DYNAMIC CROP MODELING FOR SALAD CUCUMBERS USING BIOMASS AND IRRIGATION WEIGHTS AND VISUALS

PROJECT ID: 24-25J-307

PROJECT PROPOSAL REPORT

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BSC(HONS) DEGREE IN INFORMATION TECHNOLOGY SPECIALIZING IN DATA SCIENCE

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REAL-TIME IMAGE CAPTURING AND ANALYSIS BASED ON CROP GROWTH STAGES

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Declaration

We declare that this is our own work, and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Abstract

Agriculture is an important aspect in the farming industry, where crop management takes a crucial stand particularly to crops such as cucumbers. The following is a proposal of a new, real-time approach to the determination of growth stages of the cucumber, its defects and pests such as insects. As a result, instance segmentation plus high-performance cameras, time series analysis allows achieving high accuracy and flexibility of the betting system. These technologies include a method that enables specification of the growth stages of crops and detection of problems that may occur; something that is essential towards ensuring that the crops are healthy and capable of producing the maximum yields The present technologies are not sufficient to encompass all the aspects of plant growth that is why the proposed system contains the adaptive model. This adaptive capability fills the existing gaps in agricultural monitoring systems where real-time adaptability has been missing as well as the all-round growth modeling. Also, is the recommendation tool that gives real-time information and the best practices of farming. The rationale for creation of this tool is to support farmers by giving tools which can be accessed on behalf of the farmer with a simple form of operational interface such that farmers can act on the tips given. The objective of the system is also to enhance the yield and quality of crops while at the same time reducing the time spent in monitoring crops to diagnose the problems. Finally, it is the aim of the proposed system to help and support in the development of the new agricultural technology that must provide the continuous, versatile, and client-oriented data processing for the advanced farming needs.

Keywords: Crop management, agricultural monitoring, real-time analysis, client-oriented data processing

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List of Abbreviations

ABBREVIATION	DESCRIPTION
RGB MASKING	Red, Green, Blue
K-MEANS	Popular Clustering algorithm
KNN	K-Nearest Neighbors
CNN	Convolutional Neural Network
SVM	Support Vector Machine
ML	Machine Learning
R-CNN	Region-Based Convolutional Neural Networks
U- NET	Type of Convolutional Neural Network
LSTM	Long Short-Term Memory
CV	Computer Vision
AUC ROC	Area under the curve

Table 1: List of Abbreviations

1. Introduction

With rapidly evolving business environment in modern agriculture, providing protection to crops and achieving maximum yield are two primary goals that must be regularly solved to meet the global food requirements. Vegetable farming especially of cucumbers in a controlled environment such as in green houses has own unique challenges as requires a real time-controlled monitoring of growth phases as well as timely control of defects or pests that would lead to production losses.

Traditional growth measurement approaches that essentially focus on the environmental conditions ranging from the moisture content in the soil to the general temperature are usually inadequate and may not offer clear details on the general crop health and growth conditions. These techniques fail to point out issues such as growth abnormalities or signs of vices such as destructive insects, hence slow actions and maybe low yields.

There is a high possibility in the near future for monitoring of agriculture with the help of recent developments like advancement in machine learning and image processing. Through the use of these technologies, it becomes possible to design systems that apart from tracking the progression rate of crops also provide information that can significantly improve agricultural endeavors. The application of instance segmentation algorithms along with time series analysis helps in the identification of the growth stages and the early signs of plant disease and insects.

The proposed monitoring system is to be more sophisticated, real-time compared to the existing ones, which will be integral to cucumber farming. [3] Through harnessing the best technological innovations, the project has a vision that will help in increasing the efficiency of crop monitoring for better and efficient farming. This system clearly signifies a step change in precision agriculture with the ability to increase crop yield and quality in circumstances where decision taking is time-framed and requires accurate information.

