Autonomous Agricultural Monitoring System

A Project Work Synopsis

Submitted in the partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE WITH SPECIALIZATION IN

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

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MAY 2024

Abstract

Agriculture balances both food requirement for mankind and supplies indispensable raw materials for many industries, and it is the most significant and fundamental occupation in India. The advancement in inventive farming techniques is gradually enhancing the crop yield making it more profitable and reduce irrigation wastages. The proposed model is a smart irrigation system which predicts the water requirement for a crop, using machine learning algorithm. Moisture, temperature and humidity are the three most essential parameters to determine the quantity of water required in any agriculture field. This system comprises of temperature, humidity and moisture sensor, deployed in an agricultural field, sends data through a microprocessor, developing an IoT device with cloud. Decision tree algorithm, an efficient machine learning algorithm is applied on the data sensed from the field in to predict results efficiently.

IoT architectures facilitate us to generate data for large and remote agriculture areas and the same can be utilized for Crop predictions using this machine learning algorithm. Recommendations are based on the following N, P, K, pH, Temperature, Humidity, and Rainfall these attributes decide the crop to be recommended. The data set has 2200 instances and 8 attributes. Nearly 22 different crops are recommended for a different combination of 8 attributes. Using the supervised learning method, the optimum model is attained using selected machine learning algorithms in WEKA. The Machine learning algorithm selected for classifying is multilayer perceptron rules-based classifier JRip, and decision table classifier. The main objective of this case study is to end up with a model which predicts the high yield crop and precision agriculture. The proposed system modeling incorporates the trending technology, IoT, and Agriculture needy measurements. The performance assessed by the selected classifiers is 98.2273%, the Weighted average Receiver Operator Characteristics is 1 with the maximum time taken to build the model being 8.05 s.

Keywords:
precision agriculture; **machine learning**; **multilayer perceptron**; **decision table**.

Table of Contents

1. INTRODUCTION

1.1 Problem Definition

India ranks second in the world in farm output but 64% of cultivated land depends on the monsoons. Irrigation accounts for nearly 85% of water and nearly 60% of water is wasted during irrigation. Precision agriculture can be defined as “the application of modern information technologies to provide, process, and analyze multi-source data of high spatial and temporal resolution for decision making and operations in the management of crop production. This Precise agriculture may give rise to enhance productivity, Soil degradation, Efficient water usage, reduction in chemical usage for cultivation, dissemination of modern farm practices to improve quality, quantity, and cost of production in crops. By incorporating Agriculture IoT solutions are focused on helping farmers close the supply-demand gap, by ensuring high yields, profitability, and protection of the environment. The approach of using IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs is called precision agriculture.IoT application in Precision Agriculture is focused on crop water management, Pest control and management, Precise detection and nutrients management and safely storing management.

Historical development of sensors shows the progress in measuring various parameters like temperature, pH, Humidity, Analytical parameters like potassium, phosphorous, Nitrogen measurements from a remote location and the data acquisition is possible to attain all the measurements using sensors thereby the data is stored in the cloud or network server for further processing as shown in **Figure 1**.

