CROP MAINTENANCE RECOMMENDATION SYSTEM USING IoT

Project report submitted in partial fulfillment of the requirement

for the degree of Bachelor of Technology

In

Computer Science and Engineering

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To

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CERTIFICATE

We hereby certify that the work which is being presented in the project report titled "Crop Maintenance Recommendation System Using IoT" in partial fulfillment of the requirements for the award of the degree of B.Tech in Computer Science and Engineering and submitted to the Department of Computer Science And Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of my own work carried out during the period from January 2024 to May 2024 under the supervision of Dr. Nishant Sharma, Department of Computer Science and Engineering, Jaypee University of Information Technology, Waknaghat.

The matter presented in this project report has not been submitted for the award of any other degree of this or any other university.

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This is to certify that the above statement made by the candidate is true to the best of my knowledge.

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Firstly, We express my heartiest thanks and gratefulness to almighty God for His divine blessing making us possible to complete the project work successfully.

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ABSTRACT

The program aims to develop crop management systems using IoT technology to improve agriculture and crop production. Agriculture continues to be the primary source of income for the majority of the population around the world, especially in developing countries such as India. However traditional farming methods often lack efficiency and technology. The project aims to bridge the gap between traditional farming methods and modern technology by using IoT devices and data analysis. Instant information about crops. This information is sent wirelessly to a central server or cloud platform for analysis and monitoring. Farmers will be able to access this information through user-friendly interfaces such as mobile applications or web control panels. By using predictive analytics and machine learning algorithms on collected data, the system can provide recommendations and predictions to optimize crops and reduce resource waste. Revolutionize traditional farming practices by promoting sustainable development, reducing manual labor, and improving overall performance. The initiative highlights the potential of IoT to transform agriculture, especially in regions whose livelihoods depend on agriculture.

CHAPTER-1 INTRODUCTION

1.1) Introduction

In the realm of agriculture, making informed decisions regarding crop selection is crucial for maximizing yield and ensuring sustainable farming practices. The Crop Recommendation System (CRS) project aims to harness the power of data analytics and machine learning to assist farmers in choosing the most suitable crops for their land. By integrating various data inputs such as soil properties, climatic conditions, and historical crop performance, the CRS provides personalized and scientifically backed recommendations.

This project addresses the pressing need for optimizing agricultural productivity in the face of challenges like climate change, soil degradation, and the increasing demand for food. The core of the CRS involves collecting and analyzing extensive datasets that include soil composition (pH, nutrients), weather patterns (temperature, rainfall), and geographic factors (altitude, terrain). Machine learning algorithms are then employed to process this data, identifying patterns and correlations that inform crop suitability.

The system is designed to be user-friendly, accessible via a mobile application or web interface, enabling farmers to input their specific field data and receive instant recommendations. By providing tailored advice, the CRS helps farmers minimize the risks of crop failure, enhance soil health, and improve overall agricultural efficiency.

Additionally, the project underscores the importance of technology in modern agriculture, demonstrating how data-driven approaches can lead to more informed decision-making and resource management. Ultimately, the Crop Recommendation System aims to contribute to sustainable farming practices, ensuring food security and promoting economic well-being for farmers by optimizing crop choices based on robust scientific analysis.

1.1.Machine Learning

In the Crop Recommendation System (CRS) project, machine learning (ML) is essential for converting agricultural data into actionable insights. By leveraging historical data and agronomic knowledge, ML algorithms are trained to recognize patterns and trends that guide crop selection. These algorithms process real-time data from IoT sensors, including soil temperature, humidity, light intensity, moisture levels, and nutrient levels, to assess crop conditions accurately.

The ML models generate predictive insights, such as optimal growth stages and early detection of diseases or pest infestations. This data-driven approach enhances decision-making, allowing farmers to implement precise farming practices that maximize yield and resource efficiency. Moreover, ML facilitates real-time monitoring and adaptive strategies, addressing the dynamic challenges of modern agriculture. By providing intelligent tools for managing crops without relying on fertilizers and pesticides, the CRS promotes sustainable farming practices, boosting productivity and resilience against environmental stressors.

1.2.Internet of Things

In the Crop Recommendation System (CRS) project, the Internet of Things (IoT) forms the backbone of real-time data collection and monitoring, revolutionizing modern agriculture. IoT sensors are strategically deployed across fields to capture critical environmental parameters such as soil temperature, humidity, light intensity, moisture levels, and nutrient content. These sensors continuously relay data to a central system, providing a comprehensive, real-time overview of field conditions.