2. Background and Literature Survey

The existing articles were reviewed, and three papers were chosen for comparison as a foundation for the development of the system to monitor and predict the Cucumber crop Growth stages and identify defects and pests. The first paper titled ‘Cucumber Fruits Detection in Greenhouses Based on Instance Segmentation’ deals with the issue of instance segmentation for detecting the cucumber fruits in greenhouses [1]. This technique is quite beneficial in the subject of computer vision and serves for object detection with high precision and determinacy of the object’s position within the image [2]. The findings of this particular research illustrate the feasibility of using instance segmentation for detecting cucumber fruits regardless of the instances where fruits may overlay each other or where parts thereof are obscured by the foliage [3]. This research is relevant to our work as it led to the development of a highly accurate and verified way of measuring particular stages of development of cucumber plant, which is necessary to monitor growth and breakthrough and to identify any deviations from standard trends.

The second paper titled “Design of Crop Growth Analysis Platform with Image and Time-Series Analysis” presents a complex solution based on image information to track crop growth [4]. It acquires and analyses huge amount of data from different sensors to make it possible to monitor and depict crop growth without interrupting the process.[5] This research focuses on the utilization of image assessment in combination with temporal data on crop evolution [6]. In the proposed system, time series analysis plays a big role in the prediction of subsequent growth stages and also in the identification of problems as they begin to develop, thus, increasing the system’s flexibility to changes in the crop’s environment [7].

Finally, the last paper entitled ‘Identification of Growth Stages of Crops Using Mobile Phone Images and Machine Learning’ examines use of mobile phone images and machine learning techniques to classify crop growth stages [8]. This goes to show that, thus provoking the use of labeled datasets for training machine learning models, the growth stage of a crop can be estimated from even relatively low-resolution images [9]. In light of this finding, the present study is well suited for making the following proposition, this proposal counts especially when it is taken into consideration that crop monitoring can be done using commonly available technology such as mobile phones [10]. This growing strategy raises the possibility that our system may be feasible to extend to client farmers who possibly can’t afford expensive imaging technologies.

Besides these reference sources, there are other literatures about the integration of these techniques into a single system. For example, the study of precision agriculture points out to the fact that there is a great need for monitoring systems capable of operating in real-time depending on changing environmental conditions and this is in consonance with our aim of pursuing the design of an adaptive monitoring system for cucumbers [11]. However, there are some classical works for target positioning and investigation of plant phenotyping, where growth stage prediction is a crucial factor influencing resource utilization and crop yields, and our studies are oriented to support these goals using more progressive machine learning algorithms [12]. Last but not the least, the latest research on computer vision for agriculture applications draw emphasis on instance segmentation in order to facilitate the automation of the tasks related to handling plant disorders and recognizing insects, which complements the objective of our system, namely defect identification [13].

3. Research Gap

The advancement in crop monitoring and analysis research has been studied extensively but there are still major shortcomings that have not been addressed well enough, including real-time observation, plant growth equations, and machine learning techniques. Such gaps indicate areas that have been addressed by existing solutions but require a more enhanced solution which this proposal seeks to provide for the cucumber crop.

3.1 Comprehensive Plant Growth Modeling:

Research [1]: Although, the work done on detecting cucumber fruits using instance segmentation successfully detects fruits at different stages of growth, they do not pay attention to the overall model of the plant which includes the health and size of the plant. This is the reason why the emphasis is made on the fruit only while other important stages of plant development, including the condition of leaves and the general plant's growing process, are not investigated enough.

Research [4]: The crop growth analysis platform is based on time-series analysis and image data with a lack of a unified model that is capable of capturing the entire growth process of the plant. Owing to the lack of a comprehensive growth model, explanations and forecasts are only partial with reference to the plant's health and growth.

Research [8]: This research could be considered to contribute to growth stage identification through the use of images on mobile phones fully, but it lacks a comprehensive analysis of plant growth especially in terms of plant health and size modeling. The use of such images additionally reduces the possibilities of correct representations of intricate growth patterns.

Proposed Solution: The system will also give comprehensive data on plant growth with appropriate representations of health and growth size. By incorporating the sophisticated features of machine learning algorithms with broader data feeds, the proposed solution will provide a better and more detailed picture of the plant's growth cycle.

