



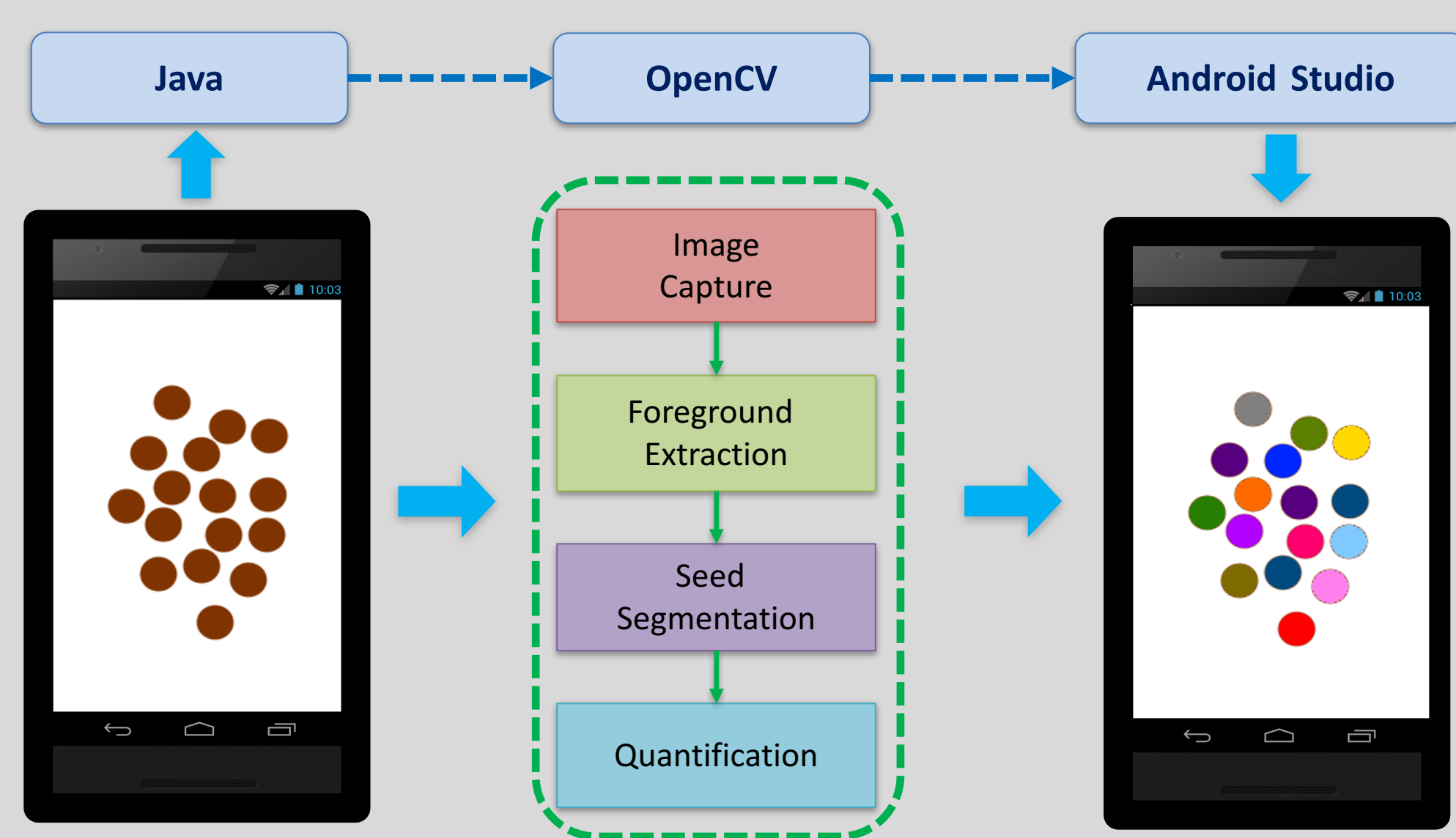
# MUSeed: A Mobile Image Analysis Application for Plant Seed Morphometry

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## Introduction

Plant phenotyping based on digital sensory datasets grow exponentially in size and contain more information thanks to advances in high throughput imaging and sensor technologies. Automated image processing and analysis methods are needed to efficiently process the acquired data and to support exploration, understanding, and discovery in plant sciences and agriculture. Advances in mobile handheld device technologies improve the promise for non-destructive and non-invasive digital plant phenotype quantification. In this poster, we present an Android-based mobile application named MUSeed that automatically computes seed morphometry utilizing image processing techniques. Unlike most of the existing tools, MUSeed does not impose restrictions on arrangement of seeds since it is capable of handling touching seed instances.

