ELEC 33542 - Research Project

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Smart Fertilisation System

Group 12

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Abstract

Pollination is a key ecological activity that is essential for plant species reproduction, notably in agriculture, where it is critical to ensuring agricultural output and food security. However, difficulties such as habitat loss, pesticide usage, and climate change have resulted in a fall in pollinator populations, posing serious dangers to world food production and sustainability. Strawberries and cucumbers stand out among agricultural crops for their unique pollination requirements, as their delicate, hermaphrodite flowers rely largely on pollinators to set fruit. To address these challenges and ensure consistent pollination, a smart fertilisation system is being developed, utilizing technology that involves suction and blowing of pollen.

This research project intends to transform pollination techniques by combining automation, robots, and precision engineering to create a sustainable and efficient alternative to traditional pollination methods. The primary goal is to lessen dependency on diminishing pollinator populations while increasing agricultural yield, lowering labor costs, and promoting agricultural sustainability. The system combines modern technology with a thorough understanding of plant biology to provide a sophisticated answer to the issues presented by fading pollinator numbers.

The smart fertilisation system is aimed at strawberries and cucumbers, providing a preview into the future of precision agriculture. The system intends to improve pollination accuracy, adaptability, and efficiency by integrating navigation and flower detecting algorithms. Real-time monitoring systems give data on pollination success, allowing for a better understanding of plant physiology and system efficiency.

Keywords: Pollination; Automation; Strawberries; Cucumber; Flower detecting algorithms

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Abbreviations

AI – Artificial Intelligence

CPU – Central Processing Unit

CNN - Convolutional Neural Network

AP - Average Precision

SE – Squeeze and Excitation

SSD – Solid State Drivers

YOLO – You Only Look Once

TTL – Transistor-Transistor Logic

PWM – Pulse with Modulation

USB – Universal Serial Bus

ICSP – In-Circuit Serial Programming

2D – 2 Dimensional

3D – 3 Dimensional

SFS – Smart Fertilisation System

SF – Smart Fertilisation

LED – Light Emitting Diode

IoT – Internet of Things

Chapter 1: Introduction

In agriculture, pollination is an important biological activity that acts as the foundation for plant species reproduction. However, the integrity of this process faces significant challenges due to concerns such as habitat loss, widespread pesticide usage, and the overarching influence of climate change. The resulting fall in pollinator populations poses a danger to global food security and the overriding goal of promoting agricultural sustainability. Amidst this complex ecological context, two key crops, strawberries, and cucumbers, stand out as archetypal examples, each facing unique pollination issues.

Smart fertilisation (SF) is a form of pollination that uses artificial intelligence to effectively accomplish pollination procedures. In this method, AI (Artificial Intelligence)-powered technologies are used to detect flowers, gather pollen from them, and automatically place pollen on flowers. These systems use sensors, robotics, and artificial intelligence algorithms to recognize flowers that require pollination, gather pollen from donor flowers, and transfer it to destination flowers with precision and efficiency. SF promotes ideal fertilisation and increases crop yields in a sustainable way by automating pollination and optimizing resource consumption. SF can pollinate crops that rely considerably on insect pollinators, like strawberries and cucumbers by ensuring effective pollination.[1]

Strawberries and cucumbers, both commonly cultivated and highly valued in agriculture, have delicate hermaphroditic flowers that rely heavily on pollinators for the crucial process of fruit setting. The complicated interplay between these crops and their pollinators exemplifies the delicate balance within ecosystems that allows agriculture to thrive. However, the current path, characterized by a fall in pollinator populations, demands novel methods to assure crop pollination and stable harvests.[1]

In response to these critical difficulties, a groundbreaking endeavor is underway: the creation of a SFS based on pollen-suction technology. This pioneering technology combines automation, robots, and precision engineering to provide a sustainable and effective alternative to traditional pollination approaches. The primary goal of this technological endeavor is to provide a sophisticated and environmentally friendly solution that not only addresses the challenges posed by declining pollinator populations, but also increases crop output, reduces labor requirements, and promotes agriculture's sustainability.

The SF device aims to change strawberry and cucumber production processes. It demonstrates the successful combination of technology with a thorough understanding of plant biology. By leveraging automation and robotics, the system aims to rethink traditional conceptions of pollination, providing a glimpse into the future of precision agriculture. This forward-thinking approach not only seeks to address the immediate issues provided by pollinator loss, but also promotes itself as a beacon of hope for guaranteeing food security in a world marked by constant change.

As progress through this research, the various features of the SFS, including its technological complexities, potential to alter agricultural methods, and broader implications for global food security and sustainability are examined. SF is an important development in agricultural technology, demonstrating the potential for artificial intelligence and automation to transform traditional farming operations.

Higher crop yields from efficient pollination can enhance profits for farmers and contribute to rural economic growth. In addition, cost savings from reduced manpower and consumption of resources increase the economic viability of farming organizations.

1.1 Research Background

The main aspect of the food supply is pollination, an ecological activity of utmost importance in agriculture. The reproduction of flowering plants is controlled by the invisible hand, assuring the development of the fruits, vegetables, and seedlings that sustain the planet. However, this important procedure is at a dangerous crossroads as we deal with a huge number of difficulties. The pollinator numbers are declining because of habitat loss, indiscriminate pesticide usage, and the constant onslaught of climate change, which raises concerns about the sustainability of the farming methods and the security of the world's food supply. The study initiative emerges as a ray of hope and innovation in the face of this worsening problem. The SFS was set out on a path, an innovative synthesis of ecological science, automation, and technology that aspires to transform the way crops are pollinated. The SFS is fundamentally a precision-driven solution that expertly navigates the challenges of plant reproduction. It uses AI, and robotics to control the complex relationship between pollen and stigma, assuring the best possible pollination conditions that result in abundant harvests.

The critical need for novel SFSs to address the sustainability, dependability, and scalability of pollination methods is the research gap that has been recognized in the backdrop. The use of expensive manual pollination has increased because of the loss in natural pollinator populations, while other alternatives like farmed bees have their own difficulties. Additionally, the precision and adaptability needed to accommodate various crops and shifting environmental circumstances are lacking in today's technological solutions. Additionally, there is still a lot of worry about how traditional agriculture affects the environment, particularly the use of pesticides and the loss of biodiversity. By creating and evaluating SFSs while analyzing their effects on the environment, economy, and society, the research project seeks to close these gaps. The eventual goal is to create a dependable and sustainable pollination system that increases crop yields, lessens reliance on dwindling natural pollinators, reduces labor demands, and advances overall agricultural sustainability. In a world where agriculture is always evolving, the project imagines a time when ecology and technology work together to secure food security and environmental protection.

1.2 Objectives

1.2.1 System Development

The primary goal of this research is to develop a system designed specifically for strawberries and cucumbers. The objective is to create a system that duplicates the accuracy of hand pollination methods while also simulating the complex behaviors of pollinating insects in their natural context. This technique uses the latest innovations to optimize the pollination process, ensuring a level of precision comparable to other, labor-intensive approaches. The goal of precise development is to create an intelligent, dependable, and effective system capable of tackling the specific challenges posed by the fragile hermaphroditic flowers of strawberries and monoecious flowers of cucumbers.