3.2 Real-time Monitoring and Adaptation:

Research [1], [4], and [8]: Each of these studies fails to meet the need for real-time monitoring and adaptive learning within the crop growth monitoring systems. There is no real-time data integration that restricts the systems from adapting to changes in the plant environment or health status instantly.

Proposed Solution: The system we suggest will also have a live monitoring panel which will give an instant update but also will alter its forecasts and suggestions with new data feed. This adaptive capability is critical for ensuring the continuity of the farmer's relevant information and insights.

3.3 Integration of Defect and Insect Detection:

Research [1]: This study affords some integration of the detection of defects but none on the detection of insects and the combined effect of both on plant health. One of the main drawbacks of this system is that it fails to address and coordinate all the aspects which are associated with plants' health.

Research [4] and [8]: There is a complete absence of any integrated defect and insect detection in both these studies; the authors were occupied with other parameters of crop monitoring. This omission is a major drawback of the means of systematic identification of plant health since defects and insect pest infestations are quite frequent and often become pivotal problems in the sphere of agriculture.

Proposed Solution: In our system, both defects and insect detection will be incorporated into the plant health monitoring system. Utilizing picture-processing and artificial intelligence, the system will offer a superior understanding of the health of the plant and work to rectify the problem quickly.

3.4 Advanced Machine Learning Techniques:

Research [1]: While using instance segmentation for this study, it is limited when it comes to the use of machine learning for other essential elements like predictive analysis or instance learning.

Research [4] and [8]: The application of machine learning in these studies is insignificant or to some extent, and there is no or little focus on the latest methods such as deep learning, reinforcement learning or the combination of both. This hiatus hinders the possibility of advancement and development in the crop monitoring systems.

Proposed Solution: All the aspects of the system will employ state-of-art machine learning algorithms during the proposed research. This is not only instance segmentation but also more sophisticated models for growth prediction, defect and adaptive learning, hence providing a more efficient and reliable monitoring.

3.5 Instance Segmentation for Growth and Defect Modeling:

Research [1]: This work shows how the instance segmentation method can be used for identifying cucumber fruits but fails to apply it in other crucial areas for instance defect detection or even modeling of plant growth.

Research [4] and [8]: These works do not employ instance segmentation which, as shown in this work, could have helped improve the accuracy of the growth stage classification and the defect detection.

Proposed Solution: Our system will also improve the utilization of instance segmentation for growth stages, and defects and other harm causing insects. This approach is going to enhance the reliability of the monitoring system and at the same time deliver more details to the farmers that will enable them to take the right action.

By addressing these gaps, our research aims to advance the current state of agricultural technology, offering a more comprehensive, accurate, and real-time solution for cucumber crop monitoring and management.

The table below summarizes the identified gaps and how our research intends to address them.

Research Gap	Research [5]	Research [6]	Research [7]	Availability in Proposed Solution
Comprehensive Plant Growth Modeling	No	No	No	Full plant growth coverage, including health and size modeling.
Real-time Monitoring and Adaptation	No	Yes	No	Real-time monitoring dashboard with adaptive learning.
Integration of Defect and Insect Detection	No	No	No	Integrated defect and insect detection for overall plant health.
Advanced Machine Learning Techniques	No	No	No	Utilizes cutting-edge ML for growth and defect modeling.
Instance Segmentation for Growth and Defect Modeling	Yes	No	No	Enhanced segmentation for growth, defect, and insect detection.

Table 3.1: Research Gap

4. Research Problem

4.1 Problem Statement:

Cucumber cultivation suffers from common challenges such as proper monitoring of the crop growth stages and defects, harmful insect detections etc. Traditional techniques like manual inspection or simple automated systems do not have what it takes to cope with the demands of large-scale agriculture in modern times. This research addresses these limitations through the development of an automated comprehensive real-time monitoring system which utilizes advanced machine learning techniques such as instance segmentation to detect growth stages and defects furthermore, insect outbreaks in cucumber cultivation.