## Overview

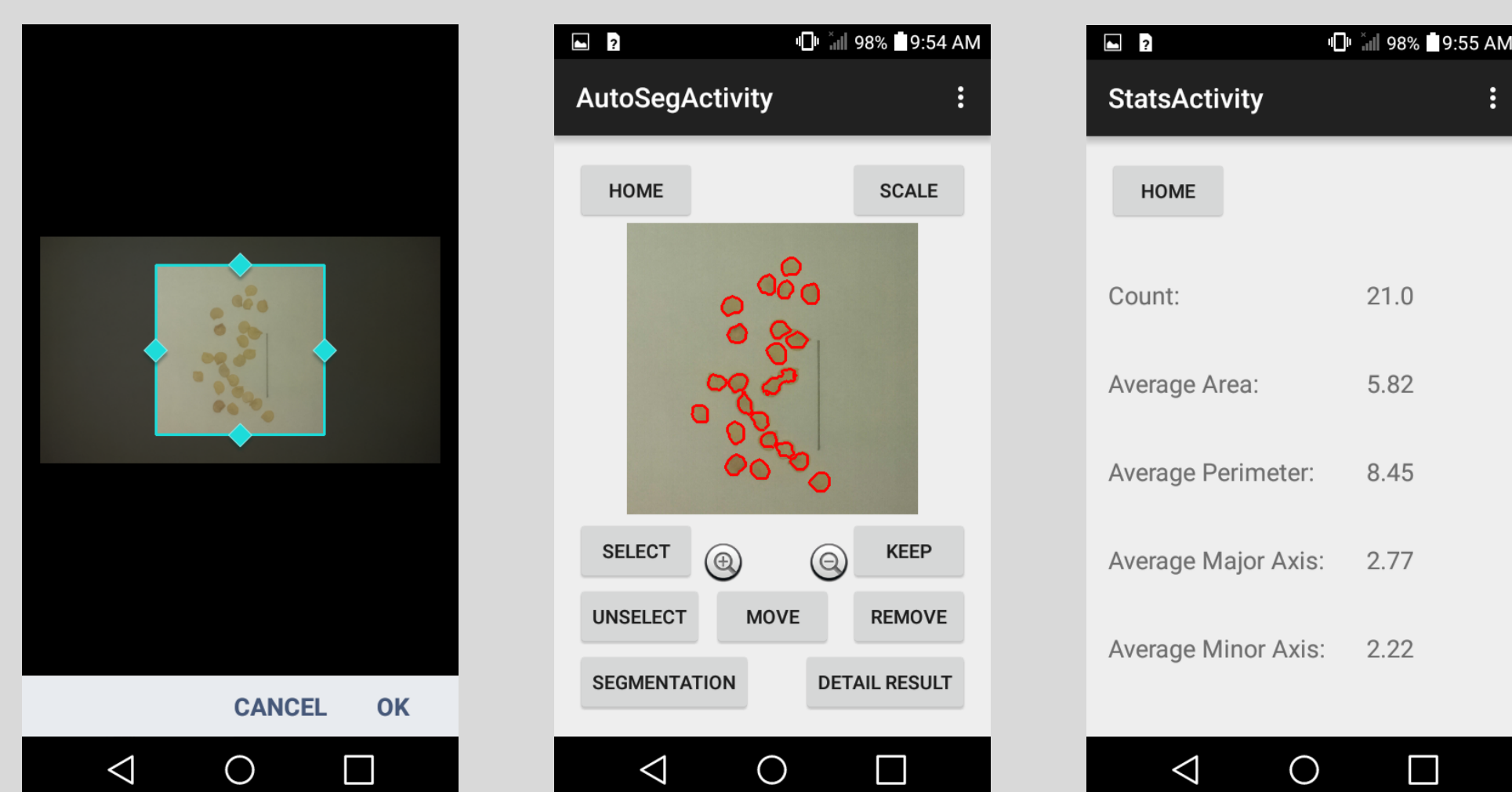


### Foreground Extraction:

- K-means

### Seed Segmentation:

- Cluster decomposition
- Segmentation selection using Fitness Function



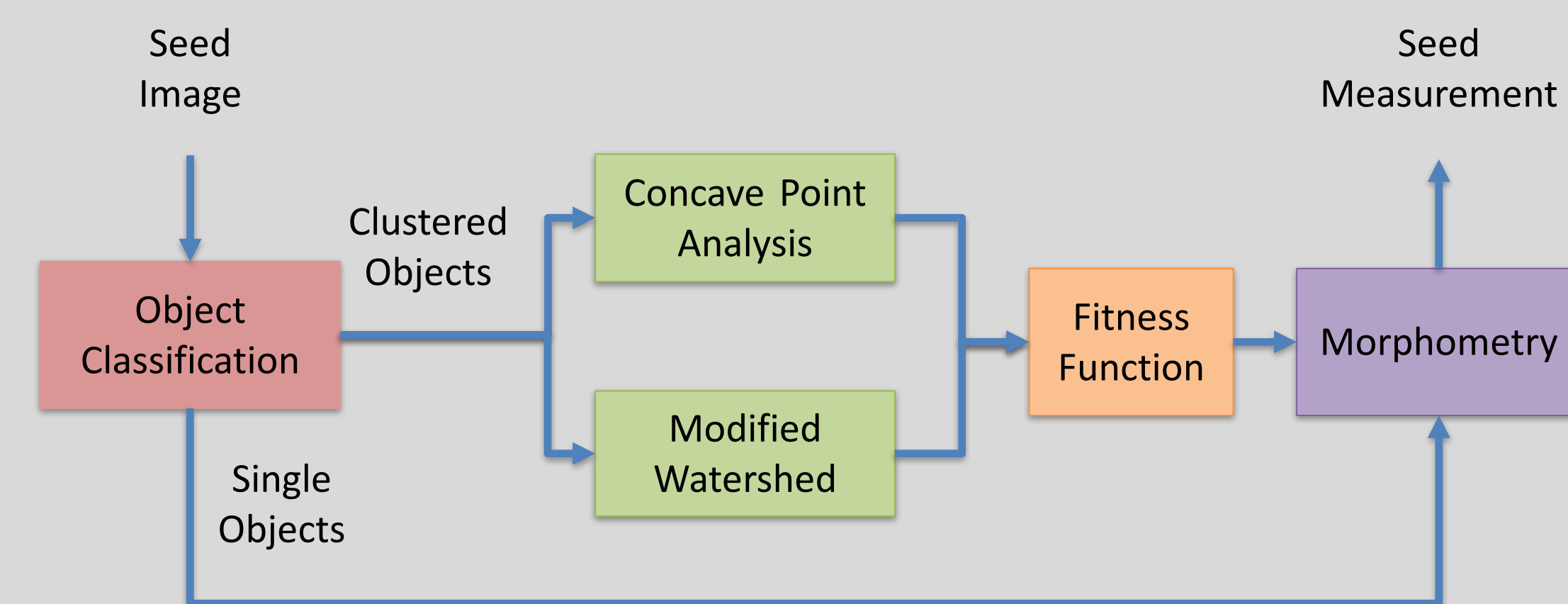
Major graphical user interface of MUSeed

MUSeed is implemented in Java with OpenCV libraries. The integrated development environment is Android Studio. The application is capable of processing seed images and generating measurements of each seed. The measurements can be exported to a text file and sent to an email address provided by the user.

