

## INTRODUCTION

Measuring broccoli heads by hand is time intensive, so sampling is used when looking at broccoli fields. This leads to food waste if the crops do not grow uniformly. A possible solution is using computer vision to measure all the broccoli heads in a field.

## PROBLEM

- Annotations are required to train a vision model. This is also time intensive and error prone.
- Can human-in-the-loop annotation speed up broccoli head annotation while maintaining the final models' segmentation and size estimation accuracy?

## METHOD

- A dataset was annotated manually, with a graph-cut-based algorithm named GrabCut, and with a prompted segmentation model named SAM2.
- The resulting masks were used to train vision models using 5-fold cross-validation. These models were used to compare the segmentation and size estimation accuracy.
- Relative difference was used for size estimation due to the variance in broccoli head size.

## RESULTS

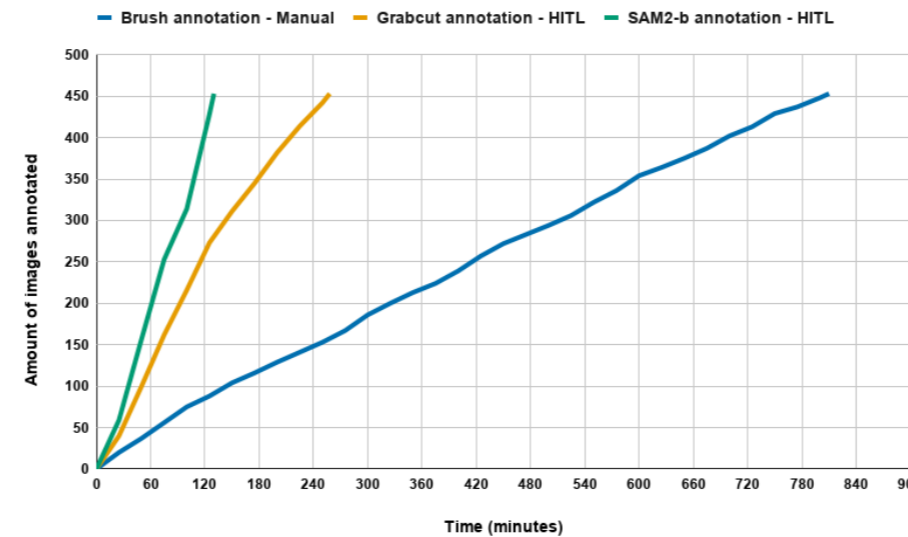


Figure 1. The time spent annotating using each method.

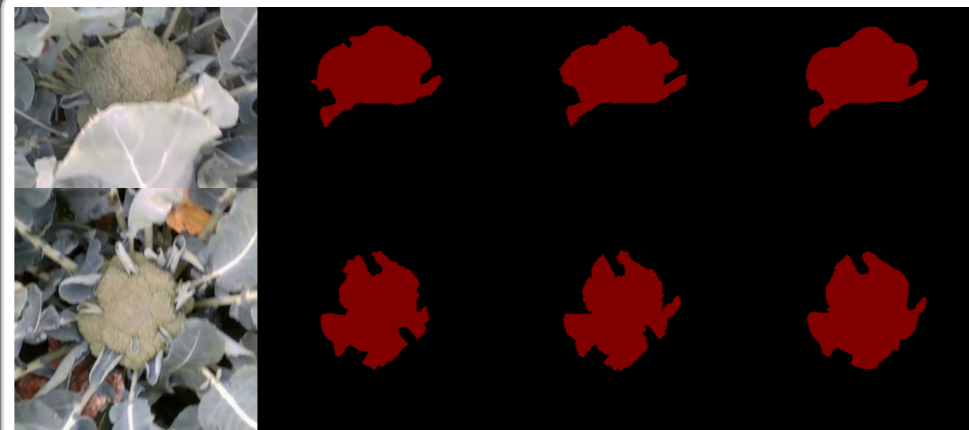


Figure 2. Two broccoli heads and the masks produced by annotating them with each method. From left to right: Base image, manual, GrabCut, SAM2.

	time per image (seconds)	IoU	F1
manual	107.28	-	-
GrabCut	34.17	0.8751	0.9320
SAM2	17.22	0.8702	0.9291

Table 1. Time spent per image in seconds and similarity of masks to the manual annotations

Method	IOU	Pixel Accuracy
Manual	0.902 ± 0.005	0.945 ± 0.007
GrabCut	0.901 ± 0.003	0.942 ± 0.005
SAM2	0.894 ± 0.006	0.937 ± 0.013

Table 2. The segmentation accuracy of each model after cross validation

Method	Relative Difference (%)		
	Pixel Area	Max Feret	Min Feret
Manual	-0.22 ± 13.40	-2.29 ± 8.60	-2.20 ± 7.83
GrabCut	-1.37 ± 12.63	-2.69 ± 8.63	-2.63 ± 7.96
SAM2	0.03 ± 16.42	-3.47 ± 9.44	-3.19 ± 8.08

Table 3. The size estimation accuracy of each model after cross validation

- Compared to manual annotation, GrabCut is 3.1x faster, and SAM2 is 6.2x faster.
- Models trained on manual annotation have the highest accuracy, followed by GrabCut.
- SAM2 has a 1.5% worse accuracy than manual.

## CONCLUSION

Human-in-the-loop methods speed up annotation with a small reduction in final model accuracy.

**Limitations:** Having only one annotator, using manual annotation as the ground truth and not hallucinating broccoli behind leaves.

**Future work:** Usage of non-mouse input devices for annotation. Continue the experiment with more annotators.