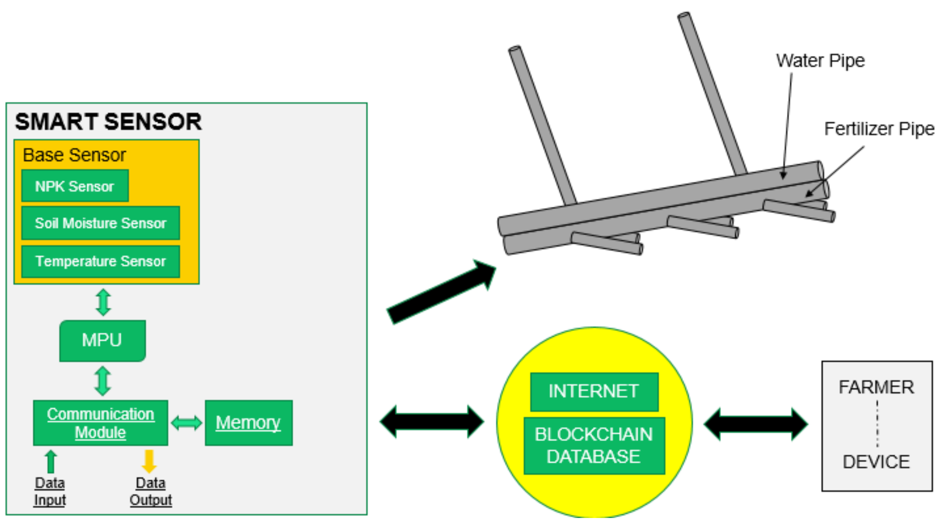

Figure 1: Proposed System Architecture

The Smart Sensor

A smart sensor takes input from the physical surroundings and performs a predefined function on the said input upon the detection to give out an output which passed onto a processing unit. More automated and accurate data are collected from the environment with a smart sensor, and this often comes with less noise.

At the simplest level, a smart sensor is made up of a sensor, a microprocessor, and communication technology of some kind. Apart from the main sensor, a smart sensor might also incorporate some other components. These components can include amplifiers, excitation control, analog filter transducers, and compensation. Tasks such as data conversion, digital signal processing and communication to external devices can be performed by a smart sensor with incorporated software-defined functions.

A smart sensor incorporates a raw base sensor- the component that provides the detecting capability, into a processing device like a microprocessor that enables the sensor's input to be processed. The base sensor is designed to sense either one of the physical quantities that can be gotten from the field like heat, light, pressure etc.

Figure 2: A Smart Farm Sensor

The base sensor senses an output from the analog signal that must be processed before it can be made use of. This is where the intelligent sensor integrates technology that comes into play. The onboard microprocessor filters out signal noise and converts the sensor's signal into a usable, digital format. The Wi-Fi Communication module interacts with the memory module (that contains processed sensor data) and immediately transmits the data over the internet to the blockchain.

The Blockchain A blockchain is a peer-to-peer immutable and decentralised system where peers (nodes) on the network are jointly responsible for verifying, authorizing, validating, and recording transactions – validate transactions on the blockchain. A blockchain consists of blocks chained together logically. Each block is represented by hash values influenced by the block that precedes it. Changing a single data in the current block will affect the hash value of the preceding blocks. *Figure 3* shows a sample blockchain block containing the block hash, timestamp, nonce, and other metadata values.

