Automating Drone Pollination in Cucumber Plants

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Abstract **- This paper proposes a framework that can be used to identify the gender of flowers and aim to remove pollination through humans in greenhouses and use mechanical bees and drones. One such application of gender identification of flowers is artificial pollination in large farmlands. The study reviews literature on flower detection, flower recognition and its applications as well. Automatic gender identification of a flower is a branch of flower recognition that the researchers have not considered yet. The challenge in any automatic flower gender identification method is that the accuracy should be nearly 100 percent, as the max. error rate of pollination attempts is twice that of identification. Our framework is based on building mathematical models of the structure which will identify the male and female flowers respectively and hence perform the pollination. It uses resolution images captured through cameras on aerial or mobile robots. Finally, it proposes to apply image processing and machine learning models together with image classification techniques to identify the gender of a given flower and hence perform the pollination.**

Keywords – percentage, maximum

INTRODUCTION

Pollination is essential for the reproduction of most plants and trees that flower. There are two types of flowers knowns as perfect and imperfect flowers. The imperfect flowers contain only male or female floral organs called stamen and pistil respectively. Imperfect flowers may be found on the same tree or on different trees of the same species. Perfect flowers contain

both male and female floral organs. The chance of cross-pollination is increased by the separation of male and female floral organs in flowers. In dichotomies of perfect flowers, the male and female organs mature at different times, promoting crosspollination rather than self-pollination. Incomplete flowers always rely on crosspollination. Perfect flowers that are open during the pollination period are generally cross-pollinated and those that are not open during that time are largely self-pollinated. Stamens in male floral organs produce a sticky powder called pollen. The top of the pistil in female floral organs is called the stigma, and is often sticky. Seeds are made at the base of the pistil, in the ovule. To be pollinated, pollen must be moved from a stamen to a stigma. Cross-pollination produces stronger plants. Usually, plants rely on animals or wind to pollinate their flowers. Plants that are pollinated by animals are often of bright color and sometimes have a strong smell to attract animal pollinators. Another way that plants are pollinated is by the wind. The wind picks up pollen from one plant and blows it onto another. Plants that are pollinated by wind often have long stamens and pistils. Since they do not need to attract animal pollinators, they can be dully colored, unscented, and with small or no petals since no insect needs to land on them. Pollination is specifically important for vegetable and fruit growers who would like to have a successful harvest. However, weather conditions limit the behavior of wind or insects which lead to poor natural pollination. Farmers of small-sized farms use artificial pollination to hand-pollinate vegetables and fruits. The first step of the process is to identify male and female flowers. Then a farmer can transfer pollen from a male to a female flower using a brush or a swab. The farmer gently swirls the brush around the male flower's stamen and carefully swirls the pollen collected on the brush onto the female flower's stigma. Another way is to pluck a male flower and gently apply the pollen from the male flower's stamen to the female flower's stigma. Manual artificial pollination is painstaking as well as time-consuming, and therefore, not suitable for large croplands. To reap maximum yields, artificial pollination using land and aerial robots can be adopted in large farmlands and in areas where there is a scarcity of wind or insects or inside the greenhouses. Pollen could be extracted from male flowers and applied to female flowers artificially. This will not only save money and time but also would increase productivity. As such, accurate recognition of the gender of a given type of imperfect flower by close-range photography has become very important for this application.

PROBLEM STATEMENT

To achieve effective autonomous pollination, a robot must be able to traverse and navigate its environment. The robotic system needs to detect its surroundings, allowing it to search for flowers within a region while avoiding obstacles. This system must be able to transfer pollen between flowers without damaging the flowers it pollinates. The robot should also avoid revisiting flowers that have already been pollinated. To contribute to autonomous pollination, we designed a drone capable of autonomously navigating a region, detecting and targeting flowers to pollinate and transfer pollen between