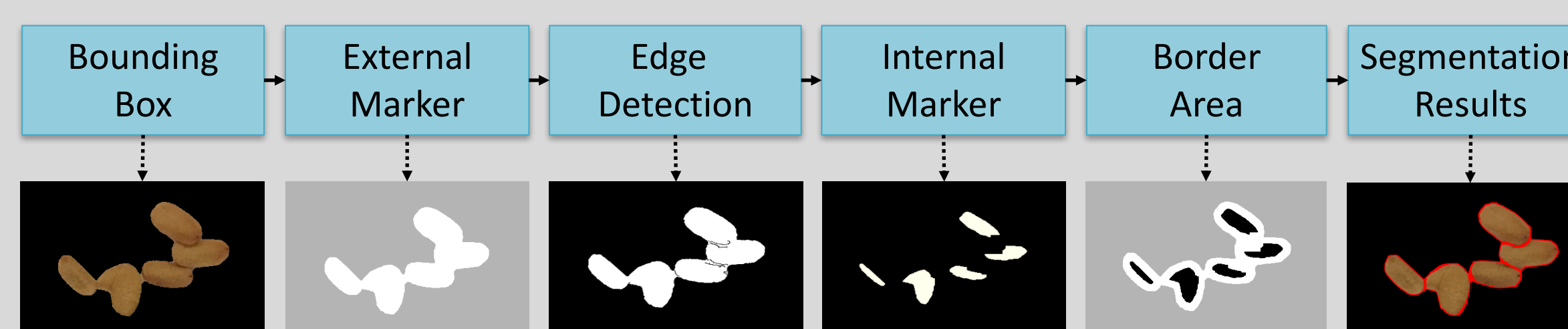


For more information, please visit:  
[www.smartmscope.com](http://www.smartmscope.com)

## Cluster Decomposition

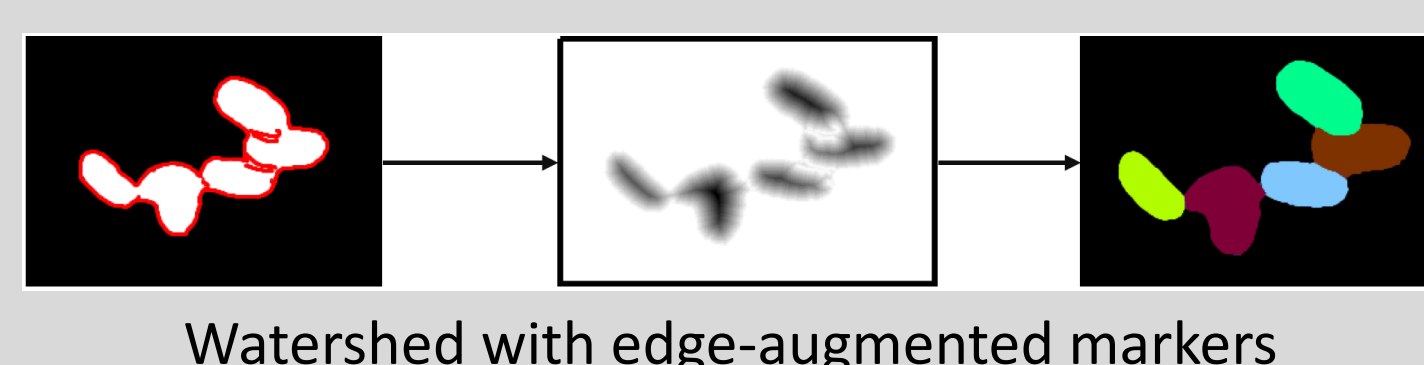
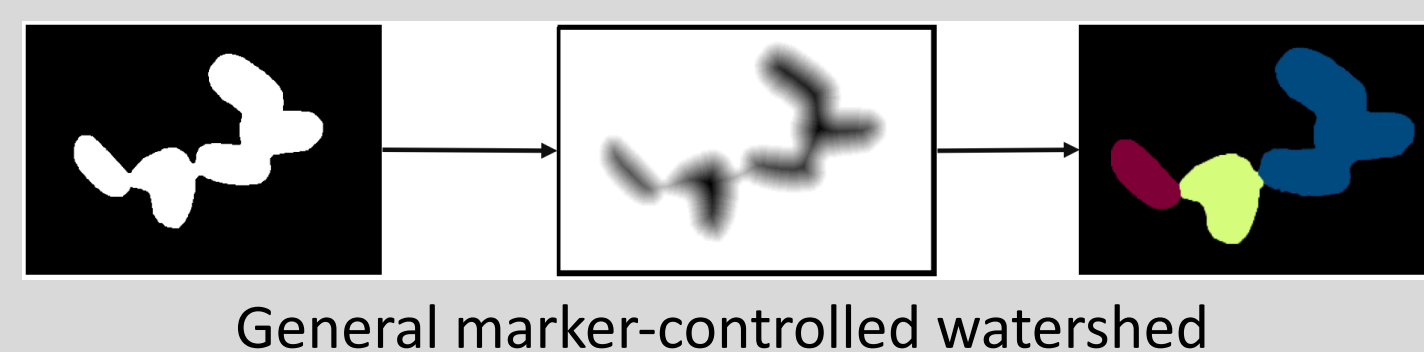


