

# AGRITECH: A Smart System for Sustainable Farming

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## Abstract

Conventional agriculture, which requires human labor and does not use any kind of mechanism, is proved to be very less efficient and cannot meet the growing food requirements of the world. The application of IoT as a means of implementing change toward precision agriculture is presented below. The following paper describes the design of a smart agricultural system using IoT devices, Raspberry Pi, and a set of sensors: soil moisture, humidity, gas, flame, and motion sensors to improve farming. High technologies like drone and image processing are used to check the health of the plant and increase the production during the farming process. The smart system substantially enhances the productivity and utilization of resources by making smart choices. A mobile application can expand the system's capabilities, data protection, low energy consumption and high reliability. This specific use of IoT makes farming more efficient to enable farmers to grow more crops and make more profits as a positive step towards sustainable farming. From the research, the authors have been able to show how IoT can be implemented in agriculture to facilitate better yield, resource utilization, and its sustainable utilization. The implementation of IoT-based smart agriculture systems significantly enhanced farming efficiency, resource utilization, and crop yield. Results indicate improved decision-making, reduced manual labor, and increased productivity through automated monitoring and mobile-based control.

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## 1 Introduction

Agriculture has been a cornerstone of humans and has been a source of livelihood for civilization for thousands of years as it supplies food and raw materials. In light of these developments, the agricultural sector has much to gain from the integration of some complex technologies such as WSNs and IoT. WSNs, which are made up of inexpensive low-power sensors, hold the promise to improve the agricultural practices by monitoring and reporting the environmental parameters like temperature, smoke, light, moisture, humidity and flame. These data help farmers and researchers control and keep track of the environmental factors that affect crop growth and production.

Similarly, temperature and humidity sensors are used to control the environment in the green houses to be conducive to crop production. Smoke sensors on the other hand can also sense the smoke of fires and measures can then be taken to avoid destruction of crops. These water sensors are useful in water irrigation regimes that save money and water in the process. These inventions are far reaching to mark the dawn of the era of precision agriculture whereby decision making can enhance both production and conservation.

To provide additional accuracy and efficiency, an Agricultural Physical Sensory Layer (APSL) is also incorporated into the WSNs which enables a full range of data to be collected regarding the environmental factors [1]. By using these sensors, farmers and researchers are afforded the precise control over the environmental conditions in their fields thus enhancing crop growth and yield. WSNs offer precise information on the environment by gathering data from several field points and sending it to a central point for processing [2].

Thus, WSNs can evaluate the state of crops and their quality with the help of digital imaging and signal processing. The IoT technologies can make improvements to the farming tasks through diagnosing the crop requirements at each developmental stage. On the other hand, 5G mobile communication provides the data access any time and anywhere. As of December 2022, about 29 billion IoT-based components were already in use in the agricultural industry; the projection for 2050 was 4.1 million daily inputs [3].

In addition, agricultural ontologies consist of the formal descriptions of the crop production knowledge that is in the form of concepts, properties, and relations. The following are some of the benefits that are provided by these ontologies; Integrated data, uniform representation, better analysis, decision making, and sharing of information. Through providing the common language for the stakeholders to use when exchanging the data, the application of ontologies enhances cooperation and increases the efficiency, sustainability, and profitability in agriculture. Developing ontologies for agriculture requires defining concepts, properties and relations belonging to this domain, sometimes by using both literature and expert's data. Once created, these ontologies can be updated with new knowledge from sensor data, historical data and experts' opinions by using the techniques such as ontology alignment and mapping [4]. The ontology architecture for agriculture comprises three layers: and the domain layer, which contains information about precision agriculture, the application layer where user interfaces are built, and the last one is the infrastructure layer, which provides tools and services for ontology management [5]. An ontology structure maintenance mechanism that is easy to use improves the method and, in turn, the quality and accuracy of ontologies employed in knowledge management, information retrieval, and decision support systems [6]. A brief assessment of the recent ontology agricultural literature shows that most of the studies do not have well-articulated evaluation procedure. Goldstein et al. (2021) have proposed a set of guidelines to review agricultural ontologies with the focus on design, content, usage as well as assessment. This framework is useful to define the areas of reformulation and is beneficial for the creation of high-quality ontologies for agriculture [7].

There are multiple contexts to the multi-context system and each of the contexts has different rules and assumptions. This can be various crop conditions, treatments, and data obtained from the sensors in the field of agriculture. Thus, contextual defeasible logic provides a possibility to reason in the conditions of incomplete and

uncertain knowledge.

The multi-agent environment develops the modeling of agents and the interactions within the multi-context system, which includes farmers, insurers, and landlords. The activities of agents can be described through communication protocols and negotiation procedures to solve the conflicts and inconsistencies [8].

This article presents the new concept of Context-Aware Agriculture as an integration of all aspects of smart agriculture into layers. It explains how the physical sensor layer can incorporate WSNs, describes an ontological modeling and transformation for WSNs' communication and standardization, and shows how MASs can cooperate over diverse knowledge sources in a context-aware manner.

