# “TEABOT” - TEA PLANTATION PRESERVATION USING AN INTELLIGENT ROBOT : A RESEARCH

TMP-23-044

Project Proposal Report

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## DECLARATION

I 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.

| Name | Student ID | Signature |
|---|---|---|
| Premathilake H.T.M | IT20265410 | |

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

Signature of the supervisor

23/04/2023

Date

# ABSTRACT

Tea is a widely consumed beverage in worldwide, and tea production is a critical industry for many countries. Most importantly when it comes to Sri Lanka, tea is one of the main income resources. Large-scale tea estates face many challenges in maintaining their plantations, including proper liquid fertilizing. However, manual labor is not always feasible, and mistakes made by laborers can lead to poor preservation. Additionally, automatic watering systems, such as Drip Irrigation, Center Pivot Irrigation require significant capital investment. Hence those may not be suitable for large-scale estates. To address these challenges, the TeaBot project proposes an intelligent robot designed to support the preservation of tea plantations by optimizing the liquid fertilizing processes. The robot's automatic navigation system allows it to reach every plant in various environmental conditions without human intervention. The robot also will be identified the end of the stem and as an output, it will be given the accurate coordinators of the stem. This may lead to fulfilling the liquid fertilizing process. Moreover, TeaBot will be analyzed if there is any erroneous situation while watering. This may lead to improving the robot's performance. To ensure that TeaBot can be used in necessary conditions, a manual robot controller will be developed to allow stakeholders to control the robot. Large-scale tea estates can use this cost-effective option because it will optimize the liquid fertilizing procedures while requiring minimal initial investment. In the final analysis, TeaBot will be tested in a large-scale tea estate to ensure that it is capable of preserving tea plantations. By using cutting-edge technology, tea estates may enhance their operations and guarantee the preservation of their plantings. Those all reasons may lead to increased profitability and sustainability of the tea industry.

**Keywords** – Robot controller, Automatic navigation, Stem identification, Fertilizing and watering

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AI | Artificial Intelligence |
| CNN | Convolutional Neural Network |
| EDB | Export Development Board |
| LKR | Lankan Rupees |
| ML | Machine Learning |
| PID | Proportional Integral Derivative |
| ResNet | Residual Neural Network |

# 1 INTRODUCTION

## 1.1 Background and Literature Survey

Agriculture is one of the world's many essential sectors. It has a main key role in the production of food, fiber as well as fuel for the world's growing population [1]. The process of growing and raising animals for human consumption, among other things, is part of agriculture. Over time, agriculture has evolved and adopted new technologies and practices to increase productivity and efficiency. The population would be increased in the coming years in an unexpected way. Hence, due to that situation, all of the wants and needs are going to be led to an increase in demand. Most importantly in food. Considering this fact this would mean that the agricultural field is going to be more important and necessary even more important than today [1]. Agriculture is an essential part of Sri Lanka's economy, providing food, income for farmers and rural communities, and the job sector. The rice and tea industries are making a huge impact on the country's well-being. More specifically in the country's economy [2]. People who have better knowledge in the agricultural field could manage sustainably this sector. As a result of that, it could lead to a positive impact on the environment [3]. Not only those specialized people, but as part of the environment everyone has opened up situations to come up with novelty ideas for improving productivity, food security, and environmental sustainability in the agricultural region [1], [3]. When considering about Sri Lanka's agriculture sector, the tea industry is one of the main important components. The International Labour Organization claims that Sri Lanka ranks as the world's fifth-largest producer among all countries [4]. Also, more than a million people are employed in this industry. Under this people category, not only the tea state workers but also small-scale owners, tea pluckers, and collectors can be defined [4]. According to the Sri Lanka EDB, the tea sector is a major revenue source in terms of foreign exchange earnings. Almost 11% of all export revenues are gained through the tea industry [5]. The tea industry is facing numerous issues [6]. One of the pressing issues in the farm sector is related to labor availability [6]. In addition, there are maintenance problems due to continuous removal of nutrients from soil through harvesting, which makes fertilizer application necessary for maintenance of yield [7].

Utilizing organic, inorganic, green manure, and bulk manure fertilizer treatments, integrated plant nutrition management has been practiced on tea plantations [8]. Farmers were permitted to start using synthetic fertilizers on tea and a few other crops while continuing to forbid their use on others, but by that time, much of the harm had already been done [9]. The disruption this created to Sri Lanka's agricultural industry couldn't have happened at a worse moment. Numerous crises had already been causing damage on the tourism sector, the primary source of foreign cash and the foundation of the nation's economy [10]. Irrigation is an essential factor in tea production, especially in the low elevation tea growing region of Sri Lanka, which produces 60% of the national production [11]. The most limiting factor affecting productivity in this region is the short but intense inter-monsoonal dry period. Irrigation, along with other methods like cultivar selection, is likely to improve productivity [11]. The trials showed that irrigated tea plants had better root and canopy structure than non-irrigated plants, resulting in higher yields [11]. In recent years, IoT-based drip irrigation has been introduced for tea plantations in Sri Lanka [12]. This technology uses precision agriculture and IoT to optimize water usage and increase crop yield. However, it is unclear how widely this technology has been adopted on Sri Lankan tea estates. Traditional tank irrigation systems are one the old system that have been using for watering. It is unclear how much these traditional tank irrigation systems have evolved specifically for use on modern-day tea estates. Overall, while there have been some advancements in irrigation technology for tea production in Sri Lanka, it is unclear how widespread these advancements are across all tea estates. Traditional tank irrigation systems continue to be used alongside more modern technologies like drip irrigation which has several numbers of disadvantages [13]. Drip irrigation systems require a lot of money to set up and also need a lot of money for upkeep. To make sure that tea plantations are well-maintained, it is important to find new and better ways to take care of them. This is where innovative sensor-driven methods come in, which use information technology [14] to improve the way tea plantations are cared for. One of the ways this has been done is by using intelligent robots [15] that can water and fertilize the plants [16]. However, it [16] can be challenging to get the robot to move around accurately in large fields. Moreover, using Lora can be expensive, and giving instructions in large fields can be complicated [17].