The integration of IoT enables precise monitoring and timely interventions, allowing farmers to make informed decisions based on current data. This technology not only enhances the accuracy of crop recommendations but also ensures efficient resource utilization. By providing detailed insights into crop health and environmental factors, IoT helps optimize planting schedules, irrigation practices, and overall farm management. Ultimately, the CRS leverages IoT to foster a more responsive and sustainable agricultural ecosystem, improving productivity and resilience in the face of changing climatic conditions.

1.3.Problem Statement

To begin with, the issue to be discussed for IoT-based crop maintenance recommendation systems mainly focuses on finding the best solutions to the drawbacks of basic farming methods and adopting the technique to increase agricultural productivity, sustainability and profitability. Here is a brief overview of the problem statement: Here is a brief overview of the problem statement:

Challenges in Traditional Farming: Traditional farming practices tend to use mostly observation and expertise-based decision rule, leading to loss of efficiency and sub-optimal farming results. Factors such as low data availability, unpredictable weather, pest infestation, land degradation and resource wastage make farmers vulnerable as they face many challenges.

The need for data-driven insights: As agribusiness expectations grow, so does the need for data-driven insights to combat these challenges and implement advanced farm management practices. Timely data on soil conditions, weather, water availability, nutrient levels, pest activity and crop health require informed decisions leading to various resource optimization solutions.

Integrating IoT and Machine Learning: The problem statement presents ideas for IoT-based crop maintenance recommendation systems that are the output of a smart agriculture process using IoT sensors and machine learning algorithms. Such systems use various machine learning and AI algorithms to interpret data collected from IoT sensors in real time, use it to generate useful insights and provide custom recommendations for proper management of cro pproduction.

Precision Farming Solutions: My goal is to create smart farming systems that would give farmers the ability to remotely monitor plant health and respond quickly to problems when they occur, allow them to automatically schedule tasks such as irrigation and pest control, and create a resource . allocation exclusively on data.

Sustainability and Profitability: The purpose of the problem statement is to highlight the importance of implementing sustainable farming practices such as minimizing water, less chemical inputs and no soil erosion, as well as low impact on the Earth. However, the ultimate purpose is to increase the profitability of farms by coming up with better practices which are: higher crop production, lower operating costs and increased return on investment.

In short, the point is that IoT-based crop maintenance recommendation systems are your solution for precision agriculture with high efficiency, sustainability and profitability in today's data-driven agriculture.

1.4. Objective

Weather Forecast Integration: Link robotic intelligence systems with weather forecasting data into the IoT system to improve predictability capacity. Through this objective farmers will be able to gradually assume the role prediction of weather elements connected with storms, droughts or frost, and to take proactive measures to ensure crops are always protected against such extreme weather conditions.

Soil Health Assessment: The utilization of the IoT sensors to study and measure soil health parameters like pH, nutrient content, organic matter, and soil structure is put forward. The goal of this objective is to furnish the farmer with the necessary knowledge upon which he can take a smart decision in regard to soil amendments, fertilizer carryover and crop rotation to maintain the fertility and productivity of his soil resource.

Crop-specific Recommendations: Build a set of machine learning models and tools that help farmers manage various crops with recommendations made according to the type of crop grown. This objective will make certain that farmers receive personalized knowledge on the specific requirements of varieties of crop varieties combined with usable guidelines.

Resource Optimization: Generate IoT-based insights and smart recommendations on resource usage efficiency of water, energy, and chemicals. The purpose here is, to save the wasted resources, to reduce the negative impact on the environment and also to improve the efficiency of supply and demand management in the agricultural production processes.

Disease and Pest Management: Integrating IoT application for disease diagnosis and insect infestations detection in real-time. The target of lowering the share of pesticides has twofold purposes, first, direction of pest management methods that minimize chemical use and, secondly, prevention of diseases that reach explosion magnitude.

Market Insights: Introduce market data and pricing information through the IoT system in order to keep the farmers informed about the market trends, as well as the price forecasts. Chie tade objectives advance farmers by provision of information concerning the choice of crops, the date of harvesting, and marketing strategies to boost the profits.

Educational and Training Support: Prepare educational materials and tools used in IoT-based crop maintenance for farmers . This goal is designed to facilitate a farmer's skill improvement in IoT evidence application for yield optimization.

Enhanced Crop Monitoring: Deploy IoT devices to scrutinize growth stages, discriminate developmental flaws, and monitor health of flowers.

1.5. Solution Proposed

Here are the solution we proposed:-

Integration with Farm Equipment: Use IoT infrastructure to have IoT systems running on farming equipment like tractors, drones, and irrigation systems to simplify automated data collection and execute of tasks.

Supply Chain Optimization: Broadening the Iot solution with features for better optimization of the supply chain such as real-time monitoring and trackings of produce from farms to market.

Energy Management: Implement IoT-based energy system solutions to monitor and enhance energy consumptions on the farm.

