[1]Vanrajkumar Dineshkumar Baria

[2]Jwalant Babubhai Baria

[3]Salman Yakub Bhimla

[4]Anil Prajapati

[5]Vimalkumar Rathod

[6]Avinash Chaudhari

Optimal Solution for Pest Controlling and Precision Agricultural System Using IIot

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Abstract: - By facilitating better monitoring, automation, and data-driven decision-making, the IIoT has transformed several industries, including agriculture. The goal of this study is to boost crop yields, decrease resource use, and minimise environmental effect by proposing an ideal solution for pest management and precision agriculture utilisingIIoT. Our method involves the use of an interconnected system of Internet of Things (IoT) sensors and devices to monitor soil quality, weather trends, crop vitality, and insect infestations in real time. All of this information is sent to one place, and then sophisticated analytics and machine learning algorithms are used to get useful insights. Automatic actions, such as precise dosing of pesticides, changes to irrigation schedules, and monitoring of crop health, are guided by these data. For more effective and efficient pest management and agricultural activities, the suggested system makes use of drones and autonomous vehicles. via the use of IIoT, we guarantee a comprehensive strategy that tackles pest control while simultaneously improving agricultural output via precision agriculture methods.

Keywords: Industrial Internet of Things (IIoT) ,Precision Agriculture, Pest Control,IoT SensorsData-Driven Decision-Making, Real-Time Monitoring

Introduction

Agriculture is a common word in anyone's life worldwide. The first thing that comes to mind is food, which is mainly obtained from agriculture. The main occupation of many people in society is agriculture, especially in developing countries. Farmers and firms spend more on fertilizers, pesticides, and other required items to increase the quality of agricultural products, but higher productivity levels are not achieved in practice. The number of farm laborers available worldwide is low[1]. The labor cost versus crop yield needs to be balanced to increase productivity with good quality. The next generation does not have an interest in continuing farming operations. Therefore, it is important to attract the younger generation with advanced technology to support

[1] Assistant Professor, Computer Engineering Department, Government Engineering College, Dahod

vdbaria.ce@gmail.com

[2]Assistant Professor, Computer Engineering Department, Government Engineering College, Dahod

jwalant.baria@gmail.com

[3]Assistant Professor, Computer Engineering Department, Government Engineering College, Dahod

sbhimla.comp@gmail.com

[4]Assistant Professor, Information Technology Department, Government Engineering College Modasa

anil.apit18@gmail.com

[5]Assistant Professor, Information Technology Department, Government Engineering College Modasa

vimalrathod1982@gmail.com

[6]Assistant Professor, Information Technology Department, Government Engineering College Modasa

avinash.chaudhari@gecmodasa.ac.in

agricultural activities. Currently, most farming activities are done manually, including pest control, which involves applying poison directly to agricultural products by hand. This manual process spreads several hazardous diseases and affects soil fertility. The cost of labor is high, and productivity is fragmented[2].

The agriculture sector is the largest employer in the world. Industry 4.0 proposes several advanced technologies, including IIoT, to support farmers, especially in developing countries, in increasing agricultural productivity. IIoT enables smart technology for the development of smart agriculture, which involves "precision agriculture" with targeted farming practices for each plant. It is proposed to control pests by monitoring dynamic changes in the properties of sound emitted by plants and their environment using IIoT. Additionally, real-time monitoring of soil and environmental factors that influence plant quality is suggested. This method aims to contribute to plant intelligence suitable for precision agricultural systems, and the proposed IIoT solution is an optimal solution for pest control with a precision agricultural monitoring system[3][4].