Although there have been several agricultural robots designed for various purposes [18], [19]. Those have not been able to address the gap highlighted in the previous issues. Developing a robot for liquid fertilization of tea plantations is a complex task due to the challenges posed by accurately identifying the stems in different environmental and weather conditions. Utilizing advanced machine learning techniques to accurately identify the end of the stem may prove to be the most effective approach [20], [21].Previous studies have primarily concentrated on the sustainability of forest operation [22], weeding [23], harvesting [24], [25] and seed cutting [26]. However, there has been a lack of research on identifying the end of stems for liquid fertilization processes. This deficiency is evident when compared these studies, as indicated in Table 1.1.

The “TeaBot” project aims to address this research gap by utilizing advanced machine learning techniques such as image processing to identify the end of the stem accurately. It is worth noting that the stem identification task performed by “TeaBot” is a critical component of the fertilization process. Therefore, the project places great emphasis on identifying the end of the stem with utmost precision, as it plays a crucial role in the overall functionality of the robot. The stem identification process under “TeaBot” has garnered significant positive effective reasons and has proven to be highly beneficial for improve the preservation of this tea plants. The advantages of this component can be summarized as follows:

1. Improved crop quality: The precision of the stem identification ensures that fertilizers are applied only where needed, which can result in higher crop quality. Also it ensures that tea plants receive the nutrients they need to grow and produce high-quality leaves.

2. Reduced fertilizer usage: By accurately identifying the end of the stem, TeaBot ensures that the liquid fertilizer is applied only where it is needed. This minimizes the amount of fertilizer used, which can significantly reduce the cost of fertilization and help preserve natural resources. Additionally, the reduced fertilizer usage can also minimize the risk of nutrient runoff, which can have negative environmental impacts.

3. Improved water conservation: “TeaBot” can also be used to apply liquid fertilizer directly to the root zone of tea plants, which can help conserve water. Traditional methods of fertilization involve spraying water and fertilizer over a wide area, which can result in significant water wastage. By using “TeaBot” to apply liquid fertilizer directly to the root zone, tea state owners can ensure that their tea plants receive the necessary nutrients while also conserving water.

4. Reduced labor costs: The stem identification process mainly led to automate the fertilization process, reducing the need for manual labor. This can result in significant cost savings for the tea state owners, particularly in areas with labor shortages or high labor costs.

5. Improved safety: By reducing the need for manual process of liquid fertilizer, “TeaBot” able to improves safety for workers on tea plantations. This reduces the risk of accidents and injuries associated with manual labor.

In summary, the “TeaBot” stem identification provides several advantages for reducing resource wastage, including reduced fertilizer usage and improved water conservation. These benefits can help tea plantation owners preserve natural resources, reduce costs, and contribute to more sustainable plantation practices. The system's precision, efficiency, and sustainability benefits make it an indispensable tool for tea state owners seeking to optimize their operations and increase their crops while also reducing their environmental impact.

## 1.2 Research Gap

The use of computer vision and deep learning techniques for detecting and tracking tree and plant stems has been extensively studied in recent years. However, there is a lack of research specifically focused on identifying the end of tea plant stems for the purpose of optimizing tea production. As mentioned before such as Real-Time Computer Vision for Tree Stem Detection and Tracking [22] and Grape stem detection using regression convolutional neural networks [24], have demonstrated the potential of computer vision and deep learning techniques in accurately detecting and tracking tree and plant stems. However, these studies do not focus on the specific problem of identifying the end of tea plant stems for the purpose of controlling a robot for liquid fertilizing. Similarly, Stem localization of sweet-pepper plants using the support wire as a visual cue [25] and X-Ray-Based Stem Detection In An Automatic Tomato Weeding System [23] focus on stem localization for the purpose of supporting plants or weed control, respectively. Sugarcane stem node detection and localization for cutting using deep learning [26] is focused on detecting and localizing nodes on sugarcane stems for harvesting purposes. Thus, there is a clear research gap in the specific area of identifying the end of tea plant stems for the purpose of optimizing tea production. The purpose of this research is to develop a machine learning model specifically trained on tea stem images and the design and implementation of a robot control system that uses the end of the tea stem coordinates as input for liquid fertilizing the plant. Additionally, there are specific challenges to be addressed in this research, such as variability in tea plant growth patterns and environmental factors, the need for real-time processing, and the need for accurate control of the robot for precise watering and fertilization. Overall, this research has the potential to make significant contributions to the field of precision agriculture and the optimization of tea production. By addressing this research gap and developing a practical solution for identifying the end of tea plant stems and controlling a robot for liquid fertilizing, it could be improved the efficiency and quality of tea production.

