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AI-Powered Disease Detection and Growth Monitoring System Using IoT for Improved Tomato Yield

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Abstract: This project introduces an advanced AI- powered disease detection and growth monitoring system designed specifically for enhancing tomato yield. With Internet of Things (IoT) technology, the system integrates Raspberry Pi as the central processing unit with temperature and humidity sensors for environmental monitoring. AI algorithms are used to predict tomato ripening stages and detect diseases, to ensure proactive management of plant health. If a disease is identified, the system provides the solutions to control its impact, thereby enhancing yield and quality. The captured data is analysed and results are displayed on a user-friendly webpage accessible to farmers, enabling informed decision-making and improved agricultural practices. This innovative approach combines technology with agricultural expertise, offering a solution to the challenges faced by tomato farmers and contributing to sustainable tomato production. ***Keywords: Image Recognition, Disease Detection.***

I. INTRODUCTION

Tomato cultivation is a vital component of global agriculture, yet it faces consistent challenges such as disease outbreaks and suboptimal monitoring methods. This project introduces a novel solution integrating AI and IoT technologies to address these challenges. By utilizing Raspberry Pi and environmental sensors, the system provides real-time data on temperature, humidity, and other crucial factors affecting tomato growth. The integration of AI algorithms enables accurate prediction of tomato ripening stages and detection of diseases. Through a user-friendly webpage interface, farmers gain access to insights and solutions for the tomato crop conditions. This proactive approach aims to maximize tomato yield, improve quality, and contribute to sustainable agricultural methods.

A. *Data Science*

Data science is an interdisciplinary domain that uses scientific methods, statistics, processes, and algorithms to extract knowledge and insights from structured and unstructured data, and apply solutions from data across a broad range of application domains.

B. *Artificial Intelligence*

Artificial intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think like humans and mimic their actions. The term may also be applied to any machine that a human mind such as learning and problem-solving. AI encompasses various subfields, including machine learning (ML) and deep learning, which allow systems to learn and adapt in novel ways from training data.

II. SYSTEM ARCHITECTURE

Develop an integrated IoT-based agriculture management system for tomato fields. Research and generate disease detection algorithms for tomato. Implement automated pest control systems triggered by disease detection. Deploy IoT-enabled monitoring systems for remote crop health monitoring. Develop decision support tools for tomato farming based on sensor data and disease detection.

1) *Dataset Collection:* Gather a large dataset of images containing healthy plants and plants with various diseases. Ensure that the images are denoted with bounding boxes around the diseased areas.

2) *Data Preprocessing:* Resize the images to a fixed size required for the YOLOv8 model and normalize the pixel values to a range between 0 and 1
3) *Model Configuration:* Configure the YOLOv8 model architecture for your specific task. YOLOv8 is typically based on the Darknet framework and can be customized based on the number of classes (disease types) you want to detect.
4) *Training:* Train the YOLOv8 model on the dataset using a deep learning framework such as PyTorch or TensorFlow. This process involves feeding the images into the model, adjusting the model's weights based on the error (loss) calculated between the predicted bounding boxes and the ground truth bounding boxes.
5) *Validation:* Validate the trained model on a different separate dataset to evaluate its performance. Adjust the parameters and training strategies as needed to improve the model's accuracy.
6) *Inference:* Once the model is trained and validated, you can use it for inference on new images to detect the plant diseases. The trained model will output bounding boxes and class labels for the detected disease.