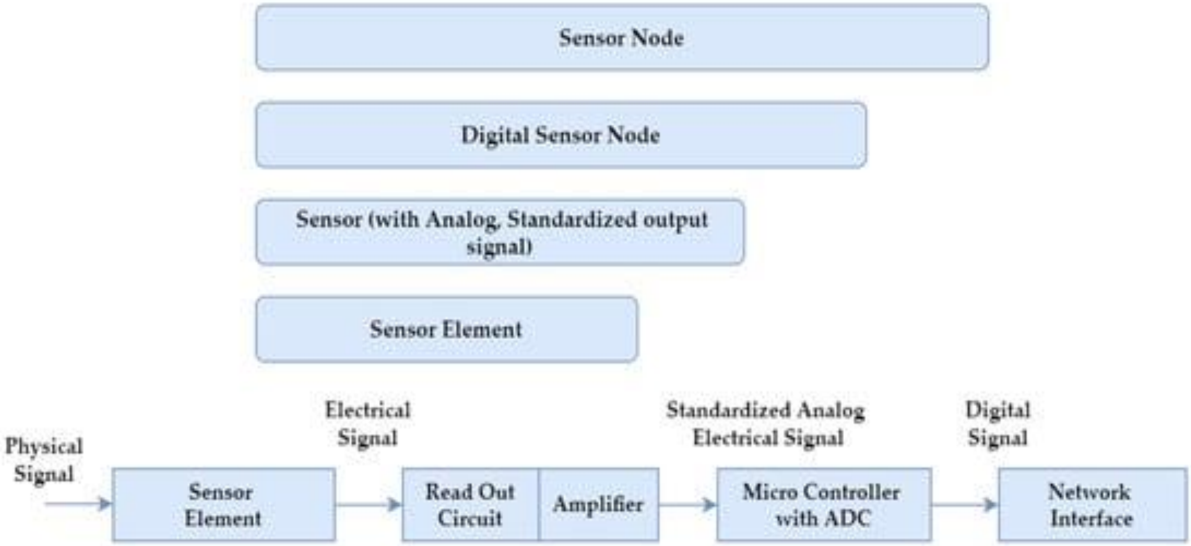

Figure 1. Historical progression of sensors.

Sensors are combined to form a network that can be accessed or linked by cloud/backend where the sensor responses in a different geographical area are linked by the cloud. There are four different phases from smart things without connectivity next progression was a local exchange of information and distributed control systems with programmable logic controllers, the network of things. The next phase includes internet-based communication for monitoring and control, things on the internet. The final phase is regional, global, and open control loops and IoT. Examples Seamless internet of things supply chain management and product life cycle management.

Organization of the paper: The article is composed of five sections and started from strengthening the concept to deploy a module to recommend the crop for irrigation and attain maximum yield with the recommended crop.

The next section is related to works from IoT in the Agriculture sector and precision agriculture using machine learning algorithms.

1.2 Problem Overview

- **Labor Intensive Monitoring:**

  Traditional agricultural monitoring methods often require significant human labor to inspect crops, monitor soil conditions, and manage irrigation systems.

- **Time-Consuming:**

  Monitoring large agricultural fields manually is time-consuming, leading to delays in detecting issues such as pest infestations, diseases, or nutrient deficiencies.

- **Inefficient Resource Allocation:**

  Without real-time data, farmers may allocate resources such as water, fertilizers, and pesticides inefficiently, leading to waste and increased costs.

- **Limited Precision:**

  Human observation may lack the precision needed to identify subtle variations in crop health or environmental conditions that could affect yield and quality.

- **Risk of Error:**

  Human error in data collection and analysis can lead to inaccurate assessments of crop health, soil moisture levels, and other critical factors.

- **Inadequate Response to Environmental Changes:**

  Rapid changes in weather patterns and environmental conditions require quick adjustments in agricultural practices, which may be challenging to achieve with manual monitoring alone.

- **Scalability Challenges:**

As agricultural operations expand, the scalability of manual monitoring becomes increasingly difficult, leading to gaps in data collection and analysis.

- **High Cost of Monitoring:**

  Employing human labor for continuous monitoring can be costly, especially for large-scale agricultural operations.

- **Environmental Impact**:

  Inefficient use of resources such as water and fertilizers due to inadequate monitoring can have negative environmental consequences, such as pollution and soil degradation.

- **Competitive Disadvantage:**

  Farms that lack advanced monitoring systems may struggle to compete with more technologically advanced counterparts that can achieve higher productivity and efficiency.

  An Autonomous Agricultural Monitoring System aims to address these challenges by leveraging technologies such as sensors, drones, satellite imagery, and machine learning algorithms to provide real-time data on crop health, soil conditions, and environmental factors, enabling more informed decision-making and proactive management of agricultural operations.

1.3Software Specification

1. Data Analytics and Processing
2. Python Libraries (NumPy, Pandas, TensorFlow, Keras, Matplotlib, Seaborn, Pytorch)
3. Machine Learning
4. Python
5. IOT
6. GIS (Geographic Information System) Software

2. LITERATURE SURVEY

2.1 Existing System

In traditional agricultural monitoring systems, farmers typically rely on manual methods and periodic sampling to assess soil conditions, monitor crop health, and manage resources. These methods often involve labor-intensive tasks such as soil sampling, visual inspections, and manual data recording. Here is a detailed overview of the existing system:

- **Manual Labor:**

  Farmers manually collect soil samples from different locations within their fields using tools such as soil augers or probes.
  Soil samples are sent to laboratories for analysis, which can be time-consuming and expensive.
  Visual inspections are conducted to assess crop health, identify pests and diseases, and monitor growth patterns.