*Table 1.1 : Comparison of former research*

| Research | Methodologies that used to identify the stem | Identify the end of the stem | Pass coordinators as the output | Aligned with liquid fertilizing process | Agricultural robot | Purpose |
|---|---|---|---|---|---|---|
| Real-Time Computer Vision for Tree Stem Detection [22] | CNN based (Object Detection) | ✗ | ✓ | ✗ | ✗ | Forest operations' sustainability |
| Stem detection in an automatic tomato weeding system [23] | X-ray based | ✗ | ✗ | ✗ | ✓ | Weeding system |
| Grape stem detection [24] | Segmented based | ✗ | ✗ | ✗ | ✓ | Harvesting |
| Stem localization of sweet pepper [25] | X-ray based | ✗ | ✗ | ✗ | ✓ | Harvesting |
| Sugarcane pre-cut seed [26] | Object detection and image processing | ✗ | ✗ | ✗ | ✗ | Seed cutting |
| TeaBot | CNN based | ✓ | ✓ | ✓ | ✓ | Liquid fertilizing |

The proposed research solution will include features that were not proposed in previous studies. This solution will be unique and innovative, incorporating compared to the prior studies. The table above demonstrates that the Teabot has the capability to detect the end of the stem, which can optimize production in tea plantations. This highlights the potential of using robotics and advanced sensing technologies to improve large scale tea state management and increase efficiency.

## 1.3 Research Problem

As mentioned above, the tea cultivation industry is facing the challenge of maintaining consistent and precise liquid fertilizing of tea plants, which is essential for optimal plant growth and yield. According to the prior studies also there were not included any methodologies for identify the end of the stem and pass the correct coordinators. Tea plant structure is different another to another. Also, above discussed studies were not adaptive for variation of the stem. However, achieving this presents a significant challenge due to the variability in tea plant structures, as well as environmental factors that may affect the performance of the identification process. Therefore, the research problem is, **How to give the coordinates of the end of the tea stem in order to fulfill the liquid fertilizing process?** Moreover, since this is the main research problem to fulfill this problem there are many other sub problems as well. Those are,

1. How to identify the end of the tea stem precisely?
2. How to identify different variations of the tea stem?
3. What type of different conditions needed to be tested to ensure its accuracy and reliability?
4. What methodologies can be used to pass the coordinators to the robot controller?

# 2 OBJECTIVES

## 2.1 Main Objective

Automation watering mechanisms have been already implemented. Although drip [27] and center pivot irrigation systems [28] and GPS or lidar technologies have been used for this purpose, they are not resilient to varying environmental conditions, and their accuracy is limited. To address these challenges, TeaBot has been proposed to navigate tea plantations and accurately, apply liquid fertilizer to the precise location where it is needed. It uses computer vision-based path identification to move through the plantation and detects the end of the tea stem using image processing. TeaBot is equipped with pressurized water nozzles that enhance the accuracy and precision of the liquid fertilization process. It helps to reduce labor costs, preserve the health and productivity of tea plantations, and improve overall sustainability.

The identification of the end of the tea stem is a critical component of the TeaBot robot's functionality, as it enables the robot to precisely target and apply liquid fertilizer to the tea plantations. Without the ability to identify the end of the stem, the robot cannot accurately locate the correct position to liquid fertilizing. If the end of the stem is not identified, the robot may apply liquid fertilizing to the wrong location, resulting in the tea plant's damage and may leading to inefficient use of resources. By using advanced image processing techniques, the TeaBot can accurately detect the end of the stem and provide the corresponding coordinates to the robot controller. This allows the robot to apply liquid fertilizer directly to the roots, promoting healthy growth and optimal crop yields. This process mainly affected to the liquid fertilizing process. This is not only promoting efficient resource use but also ensures the sustainability of the tea plantations by reducing the risk of overwatering or under fertilization, which can result in long-term damage to the soil and plants. Overall, main objective can be defined as follow, **develop an image processing algorithm to precisely identify the end of the stem and pass the coordinators to the liquid spraying controller.**

## 2.2 Specific Objectives

The above-mentioned main objective can only be achieved by accomplishing these three goals.