The article is structured as follows: section 2 reviews the related work, providing existing and advancements in IoT agriculture. Section 3 introduces proposed architecture whereas section 4 implements the Intelligent reasoning based smart agriculture. Section 5 introduces the application of AGRITECH leading to section 6 of architecture design and section 7 of elaborates the framework development mechanism. Section 8 focuses on application development followed by section 9 of discussion and conclusion. Lastly section 10 outlines the future work and potential advancements in the field.

## 2 Literature Review

In the last decade, the use of Wireless Sensor Network (WSN) systems in agriculture has gained considerable attention. Many researchers have focused on enhancing the wireless platform to provide reliable data collection and transmission for agricultural monitoring and control. For instance, a study [9] explored modifying IEEE standard attributes to align the sample frequency of sensor nodes with the requirements of precision farming applications. This study investigated how sensor deployment patterns perform in the ordinary terrains, and precision agriculture is one potential application.

The progress in the recent past has resulted in new and heterogeneous sensors in order to enhance situational awareness on crop status and environmental monitoring. It was identified in [10] that the low cost AGRITECH sensors can be used in WSN based systems to measure air quality, soil moisture and humidity, temperature. The paper has also provided a smartphone-based system of capturing, analysing and estimating disease contents by use of optical methods. Such developments show why the ability of the WSN systems, advanced data processing, and the control of the agricultural systems have been well researched.

WSN architectures have been extended to heterogeneous sensor technologies to facilitate sensor fusion technologies and to capture simultaneously multiple physical attributes. One of the most pressing problems in current times is to move beyond the sensor data measurements and make sensor functions transformable, as it is mentioned in [11]. Inclusion of decision support techniques into wireless sensor systems, use of linked data, unsupervised pattern recognition, and semantic ontology to elucidate information, knowledge integration of sensory sources are under interest, and the necessity of this is highlighted.

In [12], the authors have suggested a Cross LayerBased Expedient Routing Protocol of WSNs in order to create energy efficient clustering and routing of WSNs with the help of ASFO. This method measures variables such as the ratio of packet delivery, packet delay, throughput, power consumption, network lifetime, packet loss rate and estimate of errors.

The improvement of agricultural operations is highly dependent on the development of WSN designs and systems.

We can make our initial contribution to this work with an architecture that improves the output of agriculture by increasing the bulk transmission, decreasing the power consumption, the security monitoring, and the mobility. The second contribution that we have made is the android application to deploy, analyze, and retrieve results of our architecture.

Context based systems use various sensors and information gathering equipment to be intelligent to respond to user demands through automatic data collection and reaction to changes in the environment. These systems also provide atomicity; they automatically regulate the application functions such as the brightness of a screen and notifying the user of a catastrophic incidence. To conclude, context-aware computing systems gather sensor information, derive features, and calculate context in order to allow applications to respond to it.

In [13], A multi-agent model was proposed in the article, which is named which is context-aware and reasons over heterogeneous sources of knowledge. This model includes agents, contexts and sources of knowledge, and agents can adjust to any alterations in the environment and make choices depending on the changes in contexts. The model uses contextual defeasible logic to solve conflicts and inconsistencies, which has found application in smart environments where context agents have access to personalised services.

A different research suggested a contextual defeasible reasoning system to allow the systematic manipulation of conflicting information in heterogeneous systems [14]. This model comprises the heterogeneous system, contextual defeasible logic and a reasoning engine. The system consists of elements that have specific rules and assumptions, which apply to smart manufacturing using machines, sensors, and controllers. Contextual defeasible logic enables one to reason with uncomplete and uncertain information and resolve conflicts. The reasoning engine utilizes logic to provide explanations and suggestions to set in conflict resolution.

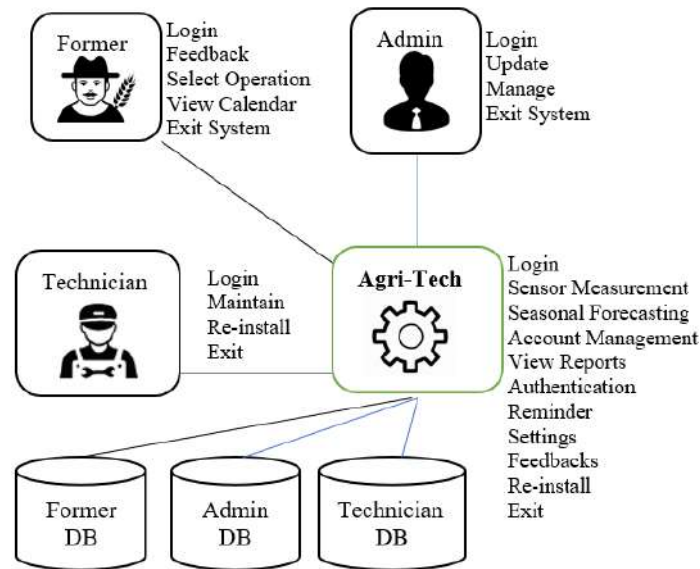
Our mission deal with the issue of traditional ways of farming, which will involve cutting down the labor expenses and getting higher outputs with an all-time supply. GRITECH mission is an environmental parameters WSN based solution, which offers on-site environmental parameters, including humidity, temperature, gas, flame, and motion detection. Agricultural modernization is the solution to enhancing the economic condition, especially when the farmers are struggling with such issues as poor rainfall, lack of water, and unpredictability. Most of the farmers are still using the traditional practices and this leads to low yields. Automation enhances profitability and this is why there is need to inject advanced science and technology in agriculture.