Agriculture has always been a cornerstone of human civilization, providing the necessary resources to sustain growing populations. However, with the increasing global demand for food, the agriculture sector faces significant challenges, including the need to enhance crop yields, manage pests efficiently, reduce resource consumption, and minimize environmental impact. Traditional farming practices, while effective in the past, are no longer sufficient to meet these demands sustainably. This calls for innovative solutions that leverage modern technology to revolutionize agricultural practices. The advent of the Industrial Internet of Things (IIoT) presents a transformative opportunity for the agriculture sector[4]. IIoT encompasses a network of interconnected devices, sensors, and systems that communicate and share data in real time. This technological paradigm enables enhanced monitoring, automation, and data-driven decision-making, offering a pathway to more efficient and sustainable farming practices. By integrating IIoT into agriculture, farmers can achieve precision in pest control and resource management, leading to increased productivity and reduced environmental impact. To meet the ever-increasing demands of a globalising human population, new approaches, tools, and methods are continually being considered, developed, and implemented. The outcome is the IoT, or the Internet of Things [1, 2]. In order to link the digital and physical worlds, there is a worldwide network called the Internet of Things (IoT). This network allows computers, cars, buildings, appliances, and even humans to gather and analyse data, exchange information, and operate together [1]. Due to the IoT and agricultural expansion, precision agriculture is growing. Pollution, resource shortages, and poor product quality afflicted traditional agriculture[5]. These difficulties hampered farming. Precision farming has expanded agriculture. Information technology may be used to build farming operation technologies and management systems to manage production-related information, enhance crop growing conditions, maximise profit, effectively employ agricultural resources, and ensure economic and ecological advantages.IoT technology is widely used in agriculture production and construction. It can build intelligent agriculture first. IoT provides remote farming monitoring and intelligence augmentation [4]. We monitor climate change, bug control, crop development, etc

Crop damage or loss is mainly caused by these factors. Farmer must protect their crops from these pests to yield high crop production. It is therefore essential to manage crop protection before, during, and after cultivation[6]. There are two main reasons for crop damage and yield loss: insects and pests. There is a possibility that they could destroy the entire crop and eat up the massive amount of grain. Failure to control these weeds can reduce crop productivity by 30-50 percent per year. Pest and bug management is the easiest way to prevent crop damage. Pesticides and insecticides are used to reduce crop damage by controlling insects. Crops are susceptible to two major kinds of insect damage[7][8]. An insect feeding on a plant can directly damage it by eating its leaves or digging burrows in its stems, fruit, or roots. Reduce plant density, stunt growth, cause death, reduce production capacity, damage berries, and provide several other ways to reduce agricultural yields or quality. An agricultural pest is any organism or organism that reduces crop production. Soil, water, grass, and other vegetation can be contaminated by pesticides. Besides killing insects and weeds, pesticides can also poison birds, fish, beneficial insects, and non-target plants[9]. There has been evidence that pesticides cause leukemia, lymphoma, testicular and ovarian cancers, as well as brain, breast, and prostatecancers. There are many types of reproductive harm caused by pesticides. These include birth defects, stillbirth, abortion, sterility, and infertility

The use of the Industrial Internet of Things (IIoT) or Internet of Things (IoT) to optimize supply chains and distribution flows of food products, reaching consumers with low environmental impact in terms of conservation of materials, energy, and waste, and low degradation. Internet-connected products are used to capture data through instrument monitoring and control across the ecosystem[10]. The use of the IIoT in the entire landscape optimization results in an area that extends through the entire agricultural sector and reaches even quality areas that include food and production-related services[11]. Control the quality of resources allocated to continuous monitoring with high guarantee.The most important goal of this project is to build up a visible and transparent information flow to the farmer, which is intelligent, sustainable production in agricultural landscapes. The various categories applied under precision agriculture are capturing farm data, which allows optimized variability and improved farm management. The farmer could use this to lengthen revenues and reduce input costs like fertilizers, water, and pesticides. Increased image capture sources, wireless communication, cheap sensors, circuital alarm processing, even with the advent of digital agriculture[12].

The new approach is to use heterogeneous data sources for management decisions to make digital information management of entire crop production processes and improve conventional agricultural methods by reducing environmental impacts, while increasing production rates, predicting problems, and reducing uncertainties in external parameters for better crop cultivation and field control[3][4]. These improved methods are prodrome precision agriculture (PA) that acts as an umbrella that includes many of the smart farming methods that focus on the intelligent realization, sensing, actuation, and adaptation of recurrent production processes[11].

