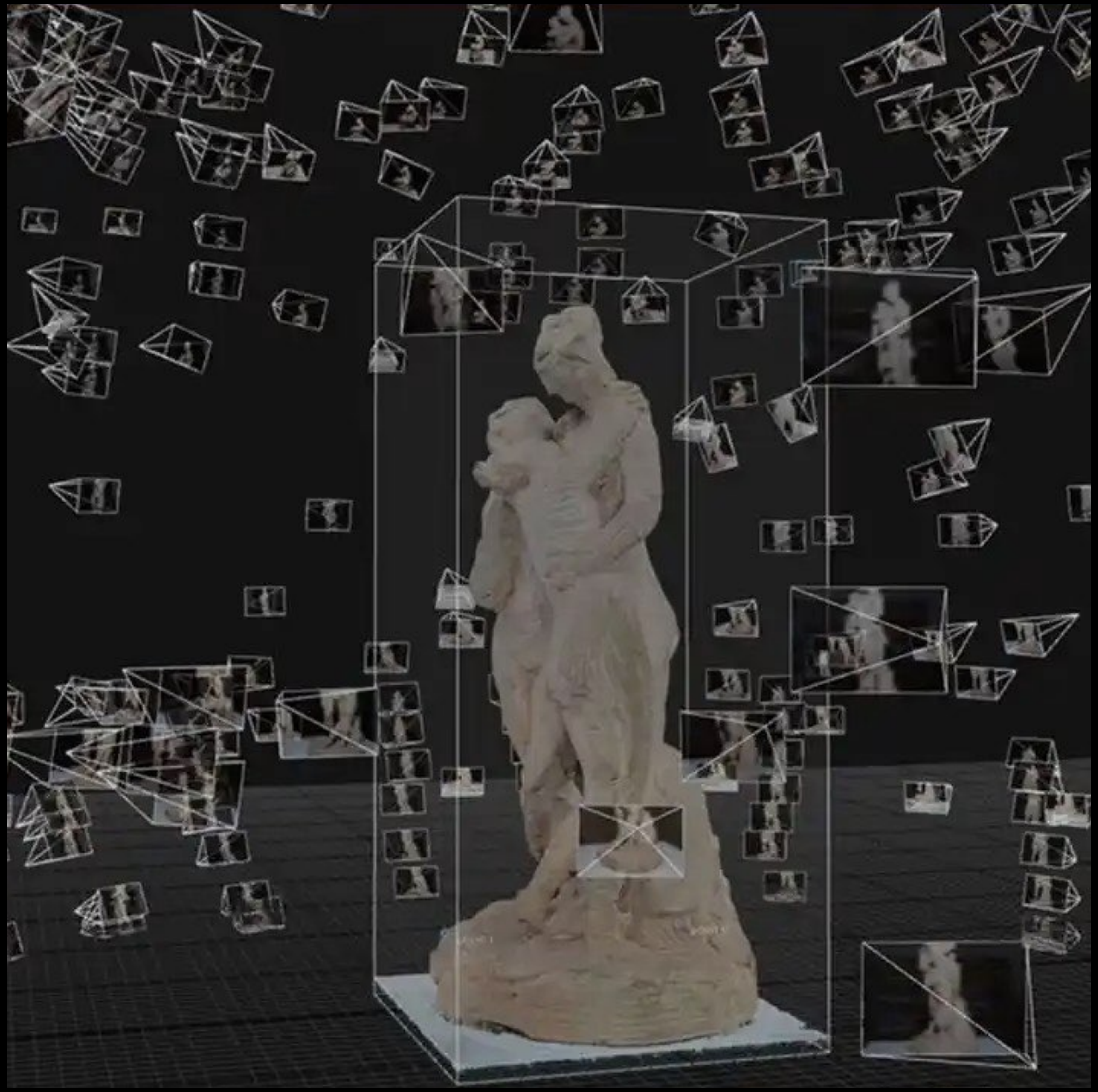
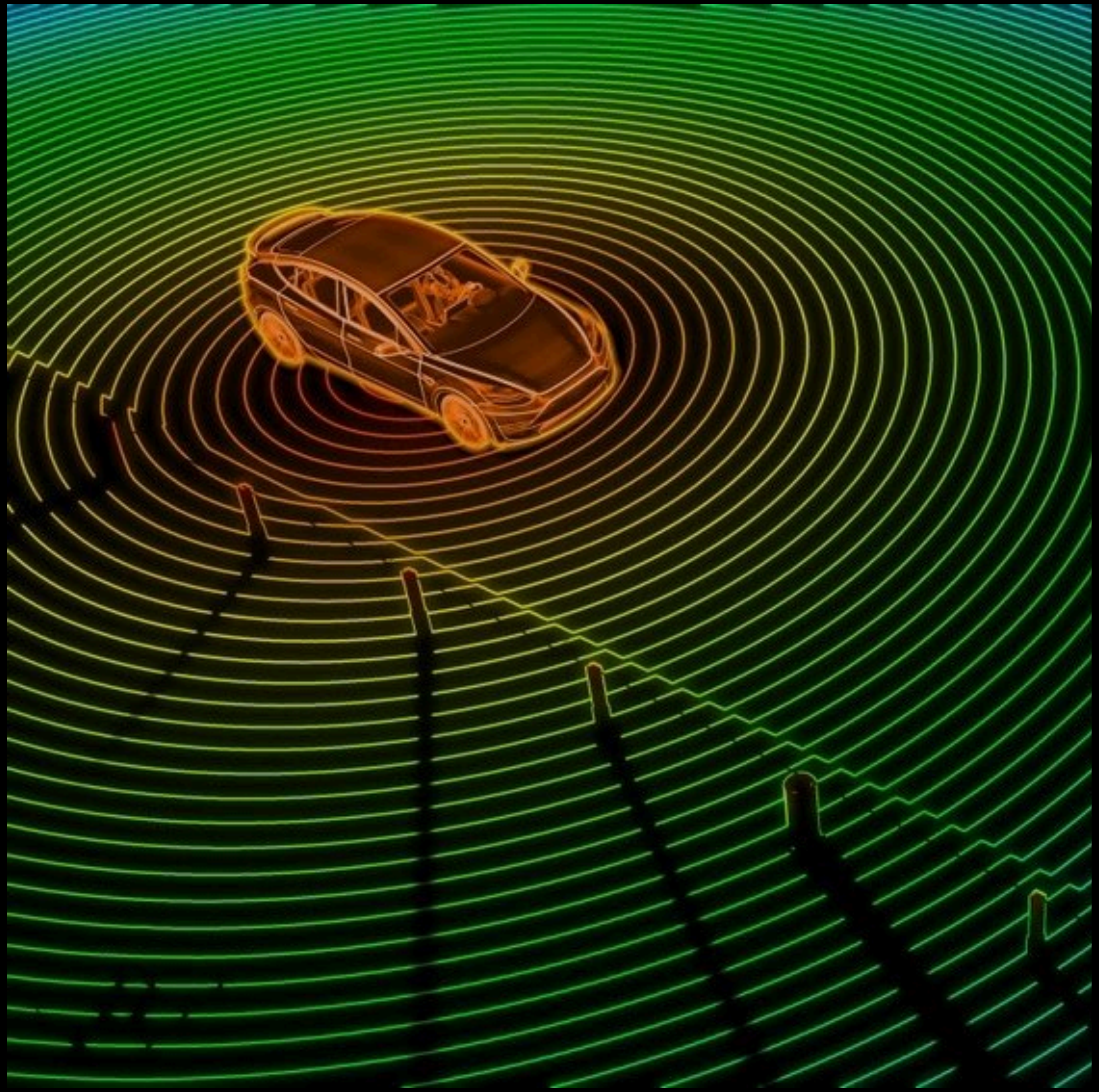
Investigating 3D Model Reconstruction from 2D Stereoscopic Plant Images with Investigation between YOLOv8 and Detectron2 AI Architectures for Plant Class Segmentation

John Ivan Diaz, Craig Joseph Goc-ong, Kaye Louise Manilong
Alvin Joseph Macapagal, Philip Virgil Astillo*



Photogrammetry



LiDAR

+

+

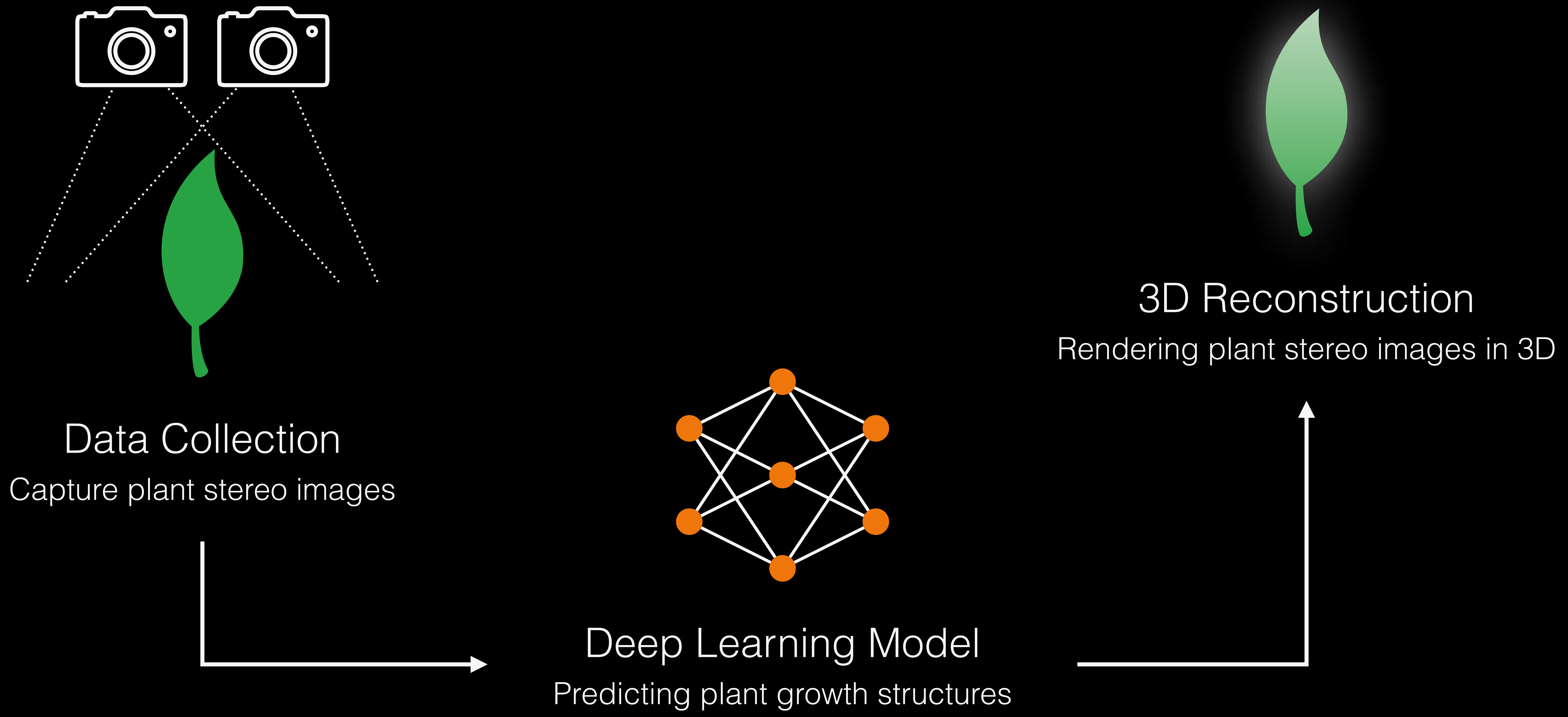
+

= ?

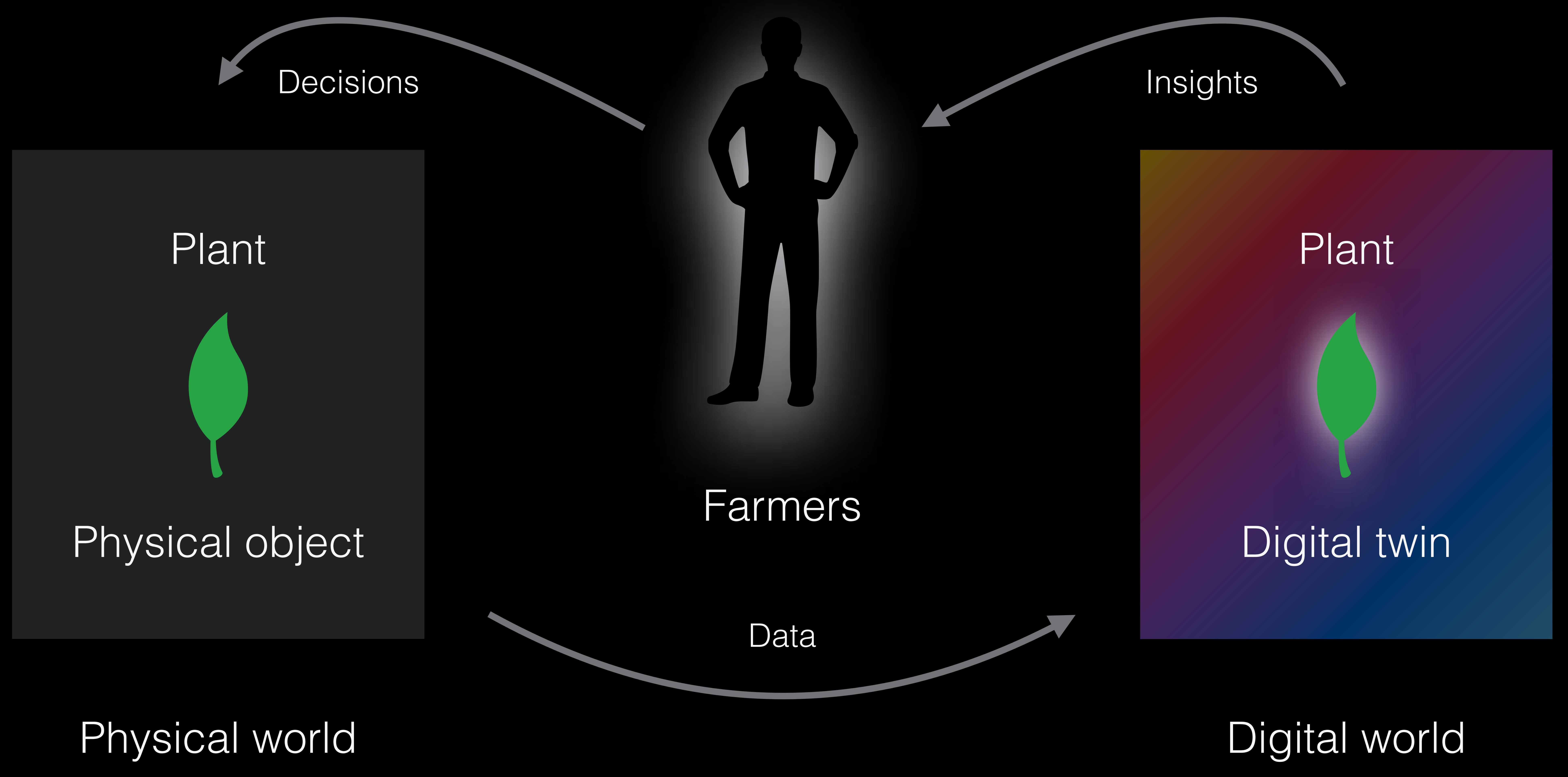
Investigating 3D Model Reconstruction from 2D Stereoscopic Plant Images with Investigation between YOLOv8 and Detectron2 AI Architectures for Plant Class Segmentation