1.2.2 Integration of Cameras

The SFS's success depends on the integration of the camera. The camera is used to detect flowers of strawberries and cucumbers. The addition of modern cameras improves the system's ability to collect real-time data, offering significant insights into the dynamic nature of the crop environment. Simultaneously, the development of path planning algorithms becomes critical to the efficient movement of the pollination device. These algorithms are intended to assure complete coverage of the pollination zone, limit resource consumption, and optimize the movement of the artificial pollinator, matching the intricate navigation patterns observed in natural pollinators.

1.2.3 AI-Based Decision-Making

The study investigates the use of AI to drive decision-making processes in an SFS. The creation of AI-based algorithms is critical for real-time assessment and adjustment based on dynamic environmental variables. These algorithms, based on current data such as flowering readiness, are intended to make informed recommendations about the most successful pollination approaches. The incorporation of AI-based decision-making is a big step forward, ensuring that the SFS remains agile and sensitive to the complexities of the agricultural landscape.

In conclusion, the thorough examination of system development, camera integration, and AI-based decision making exemplifies the research's general approach. These components work together to achieve the overriding goal of developing an efficient, adaptable, and technologically advanced SFS capable of meeting the challenges and complexities of strawberry and cucumber production.

1.3 Problem Statement

The decline in bees and other insect populations, along with the inefficiencies of hand pollination techniques, which are especially obvious in the production of strawberries and cucumbers, pose a huge challenge to modern agriculture. To achieve effective crop pollination while promoting agricultural sustainability, this decreased reliance on conventional pollination methods needs novel alternatives. To solve this crucial issue, the research project aims to create and execute a complex SFS that makes use of robotic pollinator. The system autonomously imitates the pollination behaviors seen in wild pollinators and hand-pollination techniques. With this strategy, the initiative hopes to provide an affordable, and environmentally responsible alternative that ensures ideal pollination and boosts agriculture's long-term resilience.

1.4 Scope and Limitations

1.4.1 Scope

The SFS project aimed to develop automated systems capable of transporting pollen from male to female regions of flowers (in monoecious plants), as well as flowers containing both male and female reproductive organs within a single flower (in hermaphrodites plants). The device used a camera to monitor the abundance of flowers, which helped in flower identification and path construction. The path planning system optimized pollination paths using algorithms based on bloom dispersion and readiness. Real-time flower recognition algorithms were deemed necessary for effective and targeted pollination. Data collection, preprocessing, and analysis were carried out using data analysis and visualization, while system optimization was accomplished using machine learning. A robotic pollinator prototype was created, navigation algorithms were tested, and the usability and effectiveness were assessed. Integrating with AI enabled real-time decision-making and data collection.

Cost evaluations and feasibility studies confirmed the project's viability, and thorough documentation and reporting were required to communicate the outcomes and lessons gained to stakeholders and the public.

1.4.2 Limitations

The project's limitations originate from the unique characteristics of the greenhouse environment. The plant bed's width of 60cm limits the device's navigational capabilities. To achieve optimal coverage within the limited space, path planning and navigation algorithms must be meticulously designed. Furthermore, the prescribed blossom height range of 15cm to 20cm from the ground limits the device's working scope, necessitating precise adjustments during the pollination process. Furthermore, the project functions in a regulated greenhouse environment free of insects and dust. While the lack of external elements simplifies certain aspects of the project, it also suggests that the device must be designed specifically for this area, potentially limiting its adaptability to other agricultural contexts with varying conditions. These limits highlight the significance of a planned and specialized strategy to resolve the challenges offered by the greenhouse environment.

Chapter 2: Literature Review

Smart pollination is a revolutionary agriculture strategy that combines technology and nature to produce food sustainably. Smart pollination offers a remedy in a world where dwindling bee populations and erratic weather patterns endanger conventional pollination. In addition to increasing agricultural yields, it also encourages biodiversity and lessens the negative environmental effects of conventional farming methods. Smart pollination, a novel and environmentally beneficial technique that bridges the gap between agriculture and modern technology, is becoming more and more popular among farmers worldwide. The recent developments, significant discoveries, and new patterns in the field of SFS are examined in this literature review.

Shape classification technology of pollinated tomato flowers for robotic implementation introduces a novel method for pollinating greenhouse tomatoes using robots or drones that are equipped with AI and flower classification technology. Insect-mediated pollination, manual flower vibration, and hormonal pollination utilizing plant growth regulators are all common techniques for pollinating greenhouse tomatoes. These techniques have inherent flaws, including the requirement for expert labor, potential quality problems, and higher costs.[2]

The suggested remedy uses AI-powered image classification to spot mature flowers that are prepared for pollination. This challenge is particularly difficult since it requires real-time flower detection even when robots or drones are moving, which could obscure the images. A convolutional neural network (CNN) was used as part of the AI picture classification system to handle these complications. This CNN-based system has been trained to recognize flower forms that indicate pollination readiness.[2]

A minimum accuracy rate of 70% was the goal of the study to ensure efficient and successful pollination. With a remarkable low misclassification rate (less than 5%), experimental findings showed the AI picture categorization system to be effective. Most of these errors were attributable to variables like camera shake during image capture and fluctuating lighting conditions. The results of the study show that this technology can greatly improve the productivity and quality of tomato fruit production in greenhouses while decreasing reliance on labor-intensive manual methods. [2]

The research "Automated pollination of kiwifruit flowers" provides an early evaluation of a novel robotic pollination system developed to counteract the global reduction of natural pollinators, which is especially pertinent given the wealthy kiwifruit sector in New Zealand. Numerous artificial techniques, including the application of dry pollen and liquid spray systems, have been used because bees are still necessary for the pollination of kiwifruit flowers. The development of autonomous robotic systems that can transfer pollen directly to flowers, on the other hand, is drawing more attention and could revolutionize industrial pollination procedures. With its ability to recognize 89.3% of flowers, locate them precisely in 71.9% of cases, and achieve an estimated 80.1% success rate while moving at a speed of 0.36 m/s along kiwifruit orchard rows, the wet-application robotic pollination system displayed encouraging results. This shows that the system can effectively automate pollination tasks in orchards. The methodology, which illustrated the complexity of the technology, included machine vision, circulation pumps, motorized stirrers, dual-boom systems, and different sensors. Future studies will concentrate on perfecting the system to meet commercial requirements, with a focus on strengthening shot precision, machine vision accuracy, and scaling the system to fit wider orchard rows. This study highlights the significance of robotic pollination in addressing pollinator depletion and its potential to change pollination practices in the kiwifruit sector.[3]