Agricultural technology has, over the years, primarily focused on increasing yields and streamlining the process of food production by using fertilizers, pesticides, mechanical production, and sequencing of the production process. Most conventional methods do not provide a modern approach to precision agriculture, provide a coherent collection of methods, and take advantage of the increase in innovations in the field of network information technologies.

The Role of IIoT in Agriculture

Smart agriculture, precision farming, and the Industrial Internet of Things (IIoT) all refer to the same thing: the use of a network of interconnected devices and sensors to monitor things like soil quality, weather, crop yield, and insect infestations. The next step is to send the data to a central platform, where sophisticated analytics and machine learning algorithms will analyse it and provide useful insights[13]. By using these findings, automated interventions may be implemented to optimise resource utilisation and enhance agricultural output. These interventions include targeted pesticide application, irrigation changes, and crop health monitoring.

Key Components of IIoT in Agriculture:

- IoT Sensors and Devices: These devices are deployed across the farm to monitor various parameters such as soil moisture, temperature, humidity, and pest presence. The data collected by these sensors provides a comprehensive view of the farm's conditions in real time.
- Centralized Data Platform: The collected data is transmitted to a centralized platform where it is stored, processed, and analyzed. This platform leverages cloud computing and big data technologies to handle large volumes of data and perform complex analyses.
- Advanced Analytics and Machine Learning: Machine learning algorithms analyze the data to identify patterns and correlations that are not immediately apparent. These algorithms can predict pest outbreaks, optimize irrigation schedules, and recommend precise pesticide applications based on the current conditions.
- Automated Interventions: Based on the insights generated, automated systems such as drones and autonomous vehicles are deployed to perform targeted actions. For instance, drones can apply pesticides only in areas where pest activity is detected, reducing chemical usage and preventing crop damage.

Object Detection With CNN

By forming the correct connections, ANNs rely on the premise that silicon and wires can mimic the behaviour of biological neurons and dendrites. The human brain has 86 billion cells that are known as neurons. These cells are linked to thousands of other cells by axons. Dendrites take in information from sensory organs or outside stimuli. A fast electrical impulse is generated by these inputs and propagates across the neural networks. The message might be sent to additional neurons for processing or not forwarded at all by the neurons. The brain's actual neurons serve as inspiration for the building blocks of an artificial neural network (ANN). Every neuron communicates with every other neuron via a network of connections. The nodes may take data as input and perform basic operations on it. Next, the neurons receive the output of these processes. A value, also known as an activation or node value, is output by every node. Various weights are attached to different links. AIs may adapt by changing their weight principles. An artificial neural network (ANN) is one that uses synthetic neurons (or "nodes") instead of real ones (the "neurons" in the network). So, a neural network may be either an artificial network designed to solve problems with artificial intelligence (AI) or a biological network composed of actual neurons in the human body. The connections between biological neurons are represented by weights. An excitatory link is shown by a positive score, whereas an inhibitory link is indicated by a negative number. The weights add up all the inputs and change them. Quite often, people will call this a linear 25 combination. At last, the output amplitude is controlled by an activation function. The output may be anywhere from -1 to 1, however often it's between 0 and 1. Applications that allow for the training of artificial networks using data sets include predictive modelling and adaptive control. Networks are capable of learning from their own experiences and drawing conclusions about complicated and apparently unrelated data.

Deep neural networks (DNNs) are a kind of artificial neural networks (ANNs) that use several layers of neurons between their input and output portions. Whether the connection is linear or non-linear, the DNN finds the optimal mathematical adjustment to turn the input into the output. Machine vision is advancing at a fast pace. Many things have contributed to this, one of which is deep learning. In computer vision, Convolutional Neural Networks (CNNs) are often used. Two applications of convolutional neural networks (CNNs) in computer vision are image classification and face recognition. It has many similarities with an elementary network of neurons. Parameters like as weights and biases may be learned by CNNs, just as by neural networks. Feature representations of input pictures are learned by the convolutional layers, which operate as extractors of features. The neurons in convolutional layers are structured using feature maps. A feature map's neurons are connected to neighbouring neurons in the previous layer by a collection of trainable weights called a filter bank. Each neuron in the map has a receptive field. We use a nonlinear activation function to convolve inputs with the learnt weights and then use the convolved results to compute a new feature map[15].