4.2 Issues to Address:

1) Real-Time Monitoring Deficiency: The current situation that demands a real-time monitoring of cucumber crop growth is that it cannot detect the right stage of its crop, or if there is a problem, solve it before it affects crop yield.
2) Inadequate Defect and Insect Detection: Present systems are inefficient in categorizing and identifying defects and insects on different stages of growth. Differences in the environmental characteristics and size and shape of the plants create difficulties that make accurate identification based on these methods very difficult.
3) Lack of Integrated Solutions: To date, crop growth monitoring, defect identification, insect identification are not in one system, which is a problem where farmers cannot make a decision in a short period of time.

4.3 Research Questions:

1) Which machine learning approaches could be used with most efficiency for real-time diagnostics of defects and insects in cucumber productions?
2) When can instance segmentation be used to accurately and in real-time evaluate the growth stage of cucumber crops?
3) What techniques are available that can be used to combine these steps with crop growth modeling to produce outputs that are understandable by farmers?

5. Objectives

5.1 Main Objective:

The main objective of this study is to create a sophisticated system of monitoring cucumber crops in real-time using modern machine learning algorithms for the modeling of plant growth, prediction of the growth stages, defects' detection, and identification of harmful insects. These insights will be provided through an easily understandable and accessible dashboard which will help farmers make the necessary changes to enhance farming and crop yields as well as quality.

5.2 Specific Objectives:

1. **Development of a Comprehensive Plant Growth Modeling System:**

Objective: For the construction of an elaborate model, which has to describe all stages of cucumber plants' development, the study of their conditions, and measuring plants' sizes. This will design a network that will require the data from the image sensors and the environment will need to be integrated in order to be able to provide a complete picture of the growth of the plants.

2. **Accurate Growth Stage Prediction Using Advanced Machine Learning:**

Objective: For example, the use of; Deep learning and reinforcement learning to probably estimate the growth stages of cucumber plants incidence so that corrections and farming can be done on time and efficiently.

3. **Integration of Defect and Insect Detection into the Monitoring System:**

Objective: For the development of new sophisticated techniques for image segmentation and detection of the defects and the dangerous insects during the plant health monitoring in real-time fashion.

4. **Design and Implementation of a Real-time Monitoring Dashboard:**

Objective: One must design a friendly interface through which one can display the present growth rate, the overall health of the cucumber plants and any form of disease that may impact on them. In aiding farmers to make decisions there shall be predictions, defects to be retrained and actions to be taken on the farmers dashboard.

5. **Validation and Testing of the Overall System:**

Objective: At least for the purpose of growth modeling and prediction or for the identification of subsets of the constructed model mentioned above or even for checking that the subset or the complete model that is designed by the researcher works efficiently and yields the accurate results in real farm environment.

These objectives are to address the main concerns on monitoring and managing the cucumber crop and is aimed to be a solution that is comprehensive and deep, that uses most modern techniques in machine learning and real-time analytics.

6. Methodology

6.1 Overall System Description:

The proposed system is intended to supply a fully functional, near-real-time system that addresses the problem statement by offering a complete suite of data-aware predictive tools, including the complete plant growth modeling, growth stage prediction, defect and insect detection, and precision farming advisement. This methodology clearly shows the progressive process of the research, indicating how each of the systems will help in the achievement of the set objectives.

6.2 System Components and Workflow:

6.2.1 Data Collection:

Objective: To capture sequential images of the cucumber plant from different orientations to ensure complete study.

Method: Install image sensors of a high resolution in the domains where cucumber plants are cultivated in the greenhouses. These sensors will take images after a certain number of intervals to have good coverage of plant lifecycle.

Equipment Required:

- Multispectral image sensors.
- A stable system that will enhance the storage of the image data for big volumes of data.

Time Frame: The collection of image data at regular time intervals during the operational life cycle of the plant.

6.2.2 Data Preprocessing:

Objective: To perform feature extraction on raw images enhancing them for subsequent analysis to reduce excessive noise, sharpen the image and extract the features of interest.

Method: As part of image preprocessing, apply techniques such as smoothing or filtering to reduce the amount of noise and contrast stretching to make images as clear as possible and have the same tone in the database. Execute segmentation algorithms to separate the 'significant' parts of a plant from its background such as leaves, stems, and even spots with possible defects.