- **Watershed with Edge-Augmented Markers (WEAM)**  
 - region-based segmentation



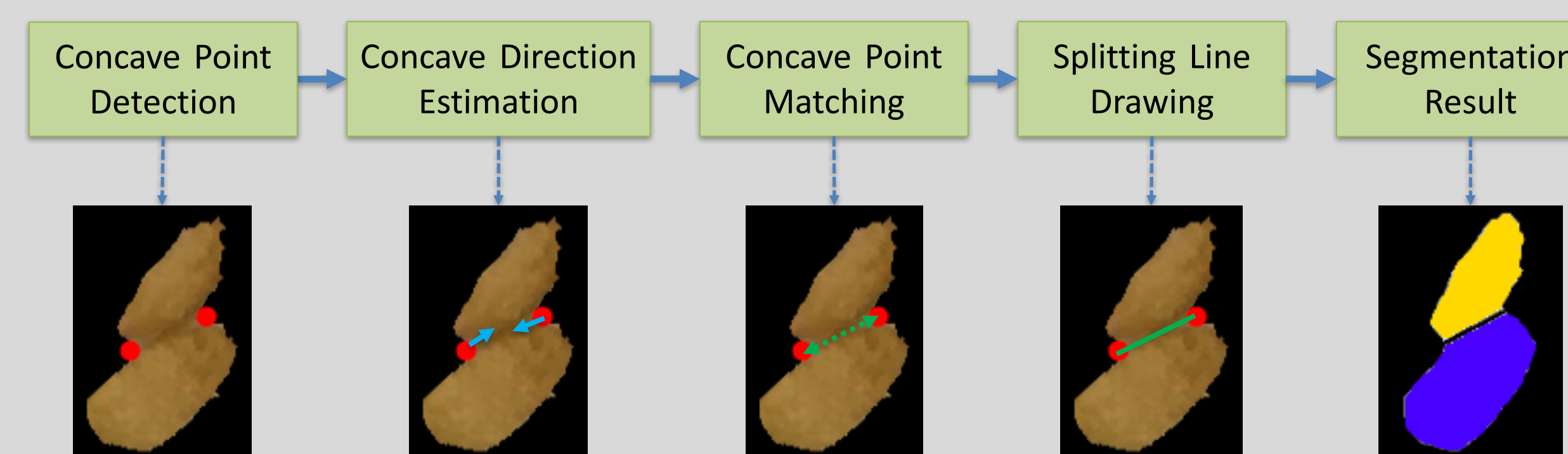
Watershed with Edge-Augmented Markers (WEAM) combines the general marker-controlled watershed algorithm with Canny edge detection to improve the segmentation performance by creating more accurate internal markers.

- Step 1.** The external marker indicating the background area is obtained using morphological dilation on the binary mask of an image.
- Step 2.** Canny edge detection is performed on the original RGB image. The binary mask is overlaid with the detected edges.
- Step 3.** The Euclidean distance transform is applied to the edge-augmented binary mask. The local maxima on the distance map are selected as the internal markers.
- Step 4.** Apply marker-controlled watershed algorithm using both original RGB image and markers as inputs.



- **Concave Point Analysis (CPA)**  
 - contour-based segmentation

- Step 1.** Concave points are detected based on a sliding kernel method and filtered out with distance to convex hull.
- Step 2.** For each concave point, direction of concavity is estimated.
- Step 3.** Concave points are matched according to a set of criteria including direction of concavity and boundary crossing information.
- Step 4.** Line joining the matching concave points are drawn to split the cluster.



## Segmentation Selection using Fitness Function

A fitness function is performed to evaluate possible combinations of parameters so it can find the best segmentation result.