The recent advancements of software design, WSNs, and sensors miniaturization provide new resources [11],[15]. Precision Agriculture (PA) makes use of these technologies, however, not many of them take the design and implementation of any specific agricultural systems. Traditionally, ITs were available and not popularized [16]. The expensive nature and intricacy of system installation and maintenance are still obstacles in agriculture. Such limitations must be overcome with new models and systems that will require more agricultural worker focused design, and integration of the IoT resources. The suggested model is an agricultural process with a subsystem of crop, soil, water, nutrient, weather, and energy management. The concept of PA has a strong relationship with the Information and Communication Technologies (ICTs) since they are major facilitators of PA systems. In recent years, stakeholders in agriculture have increasingly adopted these technologies to simplify tasks. Automation, crop monitoring, and smart DSS design have been widely researched and, in some cases, implemented [17]. More farmers and agricultural businesses are adopting PA systems to improve products and production methods [18].

Such systems require specific electronic devices for deployment in crops and ensure that large amounts of historical data are stored and transformed into actionable insights for decision making. Data management and processing, including remote data exchange, are critical in PA. Most solutions use the server-client model to manage and store data, requiring a hosting service. Dedicated hosting offers flexibility, allowing control over servers but requires specialists for management [19].

### **3 Proposed System Architecture Of AGRITECH System**

This paper presents autonomous reasoning-based AGRITECH solution which acquire contextual knowledge from the real-time environment, execute suitable reasoning processes to attain goals and then the system adapt its be-



**Figure 1.** AGRITECH System Architecture and User Role Interaction

haviour accordingly. Figure 1 illustrates the overall AGRITECH system architecture, including the roles of different users (e.g., technicians, admins, and farmers) and how they interact with the app components. The proposed formalism is developed in three layers, namely: sensory layer, context modelling layer and multi-agent inferencing layer.

### 3.1 AGRITECH Physical Sensory Layer

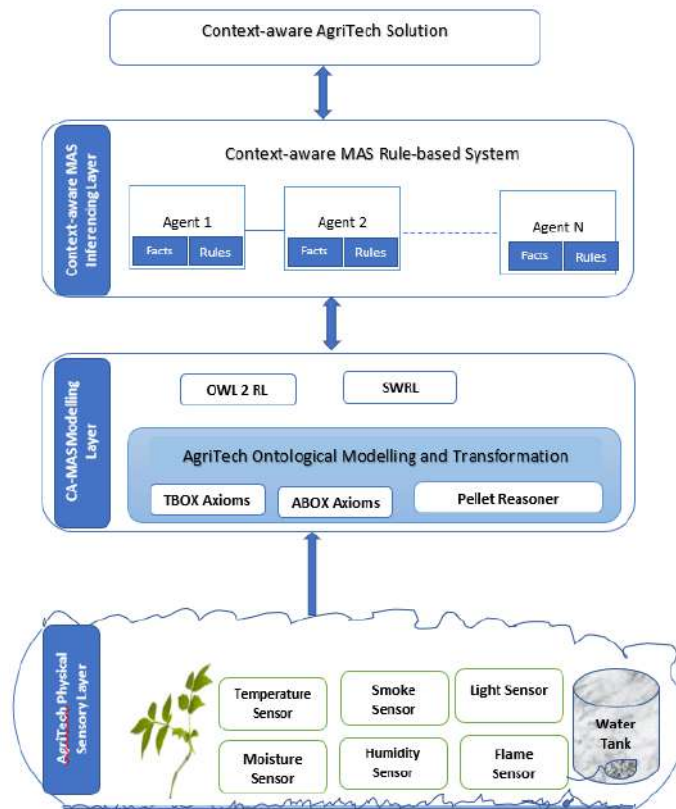
In the evolving IoT paradigm, the sensor layer is fundamental for harvesting real-world data from the physical environment. Serving as a vital conduit between the digital realm and the physical world, this layer facilitates the transmission of sensor derived inputs to real-world applications and autonomous systems for critical decision making [34]. Within this framework, the sensor layer comprises a variety of sensors such as those for soil moisture, humidity, temperature, leaf wetness, light, and flame detection—activated to gather raw data from agricultural fields. These sensors, whether connected via wired or wireless means, are selected based on various criteria including data transfer rate, mobility, and power consumption.