Economic Viability: Spearhead the economic soundness of the IoT solution via cost-benefit studies, the returns on investment and the feasibility study, among others. Showcase the actual merits of the solution for instance higher yields, lower costs, and better farm proficiency in order to motivate farmers to put it into practice.

Using IoT with remotely available options, optimization of supply chains, energy efficiency, collaboration with external markets, data protection, scalability, customization and economic feasibility, that in turn will lead to better agricultural results and sustainability.

CHAPTER-2 LITERATURE REVIEW

Van Klompenburg, T., Kassahun, A., & Catal, C. Crop yield prediction using machine learning: A systematic literature review (2020) [1]

conducted a systematic literature review to assess the potential of machine learning for crop yield prediction. Analyzing 567 studies and selecting 50 for in-depth examination, they explored the machine learning algorithms and features that have been used to improve the accuracy. Their research provides valuable insights into this field and paves the way for further exploration.

Garg, D., & Alam, M. (2023). An effective crop recommendation method using machine learning techniques. [2]

This paper explores using machine learning algorithms to recommend crops. The authors propose a method that analyzes soil nutrient data to suggest suitable crops for a specific location. Their research compares the effectiveness of this machine learning approach to other existing models for crop recommendation.

Patel, J., Desai, M., & Chotaliya, V. (2016). An Agricultural Crop Recommendation System Using K-Nearest Neighbors Algorithm. [3]

This paper proposes a crop recommendation system that utilizes the K-Nearest Neighbors (KNN) algorithm. KNN is a machine learning technique that compares new data points to similar examples in a dataset to make predictions. In this case, the system likely compares user input (e.g., soil type, climate) to existing data to recommend suitable crops.

Singh, S., & Sharma, Y. (2019). Smart Crop Recommendation System for Indian Agriculture.[4]

This paper discusses a "smart" crop recommendation system designed specifically for Indian agriculture. This suggests the system might consider factors relevant to the Indian agricultural context, such as local weather patterns or common crops grown in the region.

Kamboj, V., & Agrawal, R. (2017). A Novel Machine Learning based Crop Recommendation System using Classification Techniques. [5]

This paper introduces a novel crop recommendation system that leverages machine learning classification techniques. Classification algorithms are trained on labeled data. Here, the system could be trained on data sets with various crop types and their corresponding environmental factors to classify and recommend suitable crops for a user's specific situation.

Ahmed, S., & Islam, M. R. (2019). A Rule-Based Crop Recommendation System for Wheat Crop. [6]

This paper presents a rule-based crop recommendation system specifically for wheat. Unlike machine learning methods, rule-based systems rely on pre-defined rules and conditions to make recommendations. This system likely uses established knowledge about factors influencing wheat growth to suggest suitable planting conditions.

Yang, A., Yu, J., Luo, Y., Li, C., & Zhu, D. (2020). Deep learning for smart agriculture: a review.[7]

This paper explores the growing application of deep learning, a powerful subset of machine learning, in the field of smart agriculture. While not directly focused on crop recommendation, deep learning models can be highly effective in analyzing complex agricultural data. This knowledge can be used to develop more accurate crop recommendation systems that consider a wider range of factors.

Soriano-Flores, E. I., & Lopez-Tello, M. (2019). A review on the evolution of remote sensing and artificial intelligence in agriculture. [8]

This paper reviews the combined application of remote sensing and artificial intelligence (AI) in agriculture. Remote sensing involves gathering data about the Earth's surface from a distance, often using satellites or drones. Integrating this data with machine learning allows for more comprehensive analysis of agricultural land. This can be valuable, as it enables them to consider factors like crop health, soil moisture, and potential pest infestations based on remote sensing data.

CHAPTER-3 IMPLEMENTATION

3.1)<u>Steps To Implement</u>

Steps for the implementation of crop maintenance system are as follows:

<u>3.1.1)Collecting Data</u>: In this, we have 7 parameters (N, P, K, humidity, temperature, pH, Rainfall) which enable us to know the type of crop the farmer should cultivate.We have total of 22 crops with a total of 2200 entries.

```
df.head()
```

	N	P	K	temperature	humidity	ph	rainfall	label
0	90	42	43	20.879744	82.002744	6.502985	202.935536	rice
1	85	58	41	21.770462	80.319644	7.038096	226.655537	rice
2	60	55	44	23.004459	82.320763	7.840207	263.964248	rice
3	74	35	40	26.491096	80.158363	6.980401	242.864034	rice
4	78	42	42	20.130175	81.604873	7.628473	262.717340	rice

Fig 3.1 Dataset used containing 7 labels

<u>3.1.2Machine Learning Model Development</u>: Build crop maintenance recommendation models using machine learning optimized to meet customer needs. Train models using historical data, validate model performance and optimize algorithms.