### 2.2.1 Creating the dataset for ML model requirements.

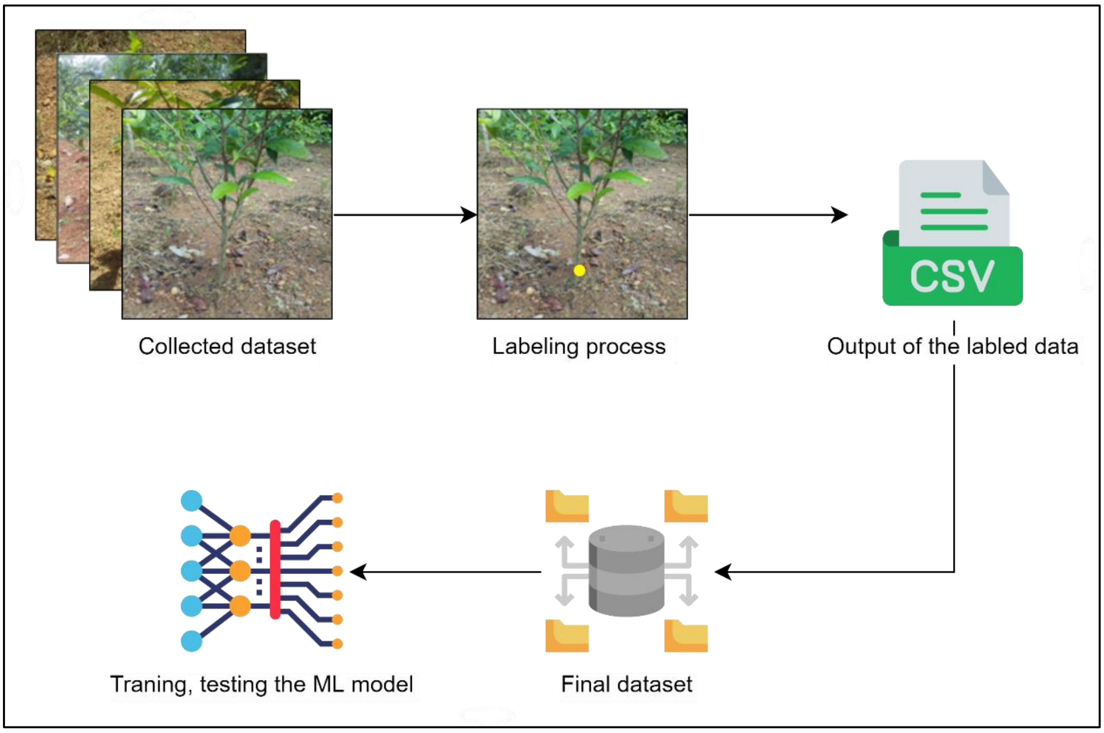


*Figure 2.1 : Dataset creation*

The proposed solution involves utilizing an image processing methodology to detect the end of the tea stem. To effectively implement a machine learning model, the creation of a high-quality dataset is essential. To accomplish this, a robot will be used to collect images by navigating through the tea plantation rows and capturing photos during the process. Approximately 3000 images of the tea stem will be collected, as this is the average number of images required to train a machine learning model [29].

To ensure that the model remains unbiased, images will be collected at different growth stages, as depicted in Figures 2.1, 2.2, and 2.3. Moreover, it is necessary to collect a dataset that can identify the end of the tea stem under varying stem structure conditions. Images will be captured under different lighting conditions as well, including varying shadow conditions in different areas with different environmental effects, as shown in Figures 2.4 and 2.5. The accuracy of the dataset labeling process is crucial to the machine learning model [30], and it should be done using the correct methodologies. Finally, the end of the tea stem image dataset will be transformed and labeled in a way that is appropriate for the machine learning model.