The creation of a light-weight robotic arm for pollinating kiwifruits is examined in the “Design of a lightweight robotic arm for kiwifruit pollination" article as a creative way to deal with the problems caused by the constraints of natural pollination. In the context of booming kiwifruit agriculture in China, where artificial pollination techniques are being used due to climate change and a lack of insect pollinators, it highlights the growing demand for automated pollination systems. The study focuses on the design, simulation, and analysis of the robotic arm's working area, trajectory planning, and parameter settings using the software packages MATLAB and SolidWorks. Materials and joint connectors for the lightweight robotic arm have been tested for rigidity and strength. The prototype and motion control system are created using the simulation's results. The research shows that the lightweight pollination robotic arm outperforms human brush pollination with a high pollination success rate of 85%, an average pollination time of 5 seconds per flower, and an efficiency of 78 minutes per mu (a unit of area). According to the study's findings, this automated pollination method is workable and presents a possible answer to the problems associated with labor-intensive manual pollination in kiwifruit plantations.[4]

2.1 Existing Solutions

Kiwifruit, New Zealand's largest horticultural export, is highly dependent on the presence of bees for pollination. A lack of bees has led to various artificial pollination processes, such as companies in the Bay of Plenty blowing dry pollen into the canopy using modified quadbikes. Bees are introduced in portable hives to help spread the pollen to the flowers, requiring 2,000-12,000 pollen grains per flower for export quality fruit. A non-bee method is the Cambrian sprayer, which uses pollen suspended in a liquid solution to spray directly onto individual flowers.

There is growing interest in replacing bee, manual, and crop dust pollination with robotic systems that can deliver the required pollen directly to the flower. For commercial viability, a robot would need to pollinate a hectare of kiwifruit orchard with between 500g and 800g of pollen. A modern orchard can contain over 500,000 flowers per hectare.[5]

Indoor gardening is popular due to the complete control over the environment, which allows growers to protect their crops from the risks of prolonged drought, torrential flooding, damaging winds, and pest infestations. However, indoor gardeners also have a responsibility to create an ideal environment for their plants, which can be achieved by choosing the correct amount and style of lighting, controlling humidity and airflow, keeping a close eye on the temperature in the growing area, and supplying water and elemental nutrients properly.

Large scale indoor growers of flowering crops may deal with several acres of plants at any given time, making it difficult for workers to hand pollinate each flower. Many commercial indoor growers buy or rent pollinators (usually honey or bumblebees) and let them loose in the growing area for a given amount of time. For hobby growers, hand pollinating plants that are not self-fertilizing (self-pollinating) is recommended to assure the best quality fruit production.

The modern cucumber plant (Cucumissativus) is usually monoecious, meaning both male and female flowers can be found separately on the same plant. Male flowers grow in small clusters and can be identified by their smooth, slender stems. Female flowers grow singularly and have a large base or stem that resembles a baby cucumber. The female flower has a pistil, which is made up of the stigma (pollen receivers) and the style, a tube-like structure that leads to the ovary.

To successfully pollinate a female flower, one must transfer pollen from the stamens of the male flower to the stigma of the female flower. A successful pollinated female flower will grow into a cucumber, while an improperly pollinated strawberry flower will produce misshapen fruits that may be less appealing to the eye and smaller than those from a successful pollination.

When hand pollinating, it is best to do so when the flower is completely open, as pollen production will be at the highest levels and the stigma of the female flower is most receptive. A small, soft-bristled paint brush or tool of your choice can be used to pick up and distribute the pollen well.[1]

2.2 Review on Existing Methodologies

The study report on the robotic kiwifruit pollination system shows a thorough and methodical approach to creating and testing the unique platform-mounted robotic pollination system. Context is presented in the background part by emphasizing the economic importance of kiwifruit, its reliance on pollinators, and current artificial pollination technologies, paving the way for the introduction of the robotic pollinator system. The research's major objectives, which include evaluating flower recognition, location, and spraying accuracy, are clearly outlined.

The techniques section provides a full explanation of the robotic pollination system, including the integration of machine vision, a wet-application spray mechanism, and the basic robotic platform. The utilization of digital cameras led lights, lidar, and a CNN for image processing is explained, giving a comprehensive picture of the technological components involved. The calibration tests, sequence timing, and realistic speed factors in the system's operation are clearly stated.

Overall, the approaches used in this study paper provide a strong and well-structured strategy, combining many technologies to handle the difficult challenges of artificial pollination in kiwifruit farms. The clarity of presentation, detailed detailing of system components, and intelligent analysis of outcomes all add to the overall strength of the research methodology.[5]

The part on hand-pollinating indoor cucumbers and strawberries is a useful and instructive resource for producers, highlighting the significance of understanding plant structure and manual pollination. The approaches used in the tale effectively depict the hands-on approach required for successful cultivation in an indoor gardening environment.

The introduction establishes the context by emphasizing the benefits of indoor gardening, particularly the control over environmental elements and the responsibilities it entails. The analogy of indoor gardeners portraying mother nature clearly conveys the level of effort and attention necessary.

The explanation of large-scale indoor operations involving pollinators such as honey or bumblebees sets the stage for the later emphasis on hand-pollination for hobby producers. The advice to hand-pollinate non-self-fertilizing plants on a lesser scale highlights the precise attention needed for high-quality fruit.

The section next investigates the anatomy and pollination methods for cucumbers and strawberries. The full description of the cucumber plant's monoecious nature, the distinctions between male and female flowers, and the usage of pollen transfer equipment serves as a step-by-step instruction. The emphasis on progressing from male to female flowers ensures a comprehensive comprehension of the pollination process.

Similarly, the mention of strawberry plants' androgynous nature, as well as the difficulty of hand-pollination due to the proximity of male and female parts, adds to the reader's knowledge. The advice to disperse pollen evenly for equally shaped fruits, as well as the note on optimal timing during the completely open flower stage, provide useful information.

The author's own tool choices, such as a small, soft-bristled paintbrush, and the possibility of utilizing an electric toothbrush, offer practical advice for growers. The emphasis on care and timing in hand-pollination strengthens the reader's understanding of the approach.

Overall, the approaches used in this part are clear, practical, and hands-on, making them ideal for hobby growers that practice indoor gardening. The combination of theoretical knowledge of plant anatomy and practical recommendations for effective hand-pollination improves the reader's capacity to utilize these approaches in their own farming practices.[1]

Chapter 3: Theory and Methodology

3.1 Theory

3.1.1 Cyclone Separator

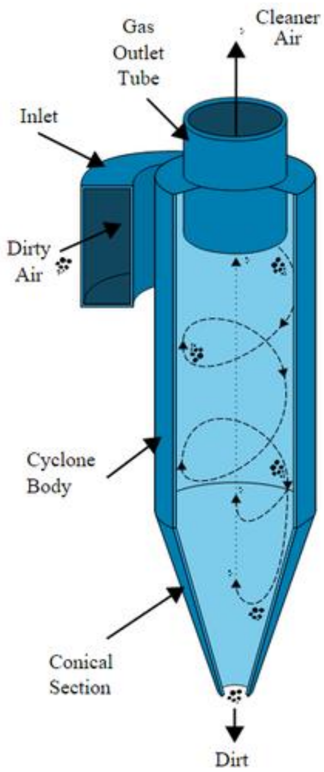

Figure 1. Cyclone separator

Cyclone separators are like centrifuges, except they use a continuous input of unclean air. A cyclone separator feeds polluted flue gas into a chamber. The inside of the chamber generates a spiral vortex, akin to a tornado. The spiral development and separation are seen in figure 1. The lighter components of this gas have less inertia, making it simpler for them to be affected by the vortex and ascend it. In contrast, bigger components of particulate matter have higher inertia and are not as easily impacted by the vortex.