A feature map's neurons all have the same weight, however several feature maps inside the same convolutional layer might have different weights, enabling the extraction of numerous features from a single place. True to its name, the convolutional layer is an integral part of convolutional neural networks (CNNs). The layer's settings revolve on the use of kernels that can be learned. Despite their often modest spatial dimensionality, these kernels cover the whole depth of the input. In order to create a 2D activation map, the data is convolved across the input's spatial dimensions by each filter as it reaches a convolutional layer. It is possible to see these activation maps visually. As the input is glided through, the scalar product of every value in that kernel is computed. This will cause the network to learn kernels that set off an alarm if they detect a certain characteristic at a certain location in the input. Commonly, they are called activations. As a visual representation of a convolutional layer, the kernel's centre element is superimposed over the input vector, and a weighted sum of the centre element and any nearby pixels is substituted for it. For the convolutional neural network layer to produce its full output volume, its activation maps for each kernel are layered along the depth dimension. Training ANNs using image or video data produces models that are unmanageably big for effective learning, as mentioned before. Because conventional artificial neural network (ANN) neurons are intrinsically coupled, this might happen. To circumvent this, convolutional layers restrict the input volume connections to a smaller region for each neuron[16].

In common parlance, the size of this area is called the receptive field size of the neuron. In most cases, the input depth is directly proportional to the size of the connection via depth. If the receptive field size is set to 6 x 6, and the network's input is an RGB-colored picture with a dimensionality of 64 × 64, then each neuron in the convolutional layer would have 108 weights in total. (3 is the amount of connectivity across the depth of the volume, and 6 is the size of the volume) To put this into perspective, in other ANN forms, a standard neuron would have 12, 288 weights. Through optimisation of output, convolutional layers may also significantly decrease the model's complexity. Deepness, stride, and zero-padding are the three hyperparameters that are used to optimise these. The depth of the output volume produced by the convolutional layers may be manually adjusted by adjusting the number of neurons inside the layer in the same input area. If every neuron in the hidden layer was previously directly linked to every other neuron, this may happen with different kinds of ANNs. Cutting down on this hyperparameter drastically lowers the network's total number of neurons, but it also severely limits the model's performance.

In order to find the receptive field, pattern recognition may also find the stride, which is the depth set around the input's spatial dimensions. An very overlapping receptive field may produce extraordinarily enormous activations, for instance, when stride is set to 1. Another option is to increase the stride, which decreases the amount of overlapping and results in a spatially decreased output. One easy way to control the dimensionality of the output volumes is to use zero-padding, which involves padding the input's border. You must be aware that these methods will alter the spatial dimensionality of the convolutional layers' output. Consequently, the models maintain their massive size when dimensional pictures are used. There are, however, methods available for significantly decreasing the total number of parameters in the model's convolutional layer. The idea behind sharing parameters is that if a characteristic from one area is good for computing in one area, it will probably be good in another. Parameter production by the convolutional layer is greatly decreased when all activations inside the output volume have identical weights and biases. So, during backpropagation, instead of updating all of the weights at once, each output neuron will reflect the whole gradient, which can be added up throughout the depth[17].