*Figure 2.2 : Stem structure of a small tea crop*

*Figure 2.3 : Stem structure of a middle tea crop*

*Figure 2.4 : Stem structure of a large tea crop*

*Figure 2.5 : Low sunlight*

*Figure 2.6 : High sunlight*

### 2.2.2 Developing and testing the machine learning model

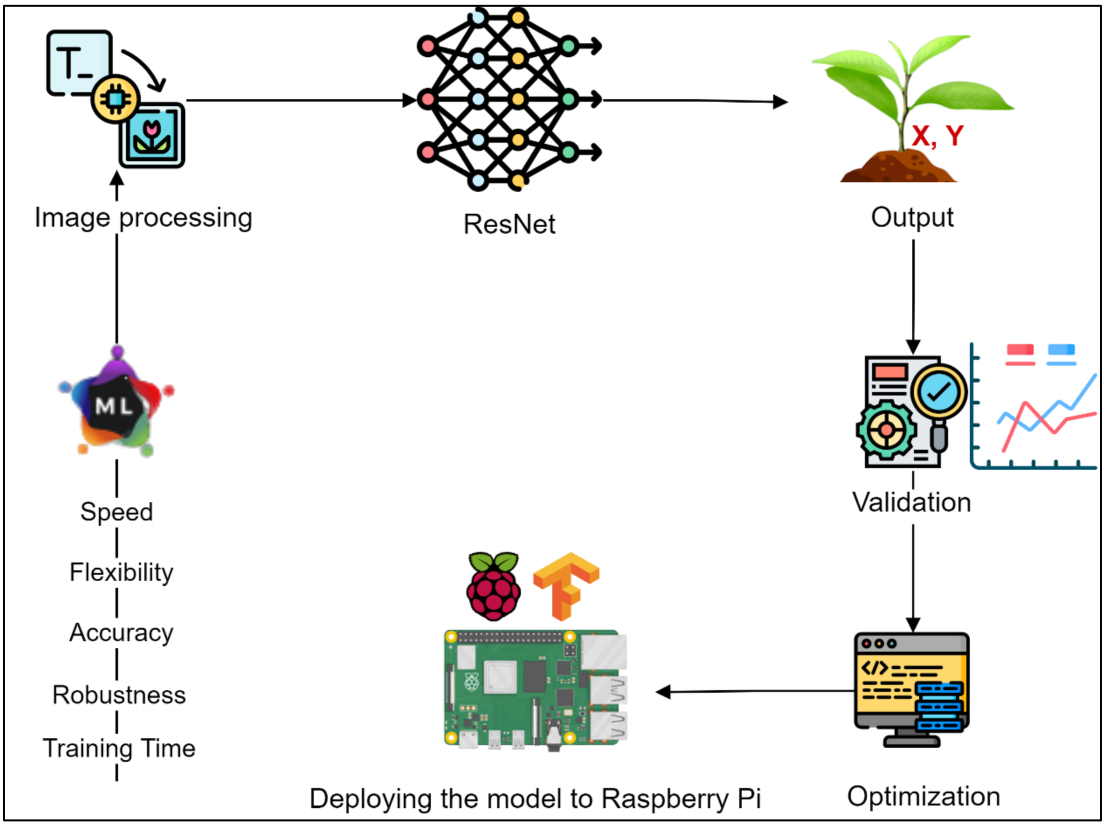


*Figure 2.7 : Machine learning model*

Once the dataset is labeled, Use ResNet architecture to train the machine learning model. ResNet is a popular deep learning architecture that has been used successfully in a wide range of computer vision tasks. Transfer learning to fine-tune a pre-built ResNet model to identify the end of the tea stem and draw a point. After training the machine learning model, evaluate its performance on a test dataset. Importantly measure the accuracy of the model by calculating metrics such as precision, recall, and F1 score. Then conduct a visual inspection of the model's output to ensure that it is correctly identifying the end of the tea stem by having correct coordinates. Finally, use the machine learning model to develop a robot that can be used by tea plant coordinators to determine the optimal time for liquid fertilizing.

### 2.2.3 Transfer coordinates to liquid fertilizer controller

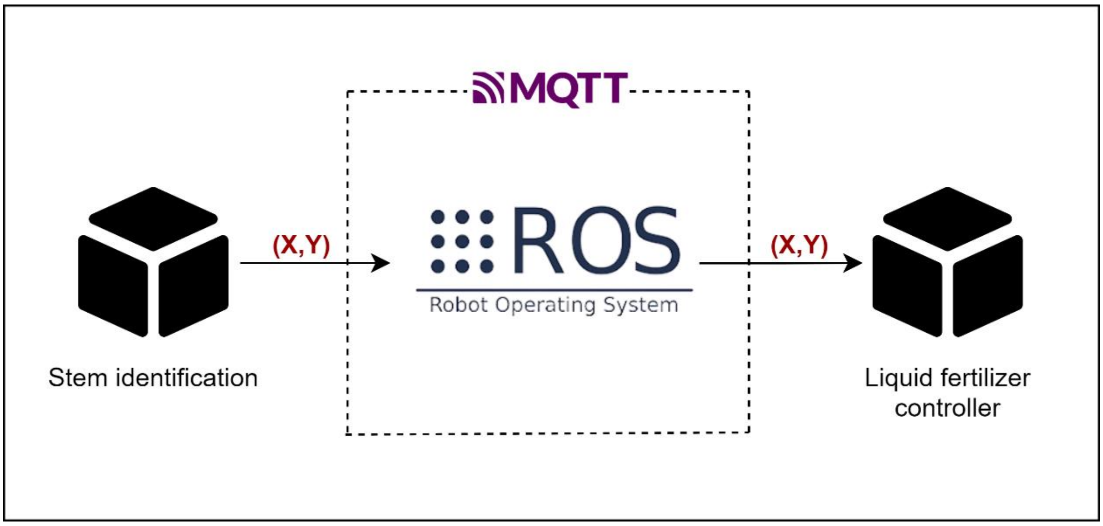


*Figure 2.8 : Communication process*

The image processing model is designed to accurately identify the end of the tea stem by analyzing various features of the image. Once the precise coordinates of the stem end are determined, they are provided to the robot controller for further processing. The robot controller uses this values to adjust the position of the water spraying nozzles to ensure that they are aligned with the identified coordinates. The accuracy of this process is crucial in order to ensure the liquid fertilization to the tea plants. Any deviation from the identified coordinates can result in an incorrect process of the fertilization, which can adversely affect the growth and yield of the tea plants. To ensure the accuracy of this task, proper communication is necessary between the image processing model and the robot controller. This involves ensuring that the correct data is transmitted to the liquid fertilizer controller, and that any errors or discrepancies are promptly identified and addressed. By maintaining clear and effective communication, the image processing model and the liquid fertilizer controller can work together seamlessly to achieve the desired outcome of accurate and precise liquid fertilization of the tea plants.