- **Periodic Monitoring:**

  Monitoring activities are typically conducted on a periodic basis, such as weekly or monthly intervals.
  This periodic approach may fail to capture rapid changes in soil conditions, weather patterns, or crop health, leading to delays in decision-making and potential crop losses.

- **Subjective Assessments:**

Assessments of soil fertility, moisture levels, and crop health are often based on subjective observations rather than quantitative data.
This subjective approach may result in inconsistencies and inaccuracies in monitoring results, leading to suboptimal decision-making.

- **Limited Spatial Coverage:**

Traditional monitoring methods are limited in their ability to cover large agricultural areas efficiently.
Farmers may only sample a small portion of their fields, leading to uncertainties about the representativeness of the data collected.

- **Resource Management:**

Resource management decisions, such as irrigation scheduling, fertilizer application, and pest control, are often based on intuition and experience rather than real-time data.
Without accurate and timely information about soil moisture, nutrient levels, and pest infestations, farmers may over-apply inputs or miss opportunities to optimize resource usage.

- **Data Recording and Management:**

Data recording is typically done manually using pen and paper or basic electronic tools.
Data management may involve storing information in spreadsheets or farm management software, which may lack integration and interoperability with other systems.

- **Challenges and Limitations:**

Labor Intensive:

Manual monitoring methods require significant time, effort, and resources, especially for large-scale farming operations.

Limited Precision:
Subjective assessments and periodic monitoring may fail to capture fine-scale variations in soil and crop conditions.

Time Consuming:
Delays in data collection, analysis, and decision-making may hinder timely interventions and optimization of farming practices.

Inefficient Resource Management:
Without accurate and timely data, farmers may struggle to optimize resource usage, leading to inefficiencies and environmental impact.

2.2 Proposed System

The proposed Autonomous Agricultural Monitoring System (AAMS) aims to revolutionize farming practices by leveraging advanced technologies such as sensors, drones, satellite imagery, IoT devices, and data analytics. Here's a detailed overview of the proposed system:

- **Sensor Network:**

Deploy a network of sensors throughout agricultural fields to monitor various parameters such as soil moisture, temperature, humidity, nutrient levels, and pest infestations.
Utilize advanced sensor technologies with high accuracy, reliability, and durability to withstand harsh environmental conditions.
Ensure proper calibration and maintenance of sensors for accurate data collection over time.

- **Drone-Based Monitoring:**

Use unmanned aerial vehicles (UAVs) equipped with cameras, multispectral sensors, and thermal imaging cameras for aerial imaging and monitoring.
Fly drones over agricultural fields at regular intervals to capture high-resolution images and collect data on crop health, growth patterns, and environmental conditions.
Incorporate autonomous flight capabilities and route planning algorithms to optimize coverage and efficiency.

- **Satellite Imagery Integration:**

Access satellite imagery services providing high-resolution images of agricultural fields to complement drone-based monitoring.

Integrate satellite data with ground-based sensor data to provide comprehensive coverage and insights into agricultural conditions on a larger scale.

- **IoT Devices and Connectivity:**

  Deploy IoT devices such as weather stations, soil moisture sensors, and GPS trackers to collect additional field data and track agricultural equipment.
  Utilize wireless communication protocols (e.g., Wi-Fi, LoRaWAN, cellular) to transmit data from sensors and IoT devices to the central monitoring system.

- **Central Monitoring and Analytics:**

  Establish a centralized monitoring system to aggregate, process, and analyze data from sensors, drones, satellite imagery, and IoT devices.
  Develop data analytics algorithms and machine learning models to extract actionable insights from the collected data, such as crop yield predictions, anomaly detection, and resource optimization recommendations.
  Implement a user-friendly interface for farmers and agricultural practitioners to access real-time monitoring data, analytics results, and decision support tools.

- **Automated Decision Support:**

  Provide automated decision support tools and recommendations to farmers based on real-time field data and analytics insights.
  Enable farmers to make informed decisions regarding irrigation scheduling, fertilizer application, pest control, and other agronomic practices to optimize crop management and resource usage.