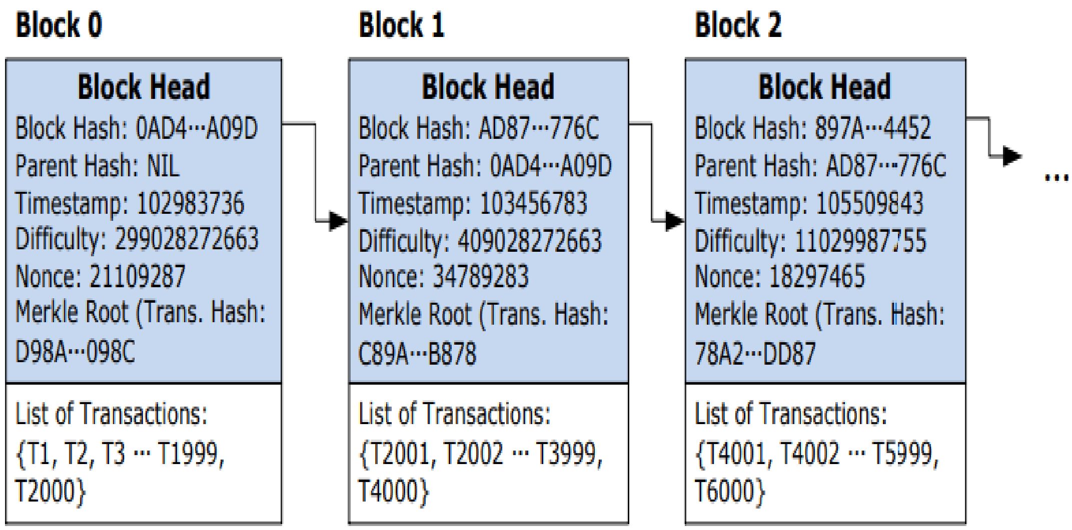

Figure 2: Blockchain

The Irrigation/Fertigation System

This system proposes a separated piping system to carry the water for irrigation and the liquid fertilizer for fertigation. A separated irrigation and fertigation system ensures water pH levels and quality used for fertigation can be monitored to prevent chemical reactions that cause chemical precipitations and clog irrigation system drippers. Poor water quality accounts for the primary reason for clogging in an irrigation and fertigation system. Water quality is dependent on physical, chemical and biological qualities. Physical qualities describe the amount of suspended solids in the water, which can plug the irrigation lines and emitters if high. The biological quality describes the bacterial growth. High bacterial population can cause clogging problems. The chemical quality describes the pH level and the concentrations of cathode ions and/or anode ions in the water. In the presence of pH greater than 5.3 (Obreza, Hanlon, & Zekri, 2011)and oxygen within the water, the ferrous iron species was exposed to oxidation in containing iron. This redox reaction did not only reduce the bioavailability of iron applied through fertigation but also causes obstructing issues. Generally, when the water's pH is greater than 5.3, the containing iron species can be oxidized. Studies shows that roughly 50% of the ferrous iron species can be oxidized to ferric iron at pH 6.3 in 20 minutes(Morgan & Lahov, 2007). The higher the pH, the more serious the obstructed problem will be if the irrigation water has a total iron concentration greater than 0.2 ppm (Table 1). Irrigation with "hard" water, which is high in minerals such as calcium and magnesium, which can also result to obstructed issues due to the fact that calcium and magnesium ions are prone to precipitation with carbonates and phosphates.(Liu & McAvoy, 2018).

Table 1: The relationships between water characteristics and the hazard level for obstruction during fertigation.

	Hazard level		
Problem	**Low**	**Moderate**	**Severe**
Physical			
Suspended solids (ppm)	< 50	50–100	> 100
Chemical			
pH	< 7.0	7.0–8.0	> 8.0
Salt (ppm)	< 500	500–2000	> 2000
Biocarbonate (ppm)	< 100	100	> 100
Manganese* (ppm)	< 0.1	0.1–1.5	> 1.5
Total iron* (ppm)	< 0.2	0.2–1.5	> 1.5
Hydrogen sulfide (ppm)	< 0.2	0.2–2.0	> 2.0
Biological			
Bacterial population per gallon	< 2642	2642–13210	> 13210

Note: When testing for iron and manganese, the water sample needs to be acidified to a pH of 3.5 immediately after sampling.
Source: Bucks and Nakayama (1980); Burt, O'Connor, and Ruehr (1995)

The End User Device

The end user device represents the farm owner's wireless communication device (not limited to mobile phones and laptops) with access to view stored information pertaining to the data processed by the smart sensors on the blockchain.