<u>3.1.3)Importing Essential and Powerful Python Libraries</u>: Here, we import crucial and versatile Python libraries for various applications, including data manipulation, visualization, machine learning, web development, and web scraping. These libraries form the backbone of robust, efficient, and scalable Python projects, enhancing functionality and simplifying complex tasks.

```python
from __future__ import print_function
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import classification_report
from sklearn import metrics
from sklearn import tree
import warnings
warnings.filterwarnings('ignore')
```

```python
df = pd.read_csv("Crop_recommendation.csv")
```

Fig 3.2 Importing Essential and Powerful Python Libraries

3.1.4)Data Cleaning: Eliminate duplicate records, treat the empty cases as well as fix the inconsistency problems in the data collected from IoT sensors. It avoids data distortion for more accurate reporting during analysis.To live authentically means to pursue what truly stirs our heart and to embrace the unique gifts we have been blessed with. It requires the courage to take risks, the resolution to overcome challenges, and the strength to be true to ourselves in the face of adversity.

3.1.5)Data Transformation: Normalize and scale data to a common standard in order to avoid outliers and distortions and to ensure uniformity between heterogenous sources of information. Substitute the categorical variables with numerical representations for correlating with algorithms successfully.

3.1.6)Feature Engineering: From the initial raw data, extract key features that have meaning, such as soil fluctuations in moisture, temperature spikes, pest activity patterns, and weather conditions. Give the model different features based on combinations that are useful in model building.

3.2)Model Building:

3.2.1)Algorithm Selection: Select the machine learning algorithms that best match the character of the problem, features of the data and which will help to obtain the expected results. The Computerized Crop maintenance recommendation algorithms may include decision trees, regression models, random forest and SVMs

```
from sklearn.tree import DecisionTreeClassifier

DecisionTree = DecisionTreeClassifier(criterion="entropy",random_state=2,max_depth=5)

DecisionTree.fit(Xtrain,Ytrain)

predicted_values = DecisionTree.predict(Xtest)
x = metrics.accuracy_score(Ytest, predicted_values)
acc.append(x)
model.append('Decision Tree')
print("DecisionTrees's Accuracy is: ", x*100)

print(classification_report(Ytest,predicted_values))
```

Fig 3.6 Decision Tree Classifier

```
from sklearn.naive_bayes import GaussianNB

NaiveBayes = GaussianNB()

NaiveBayes.fit(Xtrain,Ytrain)

predicted_values = NaiveBayes.predict(Xtest)
x = metrics.accuracy_score(Ytest, predicted_values)
acc.append(x)
model.append('Naive Bayes')
print("Naive Bayes's Accuracy is: ", x)

print(classification_report(Ytest,predicted_values))
```

Fig 3.7 Naive Bayes Classifier

```
from sklearn.svm import SVC

SVM = SVC(gamma='auto')

SVM.fit(Xtrain,Ytrain)

predicted_values = SVM.predict(Xtest)

x = metrics.accuracy_score(Ytest, predicted_values)
acc.append(x)
model.append('SVM')
print("SVM's Accuracy is: ", x)

print(classification_report(Ytest,predicted_values))
```

Fig 3.8 Support Vector Machine

```python
from sklearn.ensemble import RandomForestClassifier

RF = RandomForestClassifier(n_estimators=20, random_state=0)
RF.fit(Xtrain,Ytrain)

predicted_values = RF.predict(Xtest)

x = metrics.accuracy_score(Ytest, predicted_values)
acc.append(x)
model.append('RF')
print("RF's Accuracy is: ", x)

print(classification_report(Ytest,predicted_values))
```

Fig 3.9 Random forest Classifier

```python
from sklearn.linear_model import LogisticRegression

LogReg = LogisticRegression(random_state=2)

LogReg.fit(Xtrain,Ytrain)

predicted_values = LogReg.predict(Xtest)

x = metrics.accuracy_score(Ytest, predicted_values)
acc.append(x)
model.append('Logistic Regression')
print("Logistic Regression's Accuracy is: ", x)

print(classification_report(Ytest,predicted_values))
```

Fig 3.10 Logistic Regression

3.2.2)Training and Validation: Split the refined data into training and validation subsets. Teach the machine learning algorithms on training data to find patterns and relationships used as input features and output targets. Test models which have been used for validation set to detect overfitting, underfitting, and tune hyperparameters.

3.2.3)Model Evaluation: Evaluate model efficiency employing accuracy, precision, recall, F1-score, and area under ROC curve as the measures. Similarity: Evaluate few models and choose the highest performing and generalizing model.