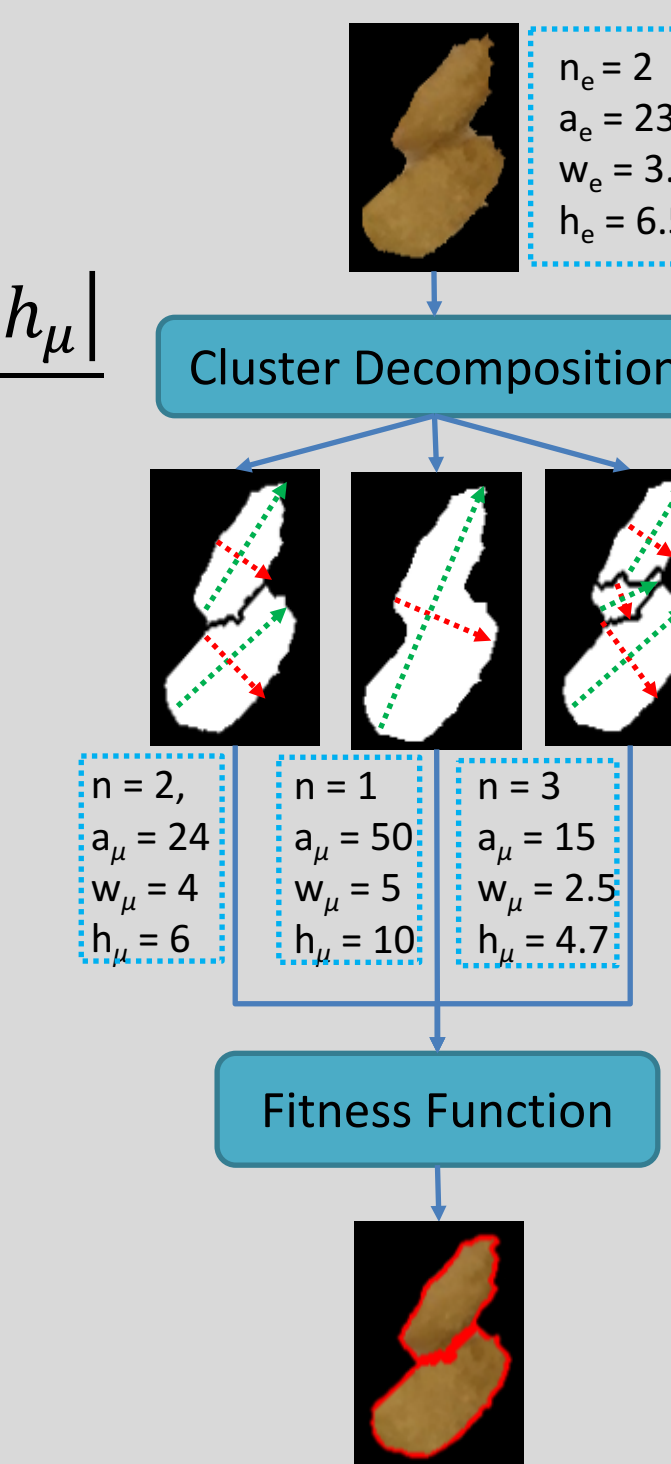
$$f_1[\text{fragmentation}] = |n - n_e|$$

$$f_2[\text{shape accuracy}] = \frac{|a_e - a_\mu|}{a_\mu} + \frac{|w_e - w_\mu|}{w_\mu} + \frac{|h_e - h_\mu|}{h_\mu}$$