Because these bigger particles struggle to follow the gas and vortex's high-speed spiral motion, they collide with the container's interior walls and fall into a collecting hopper. These chambers are formed like an upside-down cone to help particles gather at the container's bottom. The cleaned flue gas exits through the top of the chamber.[6]

3.1.2 Image Processing

In cucumber and strawberry cultivation, the quantity and timing of cucumber and strawberry appear emergence are heavily determined by final yields. However, manually documenting and counting flowers is a labor-intensive operation. To address this issue, an automated system is developed that employs computer vision technology to detect and count cucumber and strawberry flowers from images collected by cameras deployed in greenhouses. Despite advances in computer vision models such as Solid-State Drivers (SSD), and “You Only Look Once” (YOLO) object detection, problems remain, particularly in contexts with a wide field of view, resulting in significant gaps between detection accuracy and application requirements.

In this research, two cucumber flower datasets and a strawberry flower dataset with broad and medium fields of view are created. The modified model, notably with the Squeeze and Excitation (SE) attention mechanism, was found to have the greatest recognition rate of the studied approaches. The YOLOv5s-SE7 model performs better than the benchmark model and other modern approaches, with an AP (Average Precision) score of 0.905. The model also produces strong classification detection results for cucumber and strawberry flowers.[7]

3.2 Overview of the Methodology

This research project commences with the design and construction of a robotic pollinator, encompassing vital components such as cameras, and communication modules, meticulously engineered to enable autonomous pollination tasks. Simultaneously, the development of intelligent algorithms, including path navigation, and image processing, equips the robotic pollinator with adaptable capabilities and effective performance. Subsequently, the robotic pollinator prototype undergoes thorough testing within a controlled environment, where its pollination and navigation abilities are thoroughly evaluated. An extensive data analysis process entails examining camera data to gain insights into flower availability, and the effectiveness of the pollination method. Furthermore, a comprehensive economic feasibility analysis assesses the practicality of the SFS, considering potential agricultural advantages such as increased yield and reduced labor costs. In this project, two mechanisms are used to cucumber and strawberry flowers. In cucumber, pollens are collected from male flowers and the robotic pollinator deposited the collected pollens into female flowers. Before deposit the pollens, the robotic pollinator mixed the pollens with the water making them easy to spray into female flowers.

In strawberry, a small wind is given by the blower part of the robotic pollinator to the flower and the pollens are dropped on the petals making pollens touched with the female part of the flower.

Finally, an initial exploration of the environmental implications of introducing robotic pollinators seeks to understand potential impacts on regional ecosystems and biodiversity, ensuring the project's viability and relevance in contemporary agriculture.

3.3 Software Simulations

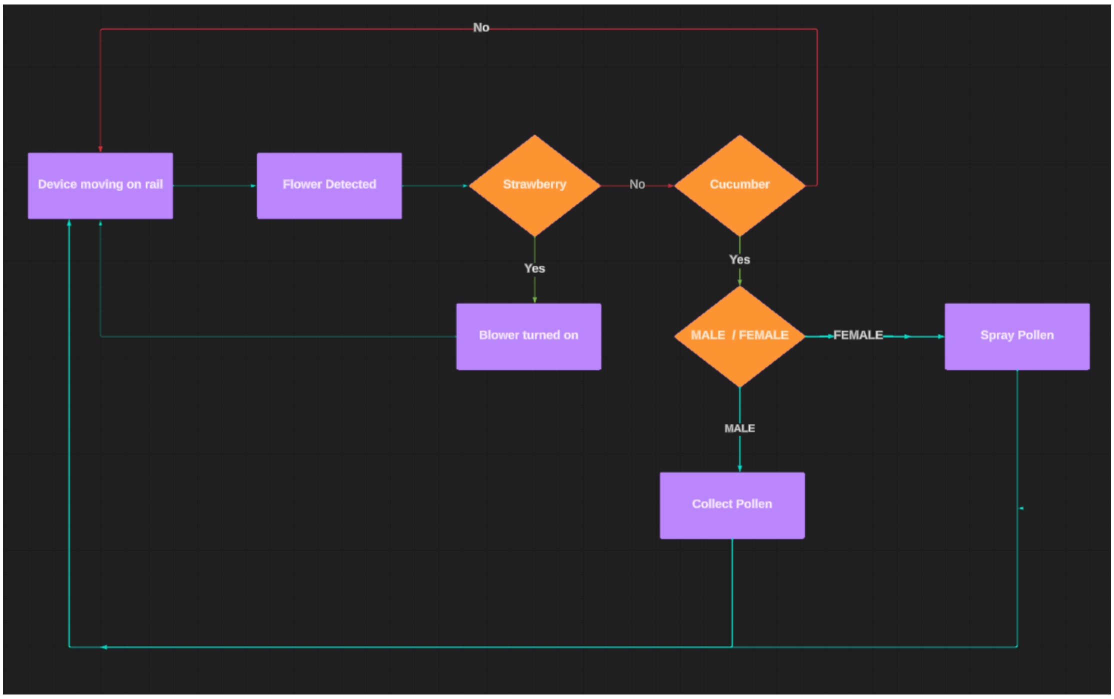

Figure 2. Process diagram

Figure 2 shows how the device works. When the device detects a cucumber male flower, the pollens are collected by the vacuum part. Then the pollens are mixed with the water and then the pollens are sprayed to the detected female flowers using a nozzle which is used to spray. When the device detects a strawberry flower, a small wind is given by the blower part.

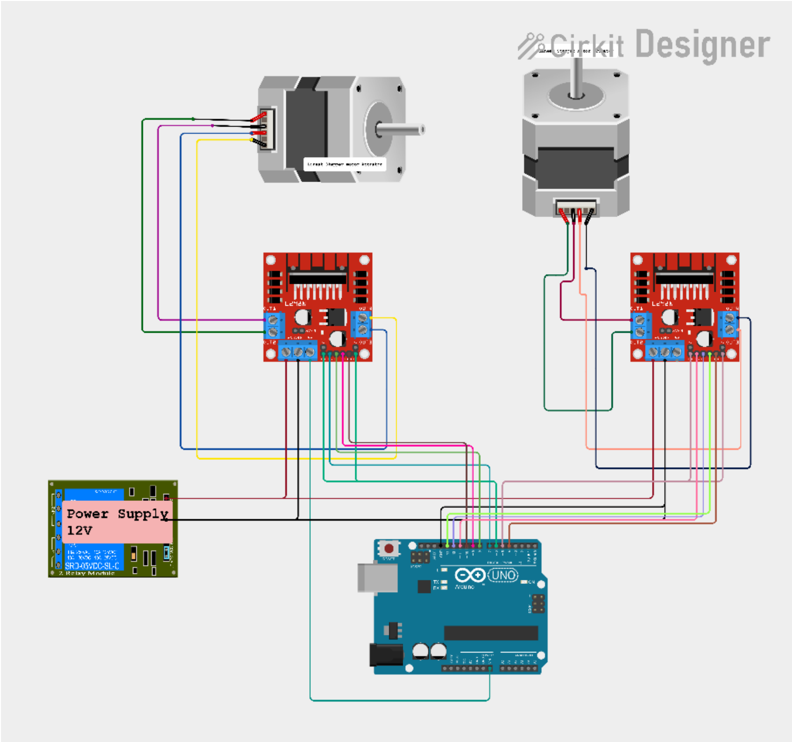

Figure 3. Navigation system

Figure 3 shows the circuit diagram of the navigation system.