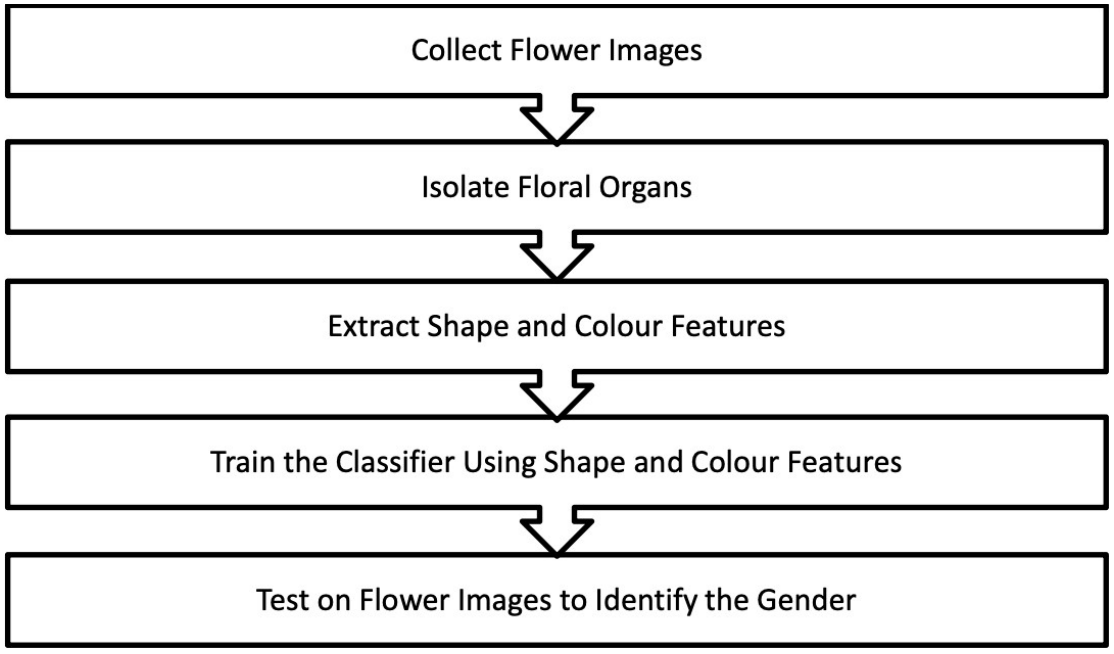
targeted flowers. This drone can localize itself relative to a home position and fly within a designated area using its onboard flight controller. Our system includes an onboard camera used for image processing to locate flowers within its field of view. The drone's camera is fixed to an actuated end-effector which is used for collecting pollen from one flower and transferring it to another.

RESEARCH REVIEW

There is no efficient algorithm to classify the flower's gender. In the research process of developing of an algorithm to automatically identification of the gender of a given imperfect flower, we need to find answers to the following research questions:

1. Using images of a given type of imperfect flowers, can a machine learning system be designed to recognize the gender of each of them with a near 100% accuracy?
2. How would such a system behave under varying brightness, capture distance, and capture angle of images?
3. How would such a system perform if the type of flower is previously unknown to the system?

In order to address the above questions, a large sample of colour images of cucumber flowers was captured from a smartphone camera in varying brightness and exposure. The next step will be to recognize the patterns and extract features. We will develop mathematical models to represent the shapes of male and female floral organs.



In order to take into account the change in the size of the flower and that of the floral organs due to the capture distance and angle, we will also develop several mathematical transformations. In the third step, the images of the floral organs are separated from the background and these

mathematical models will be applied to extract the shape and colour features.

PROPOSED METHOD

Our goal is to use transfer learning approach for the process of flower classification and predict the category(i.e male/female)of the flower in the image. Our construction process is divided into four fundamental components including,

- Image pre-processing
- Algorithm training
- Verification process
- Testing process

We propose a two-step approach for the cucumber flower classification problem. The first step localises the flower by detecting the minimum bounding box around it. The localisation is performed by segmenting the flower region using an FCN method. The second step learns a CNN to accurately classify the classes of cucumber flower. The background will be removed and the image will have only the subject of interest with no background. These segmented images are then given to the CNN as input images for training. Therefore, the proposed method is divided into two main parts; segmentation and fine-tuning the deep convolutional neural network. The base learning rate used was the 0.01 with linear learning rate decay. We trained the network for 100 epochs. A dropout layer with a dropout ratio of 0.5 was also implemented to introduce regularization. At the end, we had a SoftMax layer to give out scores of each respective class. The network took 15 minutes 9 seconds to finish training. We observed the results on the test set and found the top-1 accuracy to be 93% .