- **Scalability and Adaptability:**

  Design the AAMS to be scalable and adaptable to different farm sizes, crops, and geographical locations.
  Ensure compatibility and interoperability with existing farm management systems and agricultural practices to facilitate seamless integration and adoption.

- **Environmental Sustainability:**

  Promote sustainable agricultural practices by optimizing resource usage, reducing chemical inputs, and minimizing environmental impact.
  Enable precision agriculture techniques such as variable rate application and targeted interventions based on site-specific data and analytics insights.

- **Collaboration and Stakeholder Engagement:**

  Foster collaboration between researchers, industry stakeholders, farmers, and policymakers to co-develop and implement the AAMS.
  Engage stakeholders throughout the design, testing, and deployment phases to ensure alignment with user needs and priorities.

- **Continuous Improvement and Innovation:**

  Establish mechanisms for continuous monitoring, evaluation, and improvement of the AAMS over time.
  Invest in research and development to explore emerging technologies and innovative solutions for enhancing the capabilities and effectiveness of the AAMS.

2.3 Literature Review Summary

The literature surrounding Autonomous Agricultural Monitoring Systems (AAMS) provides a rich landscape of research, innovations, and challenges aimed at revolutionizing farming practices. Here's a concise summary of the key themes and findings from the literature:

1. **Introduction to AAMS:**

The literature emphasizes the critical role of AAMS in modern agriculture, highlighting its potential to overcome the limitations of traditional monitoring methods and improve farming efficiency, productivity, and sustainability.

2. **Sensor Technologies:**

A significant portion of the literature focuses on advancements in sensor technologies, including soil moisture sensors, temperature sensors, spectral sensors, and weather stations.

Studies discuss the development of low-cost, wireless, and high-precision sensors suitable for integration into AAMS for real-time data collection and monitoring.

3. **Drone-Based Monitoring:**

Drone technology emerges as a powerful tool for aerial imaging, mapping, and monitoring of agricultural fields.

Research explores the use of drones equipped with various sensors and cameras to collect high-resolution imagery, assess crop health, detect anomalies, and monitor environmental conditions.

4. **Satellite Imagery Integration:**

Satellite imagery complements drone-based monitoring by providing broader spatial coverage and temporal consistency.

Literature discusses the integration of satellite data with ground-based sensor data to enhance the spatial and temporal resolution of AAMS, enabling comprehensive monitoring of large agricultural regions.

5. **Data Analytics and Decision Support:**

Data analytics techniques, including statistical analysis, machine learning, and geospatial analysis, play a crucial role in processing and analyzing agricultural data collected by AAMS.

Studies highlight the development of decision support tools and recommendation systems to assist farmers in making informed decisions about crop management practices, resource allocation, and risk mitigation strategies.

6. **Challenges and Opportunities:**

The literature identifies various challenges facing the development and implementation of AAMS, such as sensor calibration, data integration, interoperability, data privacy, and cybersecurity concerns.

However, there are also opportunities for collaboration, innovation, and policy support to address these challenges and advance the adoption of AAMS in agriculture.

7. **Future Directions:**

The literature concludes by highlighting the need for interdisciplinary collaboration, stakeholder engagement, and continuous innovation to realize the full potential of AAMS.

Future research directions include exploring emerging technologies, addressing technical challenges, and promoting adoption through education, outreach, and policy support.

3. PROBLEM FORMULATION

Introduction:

Agriculture is vital for global food security and sustainable development. However, traditional agricultural monitoring methods are often labor-intensive, time-consuming, and prone to inaccuracies.

The problem arises from the limitations of conventional approaches in providing real-time, comprehensive, and precise data for effective decision-making in farming practices.

Challenges with Traditional Methods:

- **Labor Intensive:**

  Manual monitoring techniques, such as visual inspections and periodic sampling, require significant labor and resources, making them impractical for large-scale or remote agricultural areas.

  Limited Precision: Traditional methods may fail to capture fine-scale variations in soil conditions, crop health, and environmental factors, leading to suboptimal management decisions.

  Time Consuming:

  Delays in data collection, analysis, and dissemination hinder timely interventions, increasing the risk of crop losses and reduced yields.