3.4 Hardware Implementation

3.4.1 Navigation system

- This method enables the device to move on a two-dimensional(2D) horizontal plane and includes two structures rail A and rail B. Each structure has 4 nylon wheels with a diameter of 4cm.
- A threaded shafter with a 12V stepper motor is attached to the device.
- Rail B is moving on rail A as well the device is moving on rail B.
- Those movements of the rails and the device cover the whole area the underneath plantation.

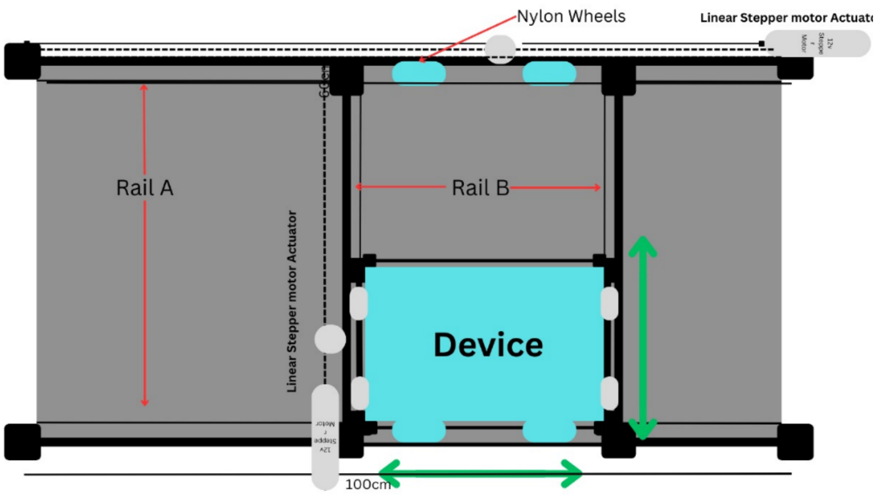

Figure 4. Rail A and rail B aerial view

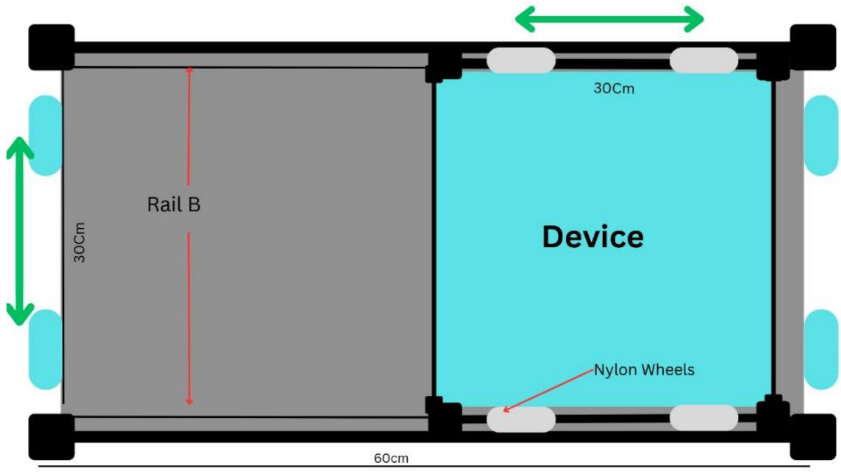

Figure 5. Rail B and device aerial view

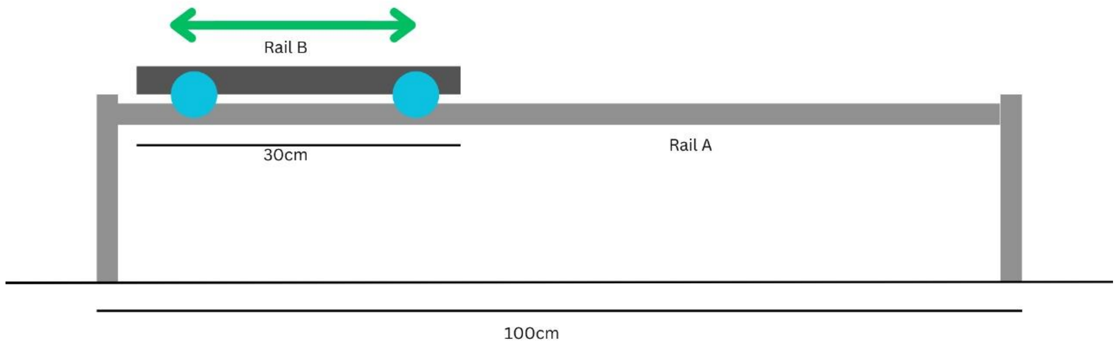

Figure 6. Side elevation of rail A and rail B

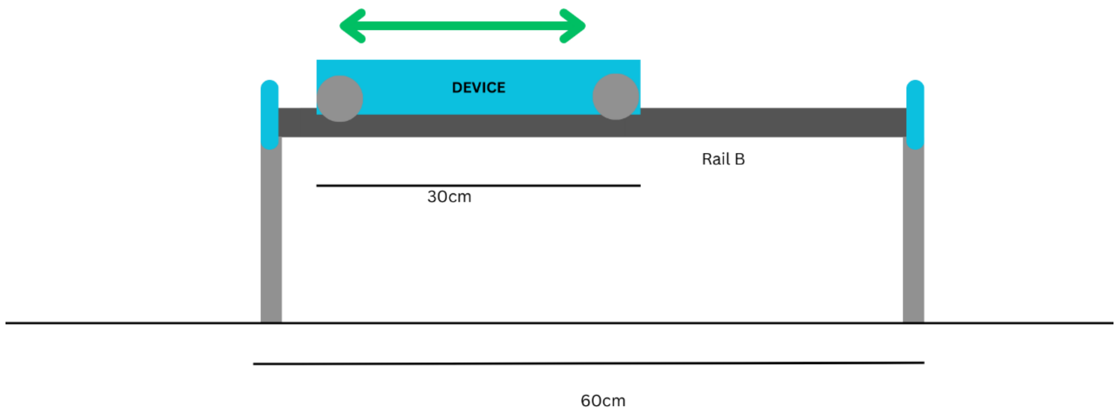

Figure 7. Side elevation of rail B and device

3.4.2 L298 Motor Driver

L298 motor driver is used to connect two stepper motors of the navigation system. The L298 Dual H-Bridge Motor Driver Integrated Circuit serves as the foundation for this dual bidirectional motor driver. With the circuit, separately operate the motors in both directions, making it perfect for robotic applications and easy to connect to a microcontroller. Relays, Transistor–Transistor Logic (TTL) gates, basic manual switches, and other interfaces can be used with it. This board has protective diodes, an on-board +5V regulator, and Light-Emitting Diode (LED) indications.[8]