Diaz, Goc-ong, Manilong
Macapagal, Astillo*

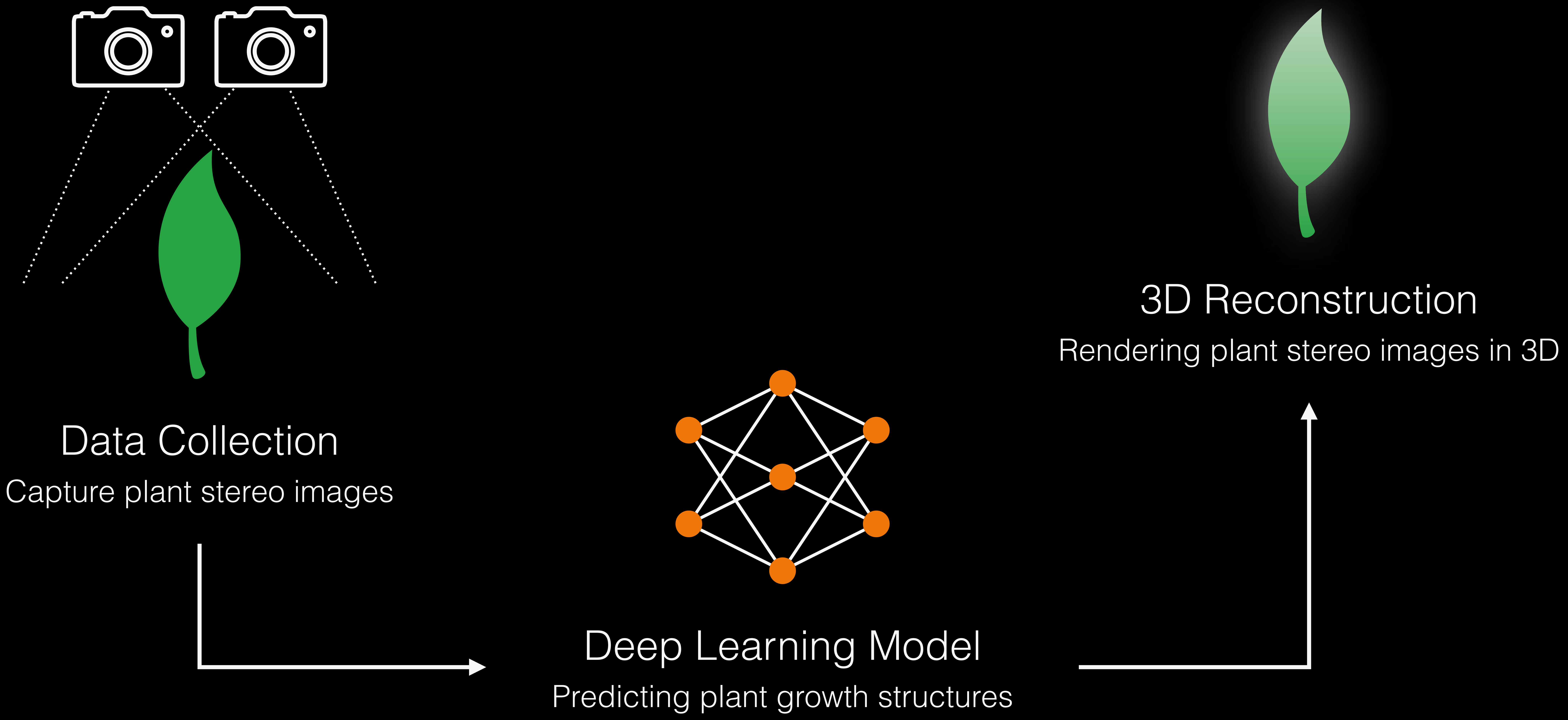
ABOUT THE PARENT STUDY



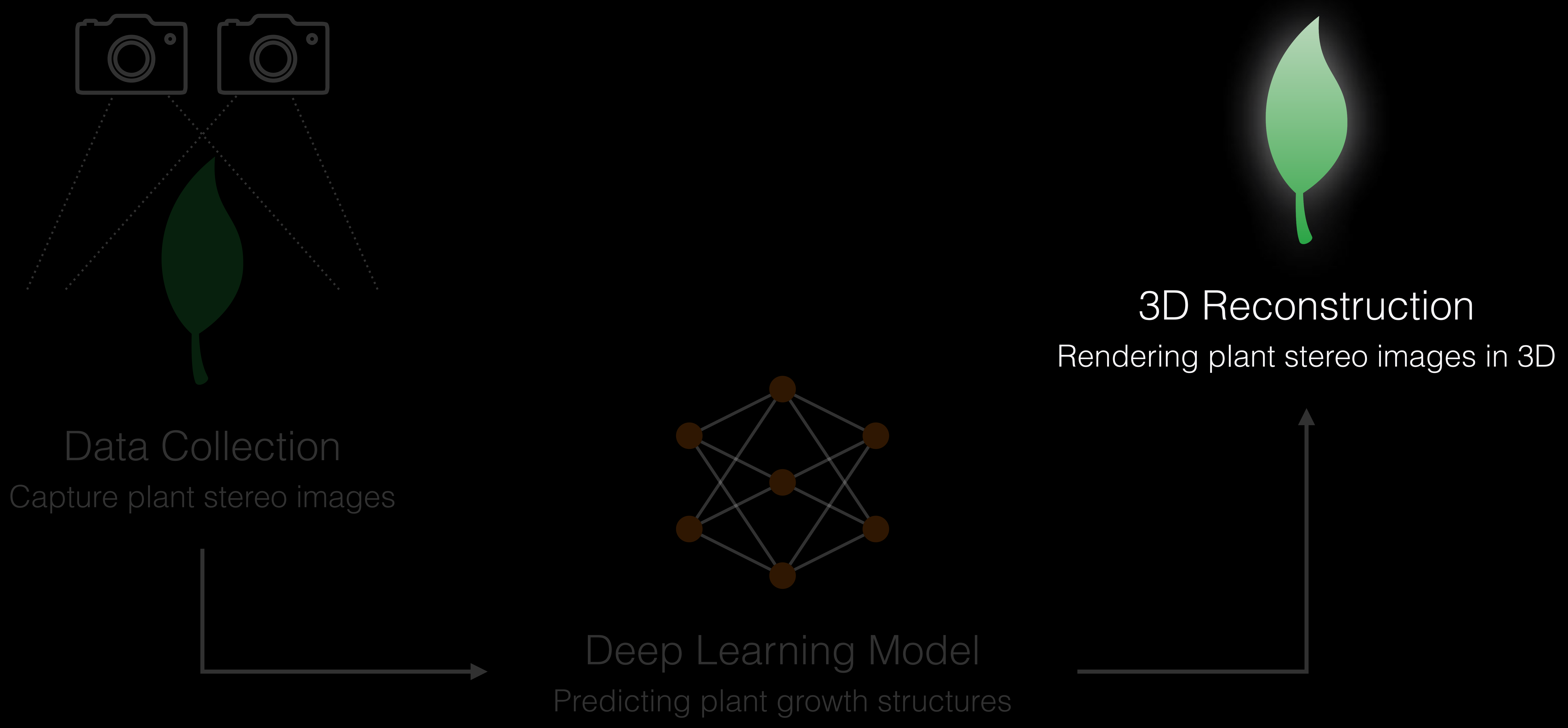
ABOUT THE PARENT STUDY



THIS CONFERENCE



THIS CONFERENCE



OBJECTIVES

1. To collect 2D stereo images that capture a plant's front, back, left, and right views with 90-degree horizontal rotations

2. To investigate AI architectures, YOLOv8 and Detectron2, and determine which performs better in image segmentation for plant class.

3. To investigate a process that transforms the 2D stereo images of plants into 3D models.

Front 2D Stereo Image | Left 2D Stereo Image | Back 2D Stereo Image | Right 2D Stereo Image

↓

Image Rectification

↓

Image Segmentation

↓

Depth Map Generation

↓

Point Cloud Generation

↓

Point Cloud Refinement

↓

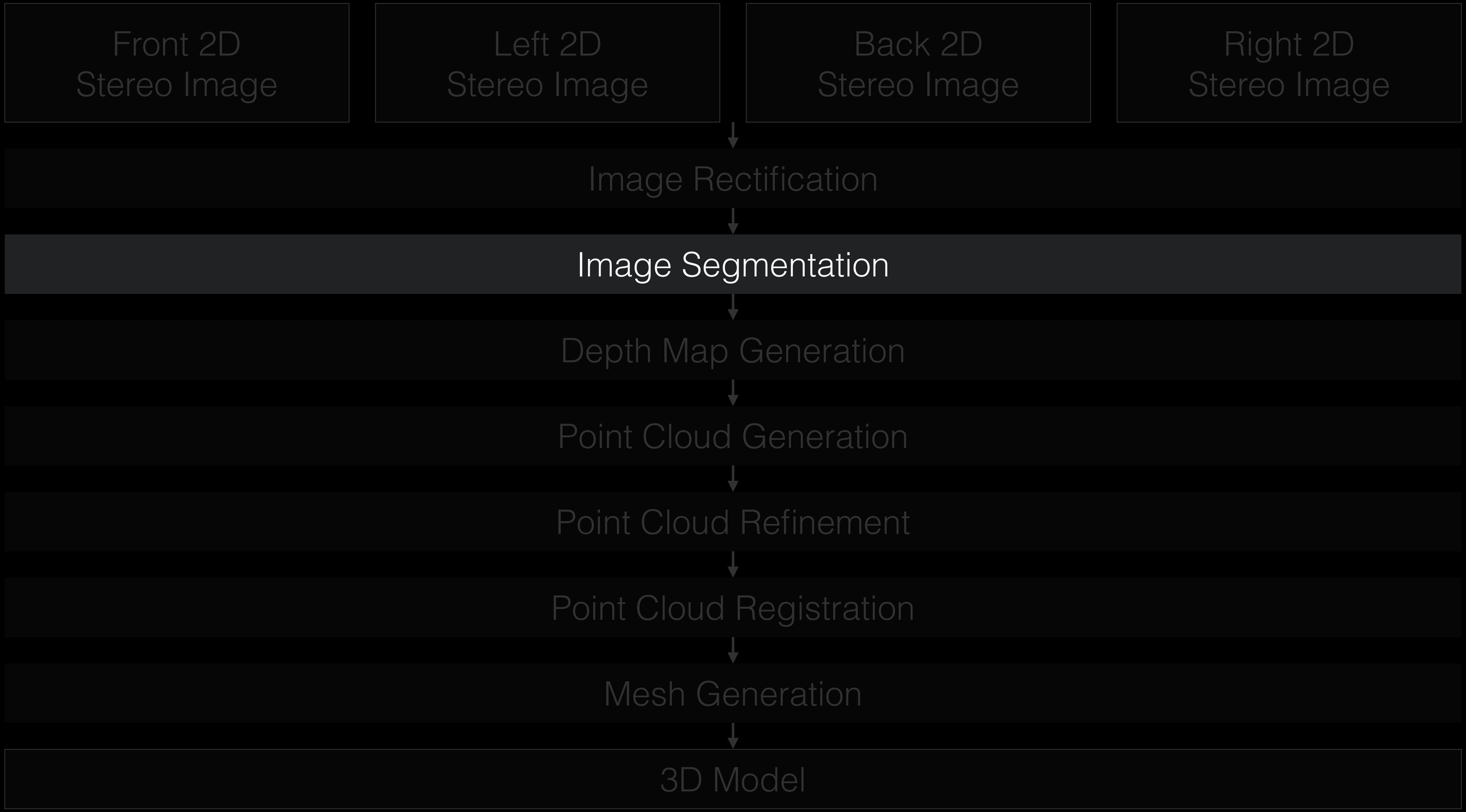
Point Cloud Registration

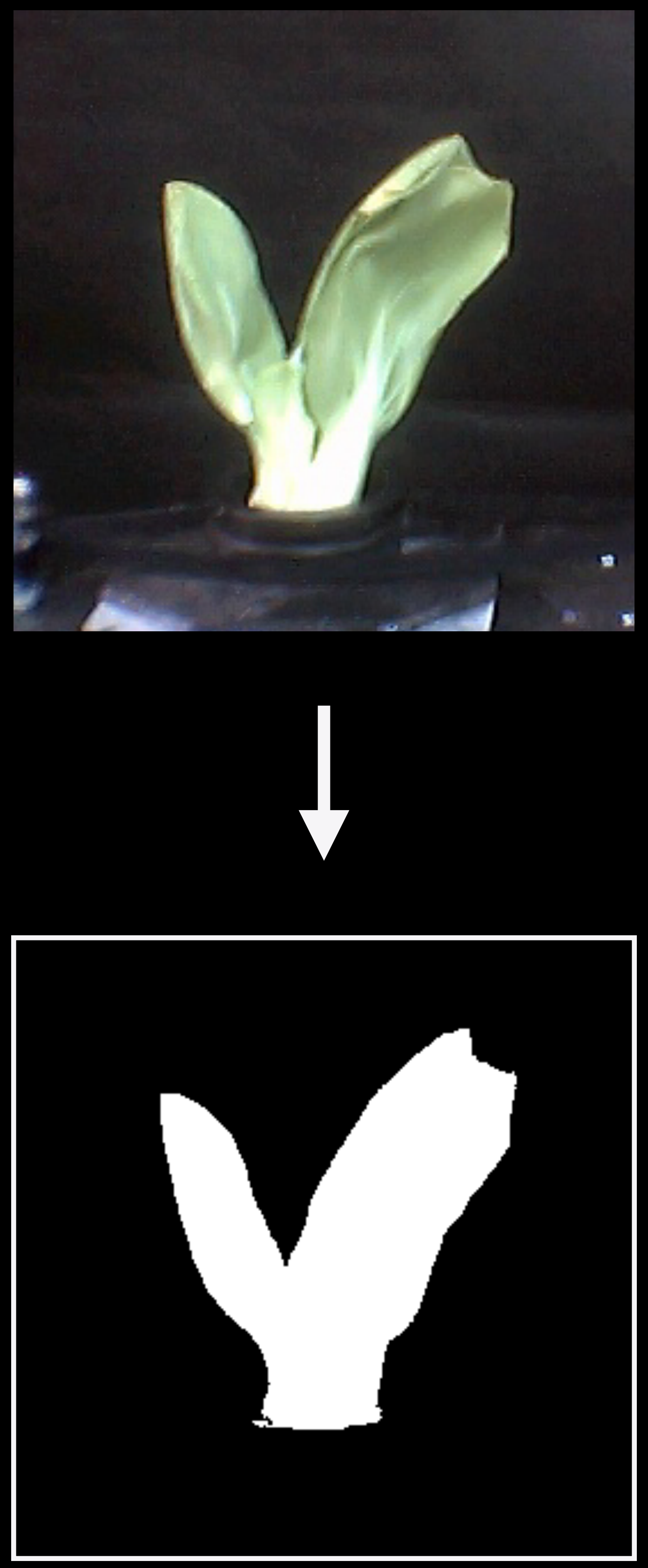
↓

Mesh Generation

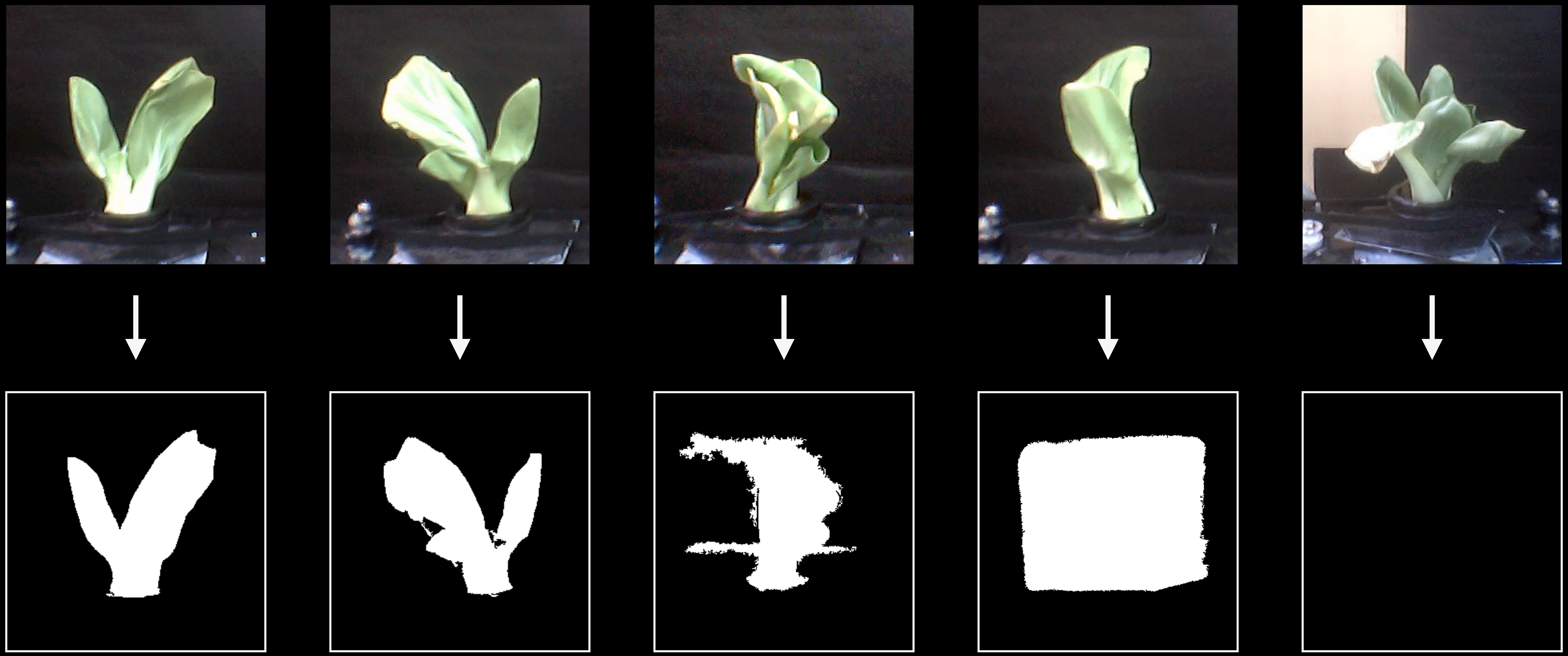
↓

3D Model


Front 2D
Stereo Image
Left 2D
Stereo Image
Back 2D
Stereo Image
Right 2D
Stereo Image
Image Rectification
Image Segmentation
Depth Map Generation
Point Cloud Generation
Point Cloud Refinement
Point Cloud Registration
Mesh Generation
3D Model