  Inefficient Resource Management: Without accurate and timely information on soil moisture, nutrient levels, and pest infestations, farmers may struggle to optimize resource usage, leading to environmental degradation and economic losses.

  Objective of AAMS:

  The primary objective of developing an Autonomous Agricultural Monitoring System (AAMS) is to address the limitations of traditional monitoring methods and provide farmers with automated, real-time monitoring capabilities.

AAMS aims to improve farming efficiency, productivity, and sustainability by offering accurate, comprehensive, and timely insights into soil conditions, crop health, and environmental factors.

- **Key Components of AAMS:**

  Sensor Network: Deploy a network of sensors to monitor soil moisture, temperature, humidity, nutrient levels, and pest infestations.

  Drone-Based Monitoring: Utilize drones equipped with cameras and multispectral sensors for aerial imaging and monitoring of agricultural fields.

- **Satellite Imagery Integration:**

  Integrate satellite data with ground-based sensor data to enhance spatial coverage and provide consistent monitoring over large agricultural regions.

  Data Analytics and Decision Support: Develop data analytics algorithms and decision support tools to process and analyze agricultural data, extract actionable insights, and assist farmers in making informed decisions.

Scope of AAMS:

The scope of AAMS encompasses the development, implementation, and deployment of an integrated monitoring system tailored to the needs of different crops, farming practices, and geographical regions.

AAMS should be scalable, adaptable, and user-friendly to accommodate the diverse requirements and technical expertise of farmers and agricultural practitioners.

4. OBJECTIVES

- **Crop Health Monitoring:** Implementing sensors and imaging technology to continuously monitor the health of crops, detecting issues like pests, diseases, and nutrient deficiencies.
- **Water Management:** Utilizing sensors to measure soil moisture levels and weather data to optimize irrigation schedules, ensuring efficient water usage and preventing both over- and under-watering.
- **Yield Prediction:** Developing algorithms based on historical data and real-time monitoring to predict crop yields, assisting farmers in making informed decisions regarding harvest planning and resource allocation.
- **Early Pest and Disease Detection:** Utilizing image recognition and AI algorithms to detect early signs of pests and diseases, enabling timely intervention to prevent crop damage and yield loss.
- **Weather Forecast Integration:** Integrating weather forecast data into the monitoring system to anticipate adverse weather conditions such as storms or frost, allowing farmers to take preventive measures to protect their crops.
- **Resource Optimization:** Analyzing data on soil quality, weather patterns, and crop health to optimize the use of fertilizers, pesticides, and other agricultural inputs, minimizing waste and environmental impact.
- **Remote Monitoring and Control:** Enabling farmers to remotely monitor and control agricultural equipment such as irrigation systems, drones, and robotic harvesters, increasing operational efficiency and reducing labor requirements.
- **Data Analytics and Decision Support:** Providing farmers with actionable insights through data analytics and visualization tools, empowering them to make informed decisions to improve productivity and profitability.
- **Integration with Farm Management Systems:** Integrating seamlessly with existing farm management software and databases to streamline data collection, analysis, and decision-making processes.

5. METHODOLOGY

The terms/materials used for this experiment are described for the sake of improving the readability of the proposed framework with clarity.

IoT Framework for Agriculture

The proposed system consists of interfacing the real-world data from storage media to cloud Database management system from where the request is sent to the Machine learning trained model as shown in Figure 2. The output of the module is one among 22 different crops for implementation as shown in Figure 3.