Tools and Software:

- Software such as Open CV or MATLAB for processing the images through noise reduction and segmentation.
- Python libraries for automatic data preprocessing for some applications like scikit-image.

6.2.3 Feature Extraction:

Objective: To define feature extraction for the preprocessed images that may act as input data for machine learning models.

Method: Purchase and use the right software including texture analysis, edge detection, and shape analysis to extract features concerning the plant health, growth stages, and other defects.

Tools and Software: Modules such as scikit-learn, TensorFlow or PyTorch in Python in order to develop feature extraction algorithms.

6.2.4 Machine Learning Model Development:

Objective: The extracted features to be processed with state-of-art machine learning algorithms for precise identification of growth stages, feature defects, and insects.

Method:

Growth Stage Classification: Develop a machine learning classifier for example, Support Vector Machine or Random Forest for the growth stages of cucumber plants according to the features extracted. Employ transfer learning features with pre-trained CNNs since they are more accurate compared to other approaches in stages classification.

Defect and Insect Detection: Build advanced models such as CNN and other specific models also based on annotated dataset for detecting the defects and identifying the dangerous insects and combine these with the growth stage classifier for a detailed check. Time-Series Analysis: Construct a type of this model like LSTM (Long Short-Term Memory) networks to forecast the growth trend and make a prognosis for the future and make a prognosis of potential problems based on the history data.

Tools and Software:

- TensorFlow, Keras, or PyTorch for the creation and training of the models of machine learning.
- Hardware resources in the form of cloud computing to support the scalability of the models to be trained and the large volume of processing to be done.

6.2.5 Model Evaluation and Validation:

Objective: To make the models converged and robust and capable to generalize on unseen data.

Method: Perform k-fold cross validation and grid search for the best hyper parameters for the model. For evaluating the models, the following parameters also can be used; the accuracy score, precision, recall or sensitivity, F1 score and AUC ROC curves to check how efficient the models are in determining the growth stage and the presence of defect.

6.2.6 Real-time Dashboard Implementation:

Objective: To give farmers an easy to understand and use-friendly interface that displays information derived from machine learning algorithms.

Method: Construct an effective web-based interface that will be able to collect all the output data from the models, such as the growth stage, defective parts' detection, and insects' identification. Ensure use of tools for live data visualization to display recommendations to the farmers and the best course of action to take, within the shortest time possible.

Tools and Software:

- Technologies behind web interfaces development such as for instance React or Angular for the frontend.
- D3 data representation libraries. js or Plotly for the construction of dynamic charts and graphs.

6.7.7 Validation and Testing:

Objective: In order to verify its efficiency and stability under various conditions to guarantee that it works perfectly in practice.

Method: Intensive testing of the proposed models performing data cross-validation and models identification, greenhouse field testing as well as user acceptance testing with core-farmers. From these tests, feedback must be obtained for the purpose of modifying the models in a bid to enhance the entire functionality of the system.