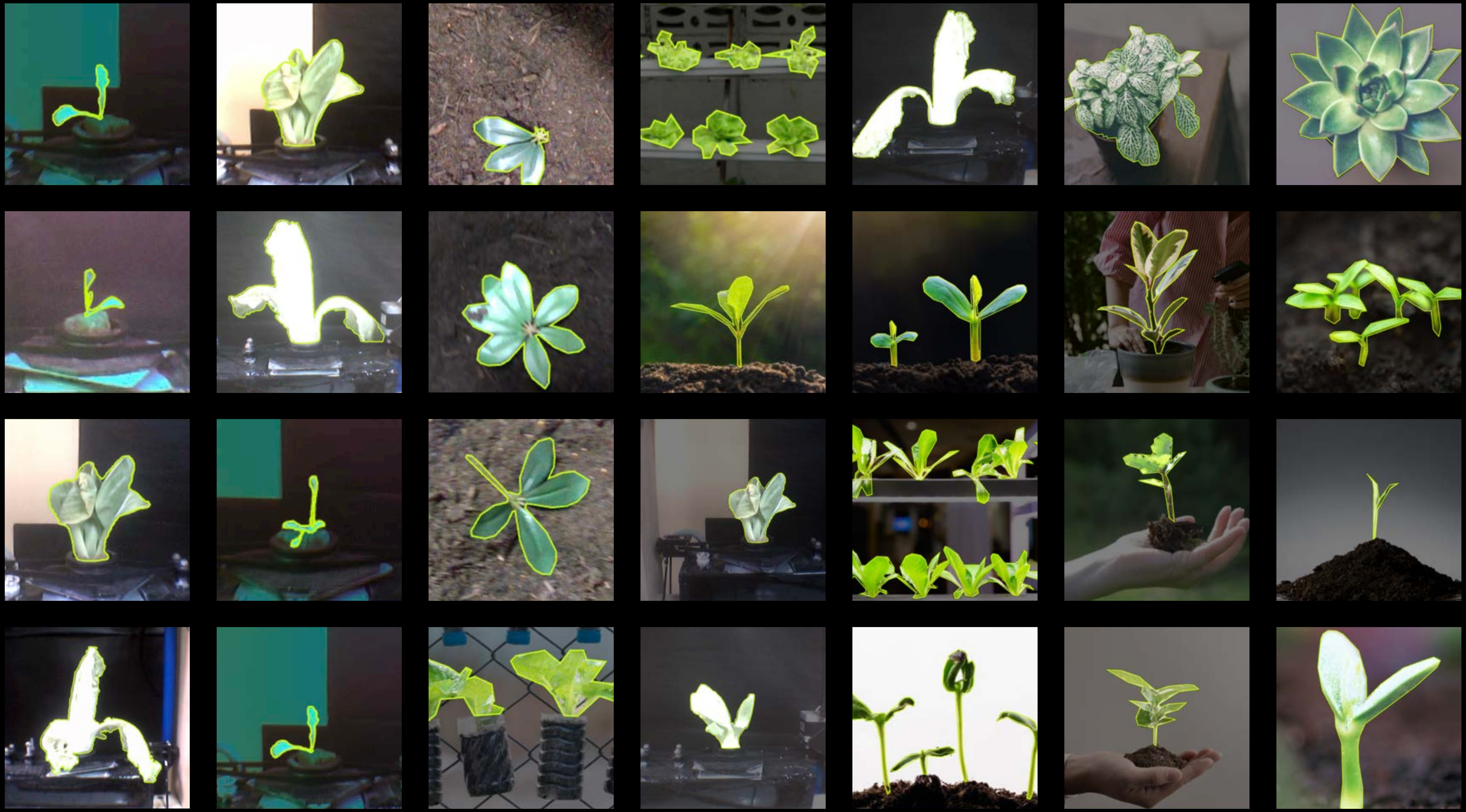
Threshold-based masking



Threshold-based masking

YOLOv8

Detectron2



EVALUATION

Segmentation
Accuracy

Training
Speed

Memory
Consumption

EVALUATION

Segmentation Accuracy	Training Speed	Memory Consumption
Box AP/50	Train Time	System RAM
Mask AP/50		GPU RAM
Box Loss		Disk Usage
Mask Loss		

EVALUATION

Hyperparameter Set A
Epoch size = 100, Batch size = 16,
Worker size = 8, …

Hyperparameter Set B
Epoch size = 75, Batch size = 8,
Worker size = 6, …

Hyperparameter Set C
Epoch size = 50, Batch size = 4,
Worker size = 4, …

Decreasing values

EVALUATION

Hyperparameter Set A
Epoch size = 100, Batch size = 16,
Worker size = 8, …

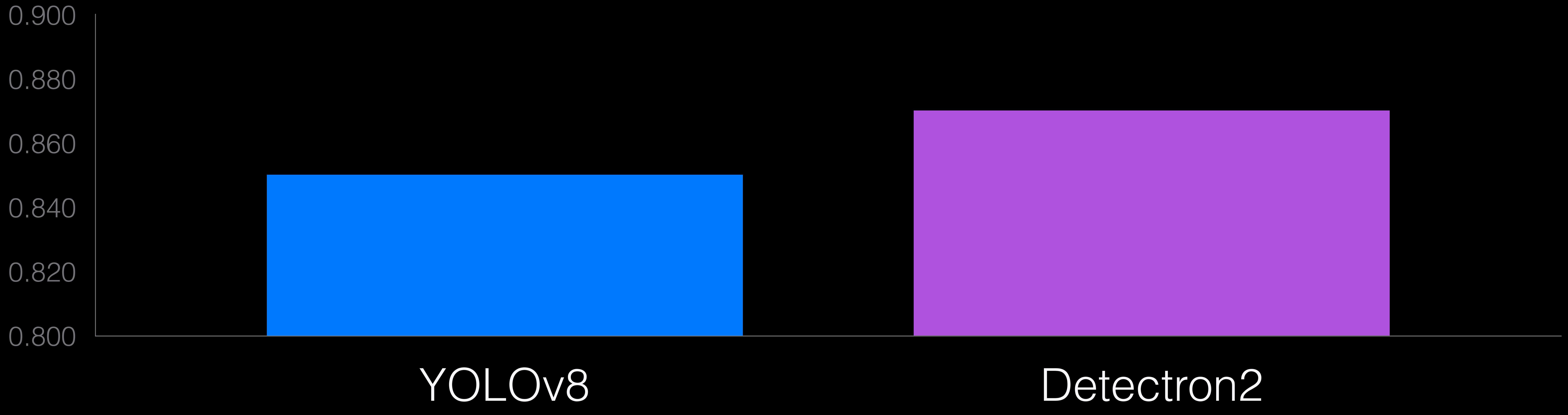
Hyperparameter Set B
Epoch size = 75, Batch size = 8,
Worker size = 6, …

Hyperparameter Set C
Epoch size = 50, Batch size = 4,
Worker size = 4, …

Decreasing values

EVALUATION

Segmentation Accuracy

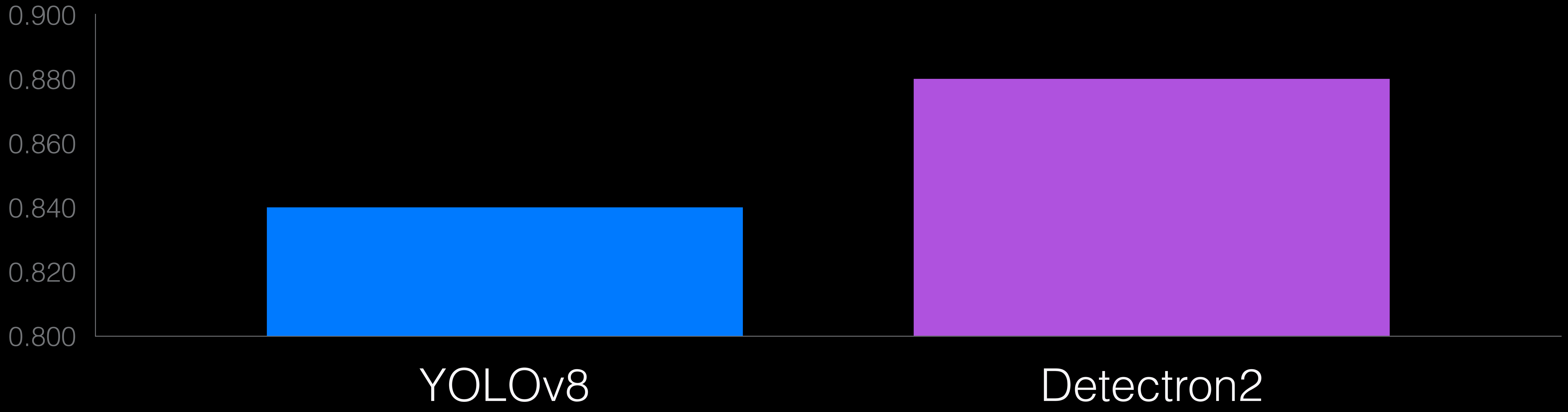


Box Average Precision at 50% IoU threshold

Higher means better in detecting and localizing objects.

EVALUATION

Segmentation Accuracy

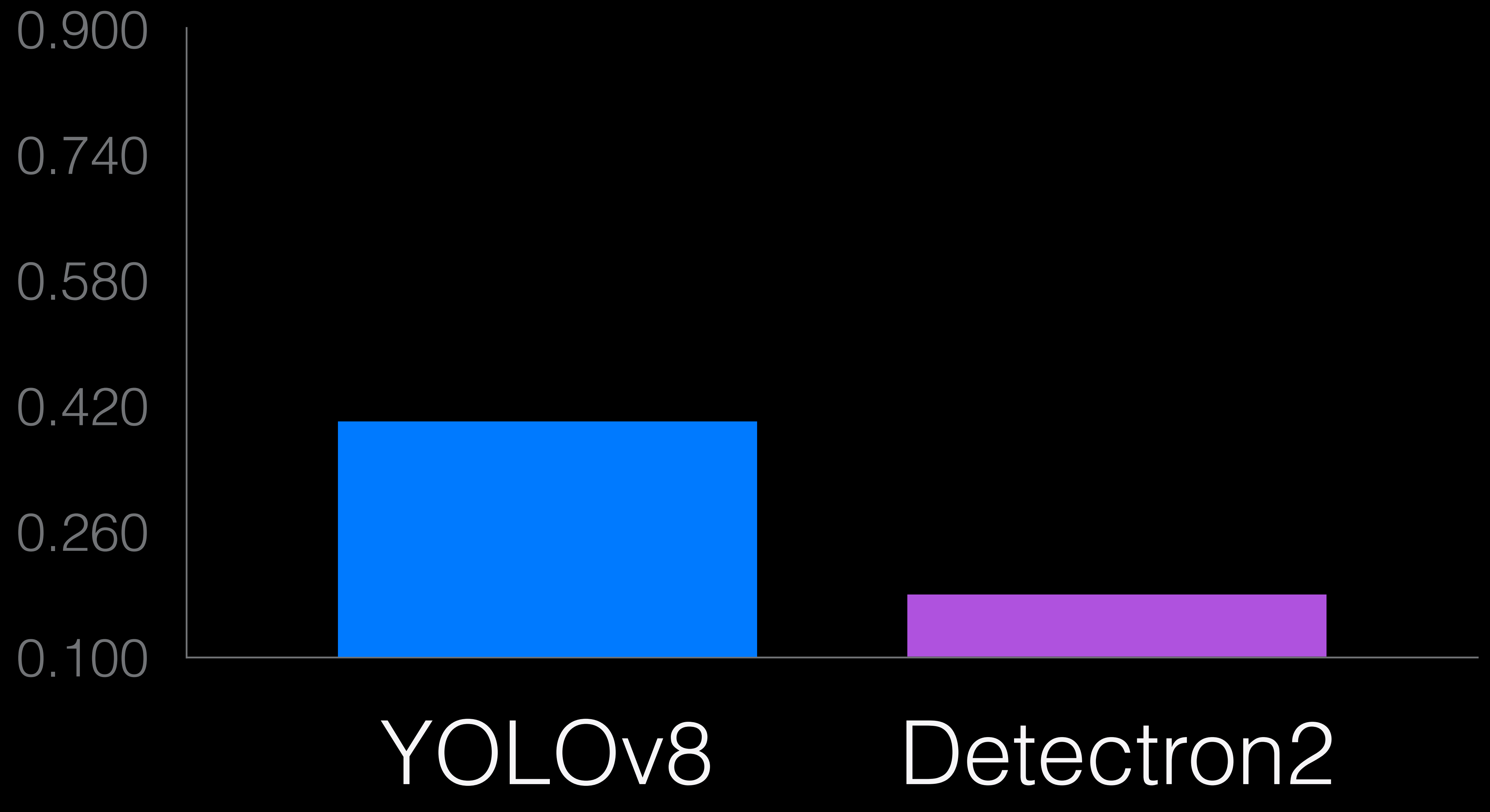


Mask Average Precision at 50% IoU threshold

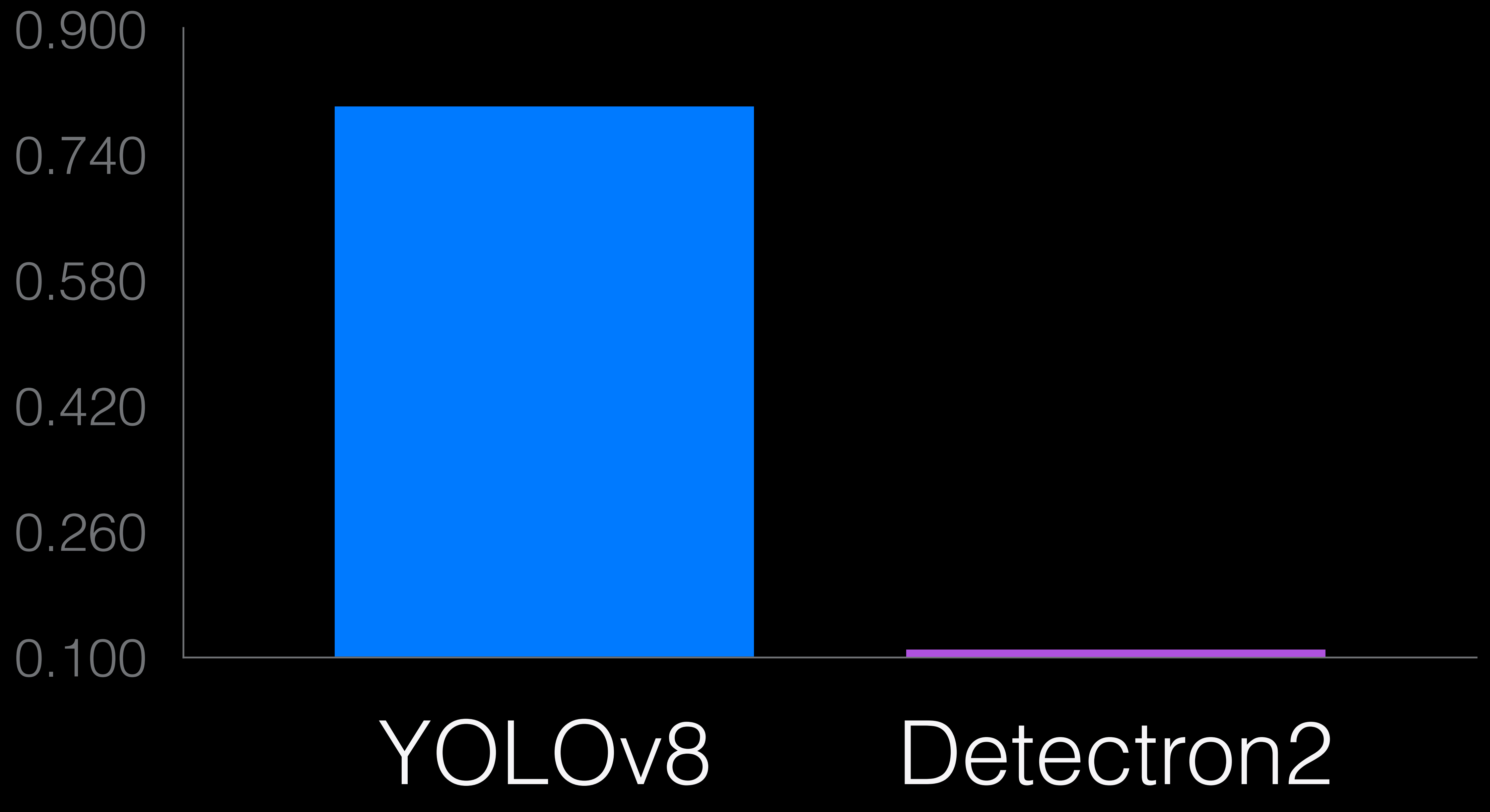
Higher means better in detecting and outlining objects.

EVALUATION

Segmentation Accuracy



Box Loss



Mask Loss

Lower is better.