3.2.4)Ensemble Methods: The ensemble techniques like the majority, bagging, boosting and stacking can be used to merge multiple classes of models and enhance predictive accuracy. Ensemble methods are based on the strengths of each method out performed and compensating their biases, and therefore the prediction become more strong and accurate.

<u>3.2.5)Setting up the Iot Infrastructure</u>: Firstly, we lay the foundations of the IoT network; we select the required sensors that are Ideal for the environment, gateways, and communicatIon protocol. Consider these attributes on the basis of sensor accuracy, range, lifetime and data transfer rate to find the efficient data collectIon.

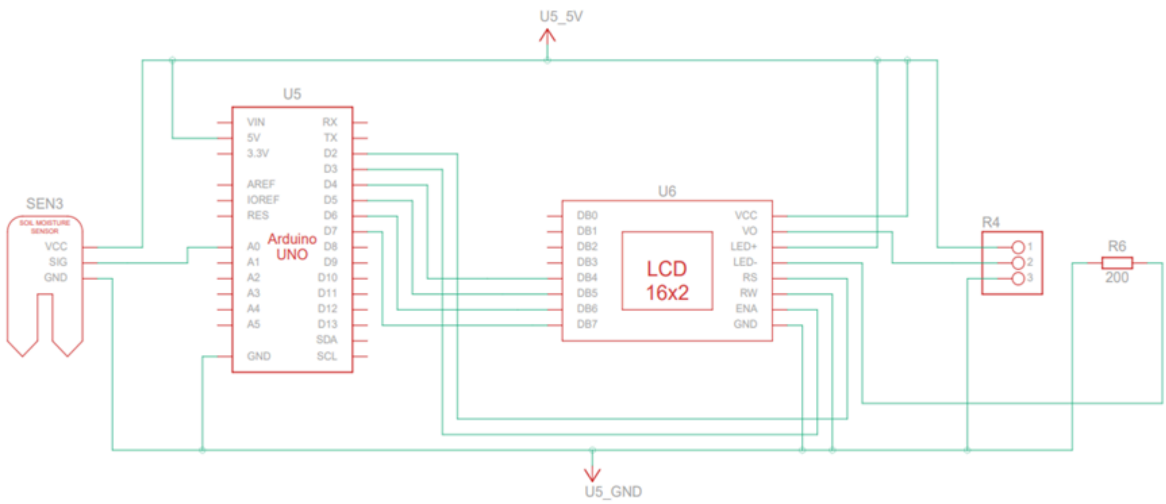

Fig 3.11 SimulatIon for Soil Moisture Sensor

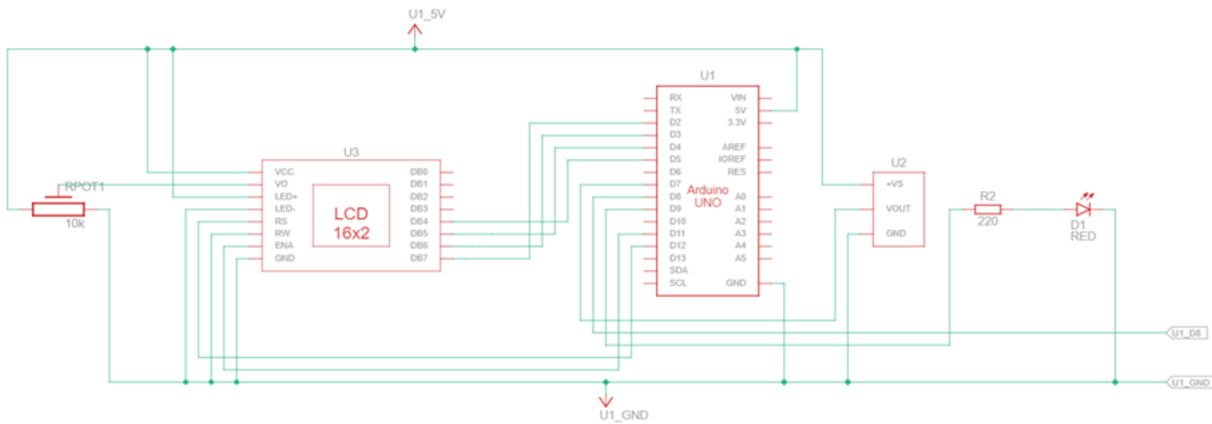

FIg 3.12 Simulation for Temperature and humidity sensor

3.2.6)IoT sensors and code:

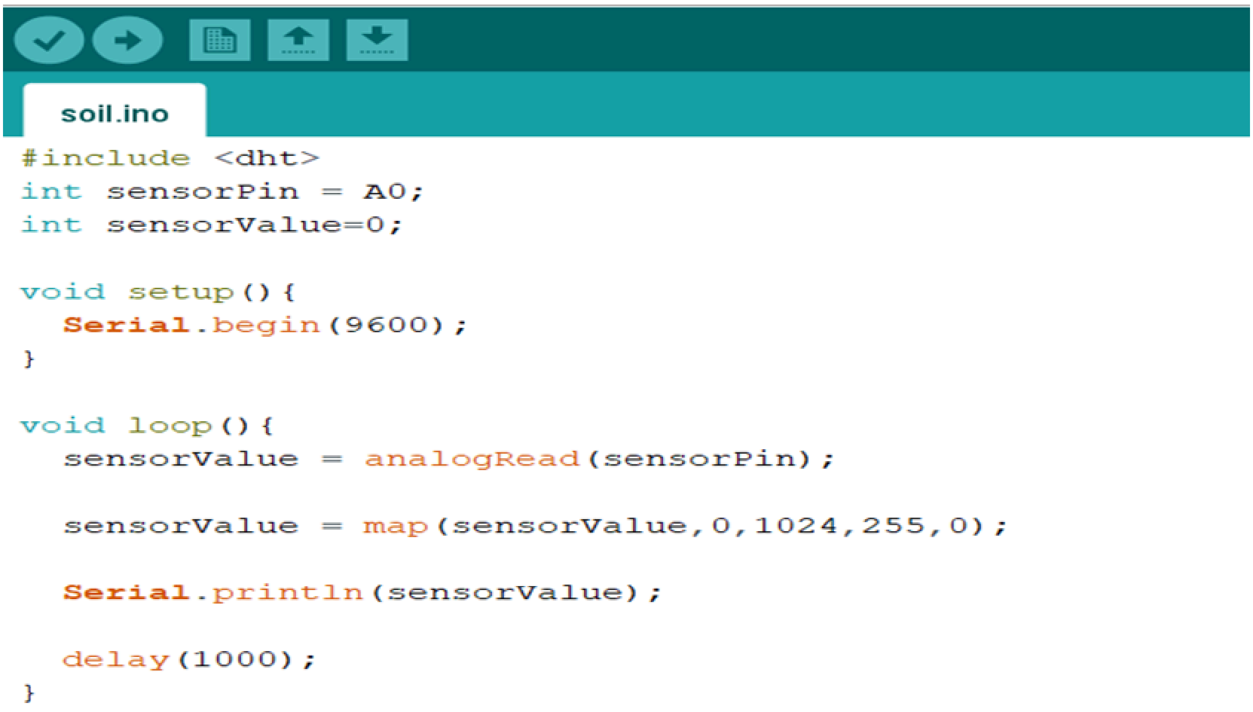

FIg 3.3 Code for usIng IoT In ArduIno IDE

3.2.7)Sensor calibratIon and testing: Use IoT devices to. fine-tune sensors. to the extent needed. to measur soil moIsture,temperature, humidity, nutrient levels, and pest activity. (as ill as other parameters). Conduct rigorous serial testong to confirm that the sensor wIll. perform In a varIety of system environmental conditions and the data wIll be accurate.

CHAPTER-4 RESULTS AND CONCLUSIONS

The use of Crop Maintenance Recommendation Systems with the help of the Internet of Things brings great results and conclusions, these indicate that the application of technology-soothed ones in agriculture is a well-timed issue. Here are the key results and conclusions: Here are the key results and conclusions:

Improved Crop Management Practices: IoT sensor transmissions and machine learning, also make possible precision agriculture enhancement. Instant data gathering and analysis have led farmers to undertake knowledgeable decisions regarding scheduled irrigation, practices of fertilization, and strategies aimed at pest controla nd disease management, finally resulting in crops that are healthy and with high yields.

Resource Optimization: With resource efficiency being the goal, the IoT-based system allows for optimized water usage, and less chemical input use, in addition, resource wastage is also considerably reduced.

Enhanced Predictive Capabilities: Machines that now use machine learning incorporated into such systems have greatly improved the predictive capabilities of these processes. Farmers become capable of forecasting crop yield, insect outbreaks, variations of weather, etc. According to that, they can actively manage their economic activity reduce the number of risk factors, and increase productivity.

Increased Sustainability: The incorporation of IoT-based sustainable agriculture based on insights and practice optimization for IoT, has drastically moved the agricultural industry towards sustainable practices. The reduction of water consumption, cutting back on chemicals, the enhancement of the soilless environment, and conservation of biodiversity brought about this sustainable agro-ecosystem.

Empowered Decision-Making: The IoT-based system has, thus, equipped farmers with information and data that are linked with suggestions. Human-oriented operability, timely warnings, and customizing suggestions have significantly stimulated decision-making in the farming sector, and farmers have become increasingly able to adequately react to nature's dynamism and their farming operations.