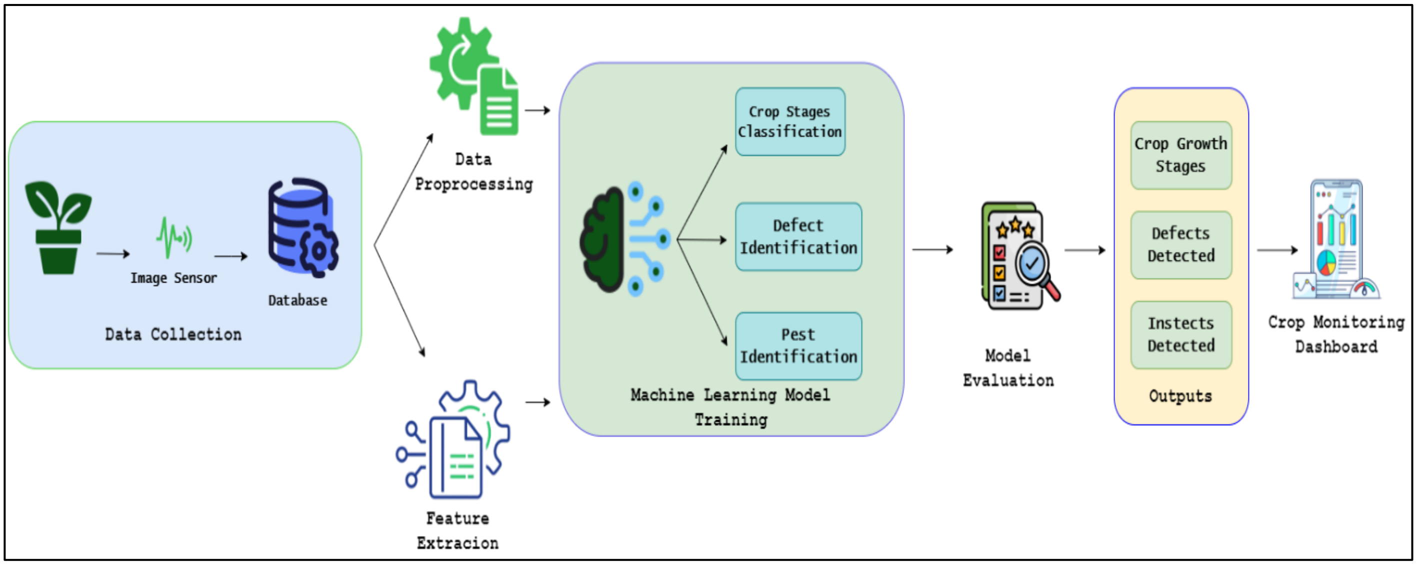

Table 6.1: System Diagram for Image Capturing based on Crop Growth Stages

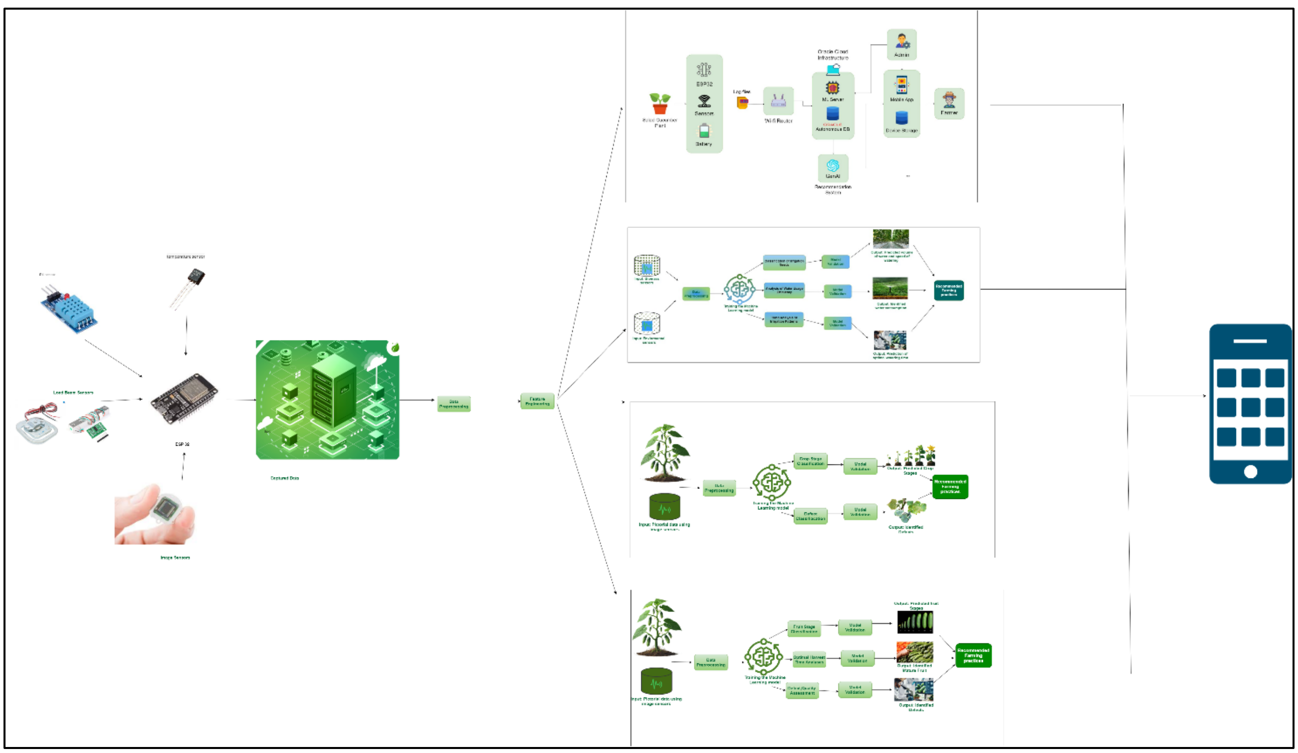

Table 6.2: Overall System Diagram

7. Project Requirements

7.1 Functional Requirements:

7.1.1 Real-time Image Capturing: The actual images of the cucumber plant should be constantly captured by the high-resolution sensors of the system. The captured images should be displayed at a remote location as well as be processed at a central server.

7.1.2 Data Preprocessing: It is important to possess image processing to clear image noises and make the result clearer. Segmentation should be applied to isolate different parts of the plant to accommodate the requirements of the precise analysis.

7.1.3 Growth Stage Monitoring: It was expected that the instance segmentation would be able to correctly differentiate the growth stages of the cucumber plants. Predictions made in the growth stage should be real-time.

7.1.4 Defect and Insect Detection: Defects in the plants and any form of hazardous insect should be recognized and categorized by the system. There should be the creation of alerts to the prespecified anomalies and suggestions for actions that should be taken.

7.1.5 Dashboard Interface: The system should offer a user interface that enables the user to monitor crop progression, defects, and infestation in real-time. The dashboard should have the capacity to store and display the historical data together with its reports.

7.2 Non-Functional Requirements:

7.2.1 Scalability: The system should also be expandable in order that it extends its monitoring to other plants or different crop types. It should be able to accommodate a huge amount of image data.

7.2.2 Accuracy: It is expected that the growth stage classification models and the defect detection models be very accurate, preferably at rates higher than 90%. There is a need to conduct the validity check regularly and revise the model in order to avoid a decline in its effectiveness.

7.2.3 Real-time Performance: The flow of images through the system has to be seamless and the online dashboard updated almost instantaneously. Any discovered signals should be promptly signaled.

7.2.4 Security: Information exchanged between sensors and a central server should be in an encrypted format. The access to the dashboard should only be permitted to the users in accordance with their credentials.