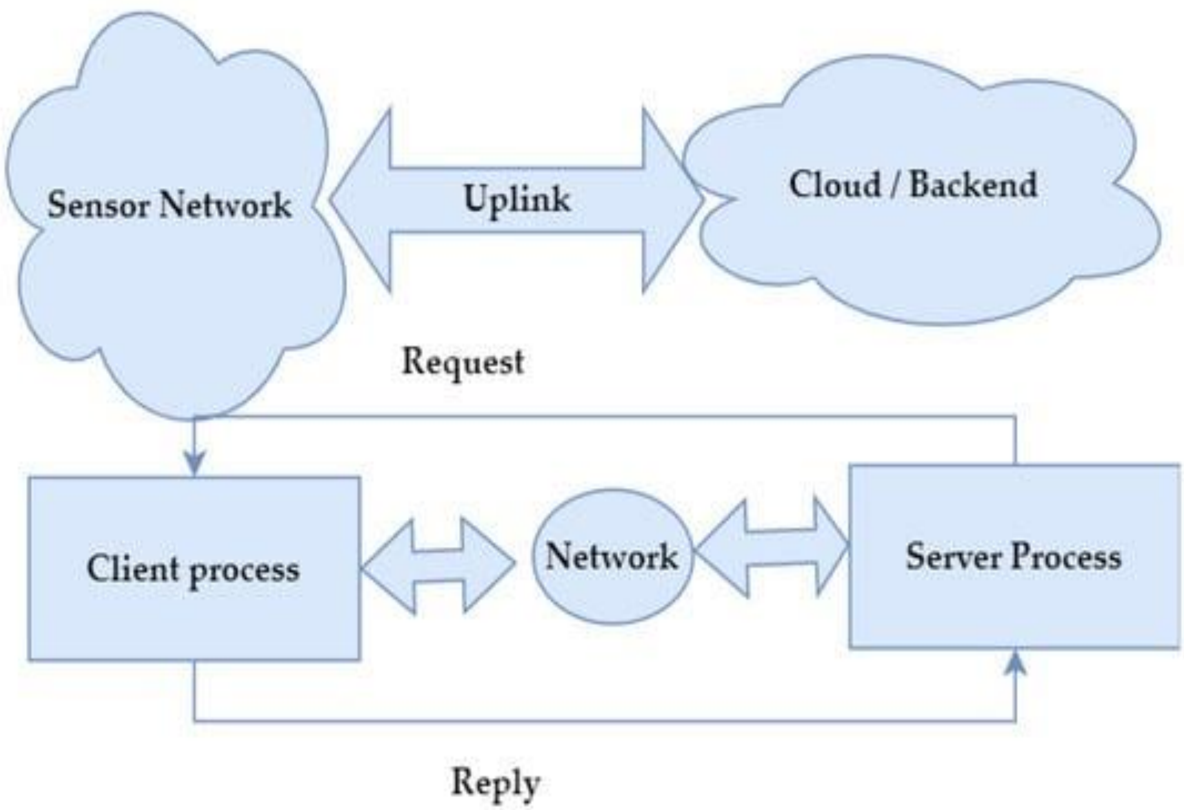

Figure 2. Proposed IoT Client-Server Model.