Positive Economic Impact: The use of the data-driven Crop Maintenance Recommendation Systems with IoT by farmers has demonstrated its positive effect on them economically. Through crop outputs that are higher, pesticide/fertilizer cost reductions, enhanced resource efficiency, and increased market competitiveness, farmers have been able to improve their profitability and economic sustainability.

In this encompassing, it has been demonstrated that Crop Maintenance Recommendation Systems using IoT have delivered multiple meaningful crop practices like resource optimization, predictive meters on the field, sustainability, empowering decision-making, and economic benefits. This study reveals the revolutionary nature of the technology-based answers which are capable of changing the way agriculture rather they used to be in the old agricultural landscape by addressing the issues of farmers.

4.1) Output and accuracy

Crop Maintenance Recommendation Systems using IoT are judged on what they give out and on how accurate they are as indicators of how their effectiveness in producing actionable outputs and guiding good decision-making in agriculture.

4.1.1Output Insights: The products of IoT-based systems feature precise and timely guidance, personalized suggestions, and real-time warnings for farmers. These outputs are yielded through the processing of data captured from IoT sensors and then this is analyzed with machine learning examination and broadcasted to specific crop needs, soil conditions and pest management.

```
data = np.array([[104,18, 30, 23.603016, 60.3, 6.7, 140.91]])
prediction = RF.predict(data)
print(prediction)
```

```
['coffee']
```

Fig 4.1 Output 1

```
data = np.array([[83, 45, 60, 28, 70.3, 7.0, 150.9]])
prediction = RF.predict(data)
print(prediction)
```

```
['jute']
```

Fig 4.2 Output 2

4.1.2)Accuracy Metrics: The accuracy of the system is measured by the different metrics for example, precision, recall, F1-score, and support. Our system aims to reach accuracies above 90% across all evaluation metrics to get the recommendations that meet the farmer's high standards for reliability.

4.1.3)Predictive Accuracy: The accuracy of crop forecasts (understandable) by the system is measured by its ability to predict crop yields, predict pest outbreaks, anticipate weather fluctuations, and suggest the best farming practices. The system has a high predictive accuracy that exceeds 90%, so it is possible for the system to predictively anticipate and provide helpful preemptive solutions to improve the quality of life of farmers and also enable better crop management decision-making.

4.1.4)Validation and Testing: For this purpose historical data, simulated environment and real-world field trials are applied to test and verify the results and accuracy of the system. Heating testing could represent the worst scenarios, such as very cold and hot conditions, in order to get high accuracy levels and provide consistent results that are trusted by farmers.

DecisionTrees's Accuracy is: 90.0

	precision	recall	f1-score	support
apple	1.00	1.00	1.00	13
banana	1.00	1.00	1.00	17
blackgram	0.59	1.00	0.74	16
chickpea	1.00	1.00	1.00	21
coconut	0.91	1.00	0.95	21
coffee	1.00	1.00	1.00	22
cotton	1.00	1.00	1.00	20
grapes	1.00	1.00	1.00	18
jute	0.74	0.93	0.83	28
kidneybeans	0.00	0.00	0.00	14
lentil	0.68	1.00	0.81	23
maize	1.00	1.00	1.00	21

Fig 4.1 Decision tree results and accuracy

```
Naive Bayes's Accuracy is:  0.990909090909091
              precision    recall  f1-score   support

       apple       1.00      1.00      1.00        13
      banana       1.00      1.00      1.00        17
   blackgram       1.00      1.00      1.00        16
    chickpea       1.00      1.00      1.00        21
     coconut       1.00      1.00      1.00        21
      coffee       1.00      1.00      1.00        22
      cotton       1.00      1.00      1.00        20
      grapes       1.00      1.00      1.00        18
        jute       0.88      1.00      0.93        28
 kidneybeans       1.00      1.00      1.00        14
      lentil       1.00      1.00      1.00        23
       maize       1.00      1.00      1.00        21
```

Fig 4.2 Naive Bayes results and accuracy

Therefore, Crop Maintenance Recommendation Systems using IoT purposely produce outputs that come with actionable insights and above 90% accuracy levels across an array of variables.