III. LITERATURE SURVEY

Pests and diseases pose a significant threat to global food supply and availability, affecting various crops. Traditional inspection methods are not practical for large plantations, making it difficult for crop production. Smart agricultural methods, including vision-based artificial intelligence (AI) and machine learning (ML) solutions, are deployed for disease and pest control. This study conducts a systematic literature review, referring 176 studies from major academic databases. Hyperspectral imagery and vision-centred approaches are commonly used for crops like grapes, rice, apples, etc. Support Vector Machines and Logistic regression classifiers show increased accuracy. Challenges include disease localization and the lack of standardized model performance assessment. The need for models with fewer parameters and broad datasets is emphasized [1]. This study introduces a robust algorithm using RGB-D cameras to detect fruit-bearing branches in tomato clusters within large, irregular groves. It employs Deeplabv3 for segmentation, removing non-fruit-bearing twigs through pre-processing. Non-parametric spatial clustering identifies fruit-bearing branches, and principal component analysis determines their locations. Experimental results using 452 RGB-D image pairs show an 83.33% detection accuracy, 17.29◦±24.57◦ positioning accuracy, and 0.464s execution time for a single branch determination. Field tests confirm the method's effectiveness in guiding robots through continuous picking tasks [2]. This study presents a compact convolutional neural network (CNN) with six layers for early detection and intervention of tomato diseases. The network, trained on Plant village's dataset, outperforms pre- trained ImageNet models, demonstrating that complex architectures are unnecessary. Data augmentation enhances the proposed network's performance, achieving 99.70% accuracy, 98.49% F1 score, 98.31% true positive rate, and 99.81% true negative rate on 9,077 test images. Results surpass or match state-of-the-art deep neural network approaches using the Plant Village database, highlighting the cost-effectiveness of the proposed architecture for superior tomato disease identification [3]. Tomato ripening in greenhouses involves distinct stages. This paper proposes an Arduino-based algorithm for monitoring tomato ripening using an image-processing system. The algorithm predicts and displays the ripening process based on colour changes in tomatoes. Images are processed using MATLAB to calculate the mean Lab colour space values, which are then sent to an Arduino microcontroller. The microcontroller communicates the tomato colour information via a GSM module to inform the farmer and send an email to a specific address [4].

IV. EXISTING METHOD

The existing model monitors various ripening growth stages of the tomato using simple Arduino based system which will predict and display the complete process according to the colour changes in tomato. Using the acquired image captured by USB camera, the mean of colour space values of tomato processed by the MATLAB and information sent to the Arduino microcontroller serially, which tells the colour of the tomato and the message informing about the colour of the tomato to the farmer using GSM module as well as to desired mail-id.

V. PROPOSED METHOD

Our model proposes the monitoring of various ripening stages of the tomato using Artificial Intelligence with Raspberry PI based system which will monitor, predict and display the complete process according to the colour changes in tomato. Instead of normal USB camera, this model includes ESP32 camera which act has a AI camera which will be connected to a Raspberry PI. The monitoring of the growth stages is processed by Artificial Intelligence and powered by Machine learning algorithm and the data is sent to the raspberry pi, which tells the colour of tomato and the message informing colour of the tomato to the farmer through an interactive web application.

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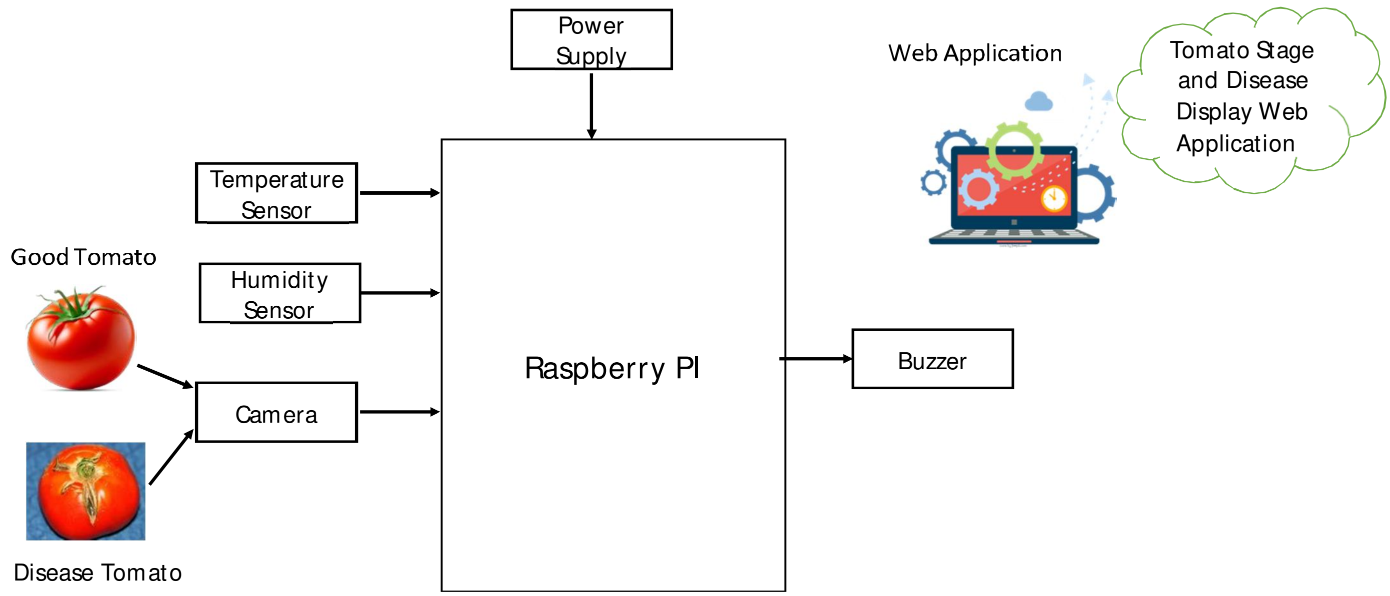
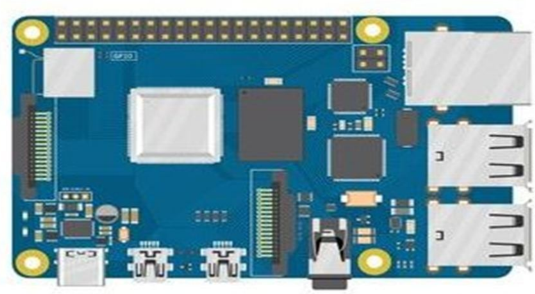
VI. BLOCK DIAGRAM