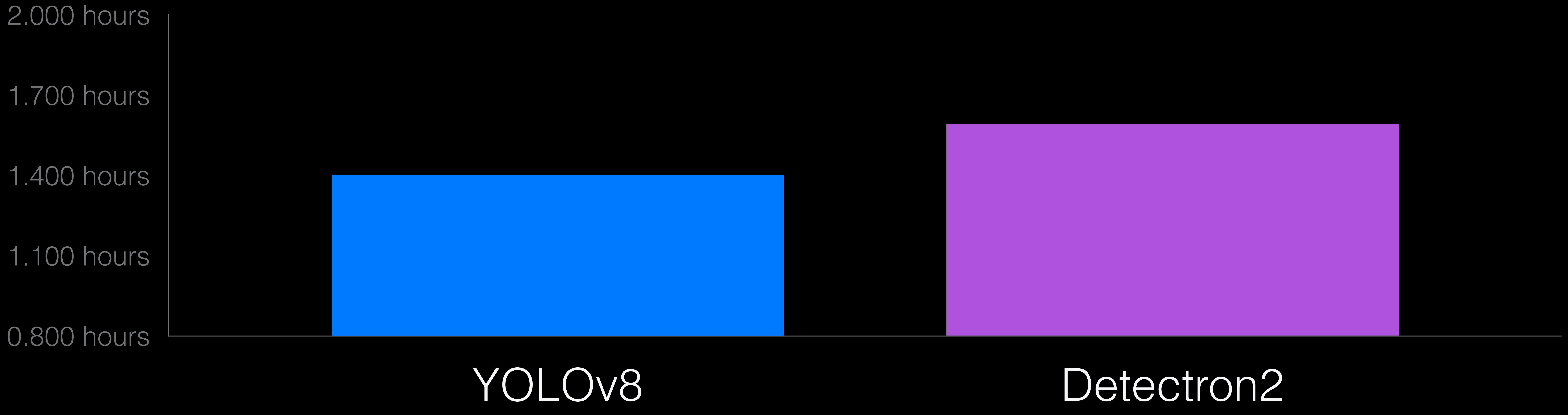
Detectron2 segments better

with higher Box and Mask Average Precisions, and lower Box and Mask Losses.

Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

EVALUATION

Training Speed



Train Time

Lower means faster model training and quicker iteration.

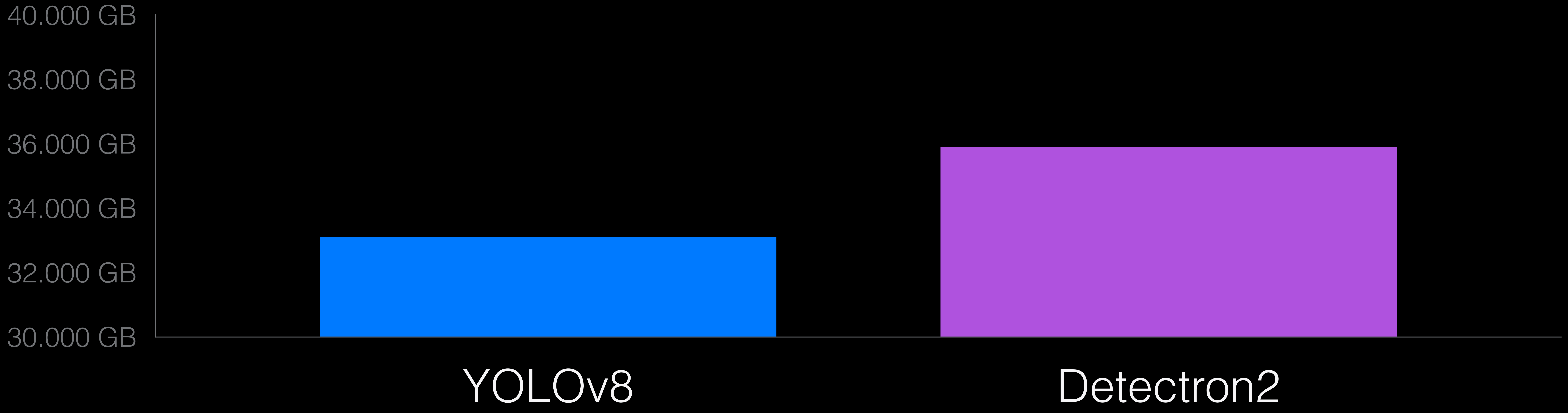
YOLOv8 trains faster

with lower Train Time.

Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

EVALUATION

Memory Consumption

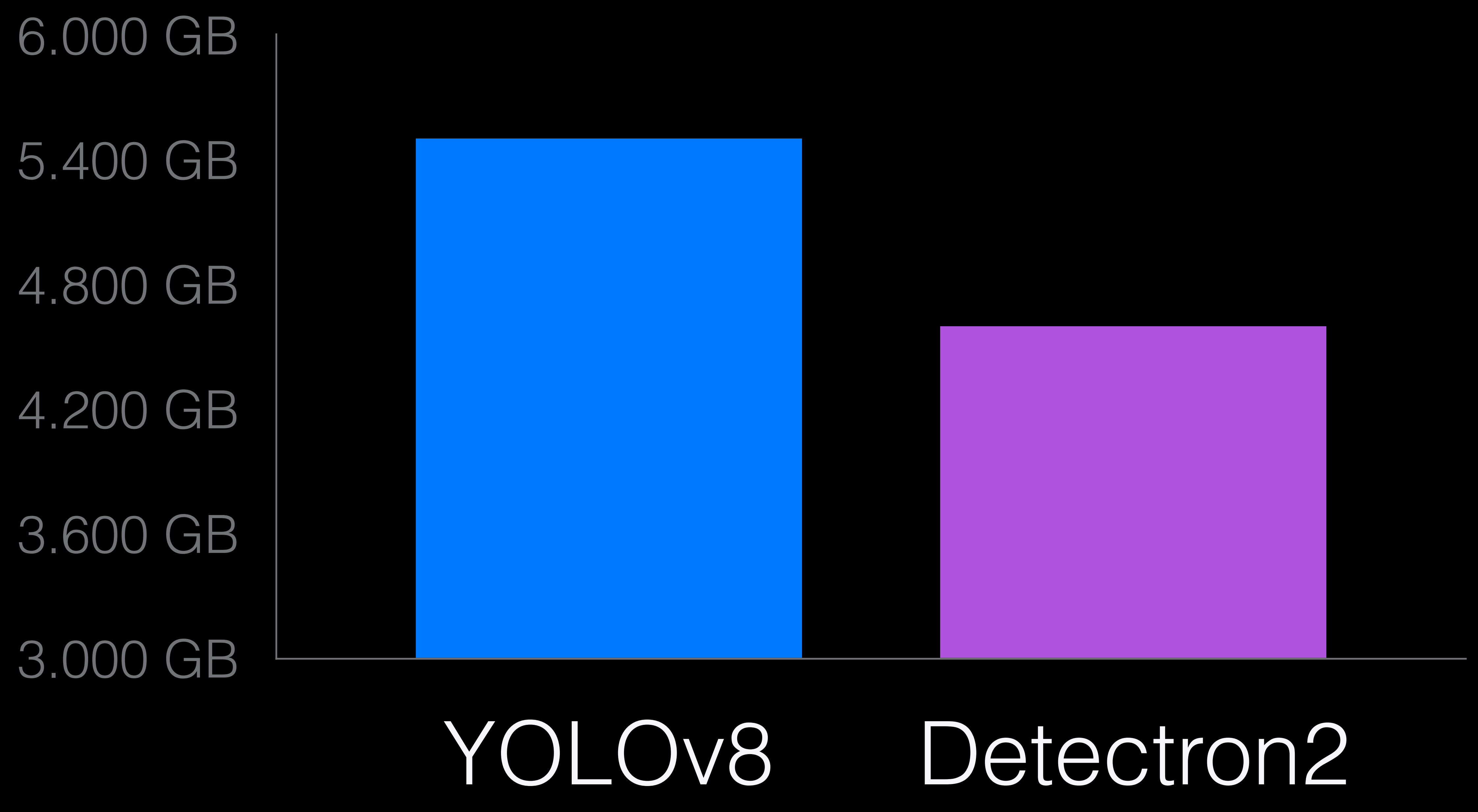


Disk Usage

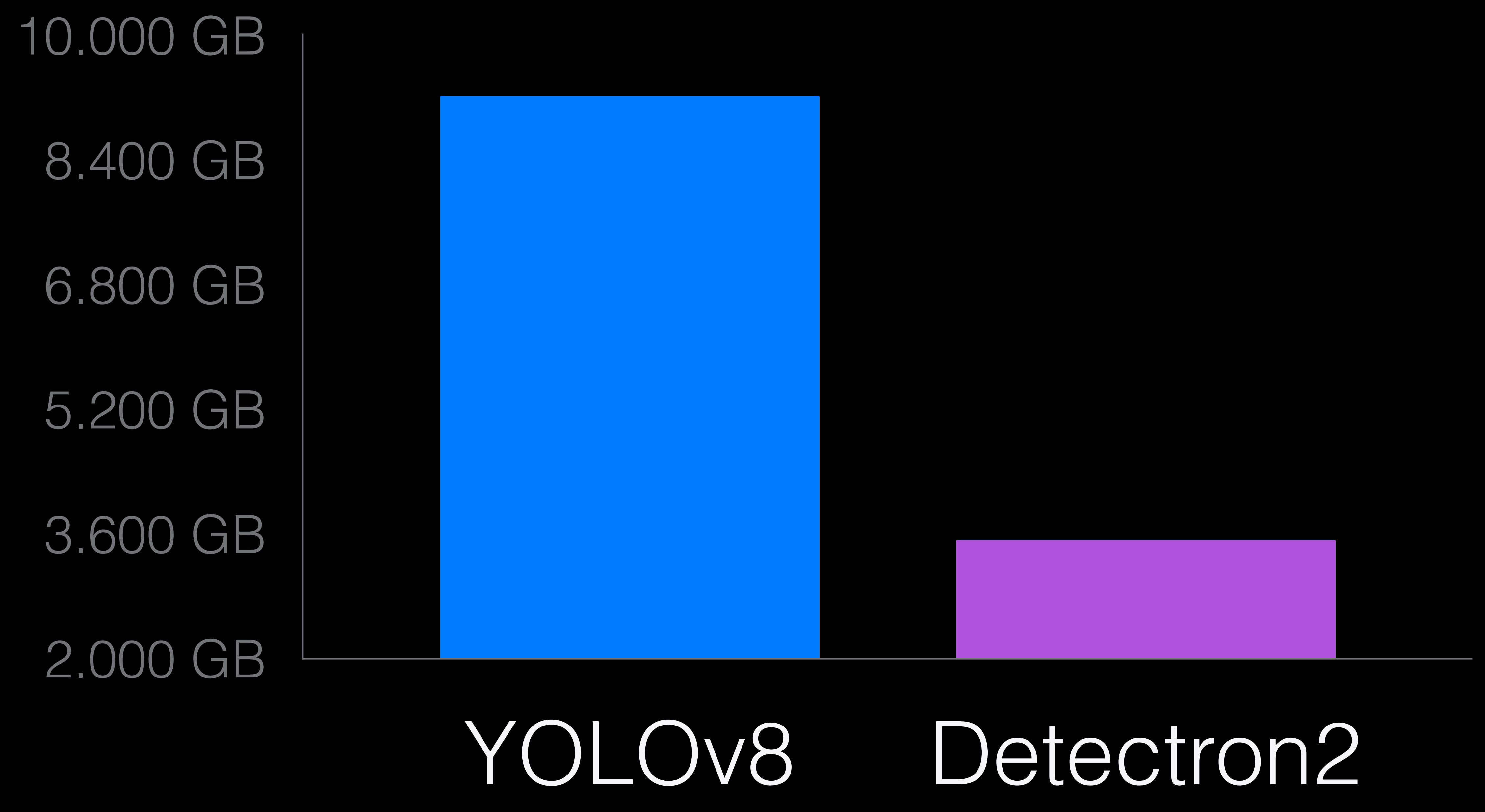
Lower is better.

EVALUATION

Memory Consumption



System RAM

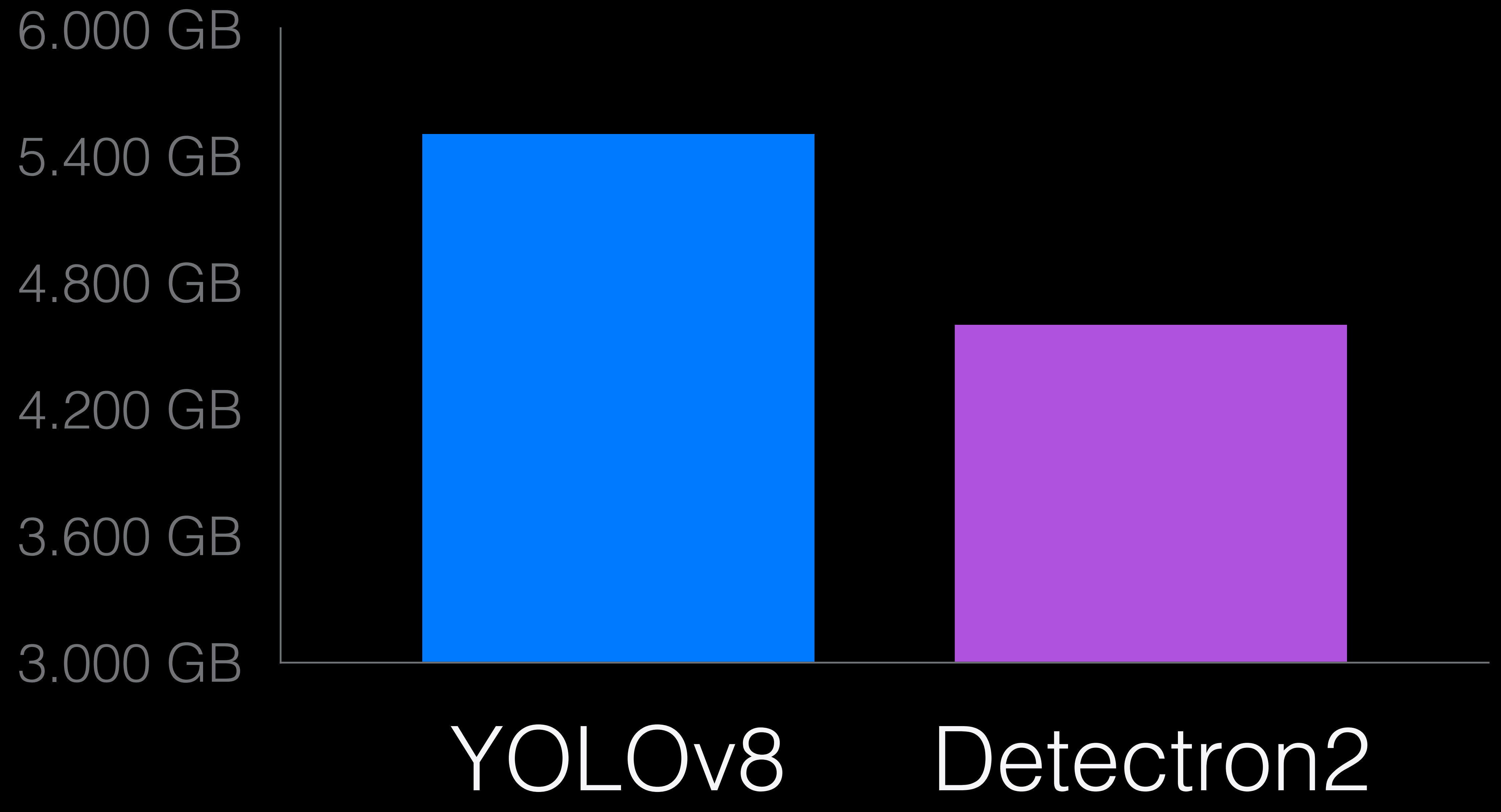


GPU RAM

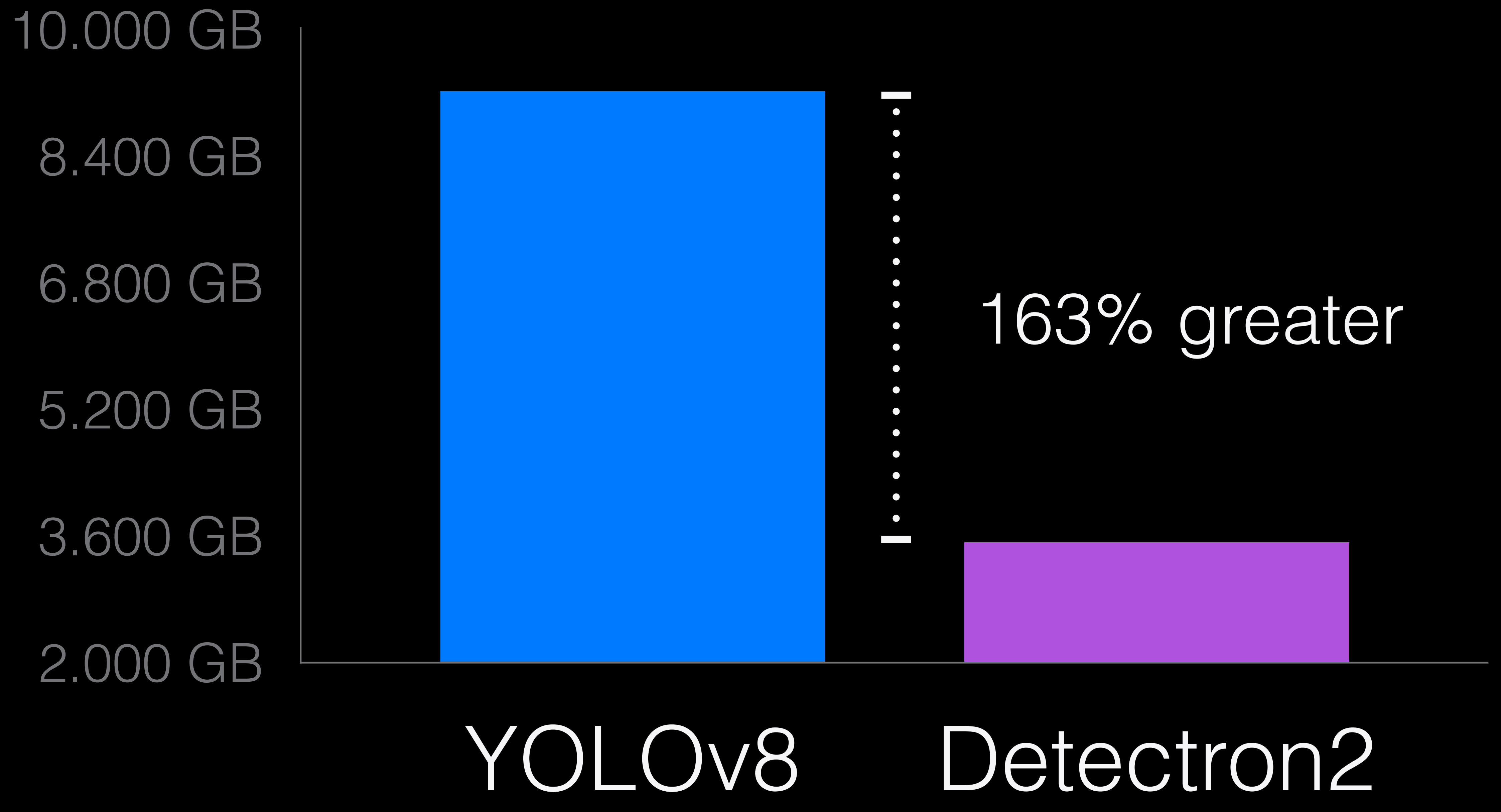
Lower is better.