The primary objective of deploying these sensors is to capture precise data from dense agricultural zones where human access may be restricted. The raw data gathered are then digitized in their respective forms by the related sensor agents. This change is important as it guarantees the quality of the data collected thus enabling an enhancement in the yield of crops and as well assists in making good decisions. Such process not only optimizes the usage of the agricultural undertakings but also benefits the sustainability of resources [39].

### 3.2 AGRITECH Context Modelling Layer

This include complex diagrams that show how different sub systems in an AGRITECH system work and interrelate. Indeed, the system's structural hierarchy and dynamic data flow relationships are shown separately in Figure 2, the structure of the context-aware AGRITECH system demonstrates how various agents interact with sensor data through ontological transformation and reasoning models. , which effectively illustrate the ways that are chosen for implementing the advanced technologies in the agricultural operations.

The class hierarchy diagram of AGRITECH System Components as shown in Figure 3 , categorizes and presents the different types of agents as well as the sensors that are of considerable importance in the system. Devices like



**Figure 2.** Structure of the Context-Aware AGRITECH Solution with Agents and Sensors

Flame Detectors and Humidity Controllers are aligned with the sensors that detect the environmental conditions including temperature as well as moisture. This diagram also classifies and specifies the interactions between systems' components, which are crucial for the structural and functional stability of the system.

Ontology relationships as exhibited in Figure 4 emphasize showing which data flows will be established to allow the communication between sensors, agents, and user interfaces at the context [35]. This diagram shows how data flows in the system from the sensor level to the data processing level using the agents. This also points to the capacity of the system in processing and feeding data in real-time, which is very important for the management of the agriculture.

Collectively, these diagrams depict the constituent parts of the AGRITECH Context Modelling Layer and stress the system's capacity to handle intricate information and eliminate redundancy to improve agricultural production and output.

### 3.2.1 Definition of Context and Ontology

Context, in the AGRITECH system, is defined as situation and environmental data gathered in real-time from sensors that are planted in the field. This data constitutes temperature, humidity, soil moisture, motion, and gas levels. All these form the operational context upon which the system bases its decisions, adjusts action, and initiates automated responses.

Conversely, ontology in AGRITECH is the orderly framework used to define and classify the components used in smart agriculture like sensors, agents, environmental conditions, and their relationship. It facilitates a com-



mon vocabulary and semantics, which enables various parts of the system (e.g., agents, applications, sensors) to semantically understand and exchange data. The ordered knowledge representation enhances interoperability, enables intelligent reasoning, and provides consistent data processing throughout the system.

### 3.3 CA-MAS Inferencing Layer

In this layer, a set of 'n' agents are deployed within the system and each agent uses the Belief-Desire-Intention (BDI) reasoning for its working and to accomplish its tasks. BDI stands for beliefs, desires, and intentions and is based on psychological concepts of human decision making where an agent works according to its perceived belief, desire, and intention. Agent in this context is defined as a program or an entity that has the ability to execute specific tasks on its own.

Each agent is to address particular issues in the system; all of them use the common communication protocol for sharing the data and addressing the multiple, integrated goals. This makes it possible for agents to cooperate and coordinate in the accomplishment of organizational objectives. In the context-aware deployment, the agents perform the real-time reasoning behaviour by taking into consideration the environmental conditions of the crops and then come up with appropriate decisions on their own. The BDI model is structured around three key components:

- **Beliefs:** The knowledge base of the agent, which contains information about the world, and may be inferred from the agent's own computations, perceptions of its environment or messages from other agents.
- **Desires:** The purpose that the agent is trying to achieve and with which it makes decisions in the process of its functioning.
- **Intentions:** The aims or tasks that the agent promises to perform in order to satisfy its wants, which illustrates the agent's obligation to perform its goals.

The BDI model, when implemented within the agents of the AGRITECH system, allows for the timely responding to changes in the environment, efficient processing of data, and decision-making that will lead to the improvement of crop yield and the other agricultural related processes. This intelligent and autonomous action is useful for timely interaction with the environment and efficient management of resources in the contemporary agriculture.

The three-tiered system architecture of AGRITECH that encompasses the Sensory Layer, Context Modeling Layer and CA-MAS Inferencing Layer was meant to offer modularity, real time feedback and scalability. The Sensory Layer supports the acquisition of different information in the environment that is critical to precision agriculture. Context Modeling Layer provides semantic interoperability to give sensor data a meaning using the ontologies, whereas CA-MAS Inferencing Layer uses the BDI (Belief-Desire-Intention) model to allow autonomous agents to make adaptive real-time decisions. The layered approach eases the updating of systems and, enables extensibility, and also translates sensor data into actionable intelligence with the least latency. All these confirm the selection of architecture of a sustainable and smart agro-ecosystem.