Fig[1]:Block Diagram for Disease Detection and Growth Stage Monitoring System.

VII. HARWARE REQUIREMENTS

1) *Raspberry PI:* Raspberry Pi-based system for growth stage monitoring and disease detection of the tomato. Leveraging Raspberry Pi's affordability, compact size, and customizable software, we integrate sensors like temperature, humidity sensors and machine learning algorithms. This scalable system offers real-time monitoring and remote access, promising significant advancements in agricultural technology.



Fig[2]:Raspberry PI

2) *Temperature Sensor:* Temperature sensors in our project play a vital role in growth stage monitoring and disease detection. They provide real-time data on environmental conditions critical for plant health. Fluctuations or anomalies in temperature can indicate disease presence, aiding in early intervention. Continuous monitoring and analysis ensure proactive management for optimal plant growth.

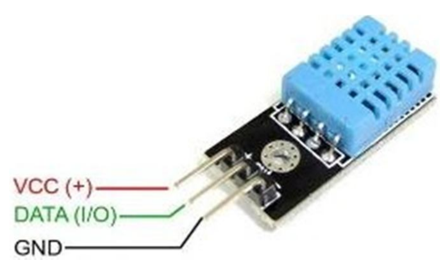


Fig [3]: Temperature sensor

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3) *Humidity Sensor:* Humidity sensors are pivotal in our project for growth stage monitoring and disease detection. They offer real-time insights into moisture levels crucial for plant health. Deviations from optimal humidity can signal potential disease risks, enabling proactive measures. Continuous monitoring and analysis empower effective management strategies for healthy plant growth
4) *PI Camera:* The Pi camera is an integral part of our project for growth stage monitoring and disease detection. It provides visual data essential for assessing plant health and growth progress. Image analysis algorithms detect anomalies or disease symptoms, enabling timely intervention. Continuous imaging enhances precision in monitoring, ensuring optimal plant management strategies.

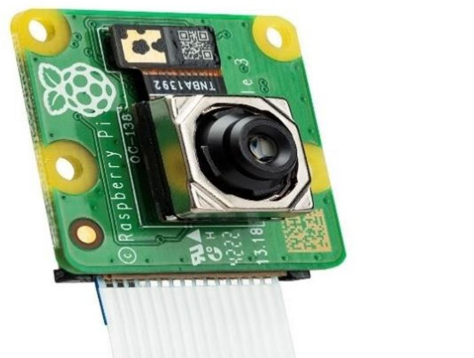

Fig [4]: PI Camera

VIII. SOFTWARE REQUIREMENTS

1) *Python Software (IDLE):* Python is utilized in our project for both growth stage detection and disease detection in tomato plants. For growth stage detection, Python scripts are developed to analyze environmental data collected from IoT sensors, such as temperature and humidity, using machine learning algorithms. These algorithms classify the growth stages of tomatoes based on the data patterns observed. Similarly, for disease detection, Python- based machine learning models are trained on labeled datasets to identify and classify diseases in tomato plants accurately.