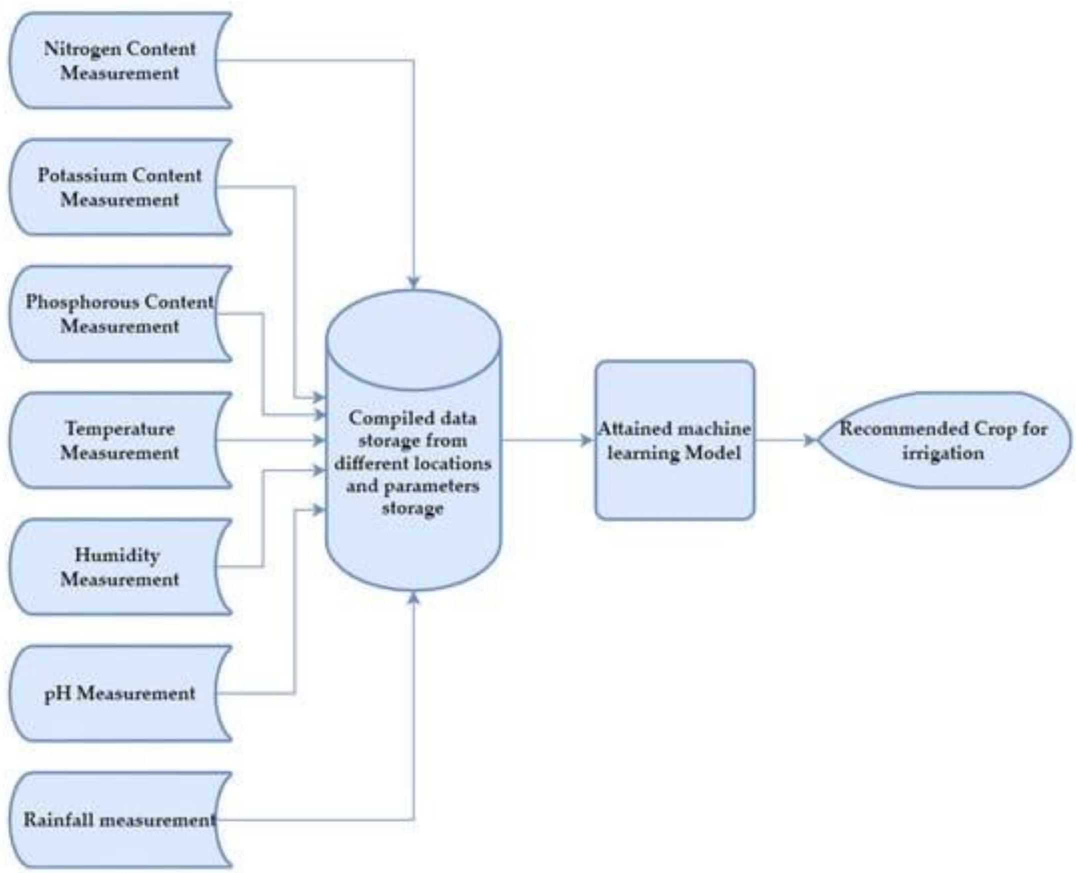

Figure 3. Block diagram using Machine learning Module.

Data capturing and communication utilities are enabled in the first level of architecture. The sensor network is linked with the gateway and the base station. In the second level, the classification specification and algorithm module are incorporated. The next level is implementing the ML algorithms to acquire the results from the server. The server has a trained module for getting the specific crop for irrigation. The parameters like Nitrogen, Phosphorous, Potassium, pH are measured using analytical sensors and stored in the module, Parameters like temperature, Humidity, and rainfall are measured using specific sensors and stored in the database. The compiled data is stored in a spreadsheet with the ground truth by having knowledge about the specified 22 different crops as shown in Figure 3. By training the module using a machine learning algorithm the attained model is ready to recommend the crop for the user for irrigation. Figure 4 shows flow procedure of IoT-based smart agriculture is possible by combining field Physical structure Data acquisition, Data processing, Data analytics for monitoring and control. The datasheet was acquired from Kaggle [33]. on a crop, the recommendation is taken for predicting the crop for irrigation and obtaining maximum yield.