EVALUATION

Memory Consumption



System RAM



GPU RAM

Lower is better.

Detectron2 is RAM-efficient

with lower System RAM and GPU RAM consumptions.

Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

EVALUATION

Hyperparameter Set A
Epoch size = 100, Batch size = 16,
Worker size = 8, …

Hyperparameter Set B
Epoch size = 75, Batch size = 8,
Worker size = 6, …

Hyperparameter Set C
Epoch size = 50, Batch size = 4,
Worker size = 4, …

Decreasing values

EVALUATION

Hyperparameter Set A
Epoch size = 100, Batch size = 16,
Worker size = 8, …

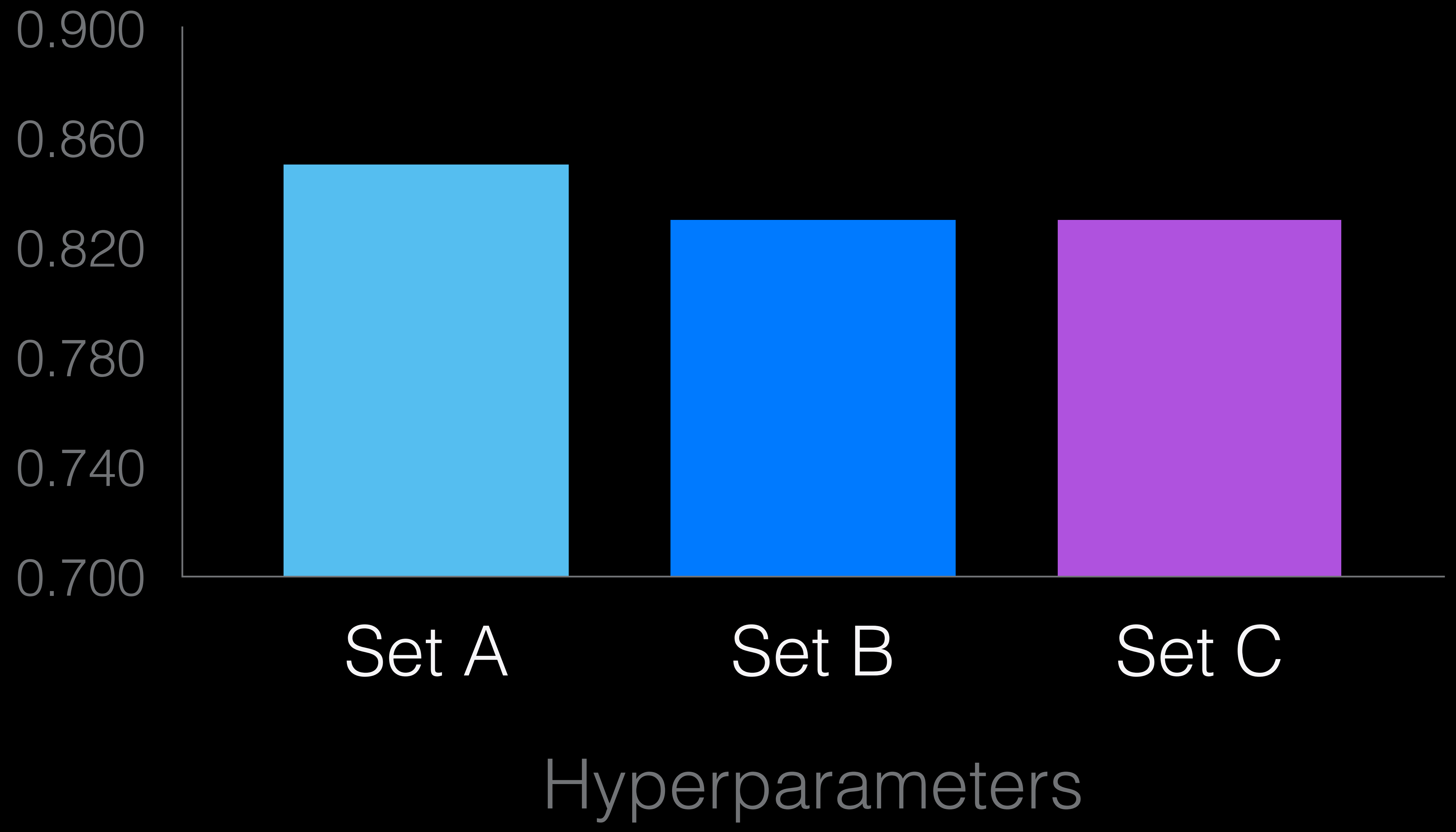
Hyperparameter Set B
Epoch size = 75, Batch size = 8,
Worker size = 6, …

Hyperparameter Set C
Epoch size = 50, Batch size = 4,
Worker size = 4, …

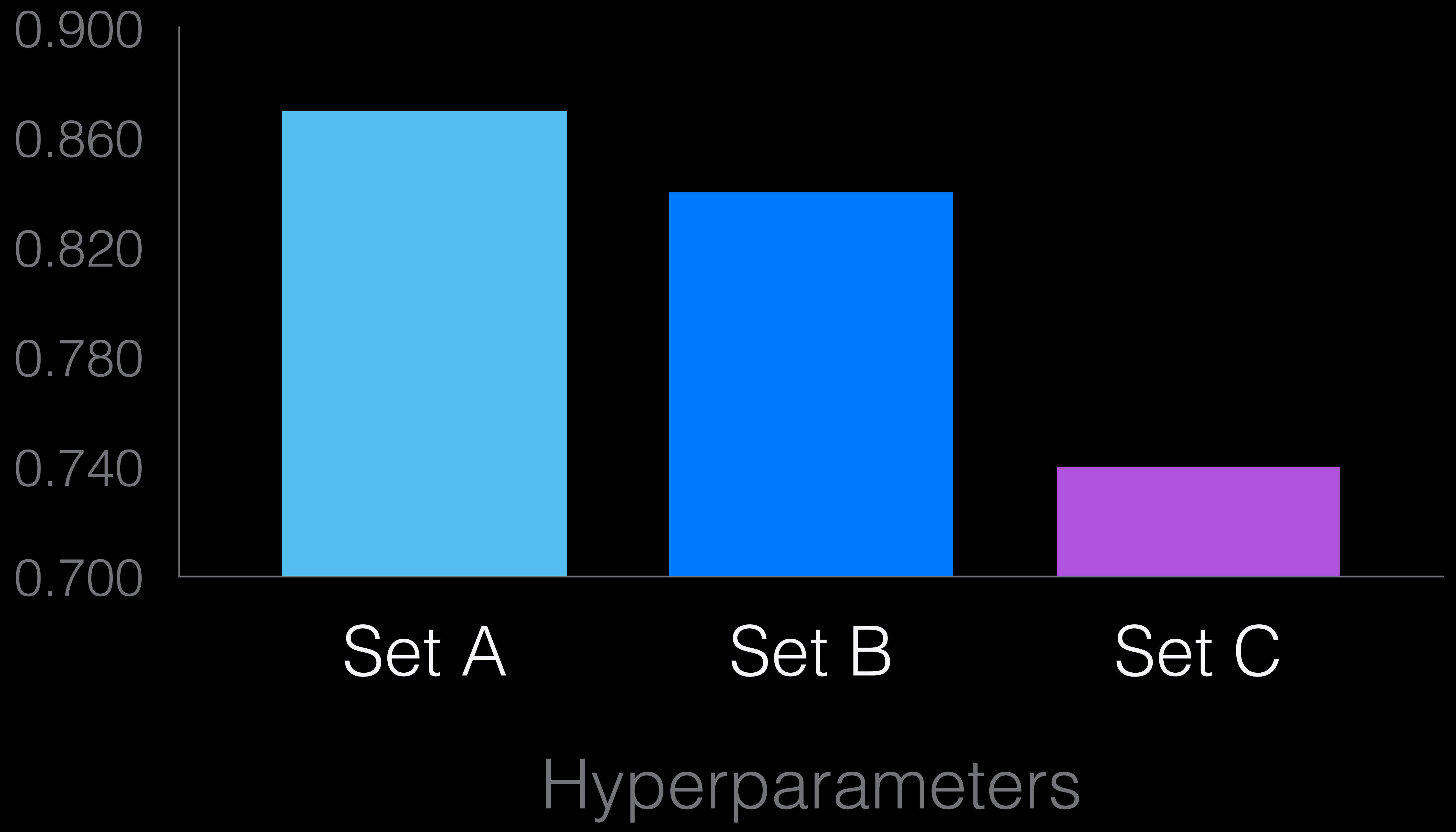
Decreasing values

EVALUATION

Segmentation Accuracy



YOLOv8

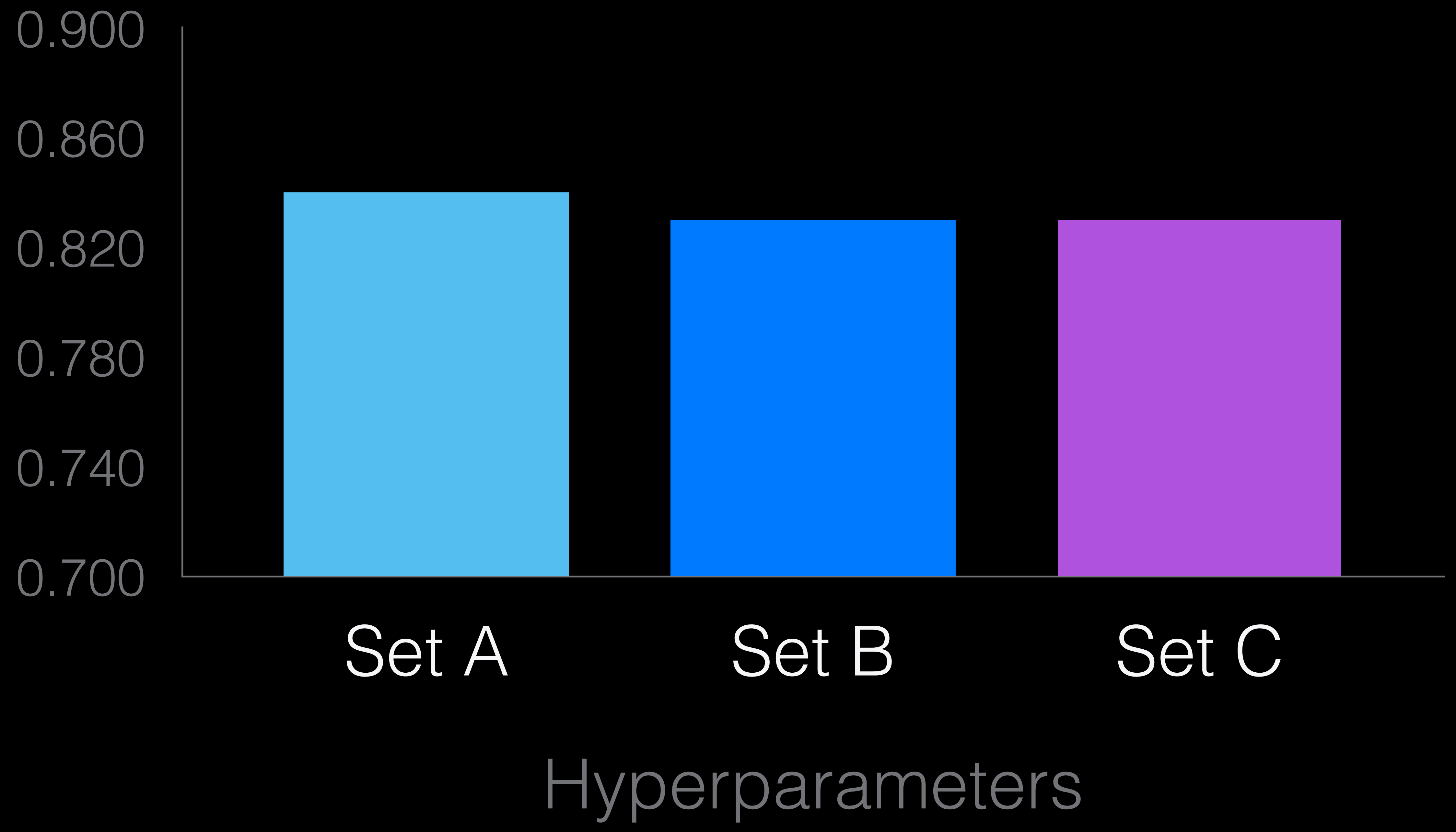


Detectron2

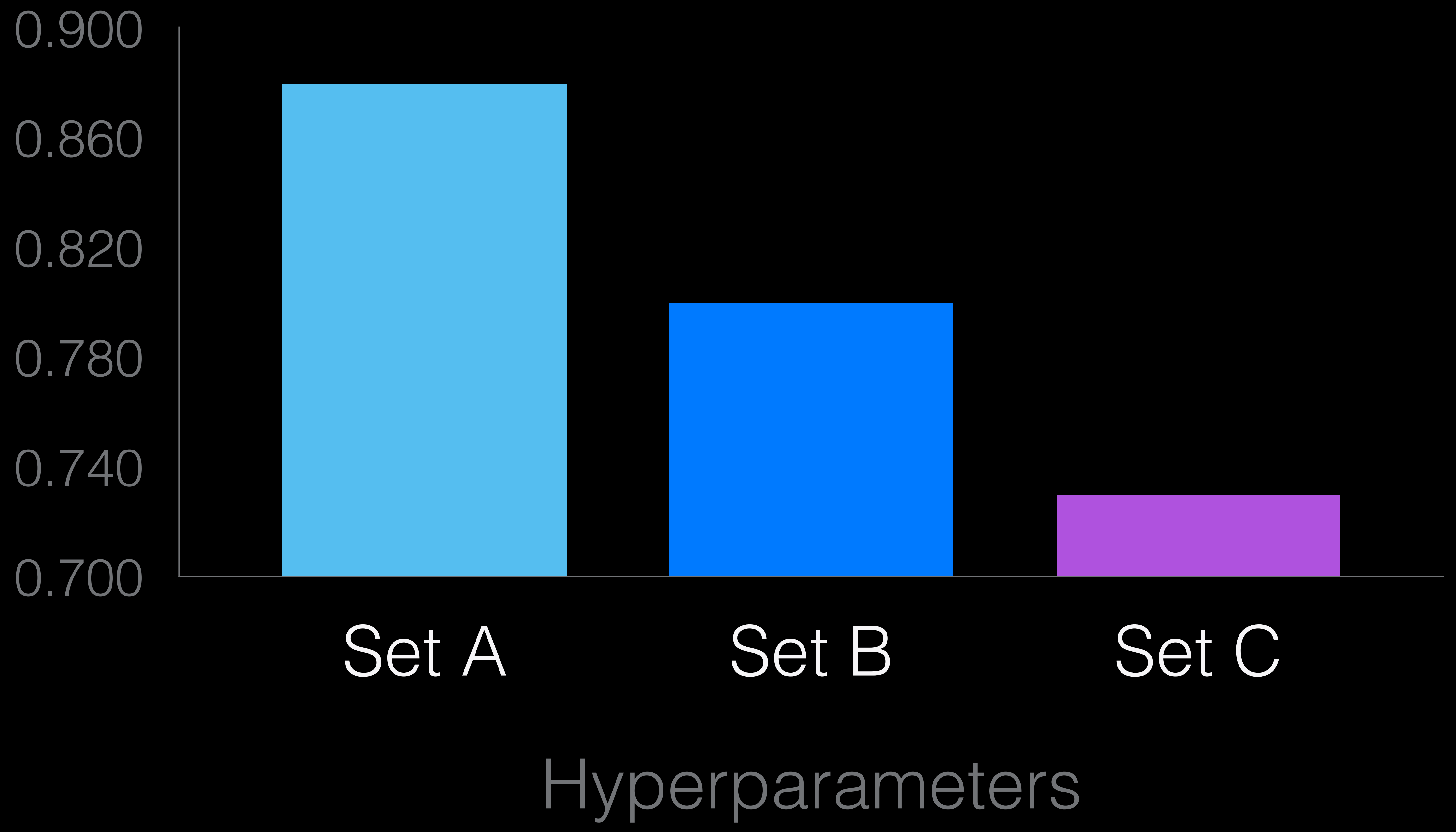
Box Average Precision at 50% IoU threshold