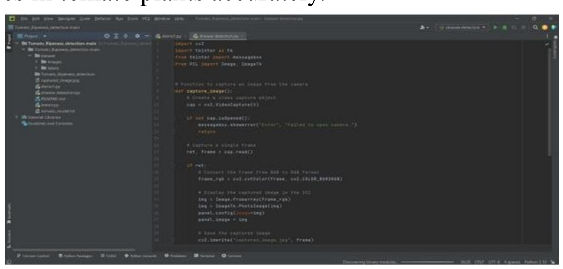

Fig [5]: Python Software (IDLE)

2) *Visual Studio (IDE):* Visual Studio as the IDE of choice, offering a comprehensive suite of features tailored for Full stack development. The integration of Django within Visual Studio streamlined the development workflow, providing a unified environment for both frontend and backend components.

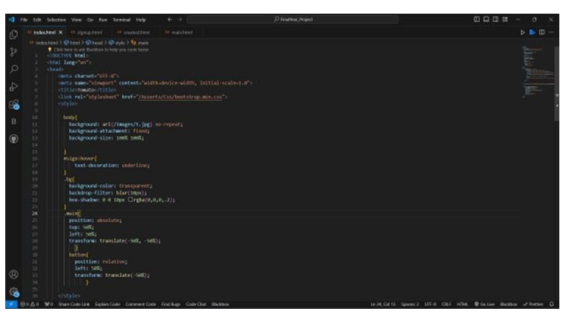

Fig [6]: Visual Studio User Interface (IDE)

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IX. EXPERMENTAL SETUP AND RESULTS

This System can describe the experimental setup used for validating the proposed Tomato Disease Detection and Growth Stage Monitoring. It can include details about the collection process and the performance used for evaluation. The section can present the results of the system in detecting overflow conditions. It can also perform the system with existing methods.

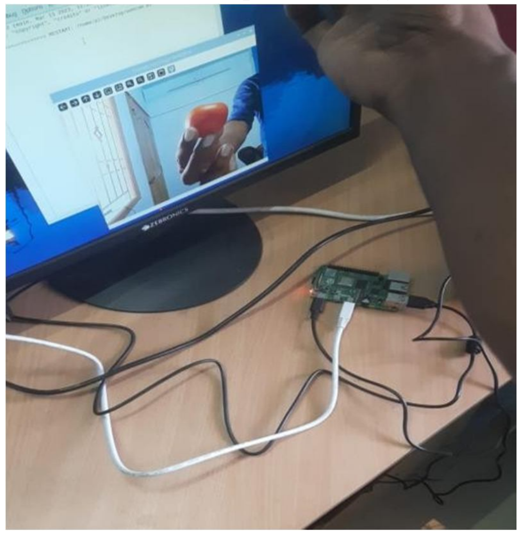

Fig [7]: Experiment Setup

This system demonstrated a high detection accuracy of over 96% and data transmission success rate was over 98% during the experiment.

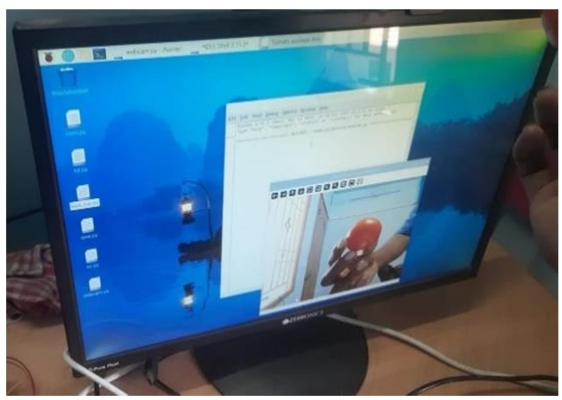

Fig [8]: Experimental Interface

Tomato Disease Detection

Date (IST)	Time (IST)	Temperature(°C)	Humidity(%)	Maturity	Disease
11-04-2024	16:58:28	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	16:58:52	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	16:59:35	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	16:59:51	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	17:00:07	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	17:00:34	34.98	78	Ripe	Bacterial-Spot
11-04-2024	17:01:00	34.98	78	Ripe	Bacterial-Spot
11-04-2024	17:01:15	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	17:01:41	34.98	78	Ripe	No Bacterial-Spot
11-04-2024	17:02:06	34.98	78	Ripe	No Bacterial-Spot

Fig [9]: Experimental Output

X. CONCLUSION

The technologies used in this system are AI and IoT that helps the farmers to grow tomatoes better by predicting when they're ripe based on color changes and Traditional methods cannot track individual tomatoes well, so this system uses camera and can observe color changes in tomatoes and figure out when they will ripe for harvesting and it can also spot any diseases that are affecting them by using this project, farmers can monitor their crops better, catch diseases early, and control pests and thus enhance the tomato yield.