## 4 AGRITECH: An Intelligent Reasoning Based Smart Agricultural System

The proposed system comprises different sensors, equipment (including drones, etc.), and a disease detection image processing model but is connected to each other via a Wireless Sensor Network (WSN) module. The internet connectivity provided by the Node MCU module, as an open-source platform [36], transmits and receives sensor data between the client and receives it at the client end of the system through the internet connection on the client end side of the system. This system is programmed to effectively sustain the best environment in the agricultural setting.

There are different kinds of sensors used in the field such as temperature sensors, moisture sensors, gas sensors, flame sensors, PIR sensors among others [10], [20]. Dark Sky API contains the forecasts of the seasonal,

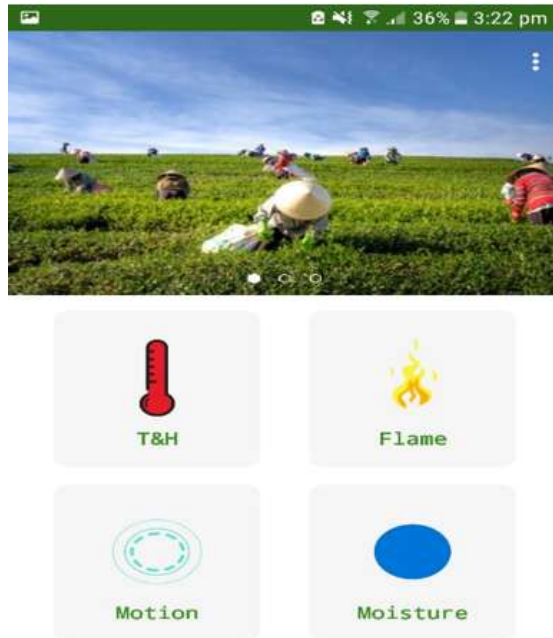


Figure 5. AGRITECH App: Essential Sensors for Agriculture

up to date, and future weather. Crop inspection, spraying of medicine, and emergency rescue uses drones. In our research project, image processing is used in detecting plant diseases. Data upon these sensors is transferred through the microcontrollers e.g. ESP8266 and Raspberry Pi 3B+ which makes the system very practicable and effective.

The obtained data is compared with some predetermined threshold values in the control section. Once any of the values surpasses its value, an alert is generated in the AGRITECH Android application as shown in Figure 5 and an LED on the sensor starts to blink and the intelligent decision-making is incorporated to minimize risks. It is triggered by an emergency tone, sends an alert message to the farmer as well as automatically switches off power when it is detected.

The values are illustrated in the Android application, the farmer is provided with a closer view of the data as illustrated in Figure 6, as illustrated through graphs and progress bars [21], [22].

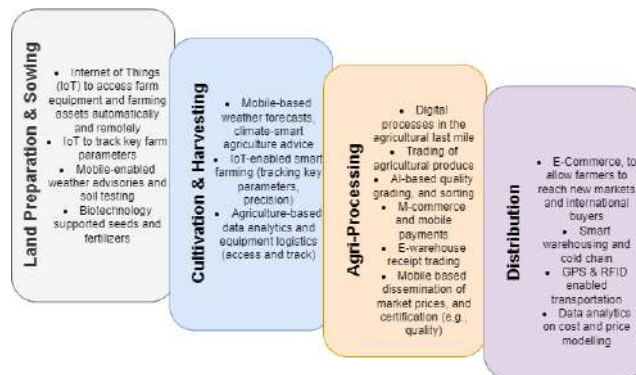


Figure 6. AGRITECH Digital Workflow of App

The AGRITECH mobile application has a highly elaborate user interface with major areas like: The Log-in and Profile page, centralized Main Screen to navigate, sensor detailed views (e.g., Motion, Temperature, Humidity, Flame and Smoke), settings, feedback, and alert configuration pages. Other capabilities are location-based visualization, QR code scanning, and Firebase, which is used to authenticate and visualize the data.

## 5 AGRITECH Application Development

The AGRITECH system is built in the form of the layered architecture, which is meant to streamline agricultural operations with the help of sophisticated technological integration. The architecture of the system includes:

**Sensory Layer:** This is an elementary section of the capability of the system and is used to collect important environmental data with the help of different types of sensors. The agricultural fields are fitted with temperature, humidity, moisture, flame and motion sensors to obtain the real image of the field conditions. This knowledge is important in changing the agricultural activities in the view of the existing environmental conditions. All forms of sensors have a purpose. All forms of sensors have a particular purpose:

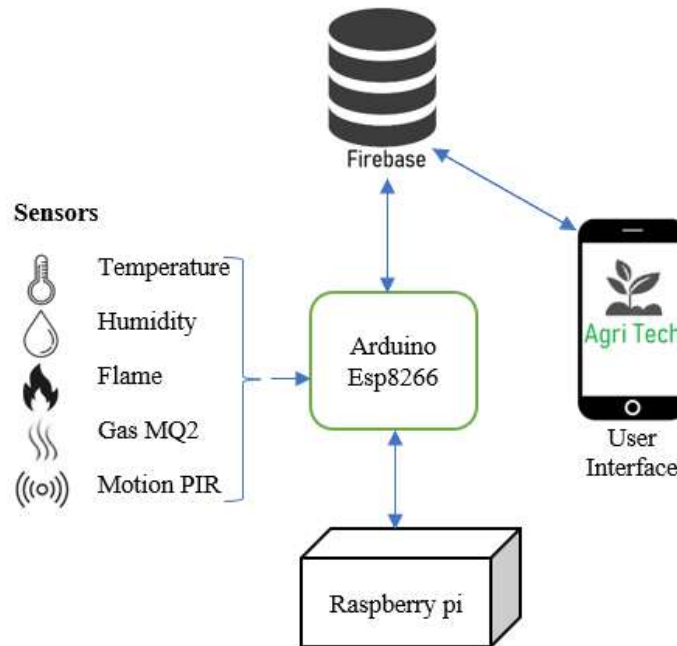
- **Temperature Sensors:** This includes the ambient and soil temperatures to assist in controlling planting and irrigation activities.
- **Humidity Sensors:** Monitor the amount of air and soil humidity as it is crucial for establishing how often the plants need to be irrigated.
- **Moisture Sensors:** Directly quantify the soil water content to ensure efficient use of water through irrigation without wastage.
- **Flame Sensors:** To give early signals on field fires so that it may be combated early to avoid losses on crops.
- **Gas Sensors (MQ2):** Identify toxic gases and pollutants which may have impact on growth of crops and well being of the farmers.
- **Motion Sensors (PIR):** Improve farm security by detecting any intruders in the field especially at odd times when business is not being transacted.

**Context Modeling Layer:** This is where the system will use Semantic Web technologies and ontologies in interpreting and modeling the data gathered. The layer improves the power of the system to make informed decisions through learning the intricate datasets and transferring such learning to actual agricultural scenarios.

**Inferencing Layer:** This layer employs a Belief-Desire-Intention (BDI) model to have intelligent agents who analyze the situation on the ground and give autonomous decisions. These are made in order to maximize resource utilization and crop productivity, a highly developed AI use in precision agriculture.

The AGRITECH application is designed to offer extensive monitoring and proactive management services to farming activities with the following:

- **Real-Time Data Analysis:** Leveraging live data feeds from the sensory layer, the application offers up-to-the minute insights into field conditions, enabling timely interventions.
- **Predictive Analytics:** Using data analytics and machine learning, the system forecasts future environmental impacts and agricultural needs, guiding farmers on optimal actions to maximize productivity and resource efficiency.
- **Remote Management Capability:** Farmers can manage their operations remotely via the AGRITECH mobile application, which provides a user friendly interface for accessing data insights and system controls[33].
- **Automated Control Systems:** Integrated automation tools respond to data insights by adjusting irrigation systems, deploying drones for crop monitoring, or initiating preventive measures against environmental risks.



**Figure 7.** AGRITECH System Architecture

**Integration with External Platforms:** To enhance its functionality, AGRITECH integrates with various external platforms:

- **Data Management with Firebase:** The system uses Firebase for robust data storage and management, ensuring high data availability and security for sensitive agricultural information.
- **Weather Forecasting Integration:** Connection to real-time weather forecasting APIs allows the system to incorporate weather predictions into its operational algorithms, improving the accuracy of its predictive analytics.
- **User Interaction and Alerts:** Through its mobile interface, the system communicates critical alerts and updates to farmers, facilitating immediate responses to potential issues as they arise.

## 6 AGRITECH Architecture Design

One of the primary goals of the system is to maintain simplicity in installation and configuration. It aims to conserve energy and resources, ensuring their optimal utilization. The system enables farmers to apply the precise amount of water at the correct time based on predictive analytics. Furthermore, it is not mandatory for the farmer to be physically present in the field, as updates about field conditions are provided directly by the system. This approach not only saves time but also reduces human errors by adjusting to the existing soil moisture conditions [27].

The complete architecture flow of sensors, micro-controllers, Firebase, and the mobile interface is illustrated in Figure 7.

## 7 AGRITECH Framework Development Mechanism

The development mechanism for AGRITECH includes:

- Temperature and Humidity sensor

- DHT22 is a basic, low-value virtual temperature and humidity sensor. In AGRITECH it makes use of a captive humidity sensor and a thermistor to degree the environment and cut up out a virtual sign at the data pin (Analog pin) to the micro-controller and that they ship values to the Firebase and that they control the facts and ship to the android utility to reveal facts in graphically and analog sensor values [10], [22] [28].
- Flame sensor:The Flame detector is a sensor designed to detect the presence of a flame or fire. It outputs a digital signal on its data pin to the micro-controller which then transmits the reading to Firebase for processing.If a fame is detected,Firestore triggers a notification that is relayed to the Andriod application, informing the user accordingly.
- Gas sensor:The sensor is a easy to apply Carbon Monoxide (CO), LPG and Smoke sensor appropriate for sensing CO concentrations with inside the air. It can locate awareness everywhere from 20 to 2000 ppm at the data pin (Analog pin) to the microcontroller and that they ship values to the Firebase and that they control the facts and ship it to the android utility to reveal facts in notifications.
- Moisture sensor:Moisture sensor usually refers to sensors that estimate volumetric water content material in fields. The AGRITECH app that allows farmers control their irrigation structures extra efficiently. Motion sensors are the spine of protection structures due to the fact they may be the number one gadgets that locate while someone must now no longer be on site. Motion is a digital device designed to locate and degree movement. A lively sensor has each a transmitter and a receiver. These sensors locate movement through measuring modifications in the quantity of sound or radiation this is meditated again to the receiver [10], [28].
- Raspberry pi B plus model: Raspberry Pi B plus is the product with inside the raspberry pi range, boasting an up to date 64-bit quad-centre processor walking at 1.4GHz with integrated metallic warmness sink, dual-band 2.4GHz, and 5GHz Wi-Fi LAN, we use a raspberry pi as a medium of sensors and microcontroller to test and control to the end-user.
- ESP8266 NodeMCU:ESP8266 is an open-supply firmware and improvement package that lets you prototype or builds IoT, it's let you software the ESP8266 Wi-Fi mode with the easy and effective LUA programming language or Arduino ID.
- Drone(Agro-Friend):We used drone to address instances like spraying while police officers have hearth place and to spray remedy if any pesticide unfavourable our plant and monitoring of thief with assist of movement sensor and image processing. The principal cause of drone is to take a look at the fitness of flowers with its digital integrating with image processing. As farmer cannot take a look at or locate all flowers [29].

AGRITECH's system architecture is depicted in Figure 7, which describes how sensor data is gathered through the Arduino ESP8266 and Raspberry Pi, and relayed to Firebase for user access via a mobile app.

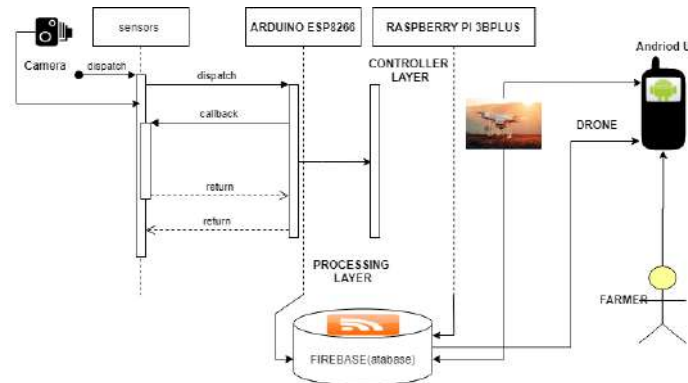
## 8 Supporting Android Based Application (AGRITECH)

### 8.1 Intelligent Reasoning Layer

This initiative aims to develop a Body Sensor Network (BSN) for monitoring agricultural environments. It regulates crucial environmental parameters such as temperature, humidity, weather forecasts, flames, and gases. The sensor node at the core of this system is built on a Raspberry Pi microcomputer, which enables Wi-Fi based data transmission. A Wireless Sensor Network (WSN) consists of sensor nodes that are topologically interconnected. The Raspberry Pi board acts as the control layer of the system, controlling the backup of the data and detection of the faults. The sensor nodes are used to collect data, which is transmitted wirelessly to a central base station through Wi-Fi. This base station has a database that keeps all the received information and has a graphical user interface, which shows important information about humidity, temperature, and the health status of the agricultural environment in general [23],[24], [37].

**Table 1.** Sensor Specifications and Costs

Sensor Type	Sensing Range	Estimated Cost (\$)	Unit
Temperature	0°C to 100°C	3.0	°C
Humidity	0% to 100%	1.5	% RH
Soil Moisture	Contact-based	7.0	Analog Value
Motion (PIR)	Up to 6 meters	11.0	Distance (m)
Flame	760–1100 nm	8.5	Wavelength (nm)
Gas (MQ2 Sensor)	100–3000 ppm	5.0	ppm

**Figure 8.** AGRITECH app displaying sensor data for farm monitoring

The sensor meeting to be evolved specially includes the subsequent components:

- Temperature Sensor
- Flame sensor
- Humidity sensor
- Gas sensor
- Raspberry Pi
- Arduino ESP8266
- Includes:
  1. Data transmission and good control
  2. Data evaluation and interpretation

## 8.2 Large Area and Cost Deviation

In our research project we estimated all costs and ranges of our mainly used sensors to fetch a conclusion to describe that how much era it's going to cover with what amount of costs as shown in Table 1.

## 8.3 Conceptual Formalism

Our AGRITECH project is based on real-time decision-making (RTDM) and the use of state-of-the-art sensing technologies and data processing. This consists of real-time analytics, passing of data to Firebase to store, operate, and make a responsive decision. The RTDM is a vital part of the modern IoT and Artificial Intelligence (AI) systems, which complements the functionality in the following aspects: adjusting the comfort, anticipatory analysis, and multilingual support. Figure 8 below displays the interfaces of the AGRITECH application with the backend devices such as the Raspberry Pi and Firebase to display live sensor data to monitor the farm.