EVALUATION

Segmentation Accuracy



YOLOv8



Detectron2

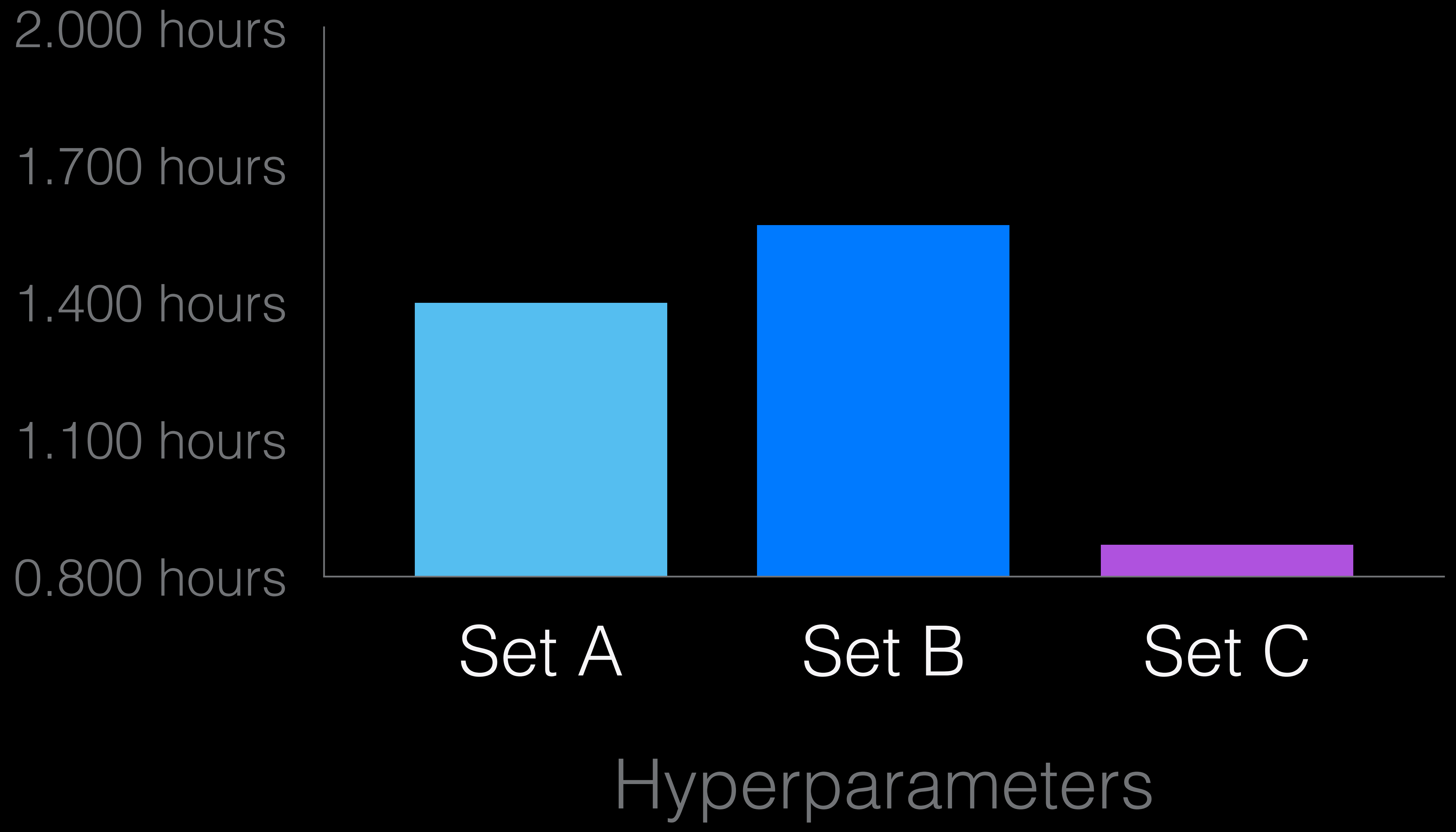
Mask Average Precision at 50% IoU threshold

Increasing hyperparameter values increase segmentation accuracy on both models.

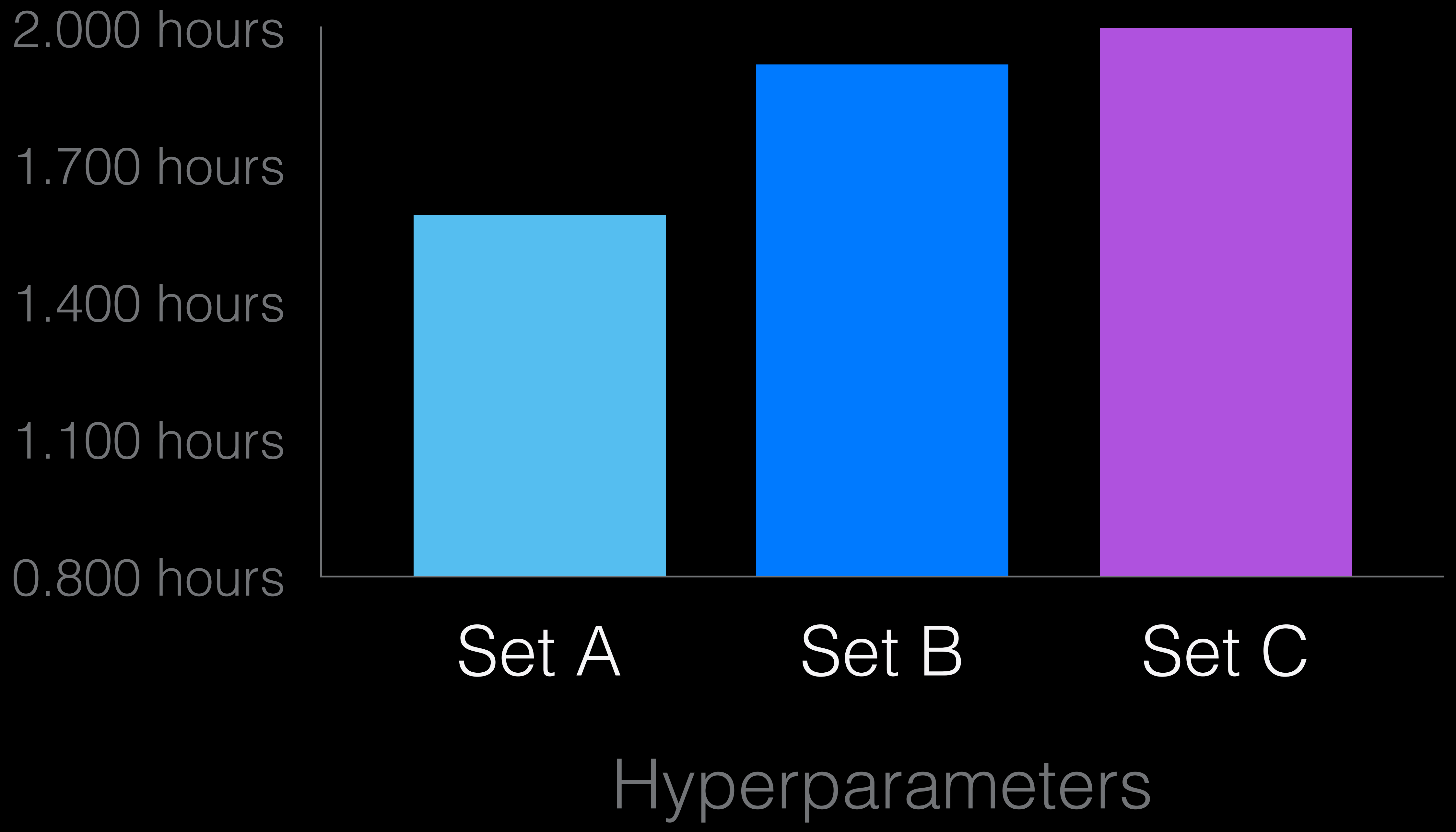
Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

EVALUATION

Training Speed



YOLOv8



Detectron2

Train Time

Decreasing hyperparameter values train faster if using YOLOv8.

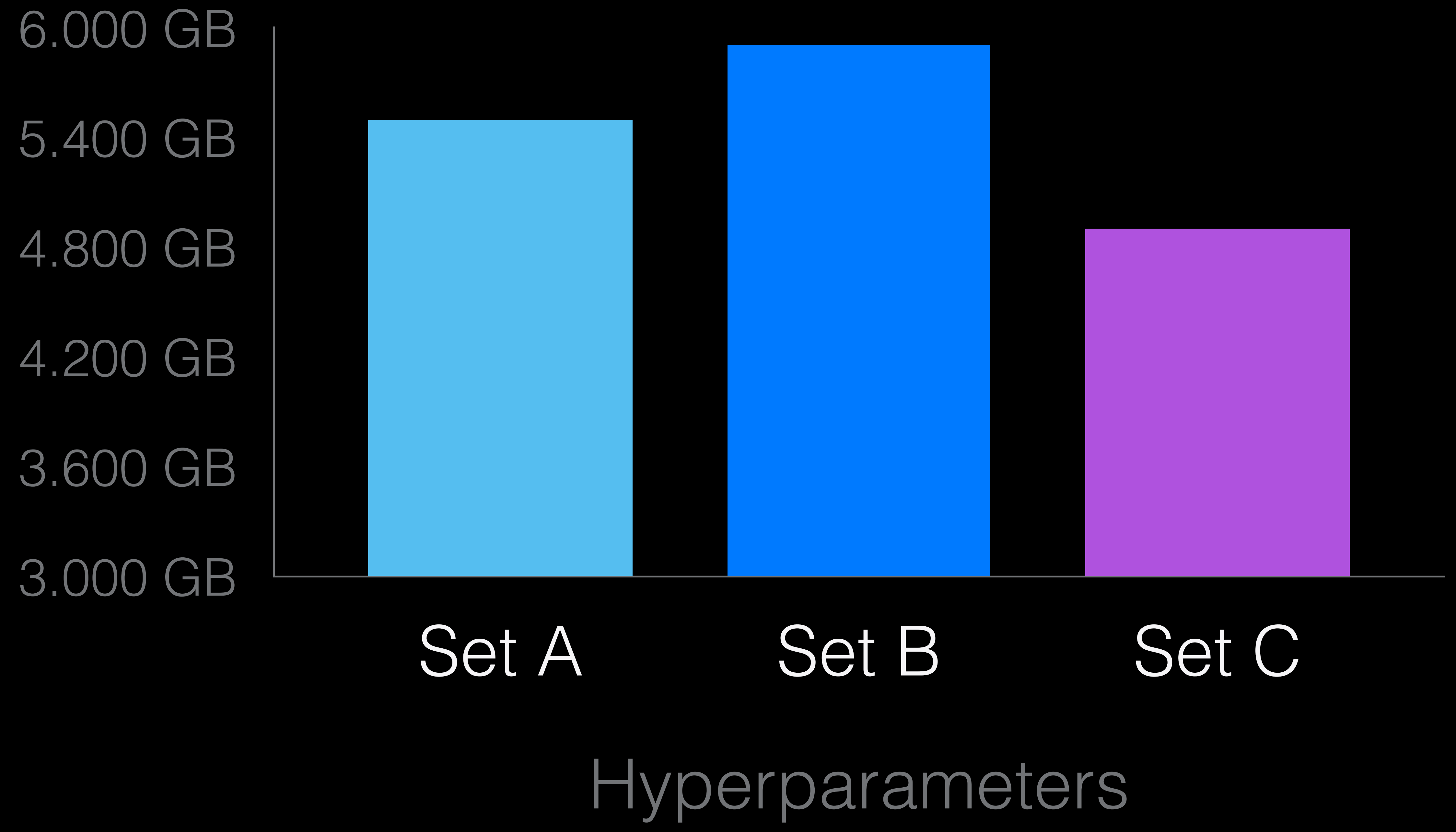
Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

If using Detectron2, it is important to note that decreasing hyperparameter values makes training slower instead.

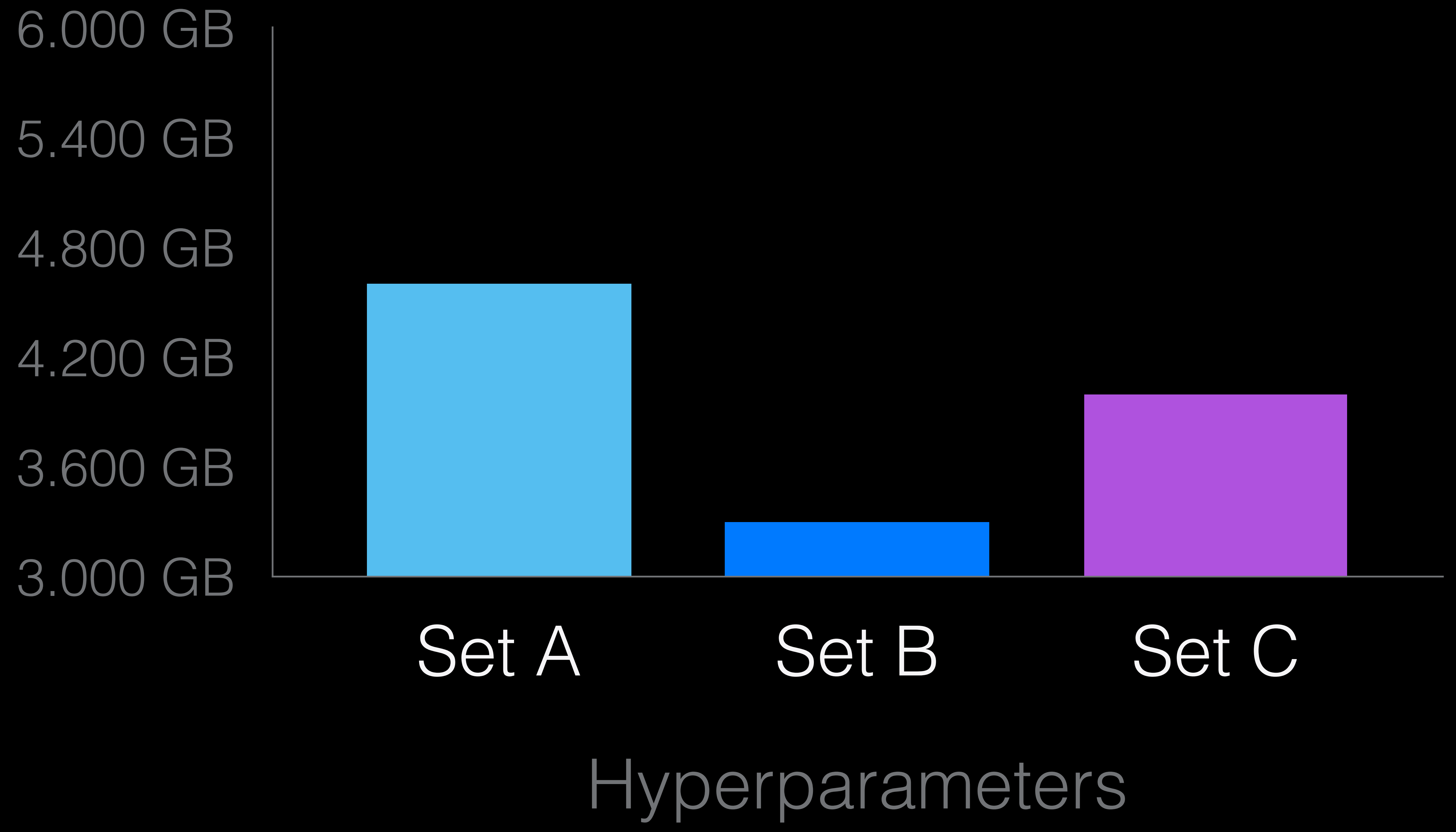
Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.