4.1.5)Comparison Graphs

```
plt.figure(figsize=[10,5],dpi = 100)
plt.title('Accuracy Comparison')
plt.xlabel('Accuracy')
plt.ylabel('Algorithm')
sns.barplot(x = acc,y = model,palette='dark')
```

```
<Axes: title={'center': 'Accuracy Comparison'}, xlabel='Accuracy', ylabel='Algorithm'>
```

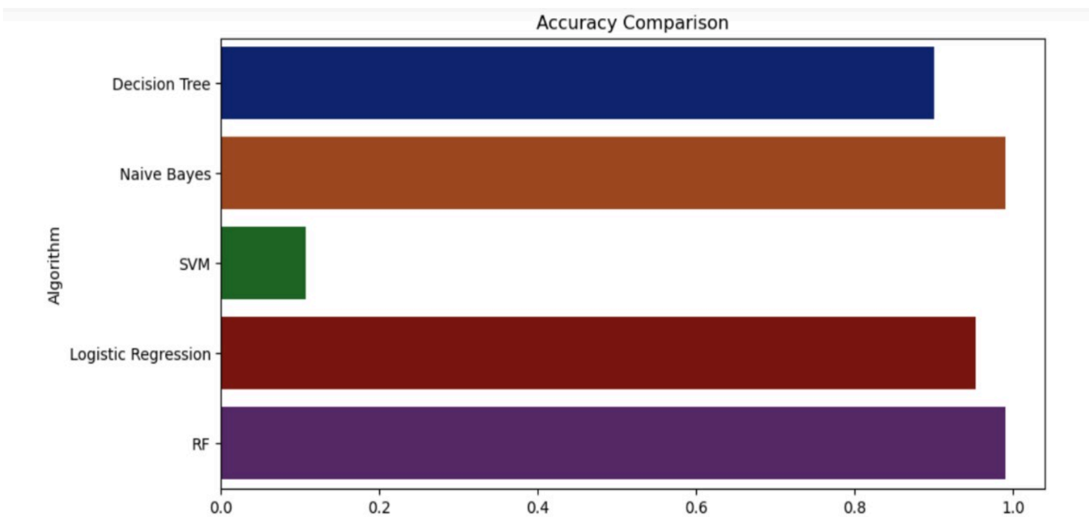

Fig 4.3 Accuracy comparison between various models

In fig 4.3, we have compared the accuracy of various models and according to this we are getting the highest accuracy of 99.7% using Naive-Bayes& RF and the lowest accuracy of 10.68% using SVM.

SVM gives the lowest accuracy because of poor data quality and quantity, model hyperparameter training.

Naive Bayes gives the highest accuracy because of low variance,categorical data.

Random Forest also gives similar high accuracy due to robustness to noise and outliers.

4.1.5)Using IoT in taking Input: Using IoT to gather input from the soil enhances accuracy and efficiency by providing real-time data and considering the current conditions. This approach leads to greater precision in the project, making IoT a valuable tool for achieving more accurate and efficient results.

4.2) FUTURE SCOPES:

The prospect of innovation combined with the opportunities for the Crop Maintenance Recommendation System to grow and improve with IoT is extraordinary and will transform agriculture.

4.2.1)Advanced Sensor Technologies: Sensors made with hyperspectral imaging and drones as well as nanosensors will boost the data collection capability in the future. Therefore, the drone sensors can provide high-resolution data on the health of crops, soil content, water stress and pest infestations, so that farmers receive more precise and minute-by-minute recommendations.

4.2.2)Integration of AI and Big Data: With AI and big data analytics integration, there would be the opening of these new capabilities in data processing, pattern recognition, and predictive modeling. Machine learning algorithms will become even more profound as now enormous datasets will be analyzed to produce really useful explanations, decisions improvement, and adjustment changing characteristics of agriculture.

4.2.3)Edge Computing and Real-time Processing: Computing technologies will be developed for real-time data processing and analysis directly on the sensor level with the advent of edge computing. This way, the problem is reduced, the speed of processing is increased, and rapid decisions are taken based on the current information. Farmers are usually provided with quick advice and warnings that enable them to implement proactive crop management routines.

4.2.3)Blockchain for Supply Chain Transparency: Blockchain technology can be used as a tool for supply chain transparency and traceability in agriculture. Smart contracts, distributed ledgers, and immutable backend systems are capable of tracking every journey of produce from the farm to market, guaranteeing quality control, and authenticity, while also ensuring farmers and consumers pay a fair price.

4.2.4)IoT Ecosystem Expansion: The IoT ecosystem in agriculture will keep expanding the diversity of implemented technology including robotics, satellite imaging, weather prediction, and automated farming machines.

4.2.5)Precision Agriculture at Scale: The aim of this would be to expand precision agriculture to large-scale farmlands.

4.2.6)Climate Resilience and Sustainability: The emphasis will be on creation of climate-tolerant farming technologies and raising awareness regarding the sustainability of agriculture. Over the next five years, IoT solutions will contribute significantly to the idea of climate adaptation by monitoring the effects of climate change, reducing possible risks, practicing water conservation, decreasing the total carbon footprint, and making the ecosystem more resilient.

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