DRONE IMPLEMENTATION

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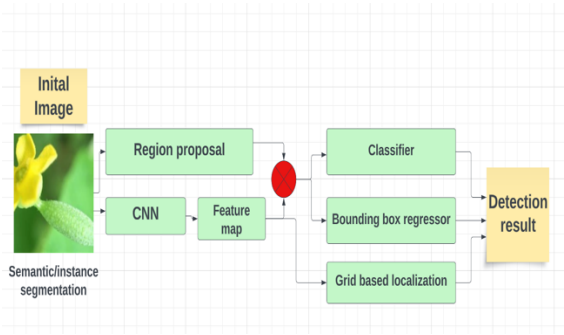
Due to the decline in the bee population, people have started seeking alternatives to pollinate crops artificially. Some of these methods involve human labour while some rely purely on automated systems such as UAVs and on-ground robots. Although hand pollination by humans is possible, it is not a viable solution because it requires extra human labour and is not cost-efficient for large-scale crop production. Furthermore, manual pollination of flowers may lead to dangerous working

environments and serious injuries. For example: to pollinate flowers on top of trees, workers either need to climb the tree or use a ladder or an automated lift, which increases the risk of work injuries.



DATASET COLLECTIONS

Datasets are the ordered collection of data. Any named group of records is called a data set. Data sets can hold information such as medical records or insurance records, to be used by a program running on the system. Data sets are also used to store information needed by applications or the operating system itself, such as source programs, macro libraries, or system variables or parameters. For data sets that contain readable text, you can print them or display them on a console (many data sets contain load modules or other binary data that is not printable).

We collected our dataset both manually and with the help of Kaggle and other websites which don't have any watermark or anything since both the female and male flowers were important, so the dataset was collected with precaution. There are around 200+ images of both male and female cucumber flowers. Our dataset is collected from all possible angles to give more accuracy to our model. Below, are some samples of our dataset; it contains two samples of male and female flower respectively providing a clear idea to the reader.

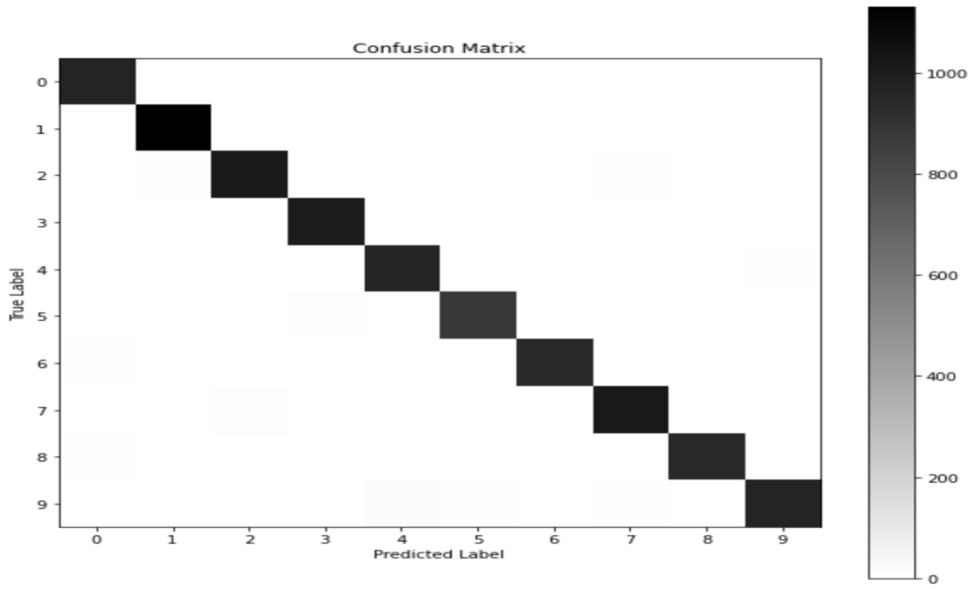
PERFORMANCE ANALYSIS

Our experiment was conducted using the Google Colab environment. The accuracy of our model during training and insulting was evaluated for 10 epochs with batch size of 64.

Parameter and results of our proposed model for dataset

Method	DenseNet121
Epoch	10
Data size	
Accuracy	0.93
Precision	
Recall	

The Confusion Matrix
for the Cucumber flower dataset



COMPARISION

In the process of achieving our goal a good comparison of algorithms is necessary to choose the suitable on for implementation. To classify the classes of cucumber flower Single-shot-detector(SSD) algorithms can be one of the approaches. It uses feature maps of convolutional layer to predict the bounding boxes. After consolidating all the feature maps, it runs a 3x3 convolutional kernel on them to predict bounding boxes and classification probability. Training of SSD model gave the results on the test set and found the top-1 accuracy to be 56.39% .

The algorithm has lower accuracy compared to CNN as SSD is not good at detecting small objects in spaces but it helps in improving the frames per second to almost five times better than CNN.In CNN image detection accuracy is more while SSD proves to be faster in training time comparison.