EVALUATION

Memory Consumption



YOLOv8

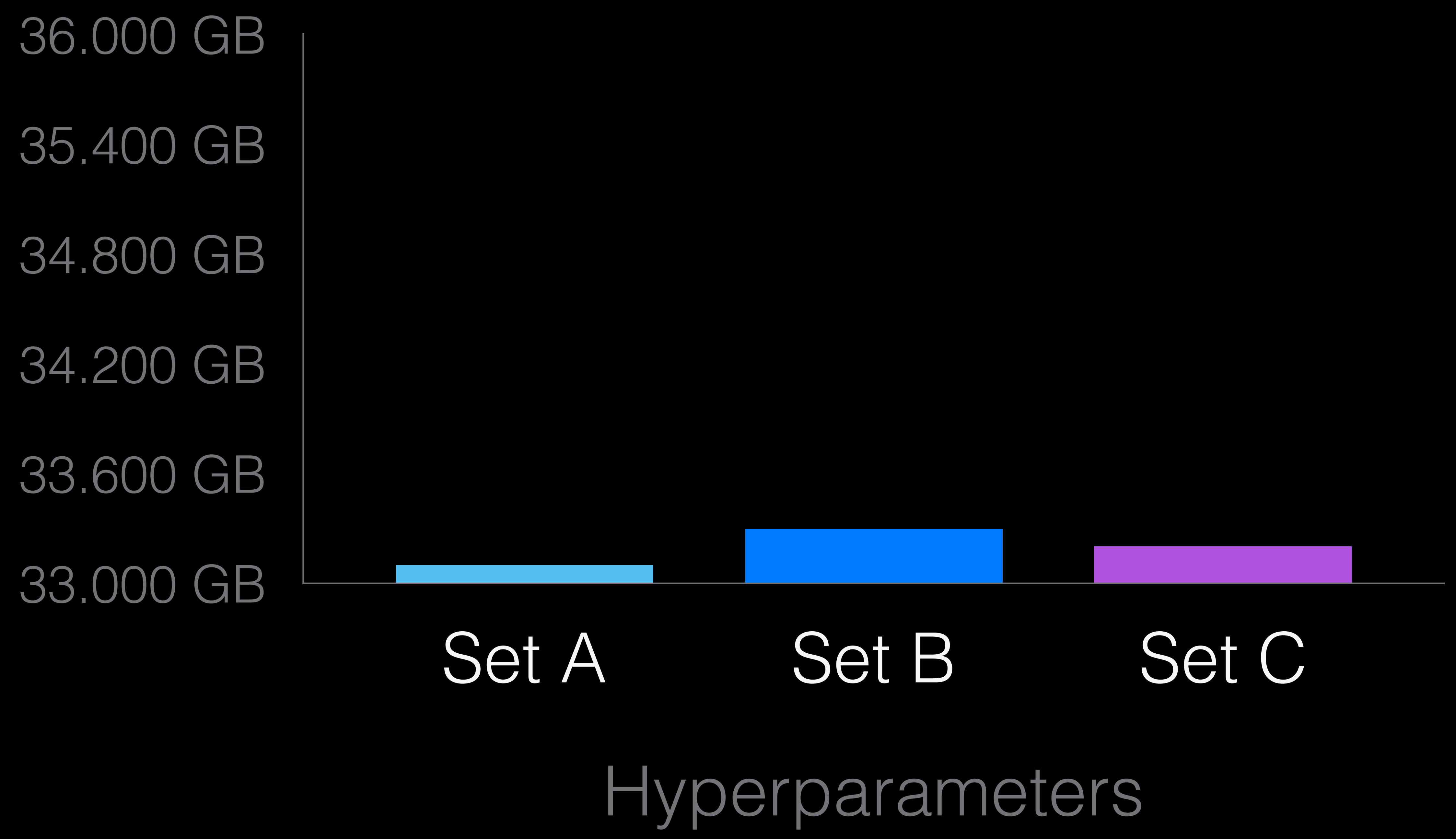


Detectron2

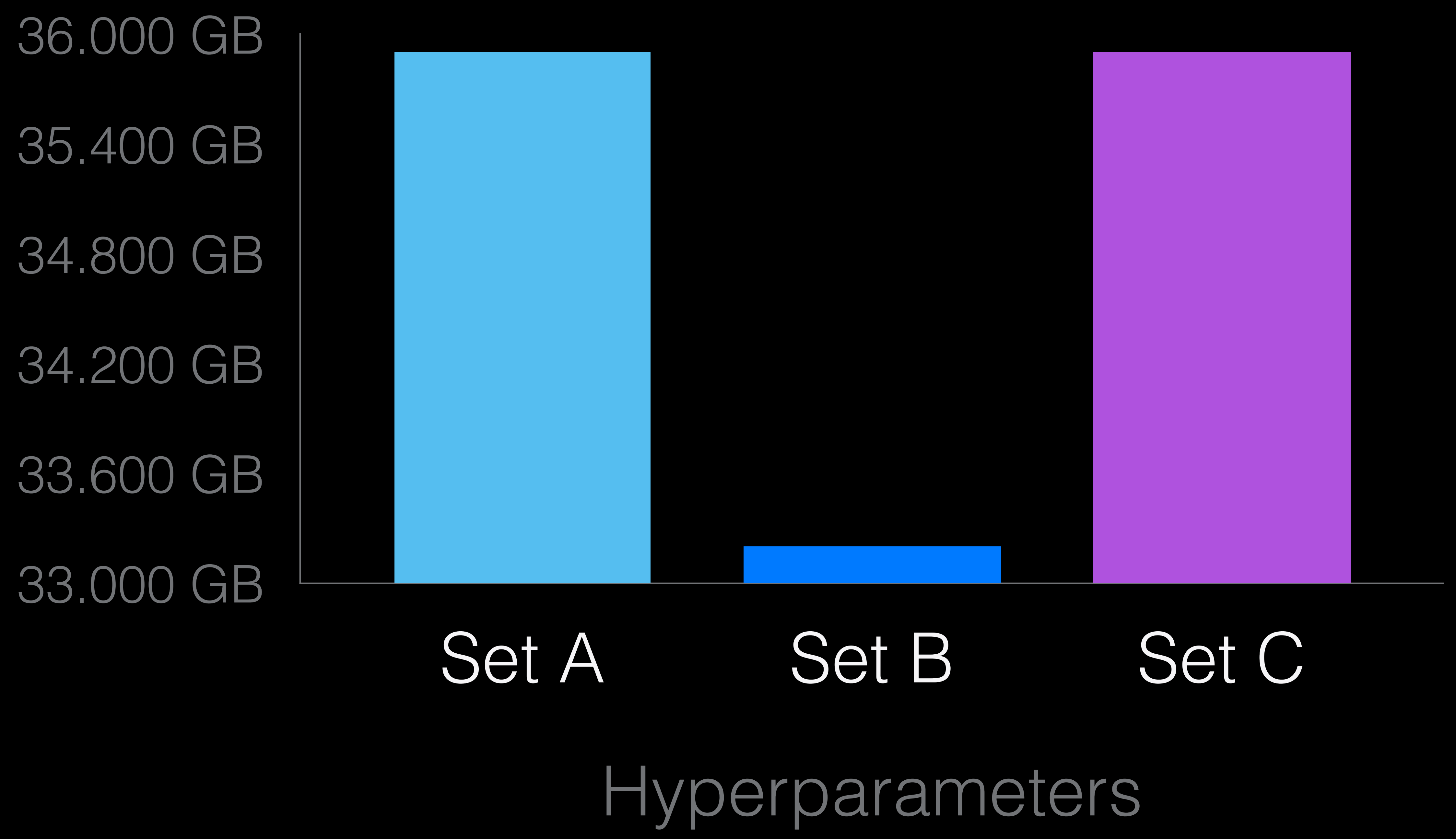
System RAM consumption

EVALUATION

Memory Consumption



YOLOv8

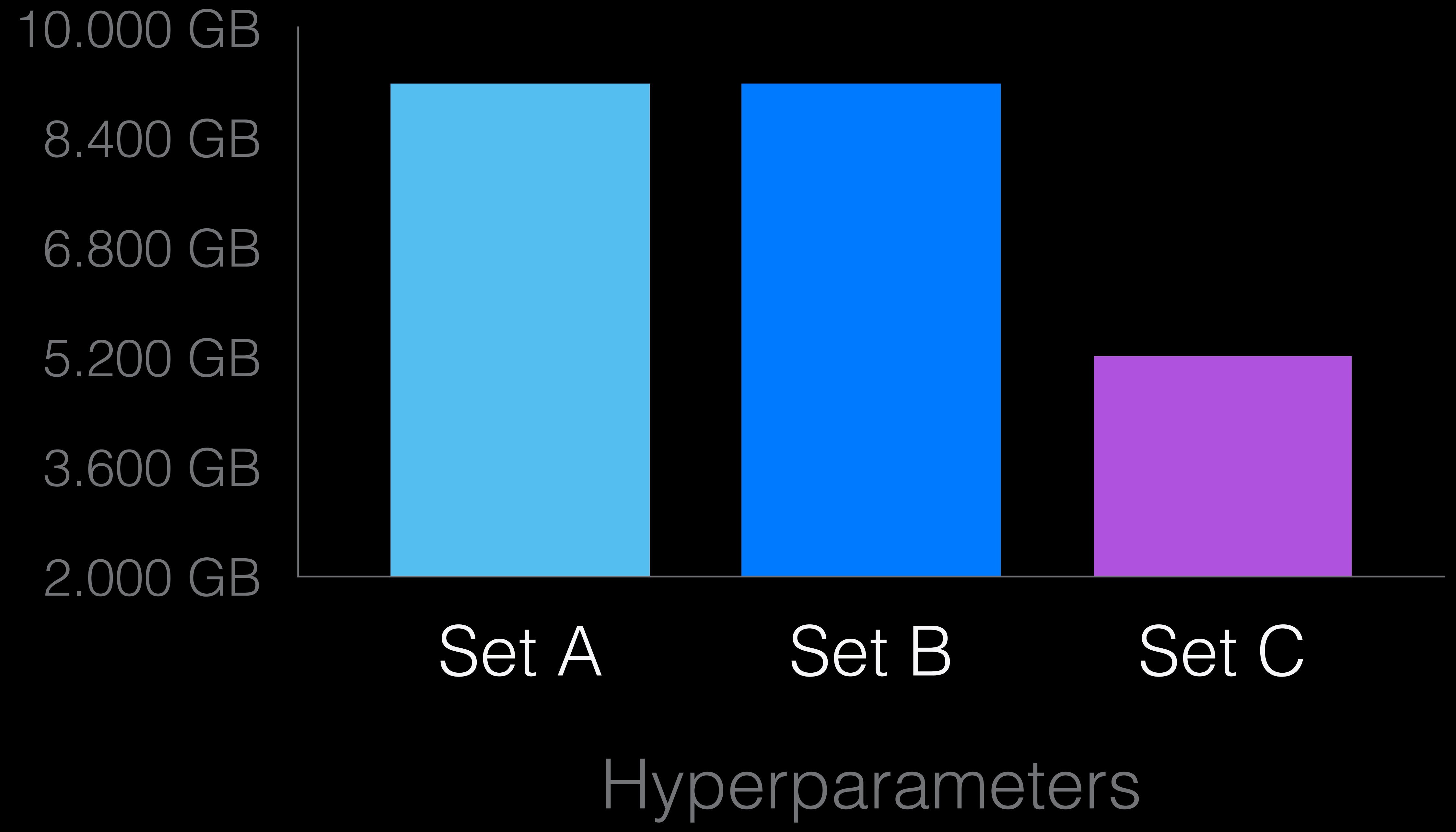


Detectron2

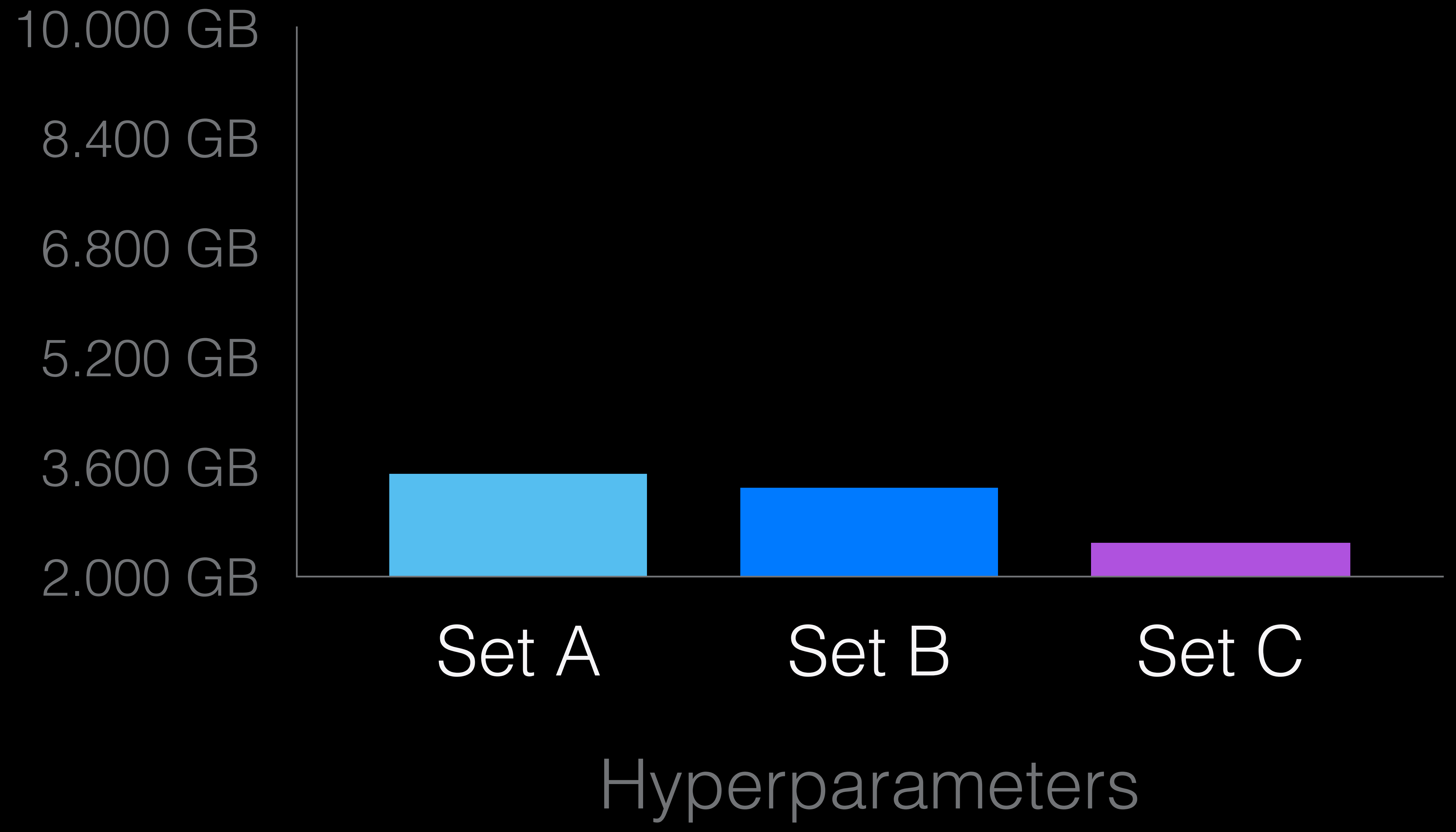
Disk Usage

EVALUATION

Memory Consumption



YOLOv8

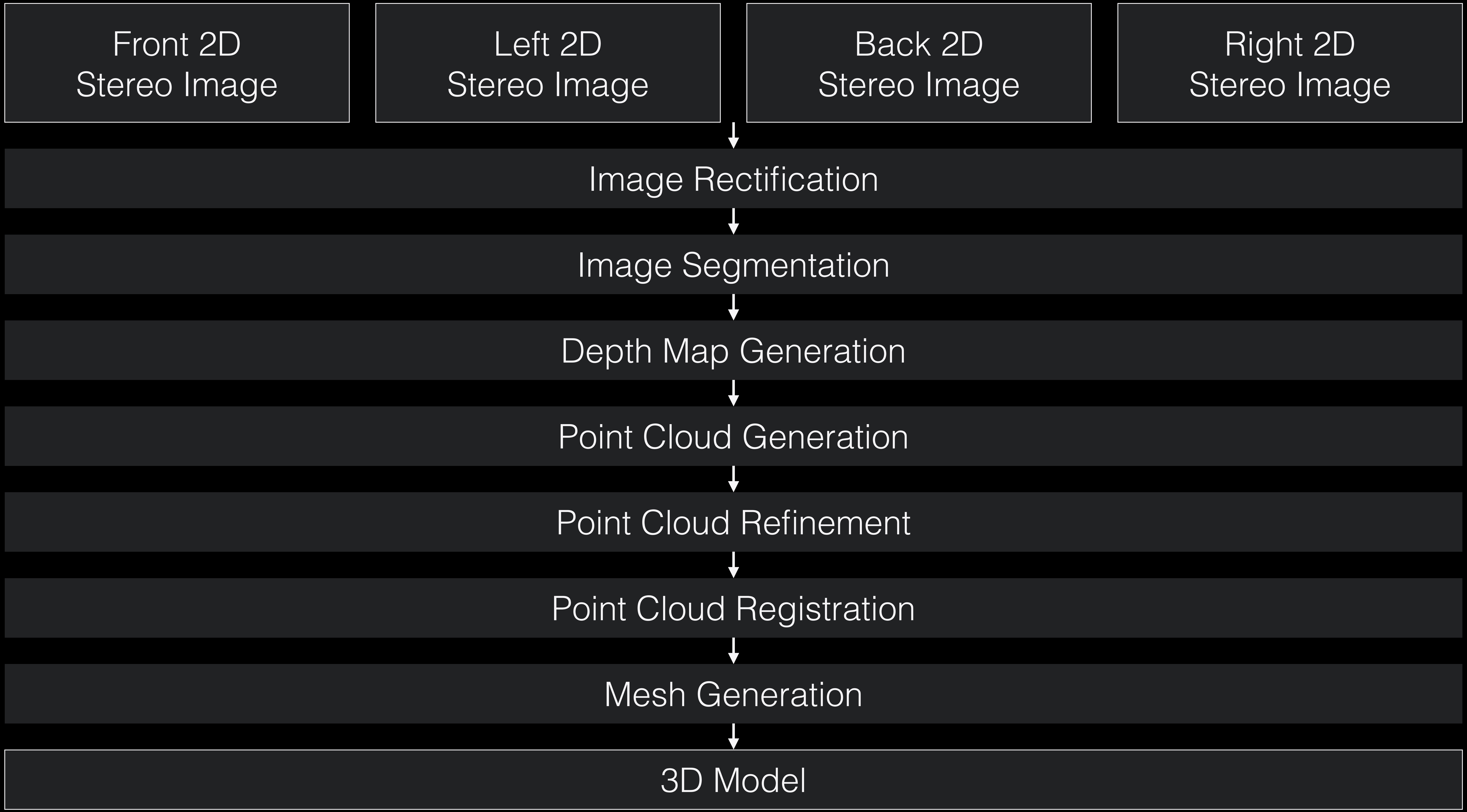


Detectron2

GPU RAM consumption

Decreasing hyperparameter values lower GPU requirements on both models.

Results are based on the plant class, with specified hyperparameter values, and the images and size of the dataset used for training.



Front 2D Stereo Image
Left 2D Stereo Image
Back 2D Stereo Image
Right 2D Stereo Image
Image Rectification
Image Segmentation
Depth Map Generation