$$f_3[\text{size \& shape variability}] = \sigma_a + \sigma_w + \sigma_h$$

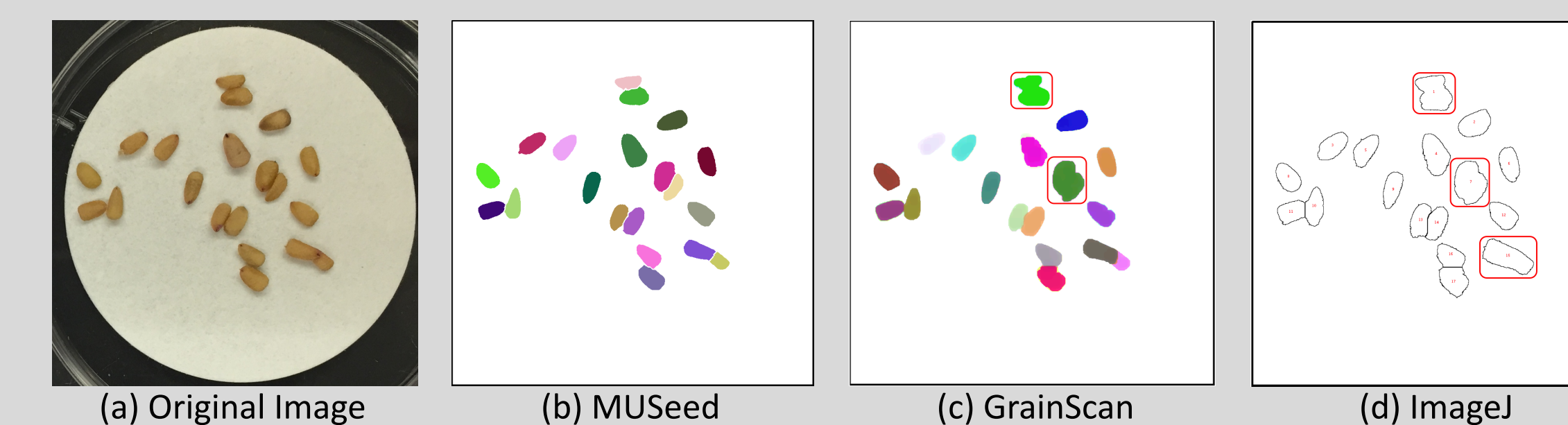
$$\text{fitness} = \frac{1}{\lambda_1 f_1 + \lambda_2 f_2 + \lambda_3 f_3}$$

where  $a_e$ ,  $w_e$ , and  $h_e$  are the estimated area, width, and height of a regular-size seed, respectively. Likewise,  $a_\mu$ ,  $w_\mu$ , and  $h_\mu$  are the average area, width, and height of segments.  $\sigma_a$ ,  $\sigma_w$ , and  $\sigma_h$  are the standard deviation of area, width, and height of segments.