7.3 Expected Test Cases:

1. **Image Capture and Transmission:** Thoroughly examine whether the system provides the ability for taking and transmitting images depending on various conditions such as lighting, weather etc.
2. **Data Preprocessing:** Ensure that some of the preprocessing algorithms used improve image quality and that the segmentation of plant features is as accurate as possible.
3. **Growth Stage Classification:** Verify the effectiveness of the instance segmentation model in providing accurate state-of-the-art growth stages of the cucumber plants.
4. **Defect and Insect Detection:** Establish the efficiency of the system in the identification of basic plant vices and other damaging insects.
5. **Dashboard Functionality:** Make sure the data collected is updated in real-time and shown accurately in the dashboard with the least interference with the end-users.

8. Ability of Commercialization and Potential for Entrepreneurship

In the field of agricultural technology, the capacity to bring a research project to commercial production is often the key factor in its viability. The proposed system has potential for commercialization because the system focuses on monitoring and analyzing the cucumber crop in real time.

8.1 Market Need and Consumer Value

It has become apparent that modern agriculture can no longer rely on manual analysis of the farming state, and thus the concept of precision farming and automated monitoring systems emerge. [1] The advantages derived by users of the components of our system in terms of crop growth stages, estimated future growth, and signs of defect or presence of sinister insect include the following: They are better decisions, less loss of crops, and optimization of resource utilization. The result is the prepared user-friendly dashboard that helps to improve the system's convenience and make it more useful for farmers of different levels of IT literacy.

8.2 Commercialization Strategy

Due to the fact that our system has scalable technology in the agricultural sector the commercialization strategy will include ensuring the technology is available to the various players in the sector including commercial farmers and the big players in the agricultural market. Another important factor is that the system is modular, and thus may be customized depending on the needs of target customers, which also contributes to the growth of demand within the market.