LIMITATIONS

1. Accuracy Limitations: The accuracy of flower gender identification should be nearly 100% to ensure effective pollination. However, achieving this level of accuracy may be a risk of misidentification, which could result in ineffective pollination. This can affect the accuracy and reliability of the proposed system

2. Environmental Obstacles: System relies on cameras or robots to capture images for flower gender identification. However, environmental factors such as lighting, weather conditions, and background clutter may affect the accuracy of image processing algorithms and machine learning models. Also, the use of drones could disrupt the natural pollination process and impact the ecosystem's balance.

3. Technical Issues: The robotic system designed for autonomous pollination needs to navigate its environment and detect obstacles while locating and pollinating flowers. However, the technical capabilities of the drone, such as its battery life, payload capacity, and obstacle detection sensors, may limit its ability to operate in real-world environments effectively.

4. Incompatibility with Certain Flowers: The proposed system focuses on identifying male and female flowers and performing pollination. However, not all flowers have distinct male and female parts, and some flowers rely on wind or insects for pollination. This could limit the applicability of the proposed system to certain types of flowers.

5. Cost Limitations: Implementing a system for autonomous pollination using mechanical bees and drones may involve significant costs, including the purchase and maintenance of the drones, image processing software, and machine learning models, which could limit its practicality and scalability.

SCOPE OF THE PROJECT

The scope of the project appears to be focused on developing a framework and system for autonomously pollinating cucumber flowers using mechanical bees and drones. The project aims to address the challenges of identifying the gender of cucumber flowers and performing pollination without relying on human intervention.

The proposed system aims to develop a framework for automatically identifying the gender of cucumber flowers using image processing and machine learning models. This includes identifying male and female flowers and distinguishing between them with a high level of accuracy.

Since, the proposed system uses image processing and machine learning models to identify male and female cucumber flowers and transfer pollen between them using a drone with an onboard camera and an actuated end-effector. The system is designed to operate in a greenhouse environment, and the paper suggests that the proposed approach could also be applied to large farmlands.

The project includes evaluating the effectiveness of the proposed system in

terms of its ability to accurately identify flower gender, transfer pollen between flowers, and increase pollination efficiency compared to traditional methods. This may involve conducting experiments and comparing results with manual or traditional pollination methods.

The project contributes to the growing field of autonomous agriculture by exploring new ways to reduce human intervention in farming processes and increase efficiency and productivity. The results of the project may have broader implications for the development of new technologies and approaches to crop pollination and agriculture.

REFERENCE PAPERS

1. "Automated Cucumber Flower Detection and Pollination Using Unmanned Aerial Vehicles" by Raviv et al. This paper proposes a method for automated cucumber flower detection and pollination using unmanned aerial vehicles. The approach uses high-resolution images captured by a camera mounted on the drone to detect cucumber flowers and an actuator system to pollinate them.
2. "Automatic Recognition of Flower Gender in Cucumber using Machine Learning Techniques" by Lu et al. This study presents a machine learning-based approach for automatic recognition of flower gender in cucumber plants. The approach uses colour and texture features extracted from flower images to classify them as male or female.
3. "An Image Processing-Based Approach for Detecting Cucumber Flowers in Greenhouses" by Zhang et al. This paper presents an image processing-based approach for detecting cucumber flowers in greenhouses. The method uses a combination of colour and texture features extracted from flower images to detect and locate them.
4. "Design of a Robotic Pollinator for Cucumber Plants" by Chatterjee et al. This study proposes the design of a robotic pollinator for cucumber plants. The system uses a camera-based detection system to locate flowers and a robotic arm to pollinate them.
5. "Machine Vision-Based Automated Pollination System for Cucumber Plants" by Chen et al. This paper presents a machine vision-based automated pollination system for cucumber plants. The system uses image processing techniques to locate flowers and a robotic arm to pollinate them.
6. "Development of a Mobile Robot for Autonomous Cucumber Pollination" by Jiang et al. This study presents the development of a mobile robot for autonomous cucumber pollination. The robot uses a camera and image processing techniques to locate flowers and a robotic arm to pollinate them.
7. "Robotic Pollination of Cucumber Plants Using a Flying Robot and a Ground Robot" by Huang et al. This paper proposes a robotic pollination system for cucumber plants using a combination of a flying robot and a ground robot. The system uses image processing techniques to locate flowers and robotic arms to pollinate them.