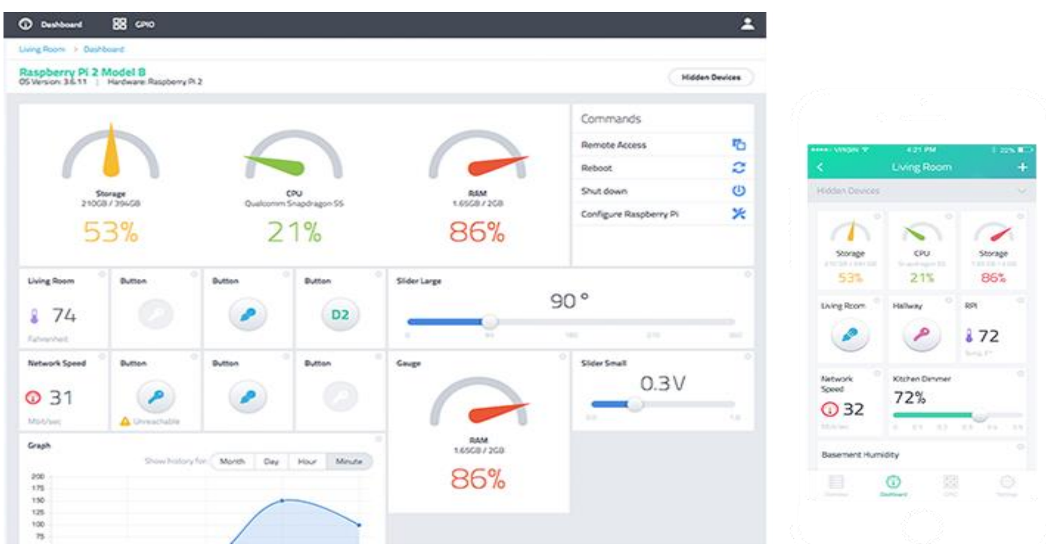

Figure 3: End user device showing smart system UI

Discussion of Results

The proposed system incorporates a smart sensor whose base sensor comprises an NPK sensor, a soil moisture sensor, and a temperature sensor. The NPK Sensor is calibrated with a resolution of 1mg/kg (mg/l). The fertigation system is triggered when the NPK nutrient ratio falls below a standard ratio of 4:1:1. To account for the difference in soil type, the ratio can be calibrated as desired. If the NPK sensor reading falls below the predefined threshold, the fertigation system is activated until the predefined value is attained. The temperature and soil moisture sensor work together to trigger the irrigation system.

Generally, optimum soil moisture ranges between 10% and 18%. For this design, a threshold of 15% is used, so the irrigation system is triggered when the soil moisture falls below the threshold, and the soil temperature is above 24°C (which is the ideal temperature for cultivating crops).

The farmer accesses the blockchain data through a smart mobile device over a dedicated web application with built-in functions to fetch the processed sensor data for a selected period and also trigger the smart sensor to activate or deactivate the fertigation or irrigation system based on circumstantial farm situations.

Conclusion and Recommendation

The proposed smart and decentralized fertigation and irrigation system can greatly improve trust between farm stakeholders (consumers, producers, and every participant along the supply chain). This system enables a fully customizable system and provides data that can be trusted and accessed readily by the farmer to make informed decisions to improve farm outputs. The system blockchain architecture makes it resistant to frauds and malpractices and facilitates real-time report issuing through the use of smart contracts. Lastly, the separated piping system greatly reduces the risk of clogging the irrigation system emitters and pipes, thus, preventing extra maintenance costs and time.

The system can be further expanded by large-scale farmers to incorporate more base sensors that measure data unrelated to farm soil and implant trigger systems for farm equipment other than an irrigation system.

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