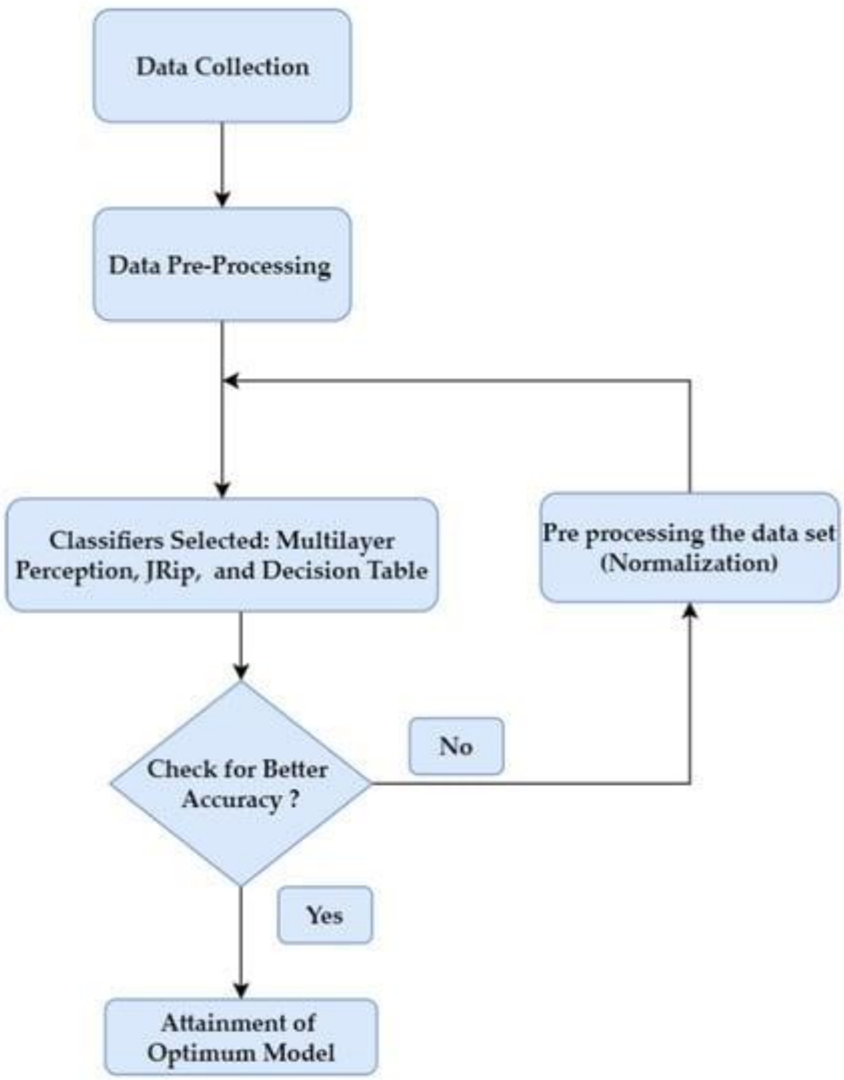

Figure 4. Modelling of crop recommended module set up.

Irrigation of crops depends on different environmental factors and soil fertility i.e., available nutrients present in the soil like nitrogen, phosphorous, and Humidity. The 7 attributes can decide a crop for irrigation so that maximum yield can be attained. This article can be used to make a strong decision making in planting different crops.

6. EXPERIMENTAL SETUP

An autonomous agricultural monitoring system can be established to continuously collect data on various environmental and crop health parameters. Here's a possible experimental setup:

Field Area: A designated field area representative of the target crop production.

Sensors:

- **Soil moisture sensors:** Regularly measure soil moisture content at various depths.
- **Temperature and humidity sensors:** Monitor ambient air temperature and humidity.
- **Light intensity sensors:** Track light levels throughout the day.
- **Imaging sensors (optional):** Cameras or spectral imaging devices can capture visual data of the crops for analysis of growth patterns, pest detection, and disease identification.

Data Acquisition System:

- **Microcontroller unit:** A central unit to collect data from all sensors and perform preliminary processing.
- **Wireless communication module:** Enables transmission of sensor data to a remote server for storage and analysis.

Software Platform:

- **Cloud-based server:** Stores sensor data securely and facilitates data visualization and analysis.
- **Data visualization tools:** Generate graphs, charts, and maps to represent collected environmental and crop health data.

- **Analytics software (optional):** Utilize machine learning algorithms to identify trends, predict potential problems, and generate automated recommendations for irrigation, pest control, or nutrient application.

7. CONCLUSION

In conclusion, IOT-enabled agriculture system is greatly beneficial to the farmers as it reduces the manpower and harmful chemicals fori ncreasing the amount of the crops. Proper design is necessary for the farming with the reduces complexities. All the data should be properly taking into count for the better agriculture. The sensor placement and the connectivity are a vital step. The data redundancy should not be there in order to meet the accurate results. The farmer should be skilled with some experience or prior knowledge otherwise it would take much time to switch him to the traditional form of thefarming.Nevertheless, the work herein represents a working prototype of a real system. For commercialization, some enhancement need to be considered. First, the use of camera with machine learning can improve detection accuracy of intruder without the help of farmer.

a smart module in recommending the crop for irrigation and obtaining maximum yield based on present environmental factors. This also serves as a guide for any unknown person who is in need of any crop recommendations than facing any trial basis error. The trending machine learning algorithm has helped us to build a model in the agriculture sector also using IoT and helping the farmers in deciding the best yield crop by just measuring the needy parameter like Nitrogen, Phosphorous, Potassium, Rainfall, Temperature, pH, and humidity. In near future, the agriculture sector will be converted into smart agriculture and will never face any decline in production, yield, and quality thereby the agriculture sector progress to AI, IoT-based Precision farming.

8. TENTATIVE CHAPTER PLAN FOR THE PROPOSED WORK

CHAPTER 1: INTRODUCTION

CHAPTER 2: LITERATURE REVIEW

CHAPTER 3: OBJECTIVE

CHAPTER 4: METHODOLOGIES

CHAPTER 5: EXPERIMENTAL SETUP

CHAPTER 6: CONCLUSION AND FUTURE SCOPE

9. REFERENCES

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