# 3 METHODOLOGY

TeaBot, the proposed research project, will be developed using the following approaches in order to provide an efficient and effective maintenance solution to tea plantations and preservation.

## 3.1 Requirement Analysis

To gain a better understanding of large-scale tea agriculture, Conducted field visits and stakeholder interviews with tea state owners and workers. One major challenge facing these fields is the ongoing maintenance of tea plantations, which requires regular watering and fertilization which is referred to as liquid fertilization. However, this presents difficulties due to factors such as a shortage of human resources, resource wastage, and the high initial cost of automating the process. The TeaBot can address these challenges. With the intention of, gathering a considerable amount of data from people who are working in this field. Then analyzed the watering and fertilization process of current large-scale tea agriculture. As mentioned above, by identifying the end of the tea stem, the liquid fertilization process can be done in an efficient way as well as it is beneficial for use recourse without wastage. To do this, needed to develop an image processing methodology to identify the end of the tea stems precisely, collected images at different growth stages as depicted in Figures 2.1, 2.2, and 2.3. Moreover, under varying lighting conditions as depicted in Figures 2.4 and 2.5.

## 3.2 Feasibility Study

The feasibility study for the requirement analysis of large-scale tea agriculture identifies technical, economic, and operational feasibility considerations. The study concludes that the image processing methodology developed appears feasible and could help optimize plantation maintenance, increase yield, and profitability. However, further study is necessary to assess the economic feasibility of the project.

## 3.3 Implementation

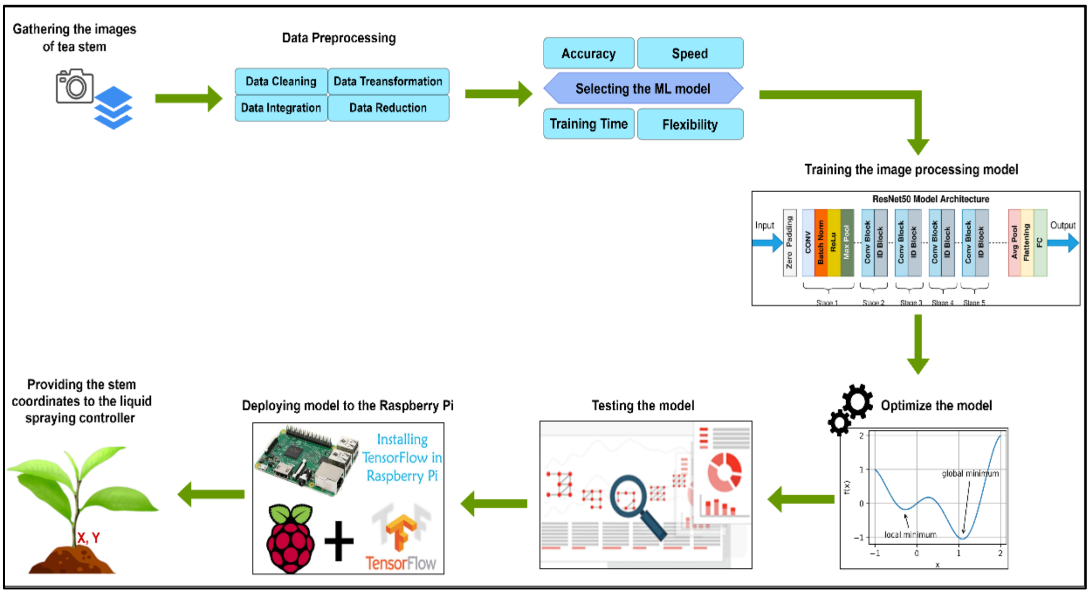


*Figure 3.1 : System overview diagram*

The research methodology for this project involves using computer vision and machine learning techniques to identify the end of the tea stem and label it as a point. Specifically, use the Residual Neural Network (ResNet) architecture to train a machine learning model that can accurately identify the end of the tea stem. The first step in this methodology is to gather a dataset of tea stem images. These images will be used to train and test the machine learning model. The dataset should include images of tea plants at various stages of growth and under different environmental conditions to ensure that the model is robust and can accurately identify the end of the tea stem under different circumstances.

The next step is to label the images by identifying the end of the tea stem and drawing a point exactly where the end of the stem locate. This is a crucial step in the process, as the quality of the labeled data affects the machine learning model's accuracy.  data. To do labeling process, use manual labeling tool which is ‘MakeSense.ai’ to ensure that the labeling is accurate and consistent across the dataset. Once the labeling process done it can be downloaded as CSV file with correct coordinators of each image.

When the dataset is labeled, Use ResNet architecture to train the machine learning model. ResNet is a popular deep learning architecture that has been used successfully in a wide range of computer vision tasks. Transfer learning to fine-tune a pre-trained ResNet model to identify the end of the tea stem. After training the machine learning model, evaluate its performance on a test dataset. Importantly measure the accuracy of the model by calculating metrics such as precision, recall, and F1 score. Then conduct a visual inspection of the model's output to ensure that it is correctly identifying the end of the tea stem and identifying an accurate point of the stem. Finally, use the machine learning model to develop a robot that can be used by tea plant coordinators to determine the optimal time for liquid fertilizing. The output of the model will be the coordinates of the point which defined the end of the tea stem. Moreover it can be used to determine the stage of growth of the tea plant and the appropriate liquid fertilizing schedule. This will be a one of the main components in the TeaBot, which is beneficial to optimize tea production without having huge investment.