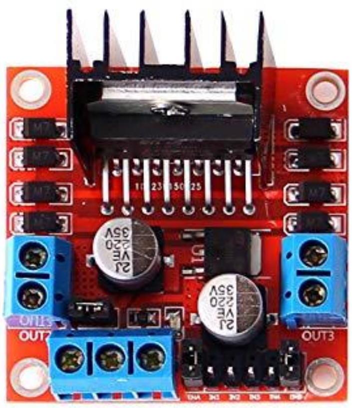

Figure 8. L298 motor driver

3.4.3 Arduino UNO

Arduino UNO is used to control the blower and navigation system and is used as the CPU of the device.

An ATmega328P-based microcontroller board is the Arduino UNO. It has a 16 MHz ceramic resonator, 6 analog inputs, 14 digital input/output pins (six of which may be used as PWM outputs), a Universal Serial Bus (USB) port, a power connector, an In-Circuit Serial Programming (ICSP) header, and a reset button. It comes with everything needed to support the microcontroller; all you need to do is power it with a battery or an AC-to-DC adapter or connect it to a computer via a USB cable to get going. [9]

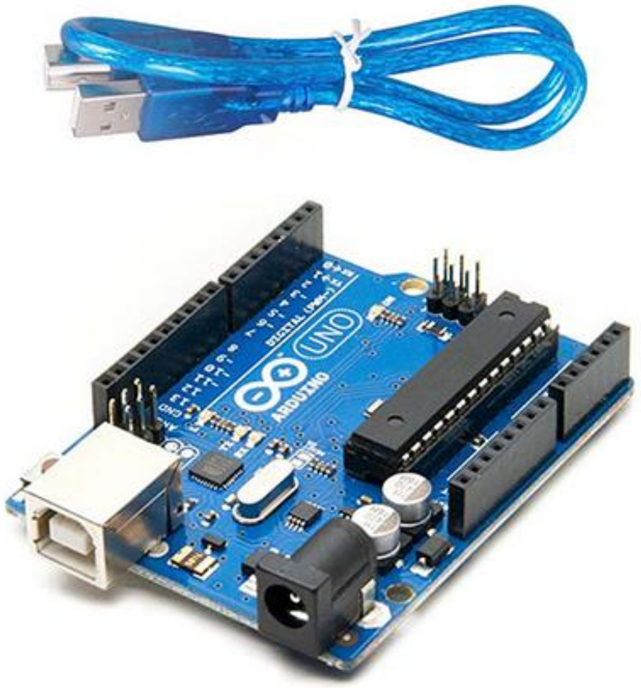

Figure 9. Arduino UNO

3.4.4 ESP32-Camera Module

ESP32-Camera Module is used to collect the video inputs for the image processing.
The ESP32 is a semiconductor that gives embedded devices, or Internet of Things (IoT) devices, Wi-Fi and (in certain variants) Bluetooth connection. Although ESP32 is only a chip, the manufacturer also frequently refers to the development boards and modules that incorporate this chip as "ESP32."
A single core Tensilica Xtensa LX6 microprocessor powered the original ESP32 chip. With a clock rate of more than 240 MHz, the CPU processed data at a comparatively fast pace.[10]

- Compact 802.11b/g/n Wi-Fi module with BT/BLE support
- 32-bit, dual-core, low-power CPU designed for application processors
- 600 DMIPS at up to 240 MHz
- 520 KB SRAM built-in, 4M PSRAM external
- Interfaces including UART, SPI, I2C, PWM, ADC, and DAC are supported.
- Encouragement OV7670 and OV2640 cameras featuring integrated flash.
- Wi-Fi upload assistance

Figure 10. ESP32-camera module

3.4.5 The Implemented Device

Figure 11. The blower and pollen collector

The overall hardware part which can be used for cucumber and strawberry flower pollination. This part includes both blower and suction parts.

Figure 12. The device with the navigation system

3.5 Calibration

For the image processing part,

The virtual environment was activated.
On a Windows system, this command launches the "vent" virtual environment, which is placed in the current directory. It creates an isolated environment for a particular project, ensuring that project-specific dependencies are utilized while running Python scripts.

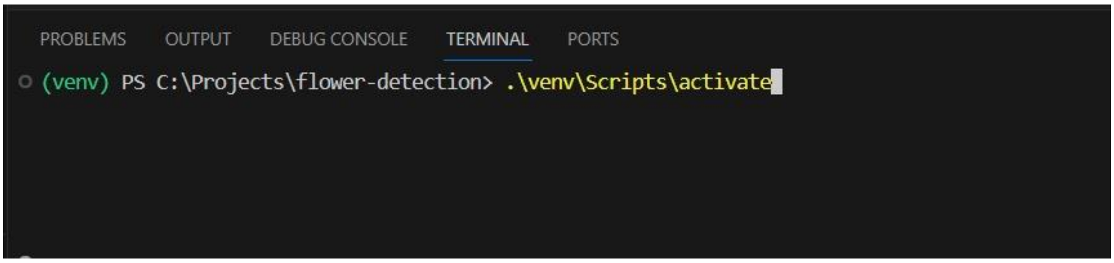

Figure 13. Starting the virtual environment.

AI model was started.
flask run creates a Flask web application and deploys it to a local development server for testing and debugging.
This message shows that the Flask application is now running and available locally at http://127.0.0.1:5000.

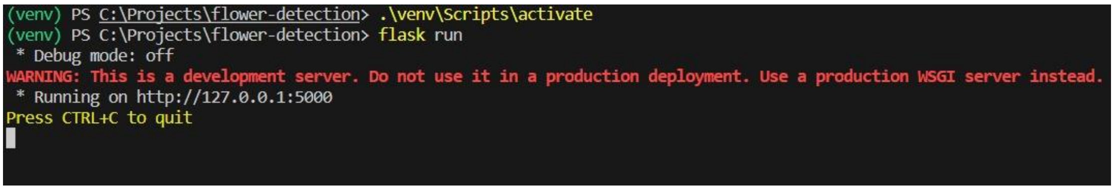

Figure 14. AI model

Streaming webpage was opened.