8.3 Entrepreneurial Potential

Entrepreneurial opportunity is quite high for the project since it can be turned into an independent product or service. The system could be sold as a commercial product with generating royalties through realizing subscriptions, constant application updates, and support for users. Furthermore, agreements with producers of agricultural equipment mean that our system can be installed in currently manufactured means of farming, generating a new source of income and broadening the scope of clients.

The integration of this project with modern technology but at the same time with tangible actual use makes the project highly feasible and viable to be undertaken as an entrepreneurial business venture in agriculture.

9. Budget

Item	Quantity	Cost per Unit (LKR)	Total Cost (LKR)
Image Sensors	10	2,500	25,000
Mounting Equipment for Sensors	10	200	2000
Routers	2	2,500	5,000
Switches	2	740	1,480
Cables and Installation	-	10,000	10,000
Total			**43,480**

Table 9.1: Budget Table

10. Appendices

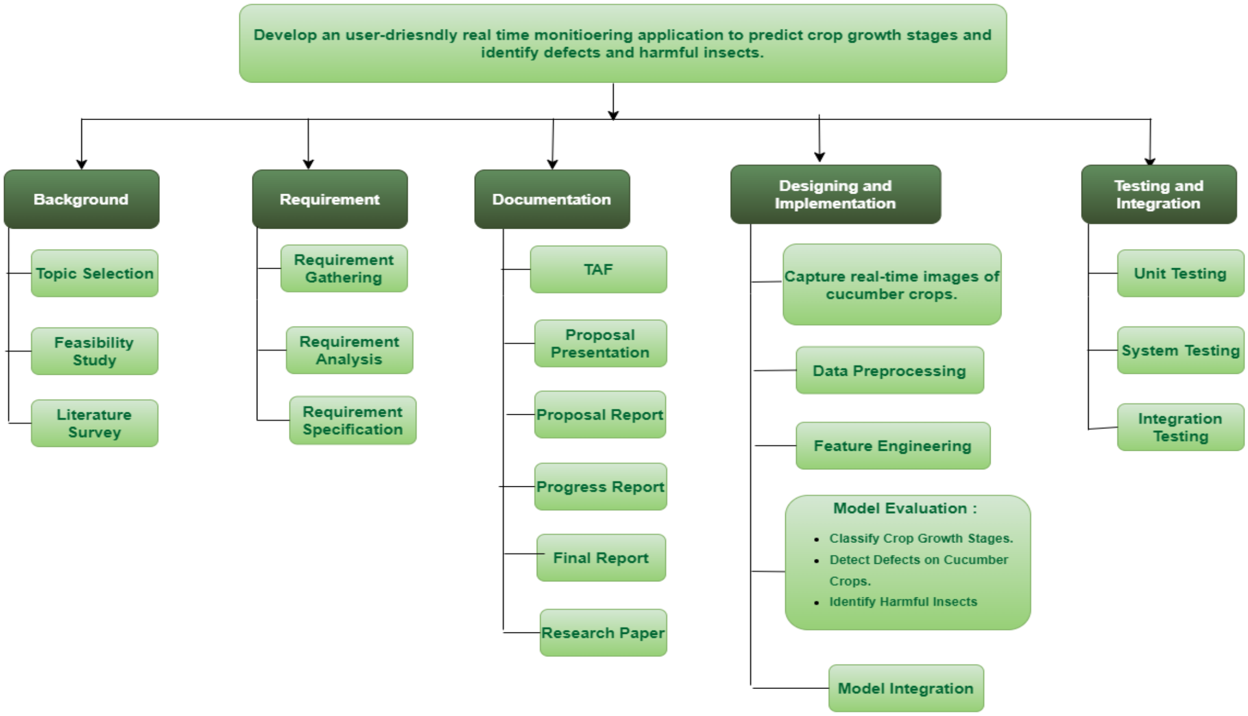

Figure10.1: Work Breakdown Chart

Figure 10.2: Grantt Chart

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