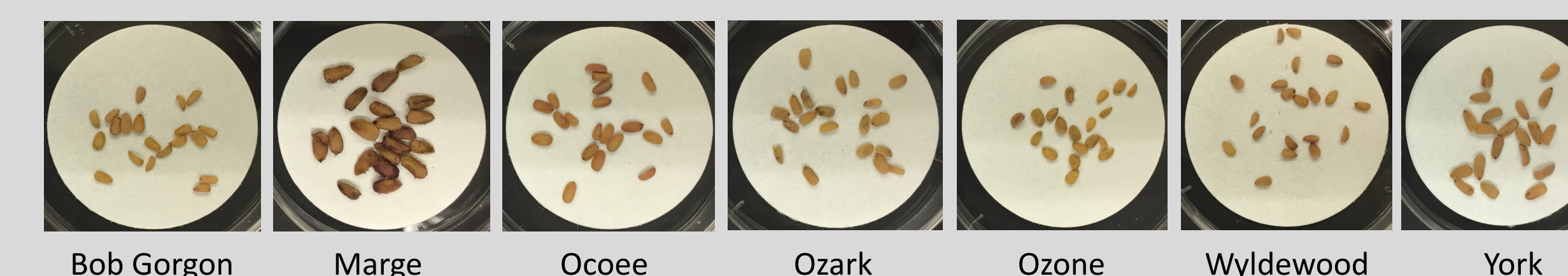
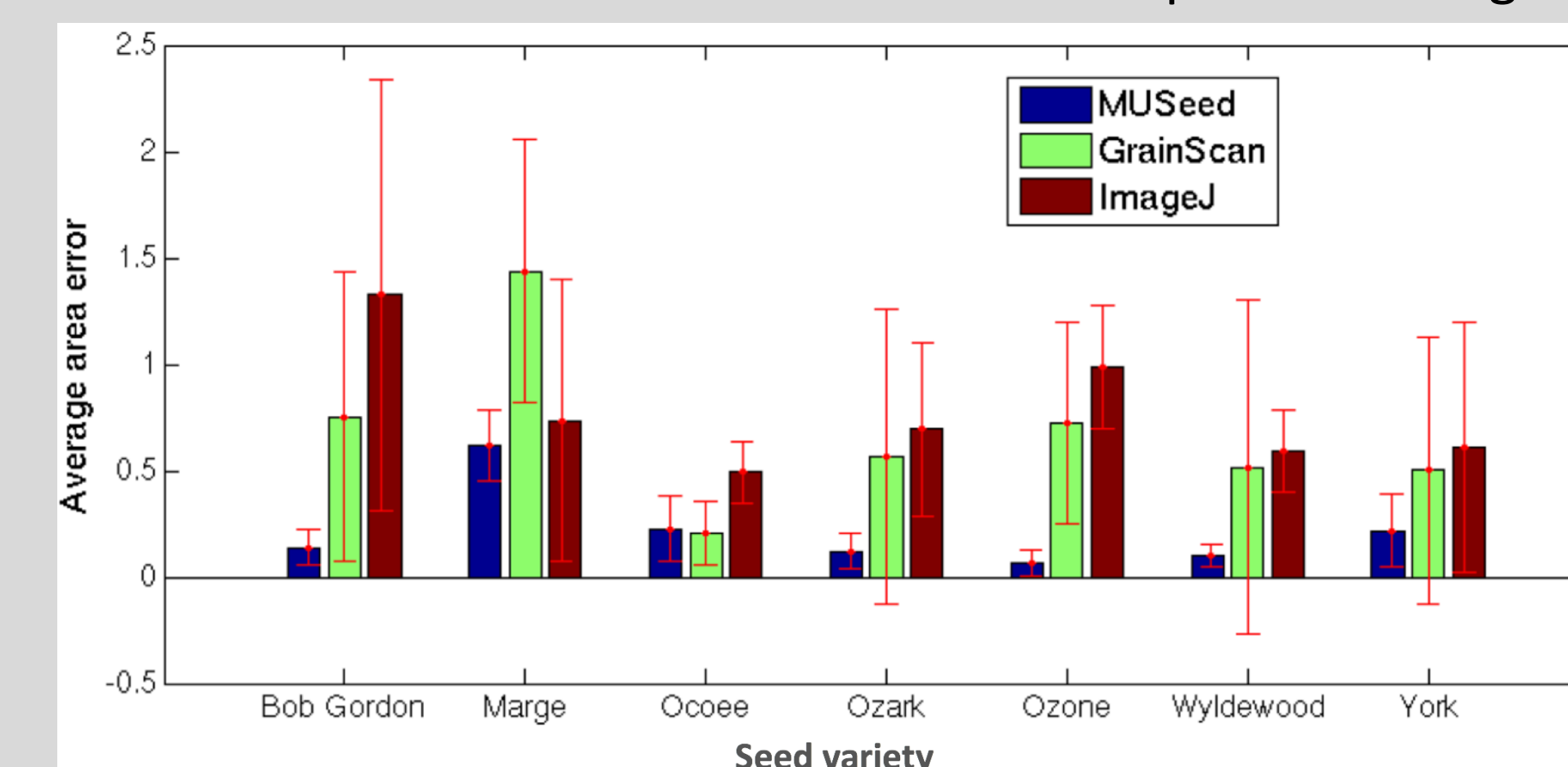


## Results

Sample outputs from MUSeed, GrainScan, and ImageJ. Red rectangles mark the failed segmentation.



Mean and standard deviation of seed area error compared to the ground truth.



Average recall, precision, and F-measure of MUSeed, GrainScan, and ImageJ on 7 seed datasets.

Data	Average recall / Precision / F-measure		
	MUSeed	GrainScan	ImageJ
Bob Gordon	0.98/0.97/0.97	0.79/0.84/0.81	0.80/0.57/0.67
Marge	0.95/0.98/0.96	0.73/0.53/0.61	0.66/0.21/0.32
Ocoee	0.95/0.97/0.96	0.90/0.85/0.87	0.92/0.60/0.73
Ozark	1.00/1.00/1.00	0.89/0.90/0.89	0.86/0.51/0.64
Ozone	0.91/0.96/0.93	0.80/0.87/0.83	0.85/0.66/0.74
Wyldeewood	0.97/0.99/0.98	0.81/0.77/0.79	0.83/0.48/0.57
York	0.96/0.94/0.95	0.62/0.52/0.57	0.63/0.32/0.42
<b>Average</b>	<b>0.96/0.97/0.96</b>	<b>0.79/0.75/0.77</b>	<b>0.79/0.48/0.60</b>