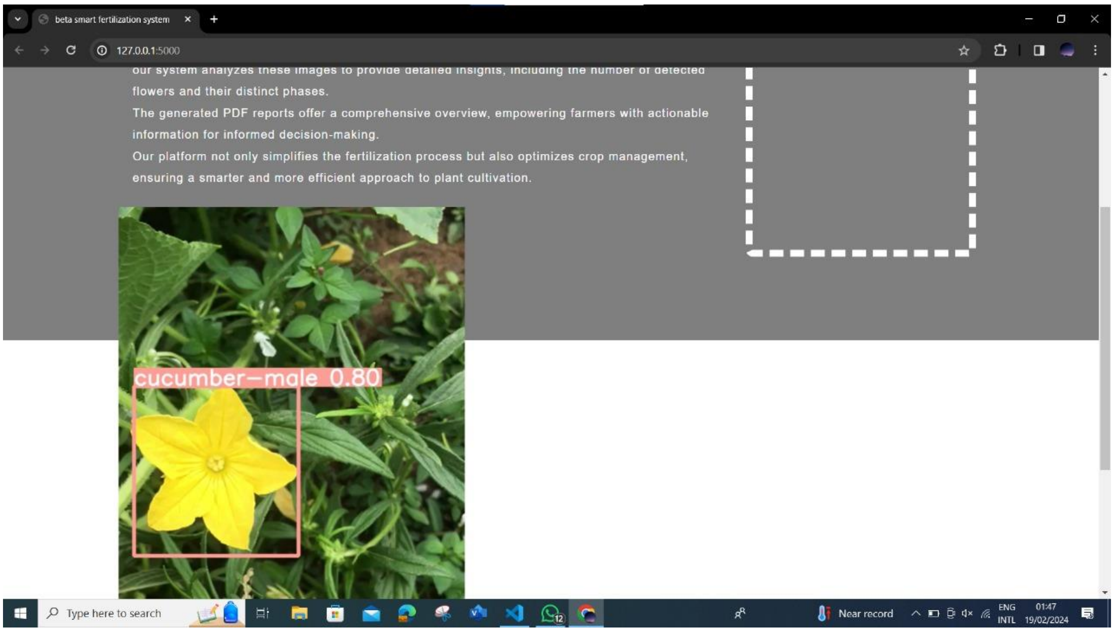

Figure 15. Streaming web page

Flower detected log activated.

```
Fusing layers...
custom_YOLOv5s summary: 182 layers, 7249215 parameters, 0 gradients
Error making GET request to endpoint: HTTPConnectionPool(host='192.168.8.132', port=80): Max retries exceeded with url: /custom_endpoint (Caused by ConnectTimeo
utError(<urllib3.connection.HTTPConnection object at 0x000001F0E2AC0C70>, 'Connection to 192.168.8.132 timed out. (connect timeout=None)'))
127.0.0.1 - - [19/Feb/2024 01:47:22] "GET /video_feed HTTP/1.1" 200 -
video 1/1 (1/1540) C:\Projects\flower-detection\vid.mp4: 640x384 1 cucumber-male, 508.7ms
Error making GET request to endpoint: HTTPConnectionPool(host='192.168.8.132', port=80): Max retries exceeded with url: /custom_endpoint (Caused by ConnectTimeo
utError(<urllib3.connection.HTTPConnection object at 0x000001F0E2AC1DE0>, 'Connection to 192.168.8.132 timed out. (connect timeout=None)'))
video 1/1 (2/1540) C:\Projects\flower-detection\vid.mp4: 640x384 1 cucumber-male, 388.0ms
127.0.0.1 - - [19/Feb/2024 01:47:44] "GET /favicon.ico HTTP/1.1" 404 -
Error making GET request to endpoint: HTTPConnectionPool(host='192.168.8.132', port=80): Max retries exceeded with url: /custom_endpoint (Caused by ConnectTimeo
utError(<urllib3.connection.HTTPConnection object at 0x000001F0E2AC1B70>, 'Connection to 192.168.8.132 timed out. (connect timeout=None)'))
video 1/1 (3/1540) C:\Projects\flower-detection\vid.mp4: 640x384 1 cucumber-male, 422.5ms
```

Figure 16. Flower detection log

3.6 Optimization

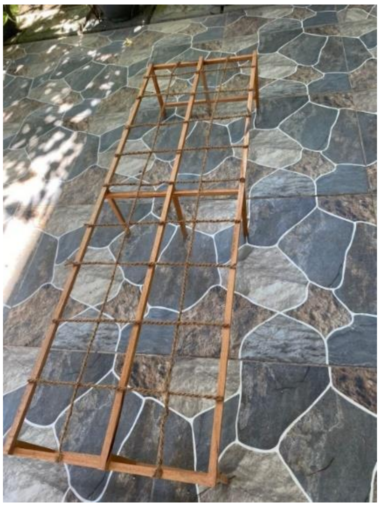

Figure 17. Cucumber plant arrangement (without the plant)

Figure 18. Cucumber plant arrangement (with plant)

In cucumber plants, most of the flowers are under the leaves. Because of that the device cannot detect the flowers under the leaves. The arrangement shown in figure 17 can be used to solve that problem. It can detect more flowers because the leaves are under the ropes as shown in figure 18. This is a solution to detect the flowers which are behind the leaves.

Chapter 4: Results

Cucumber Flower Detection

In greenhouse conditions, the model successfully detects cucumber flowers. Results show great precision in identifying cucumber flowers.

Figure 19. Cucumber male flower detection testing

Figure 20. Cucumber female flower detection testing

Strawberry Flower Detection

Similarly, the model can detect strawberry flowers in greenhouse conditions. Initial experiments indicate encouraging results for recognizing strawberry flowers of various sizes and looks.

Figure 21. Strawberry flower detection testing

Figure 22. Results

Chapter 5: Discussion and Conclusion

5.1 Discussion

5.1.1 Discussion by PE/2019/043

The navigation system, utilizing a 2D plane rail (Parallel to the Ground) with two main parts as Rail A and Rail B, provided the pollination device with precise movement capabilities during past stages of the project. The research focused on developing algorithms for efficient movement in both x (from rail A) and y (from rail B) directions within the 2D plane. This navigation system demonstrated effectiveness in guiding the device through crop rows, incorporating considerations for real-time adjustments. The 2D plane rail system contributed significantly to the device's adaptability to different field layouts. Past enhancements involved optimizing navigation algorithms for increased speed and energy efficiency. Two powerful stepper motors (12V) were used for each rail (A, B) considering the factors such as weight of the device, radius of the wheels and required speed of the device.

The navigation system was set up to cover the entire plantation in both x and y directions with the help of two threaded shafters with stepper motors. Motion will continue until a flower is detected, at which point it stops the motion for processing of the pollination part and then resume the motion. The programming part was done with the Arduino IDE.