Overall, the TeaBot is a state-of-the-art robot that utilizes cutting-edge software, hardware, and cloud technologies. Its sturdy mechanical structure has a 2 x 2 feet chassis and four 8-inch wheels that are powered by 12V motors connected to motor drivers, which are in turn connected to the Raspberry Pi. The robot runs on a 45-ampere battery and a 12V battery. Python is used for programming, and ROS is used for the software operations, with separate nodes for data transmission. Raspberry Pi centralizes the motor, camera, pressure pump, and water nozzle control, and can execute python libraries for image segmentation as well as image processing. The robot operates as a single package.

## 3.4 Work Breakdown Structure

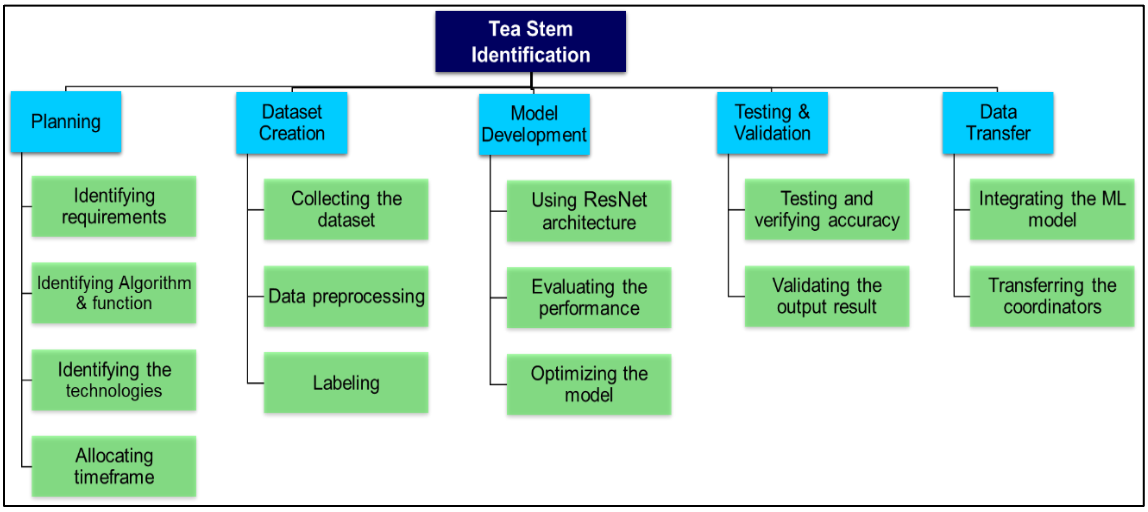


*Figure 3.2: Work breakdown structure*

## 3.5 Testing

Multiple stages of testing will be conducted using various methodologies. Upon completion of dataset creation, it will be partitioned into two datasets in an 80:20 ratio for training and testing purposes. The model will subsequently be implemented and trained using the training dataset.

1. Gather a set of representative test images
    - Gather a set of test images that the model has not seen during training.

2. Load to the trained model
    - Once the test data is ready, need to load the trained ResNet model, to do this using a deep learning framework such as TensorFlow or PyTorch.

3. Preprocess the test data (resize, normalize, format)
    - ResNet models typically require the test data to be preprocessed before feeding it into the model.

4. Run the test by passing images through the model
    - Once the test data has been preprocessed, run the test by passing the images through the ResNet model and obtaining the model's predictions. Evaluate the following metrics such as Model's accuracy, precision, recall, F1 score.

5. Analyze the results
    - Visualizing the model's predictions, calculating the performance metrics, and comparing the results to the expected outcomes.

### 3.6 Gantt Chart

This proposing research is planned to carry out as follows to meet the required deadlines without any conflicts. Project implementation will be started in late March and expected to complete by late September while testing will be carried out from mid-August to end of October. The proposing research project will be completed by December 2023.