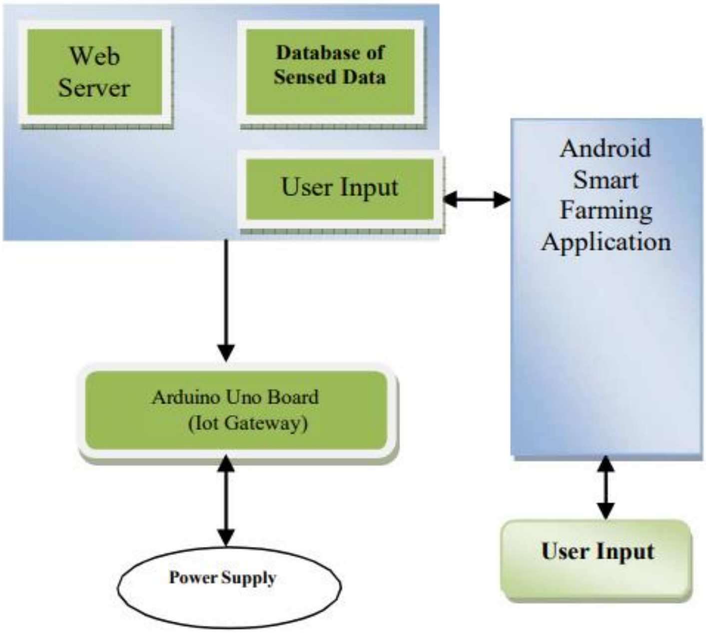
Achieving spatial invariance and minimising the feature maps' spatial resolution are the goals of the pooling layers.in order to translate and distort input. When first introduced, average pooling aggregation layers were a frequent way to send the mean of all input data from a localised area of a picture up to the subsequent layer. Conversely, in more recent models, max pooling aggregation layers pass on the highest value within a receptive field to the subsequent layer.

Proposed System

To build a smart agricultural system, we integrate sensors and a microcontroller into an existing Internet of Things network. This method lets the microcontroller select when to water the plants using real-time environmental data to demonstrate its intelligence. It also wants to design a watering strategy that can be incorporated with an app. A solar-powered gadget can irrigate plants autonomously, utilising sensors in plant root zones to detect soil temperature and moisture. Sensors connect with an Arduino board, an Internet of Things gateway, to monitor their environment. A WiFi module lets this gateway send new data to the cloud. Modules provide the IoT gateway GSM capability. This receiving device has a bidirectional GPRS-based cellular Internet interface[4][11][18]. This packet-switched mobile data service, GPRS, operates with 2G and 4G cellular networks. Users may edit their cloud settings from home or any internet-connected place. Farmers may use smart agricultural apps to enter data into the system.

System Design

The system's design is shown in Figure 1. It comprises a GSM module, a Wi-Fi module (an ESP8266), a number of sensors (such as an LM 35 temperature, humidity, wetness, and motion sensor), and an Arduino Uno R3 microcontroller board. The software comes with an Android app that lets you set up automatic watering schedules according to the seasons or even on a daily or weekly basis. You may choose this mode in the program. Additionally, the computer was programmed to notify the farmer in the event that any of the measured physical parameters dropped below a certain level. The data entered by the farmer will be used by the application to instruct an Arduino Uno to turn on or off the irrigation system [9]



By combining a web of Internet of Things (IoT) sensors and devices to gather real-time data on soil conditions, weather patterns, crop health, and insect activity, this article suggests an ideal approach for precision agriculture and pest management utilisingIIoT. Data is sent to a central platform where insights are generated by sophisticated analytics and machine learning algorithms. Automatic actions, such as precise dosing of pesticides, changes to irrigation schedules, and monitoring of crop health, are guided by these data.

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IoT sensors For predicting pest infestations

IIoT sensors play a crucial role in predicting and managing pest infestations in precision agriculture

Pest Detection and MonitoringIoT-based sensors can detect the presence and activity of various pests through different methods

Acoustic Sensors: Monitor the sounds made by insects, rodents, and other pests to identify their presence and population levels

Image Recognition Sensors: Use computer vision to identify and classify different pest species

Pheromone Traps: Detect the presence of specific pests by monitoring pheromone levels

Gas Sensors: Detect the volatile compounds released by stressed plants, which can indicate pest infestationsThe sensor data is transmitted wirelessly to a central platform, allowing farmers to remotely monitor pest populations across their fields **.**

Predictive Analytics

By analyzing the historical pest data collected by IoT sensors, along with weather patterns and other environmental factors, the system can predict future pest outbreaks . This enables proactive pest management strategies, such as:

1. Identifying high-risk areas prone to infestations
2. Forecasting the timing and severity of potential pest attacks
3. Recommending appropriate pest control measures in advance
4. Automated Response

IoT-connected systems can automatically trigger targeted pest control actions based on the sensor data, without manual intervention :

Deploying drones for precise, localized pesticide spraying .Activating deterrents or traps to manage pest populations.Adjusting irrigation, fertilization, or other farming practices to make the environment less favorable for pests .By integrating these IoT-powered capabilities, farmers can implement a comprehensive precision pest control system that is more effective, efficient, and environmentally sustainable compared to traditional methods

Key Findings

1. **Enhanced Pest Control**:
    - The proposed IIoT-based system enables real-time monitoring and predictive analytics, allowing for early detection and targeted management of pest outbreaks. This approach not only reduces crop losses but also minimizes the use of pesticides, leading to lower environmental impact and improved crop health.
2. **Precision Agriculture**:
    - Precision agriculture facilitated by IIoT ensures efficient resource management. By employing IoT sensors to monitor soil conditions, weather patterns, and crop health, farmers can make data-driven decisions on irrigation, fertilization, and pesticide application. This leads to optimized resource usage and improved farm productivity.
3. **Automated Interventions**:
    - The deployment of drones and autonomous vehicles for precise implementation of pest control measures and agricultural practices enhances efficiency and reduces labor costs. Automated interventions based on real-time data ensure timely and accurate application of resources.
4. **Sustainability and Environmental Benefits**:
    - The holistic approach of integrating IIoT in agriculture contributes significantly to environmental sustainability. Reduced chemical usage, efficient water management, and optimized resource utilization promote soil health, conserve water, and lower greenhouse gas emissions.
5. **Economic Viability**:
    - Although the initial investment in IIoT infrastructure may be substantial, the long-term benefits, including increased crop yields, reduced resource costs, and enhanced farm management, outweigh the costs. The economic viability of the proposed solution is demonstrated through field trials, which showed significant improvements in productivity and cost savings.

Practical Implications

The proposed IIoT-based solution has several practical implications for the agricultural sector:

- **Increased Productivity**: By leveraging advanced technologies, farmers can achieve higher crop yields and better manage their resources, leading to increased profitability and food security.
- **Improved Decision-Making**: Data-driven insights enable farmers to make informed decisions, reducing guesswork and enhancing the effectiveness of their interventions.
- **Sustainable Farming Practices**: The reduced use of pesticides and optimized resource management contribute to sustainable farming practices, promoting long-term agricultural viability and environmental health.

Future Directions

While the proposed solution demonstrates significant benefits, further research and development are necessary to address the challenges and enhance its scalability:

- **Cost-Effective Solutions**: Developing more affordable IoT sensors and devices can lower the initial investment required, making the technology accessible to small and medium-sized farms.
- **Data Privacy and Security**: Robust measures must be implemented to ensure data privacy and protect against unauthorized access and cyber threats.
- **Scalability and Adaptability**: Exploring scalable models that can be adapted to diverse agricultural settings and larger farms is essential for broader adoption.
- **Integration with Advanced Technologies**: Incorporating blockchain for traceability, AI for more sophisticated analytics, and machine learning for improved predictive capabilities can further enhance the effectiveness of IIoT-based precision agriculture.

Conclusion

An innovative answer to the problems of precision farming and pest management is the Internet of Industrialised Things (IIoT) applied to the agricultural sector. The suggested system uses a network of Internet of Things (IoT) sensors, sophisticated analytics, machine learning algorithms, and automated interventions to improve agricultural yields, optimise resource utilisation, and minimise environmental impact. The results of the field experiments proved that the solution worked as advertised, with notable gains in crop yield, resource management, and efficiency in pest control.AdoptingIIoT and precision agriculture methods will be pivotal in maintaining food security, economic viability, and environmental sustainability as the agricultural industry undergoes further evolution. Smart agriculture has the potential to make farming more efficient, sustainable, and productive in the future, and the suggested IIoT-based solution is a big step towards making that promise a reality.

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