5.1.2 Discussion by PE/2019/045

A critical phase in the research was the physical implementation of the pollination apparatus, which included both a blower for strawberry pollination and a pollen suction mechanism for cucumber flowers. This device is a prototype of the expected device. The research entailed choosing the necessary components, constructing, the device to be durable, and incorporating the cyclone separator method for efficient pollen collection. The device's dual functioning, which included blowing wind for strawberry pollination and suction for cucumber pollen transfer, displayed its adaptability. Practical factors such as energy consumption and maintenance, have previously been considered to assure the device's suitability for real-world agricultural applications. The use of the cyclonic approach adds an original touch, increasing the system's overall efficiency. Previous advancements aimed to optimize the device design for scalability and cost-effectiveness, opening the path for widespread implementation in precision agriculture operations.

5.1.3 Discussion by PE/2019/054

The experiment focused on detecting cucumber flowers using sophisticated image processing algorithms, considering cucumber plants' particular pollination requirements. Extensive study has been performed to develop ways for distinguishing male and female cucumber flowers while overcoming constraints such as color, size, and potential occlusions. The chosen image processing algorithms were highly accurate in identifying and distinguishing the two flower kinds, laying the groundwork for the accuracy of the device in cucumber fields. Ongoing work has focused on fine-tuning the algorithms to adapt to diverse cucumber kinds and make them scalable in a variety of environments. Furthermore, the enhancement of image processing capabilities to cover a broader range of crops was examined, increasing the system's adaptability.

5.1.4 Discussion by PE/2019/066

During the project's initial phase, powerful image processing techniques were used to recognize strawberry flowers. We used complex algorithms to solve the problem of detecting strawberry flowers in outdoor settings with varied illumination conditions. These algorithms, chosen for their resilience-enabled effective differentiation of flowers at different phases of development. This precision laid the groundwork for the device, which allows for precise targeting of flowers. The study entailed a thorough examination of image processing technologies, with particular attention paid to potential field interference. Achieving a high level of accuracy in detecting strawberry flowers was critical to ensure that the wind-blown mechanism efficiently pollinated the female parts in contact with the male components. Subsequent developments sought to enhance the algorithms for more adaptation to climatic circumstances and to broaden the system's applicability to a wider range of crops.

The creation of the Smart Fertilisation System has been a dynamic and iterative process characterized by continual investigation, issue solving, and technological advancement. Each component (image processing, navigation, and device implementation) is critical to system effectiveness, and a full examination of obstacles, solutions, and future advancements provides a complete picture of the research path.

The inherent variety of outside surroundings, including swings in lighting conditions and potential interference, creates challenges for image processing. Sophisticated algorithms were the foundation of solutions, undergoing iterative optimization to respond to changing environmental conditions. These advancements not only provided precise flower detection, but also laid the groundwork for the system's adaptation to varied crops.

Implementing a 2D planar rail system for navigation provided unique issues, such as path planning, collision avoidance, and real-time corrections. Algorithmic advancements have been critical in overcoming these issues, increasing the efficiency of device movements, and maintaining seamless navigation over crop rows. The success of the navigation system has contributed not only to efficient crossing, but also to the device's scalability and applicability in a variety of agricultural settings.

The actual installation of the pollination device was a vital phase, with issues relating to component selection, sustainability, and efficiency. To maximize the device's scalability and cost-effectiveness, careful design considerations and the incorporation of unique features, such as the cyclone method for pollen collection, were required. The device's dual functioning-blowing wind to pollinate strawberries and suction to transfer cucumber pollen-demonstrated its adaptability and usefulness.

Despite advancements, issues remain in responding to environmental unpredictability, dealing with unexpected interference, and assuring real-time adaptability. The unpredictable nature of outdoor conditions necessitates ongoing changes to ensure system reliability. Unexpected interferences, such as crop distribution changes or the introduction of new plant kinds, might create problems that necessitate adaptive algorithms and real-time resolution adjustments.

Looking ahead, the smart fertilisation system foresees developments that solve present difficulties while incorporating modern technologies for more efficiency and adaptability. The switch to an advanced coordinate-based flower navigation system is intended to improve the accuracy of the pollination device, allowing for more accurate and adaptive movement.

Furthermore, the addition of a flower detecting approach based on a 3D model is projected to transform the device’s capabilities, allowing travel in the Z plane and access to flowers hidden beneath foliage.

5.2 Conclusion

Finally, the research concluded in the creation of a SFS specifically intended to suit the unique pollination needs of strawberry and cucumber crops. The combination of image processing, navigation, and device implementation technologies has resulted in a consistent and novel approach to precision agriculture. Each team member’s meticulous exploration and implementation helped to increase the system’s effectiveness and adaptability.

The success of image processing components on successfully detecting strawberries and cucumber flowers has laid the groundwork for targeted pollination. The navigation system traversed the crop rows efficiently thanks to precise control over the device’s movements in a 2D plane.

The physical execution of the pollination system, which included a fan for strawberry pollination and a pollen suction mechanism for cucumbers, confirmed its adaptability and usefulness.

Looking ahead, objectives included integrating new navigation methods based on coordinates and extending the device’s reach to the flowers beneath the leaves. The incorporation of 3D-based flower identification technology was a significant step forward, allowing for movement in the Z plane for improved accessibility.

Furthermore, the dedication to strengthening pollination detecting mechanisms was meant to increase the system’s efficiency and dependability.

To summarize, the Smart Fertilisation System presented here is at the confluence of technology and agriculture, and it offers a promising answer to crop pollination difficulties. The sustained commitment to innovation and future efforts indicated in this report emphasized the importance of enhancing precision farming methods and contributing to sustainable development. Through continuing research and improvement, the system has been recognized as a vital asset for improving crop yields and fostering agricultural sustainability in the ever-changing terrain of modern agriculture.

5.3 Future Work

In future implementations, flower navigation will be assisted using a coordinate-based technique, introducing a paradigm change to improve the pollination device's accuracy and adaptability. The application of this enhanced navigation technique is predicted to result in increased precision when navigating different agricultural landscapes in response to dynamic crop spatial arrangements.

Furthermore, a potential improvement is the addition of a 3D model-based flower detecting system capable of manipulating the device in the Z plane. This innovation is likely to increase the device's reach to flowers behind leaves, addressing an important component of accessibility. The integration of such a system seeks to revolutionize navigation capabilities, providing total coverage of the agricultural area and allowing the device to reach until inaccessible flowers.

Additionally, a future goal is to improve the system's ability to recognize successful flower pollination. This anticipated upgrade is consistent with the continued commitment to improving the precision farming practices included within the Smart Fertilisation System. The incorporation of modern sensors or image processing techniques is likely to play a critical role in detecting small physiological changes in flowers following pollination, allowing for real-time input on pollination status.

In future implementations, SFS will be expanded to more other crops and this will be used in larger areas. In this project, mainly focused on two types of pollinations and the project will be expanded to other types of pollinations. This project,

The collaboration pursuit of these future enhancements is likely to have a substantial impact on the evolution of the Smart Fertilisation System, making it more adaptable, adaptive, and efficient in meeting the challenges of precision agriculture. The system's forward-looking activities aim to drive increased agricultural production optimization and sustainable farming practices in the ever-changing terrain of modern agriculture.

Chapter 6: References

Website

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Appendixes

Appendix A: Code Segments

Figure 23. QR code for the code segments