# Automated Strawberry Flower Counting using Machine Vision for Yield Prediction

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## Summary

**The objective of this project was to develop a machine learning based computer vision algorithm for strawberry flower detection and counting from digital color images. The number of flowers will be used to estimate strawberry yield at different locations of the field based on flower count. The developed algorithm performed at an 88% accuracy for flower detection in validation images.**

## Methods

### Image Acquisition:

Images of strawberry plants were acquired at the Gulf Coast Research and Education Center (GCREC) during the 2016-17 growing season, using commercial digital cameras of different resolutions and sensor sizes. Images acquired by a Canon DSLR camera at a high resolution (18 Megapixels) were used primarily during algorithm development. The developed algorithm was later tested using images from a lower-end Sony digital camera at a lower resolution (9 Megapixels). Images were taken under different illumination conditions and at different distances to determine the best conditions for the algorithm to work. They were categorized into three different datasets based on illumination conditions.

### Algorithm Description:

The images were resized to a lower resolution for faster processing. Pixels from images were analyzed using parameters such as color, shape and geometry in increasing order of complexity in order to identify locations of strawberry flowers. A carefully chosen combination of techniques from computer vision and machine learning were used to obtain the final flower count.

### Experimental Setup:

The entire algorithm was implemented as a Python program. The collected images were partitioned into training, testing and validation datasets with a ratio of 60:20:20. Care was taken to ensure that each of these datasets covered varying working distances, angles, and flower orientations.



**Figure 1.** Flower recognition in a high resolution image.

**Figure 2.** Flower recognition in a low resolution image.

## Results & Observations

The developed algorithm was evaluated against the number of flowers counted manually for each test image. Using this metric, the algorithm performed at an accuracy of 88% on a validation set consisting of 209 images spanning various illumination conditions. The algorithm was robust to conditions such as highly contrasted image regions due to direct sunlight, noise due to imaging artifacts and blur due to flowers falling outside the depth of focus of the camera. Percentage split of errors are shown in Table 1, and sources of errors are discussed below. Sample results are shown in Figs. 3 and 4 in the last section. In the results shown, red boxes indicate flowers correctly detected using the developed algorithm.

The algorithm performed well when lighting was uniform in the camera's entire field-of-view, flowers were within acceptable working distances and were not significantly occluded. The validation set consisted of approximately 25% Sensation® variety and the remaining 75% Radiance variety. Lighting and imaging setup were seen to have a greater effect on accuracy than the variety of strawberry.

## Conclusions

In this phase of the project, a prototype software that uses state-of-the-art techniques in artificial intelligence was developed to identify and quantify the number of flowers in the images acquired from strawberry fields. Results obtained by image analysis

have shown that computer vision techniques could be applied effectively for yield prediction in strawberry fields. Although various stages of the work-flow were done manually for obtaining current results, the end goal is to build a system that can eventually work autonomously. Such a system could help improve overall profit for farmers by helping them make reliable yield predictions and resource allocations during the entire strawberry season.

## Future Work

During the next phase of this project, a complete system consisting of imaging hardware and computer vision software will be developed to provide yield estimation to farmers. The following section provides a brief description of proposed tasks.

**Imaging Hardware:**
The system would include cameras and a GPS device placed at carefully chosen locations within an enclosed box, which will be towed by a small tractor or a truck. GPS coordinates will be recorded in parallel to image acquisition. The enclosed box is expected to minimize errors due to strong external lighting conditions. Such hardware setup will also allow us to ensure that flowers are within a reasonable working distance from the camera.

**Computer Vision Software:**
Further research will be conducted to identify and make robust specific parts of the flower detection algorithm. GPS information collected in parallel during imaging will be used to provide farmers with a map of flower counts, which will then be used to estimate strawberry yield at different locations.

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**Table 1.** Flower detection results from the validation images of strawberry flowers collected from the University of Florida, GCREC. Collected flowers include two varieties of strawberries – Radiance and Sensation®.

| Number of flowers | Correctly identified flowers (True positives) | Missed flowers (False negatives) | Non-flower objects incorrectly identified as flowers (False positives) |
|---|---|---|---|
| 400 | 352 | 32 | 15 |
| 100% | 88% | 8% | 4% |



(a) Input image

(b) Intermediate detection step (Quickshift segmentation)
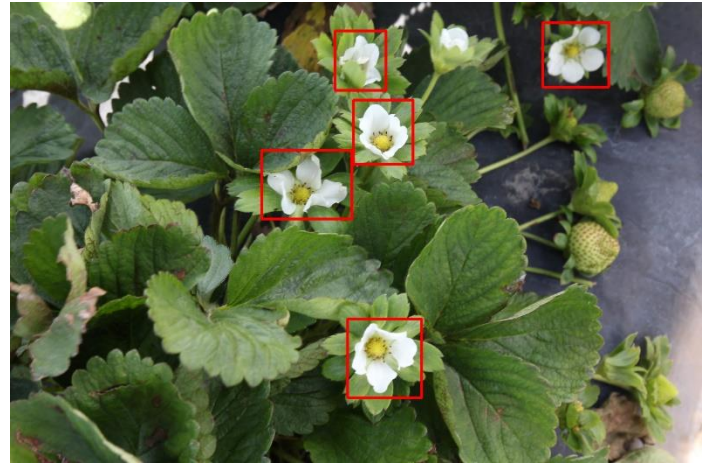
(c) Merged segments

(d) Final detection result

**Figure 3.** Output examples from different stages of the developed algorithm.

(a) Uniformly lit (Radiance)


(b) Uniformly lit (Radiance)


(c) Blur at close working distance (Sensation)


(e) Larger working distance (Radiance)

**Figure 4.** Sample outputs under different illumination conditions and distances.

**References:**

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[2] Vedaldi, A. and Soatto, S. Quick shift and kernel methods for mode seeking. European Conference on Computer Vision, 2008.