We have implemented sophisticated algorithms that accurately predict sensor readings and offer interfaces in both Urdu and English, tailored to fit the cultural context of local agriculture. Additionally, our system keeps farmers informed about new developments and events in agriculture through regular social media updates. Firebase

Round	Operations
Initial round	Add round key
Medium round	Sub bytes Shift rows Mix columns Add round key
Final round	Sub bytes Shift rows Add round key

**Table 2.** AES Encryption Rounds.

*Note:* AES-128 uses 9 iterations in the main round, AES-192 uses 11 iterations, and AES-256 uses 13 iterations in the main round [23].

integration allows for secure data storage, backup, and management, enabling authentication of farmer identities and generating alerts based on predefined sensor thresholds [9], [25]

#### 8.4 Security Defence (Advance Encryption System)

With the rapid development of IoT, many security problems had emerged. How to securely transmit data in IoT is one of these important problems. To deal with these problem using encryption, decryption we have used AES algorithm in our smart agriculture research project to transfer data securely from user to firebase and vice versa. AES symmetric algorithm protects data from hacking or destruction from any unknown person. AES uses three main phase including initial, medium and final rounds converting plain text into cipher text called encryption and vice versa cipher text into plain text called decryption [24], [26]. The structure of AES rounds used in the AGRITECH system is summarized in Table 2.

### 9 Discussion And Conclusion

The AGRITECH project has improved the knowledge and skills in using IoT in agricultural automation [38]. The creation of a primitive Android platform guarantees continual functionality to perform farming procedures on a round-the-clock basis. The AGRITECH app is helpful in improving the farmers' accessibility through constant notifications, scheduling, and alerts for shielding sensitive regions [9], [17],[30]. It is supposed to be rather simple to use, which means that any farmer no matter how advanced he is in the use of technologies will be able to use it.

The integration of AI routines complements the training and understanding of the farmers concerning the use of automated technologies in conjunction with traditional practices [25], [27].

The project highlights the significance of time and task organization together with effective cooperation between members of the development team when it comes creation of efficient technologies. The digital AGRITECH adoption by FPOs can change the start-ups by removing the technology divergence and increasing the productivity of agriculture [31],[32]. The experience from this project prepares the stakeholders to work on any future obstacles arising in the advancement of technologies in agriculture hence fostering the growth of agritechnology.

### 10 Future Work

In the subsequent releases of the system, we are going to expand its functionality greatly by adding more sophisticated sensors and improving the possibilities of interaction with the user. Future work will include:

- **Enhanced Sensor Integration:** To enhance the benefit given to the farmers, we will incorporate a variety of advanced sensors that will collect more elaborate information. This will make it possible to monitor and control agricultural environments even to a higher level of sophistication.

- **Voice-Controlled Interface:** To make the user feel comfortable and convenient while using the application, we will incorporate voice commands. This feature will enable a farmer to interact with the system through voice commands thus enabling the farmer to easily operate the system while conducting farming activities.
- **Customizable System Settings:** The new system will feature extensive customization options, allowing farmers to configure both hardware settings and software updates according to their specific needs. This flexibility will ensure that the system can adapt to a variety of farming operations and preferences.
- **iOS Application Development:** Recognizing the diverse technology preferences among farmers, we will develop an iOS version of our application to ensure accessibility for Apple users. This expansion will help us reach a wider audience and provide more farmers with access to our innovative agricultural solutions.
- **Advanced Disease Detection:** Within the system we will define special categories for disease detection will be introduced. This feature will assist the farmers in tackling crop diseases more efficiently, since the system will advise on treatment depending on the existing conditions.
- **Enhanced Communication Features:** The system will also incorporate better communication interfaces through which the farmers will be able to better deal with the sellers and support services. This will enhance information exchange, quick problem solving, and most importantly the delivery of services.

All these improvements are aimed at making the system not only better in terms of capability but also easier to use and friendly to farmers, thus making sure that technology is a friend in farming .

### Author Contributions

**Abdullah:** Led the design and development of the IoT-based smart agricultural system **Hafiz Mahfooz Ul Haque:** Contributed to the implementation of machine learning models for precision agriculture. **Nadeem Ahmad:** Supervised the research and contributed to the conceptual framework for smart farming solutions. **Qurat Ul Ain Aini:** Worked on integrating wireless sensor networks and real-time environmental monitoring. **Ali Saeed:** Assisted in system optimization, data analysis, and hardware implementation for IoT devices.

### Compliance with Ethical Standards

It is declared that all authors don't have any conflict of interest. It is also declare that this article does not contain any studies with human participants or animals performed by any of the authors. Furthermore, informed consent was obtained from all individual participants included in the study.

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