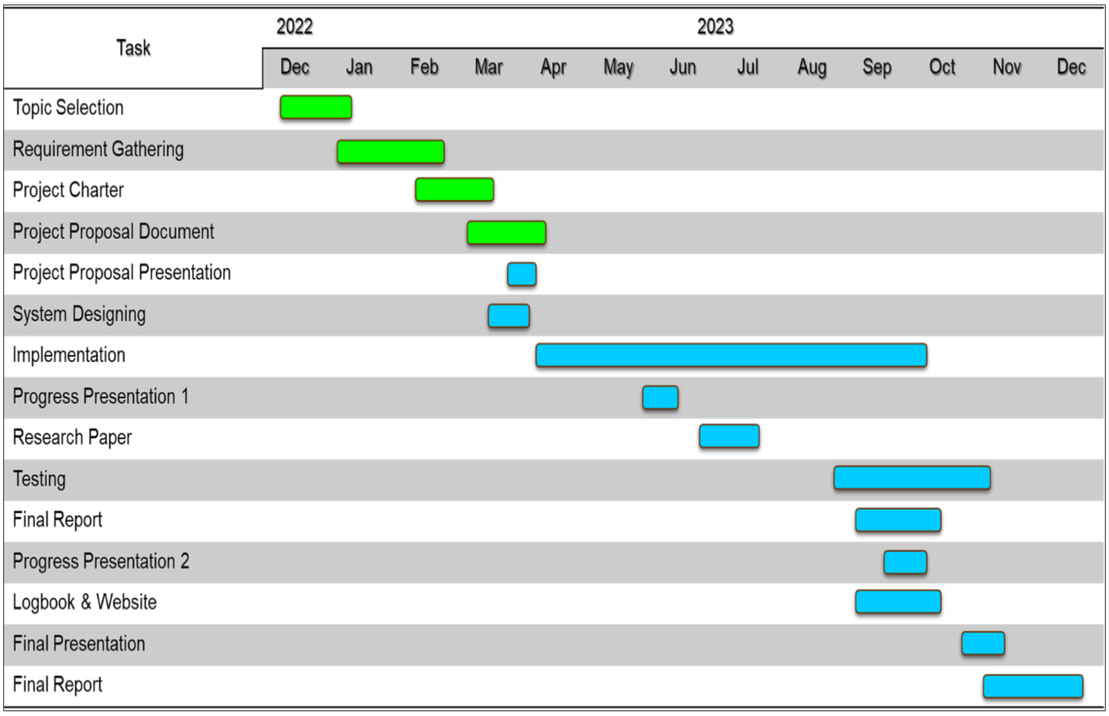


*Figure 3.3 : Gantt chart*

# 4 DESCRIPTION OF PERSONNEL AND FACILITIES

Ms Shashika Lokuliyana is in charge of this study. She teaches Information Security, Computer Systems and Networking, and Computer Systems Engineering as a Senior Lecturer. She is now employed with the Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka, in the Information Systems Engineering Department.

As an Assistant Lecturer in the Department of Information Systems Engineering, Faculty of Computing, Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka, Ms Narmada Gamage is co-supervising this project.

Mr. Rajitha de Silva joins this research as the external supervisor. He is a PhD scholar of University of Lincoln, England, UK.

This research will be conducted by the following 4 members as shown below.

1. Gunawardana I.I.E - He is responsible for developing an algorithm for the robot controller to navigate the robot with the coordinates given by the computer vision and identify hazards.

    - Creating the robot chassis and the mechanical parts.
    - Creating the PID (Proportional Integral Derivative) controller to navigate the robot.
    - Creating the robot's autonomous drive with the given coordinates by the computer vision and creating the manual controller for the robot.
    - Identify the front-facing hazard object using yolov5 and capture the distance to the object using ultrasonic sensors and emergency stop the robot, then notify the administrator.

2. Perera P.V.Y - She is responsible for developing an image segmentation algorithm to detect the tea plantation rows in varying environmental conditions for the automatic navigation of the robot and detecting the end of the tea plantation path.

    - Collect the dataset, and apply data transforming, and normalizing techniques.
    - Select the most suitable image segmentation model to detect the crop rows considering the above requirements.
    - Develop the image segmentation model to detect the tea plantation rows.
    - Train the image segmentation model, apply hyperparameter tuning techniques, and test the model.
    - Deploy the model to the robot controller.

3. Premathilake H. T. M – She is responsible for developing an image processing algorithm to precisely identify the end of the stem and pass the coordinators to the robot controller.

    - Initially identify the data requirements and gather the dataset.
    - Apply data preprocessing techniques for the collected dataset.
    - Select an image processing algorithm to develop the model.
    - Training an image processing algorithm to detect the endpoint of a stem.
    - Testing the model and tune its hyperparameters to improve its performance.
    - Deploy the model to the “TeaBot” robot controller.

4. Bamunusinghe G.P – He is responsible for develop an algorithm to operate the liquid fertilizer spraying function in real-time with respect to the relative movement of the robot.

    - Creating the hardware mechanism for liquid spraying.
    - Tuning the liquid spray motors according to the robot's motion.
    - Spraying liquid fertilizer (water + fertilizer) to the plants according to the relative velocity of the robot by using the 4 nozzles (nozzles will be controlled with stepper motors) to the groups of plants.

# 5 BUDGET AND BUDGET JUSTIFICATION

*Table 5.1 : Estimated budget*

| Item | Quantity | Amount<br>(LKR- Lankan Rupees) |
|---|---|---|
| Rubber wheels | 4 | 4,000 |
| Sprocket, chain and wheel (Gear system) | 4 | 10,800 |
| Iron frame | 1 | 15,500 |
| Motors | 4 | 14,000 |
| 43A Motor drivers | 4 | 5,400 |
| Raspberry Pi zero w | 1 | 5,600 |
| 12V 45A battery | 1 | 30,000 |
| Camera | 3 | 15,000 |
| Liquid nozzles | 2 | 3,000 |
| Servo motors | 8 | 9,600 |
| **Total** | | **112,900** |

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# APPENDICES

## Appendix A : Plagiarism Report

Proposal Report

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