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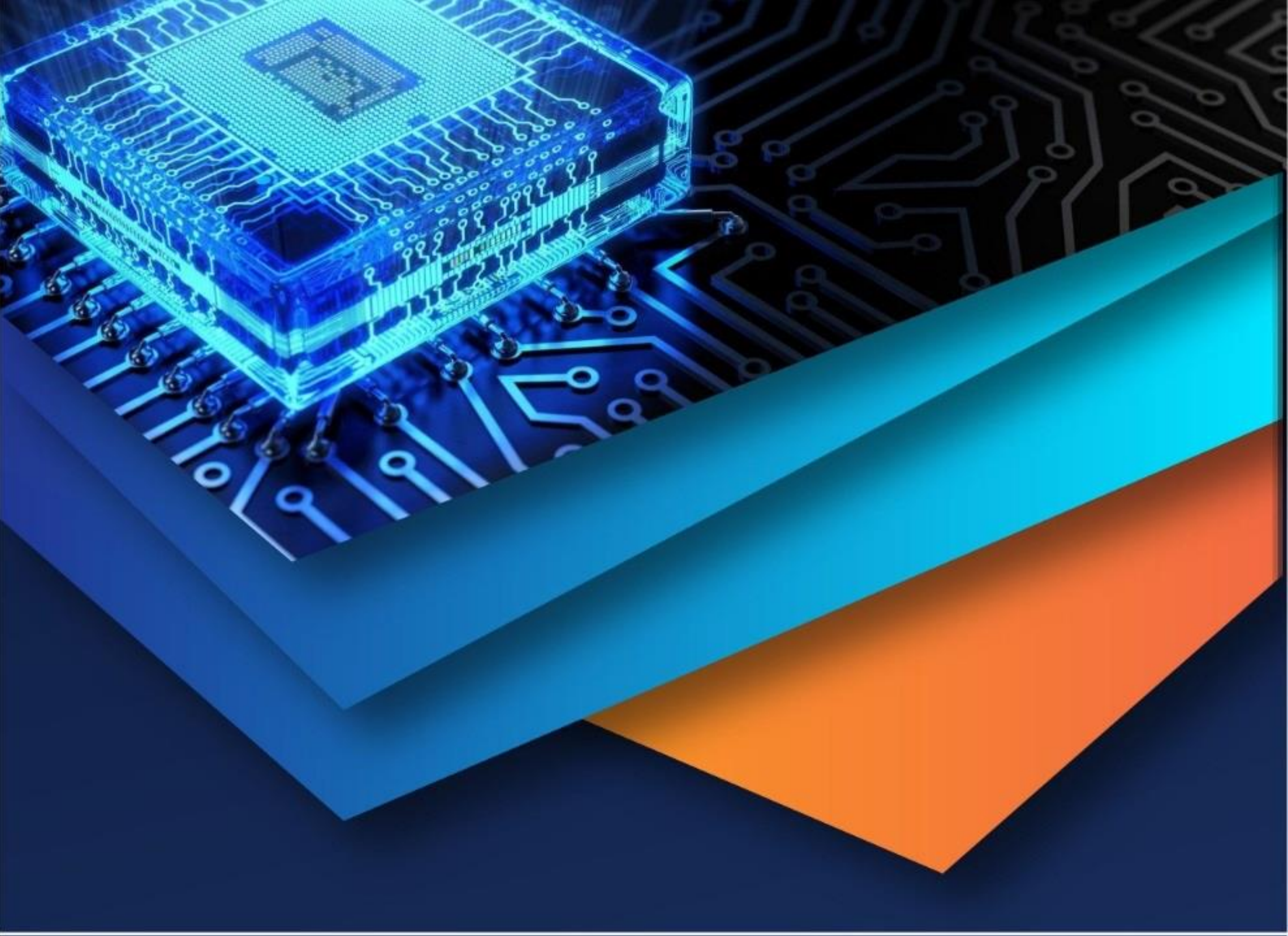

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