Point Cloud Generation
Point Cloud Refinement
Point Cloud Registration
Mesh Generation
3D Model

Front 2D Stereo Image | Left 2D Stereo Image | Back 2D Stereo Image | Right 2D Stereo Image

Image Rectification

Image Segmentation

Depth Map Generation

Point Cloud Generation

Point Cloud Refinement

Point Cloud Registration

Mesh Generation

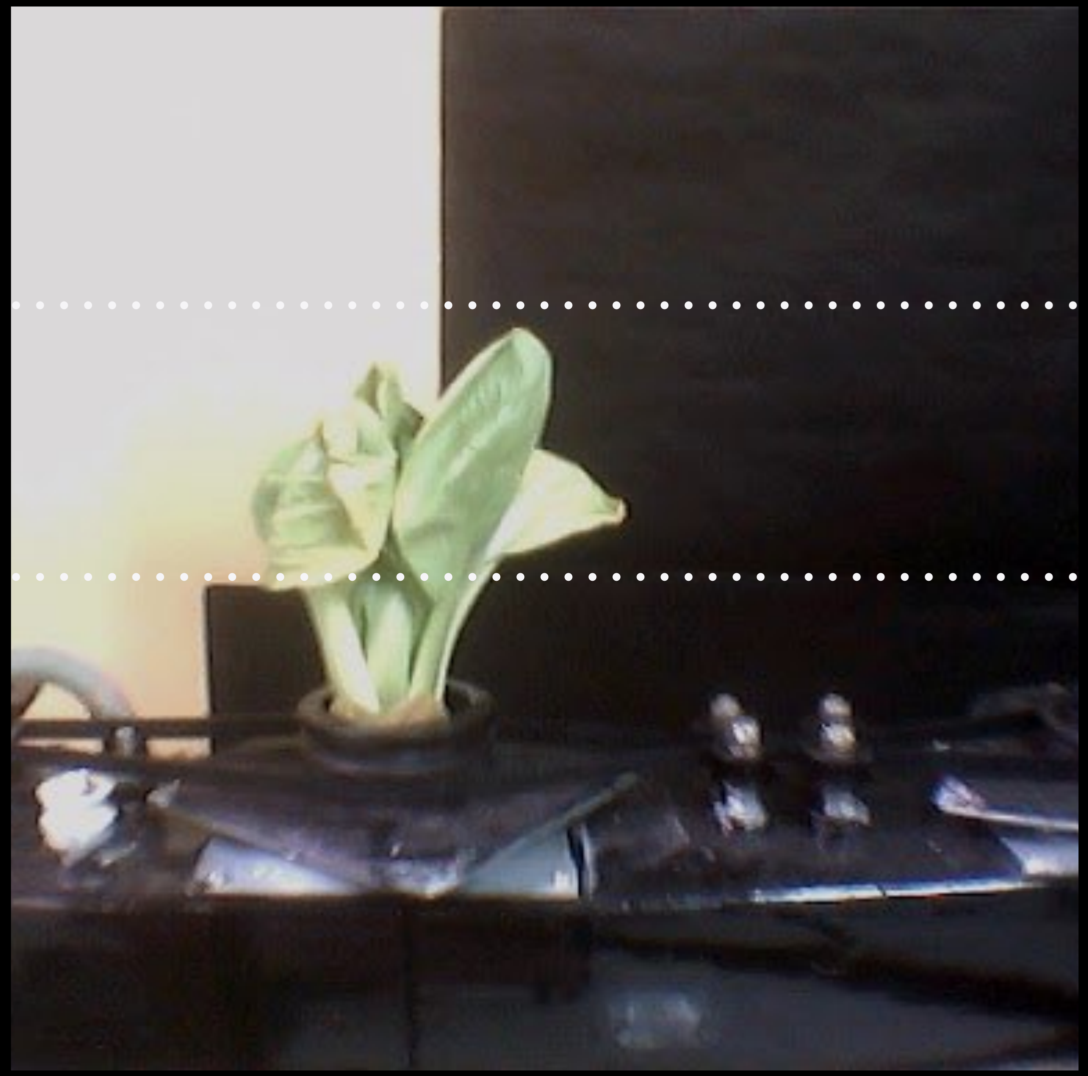
3D Model

DEPTH MAP GENERATION

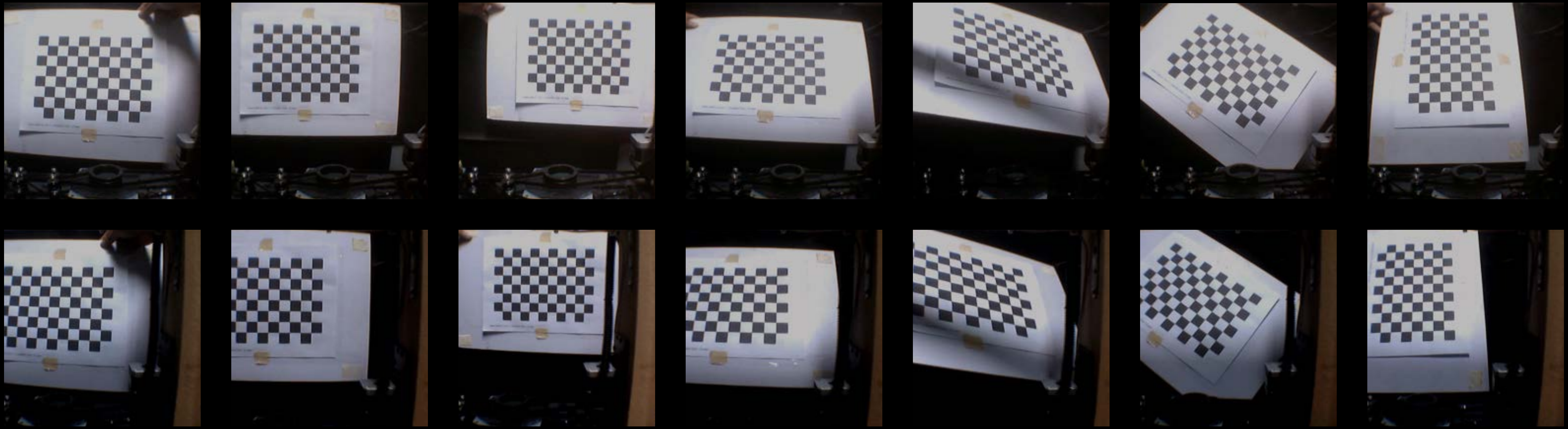
DEPTH MAP GENERATION

Distortions

Misalignments



DEPTH MAP GENERATION



Checkerboard images captured by the stereo cameras

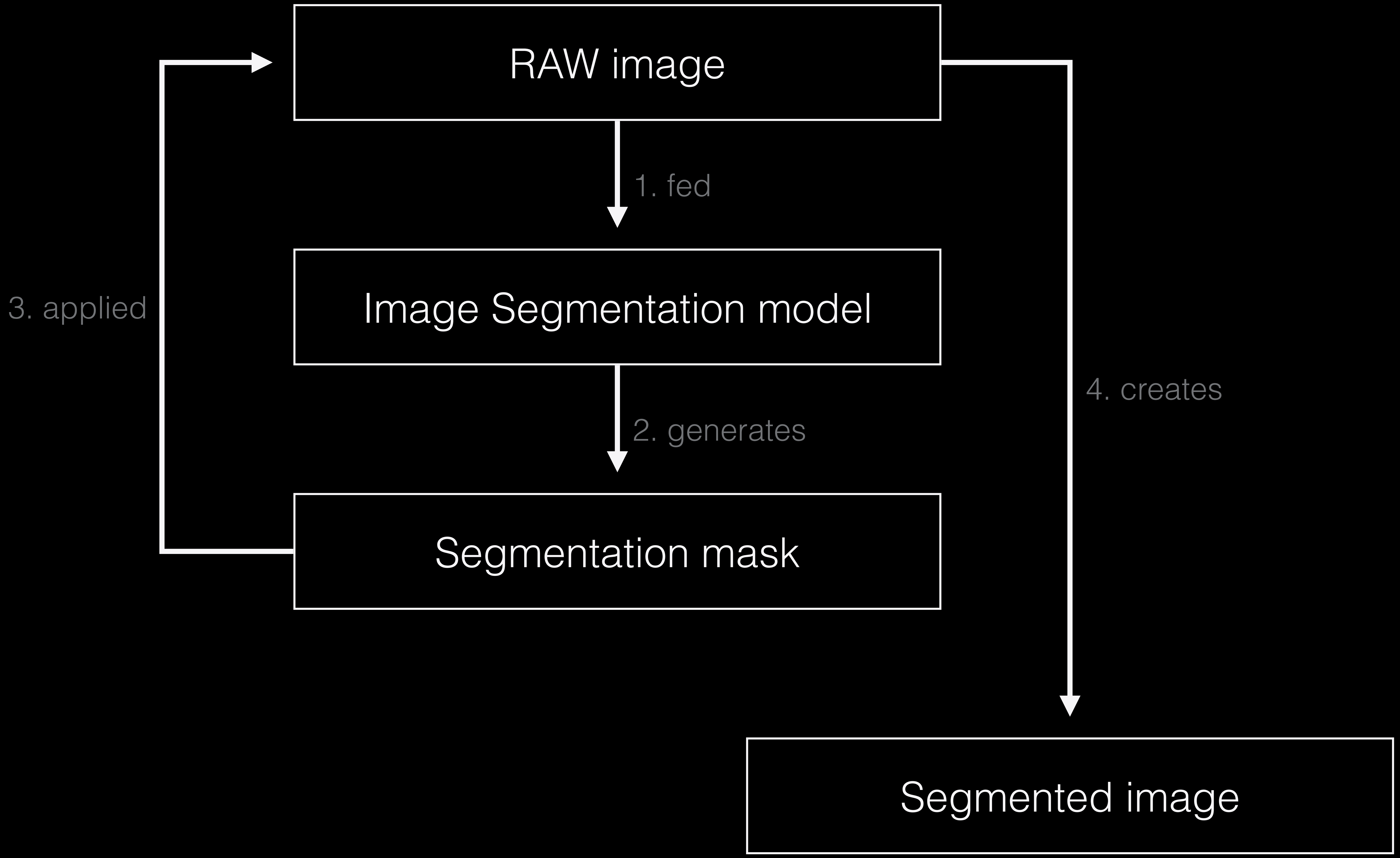
↓

Calibration Map

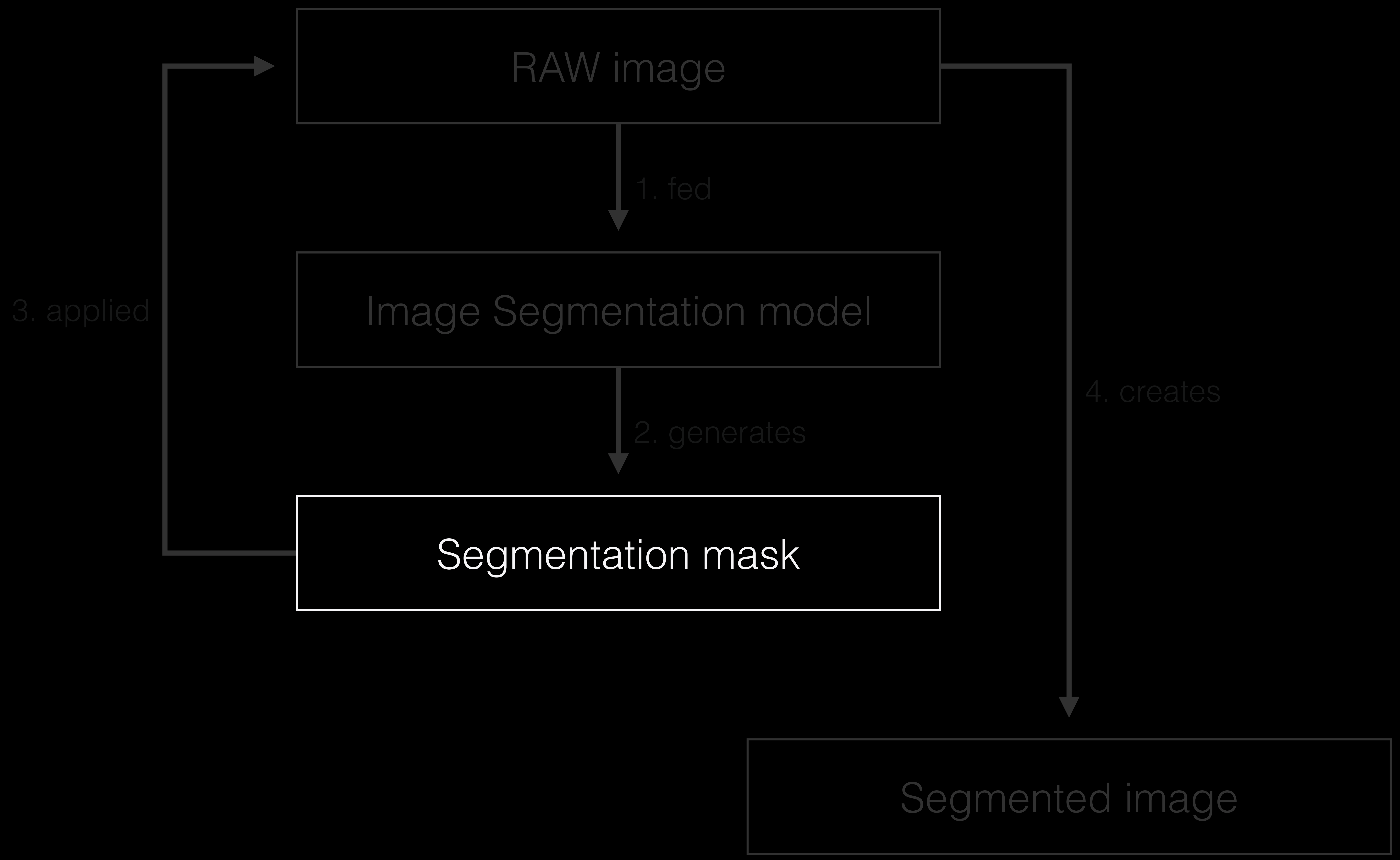
↓ undistorts

Distorted stereo images

DEPTH MAP GENERATION



DEPTH MAP GENERATION



DEPTH MAP GENERATION

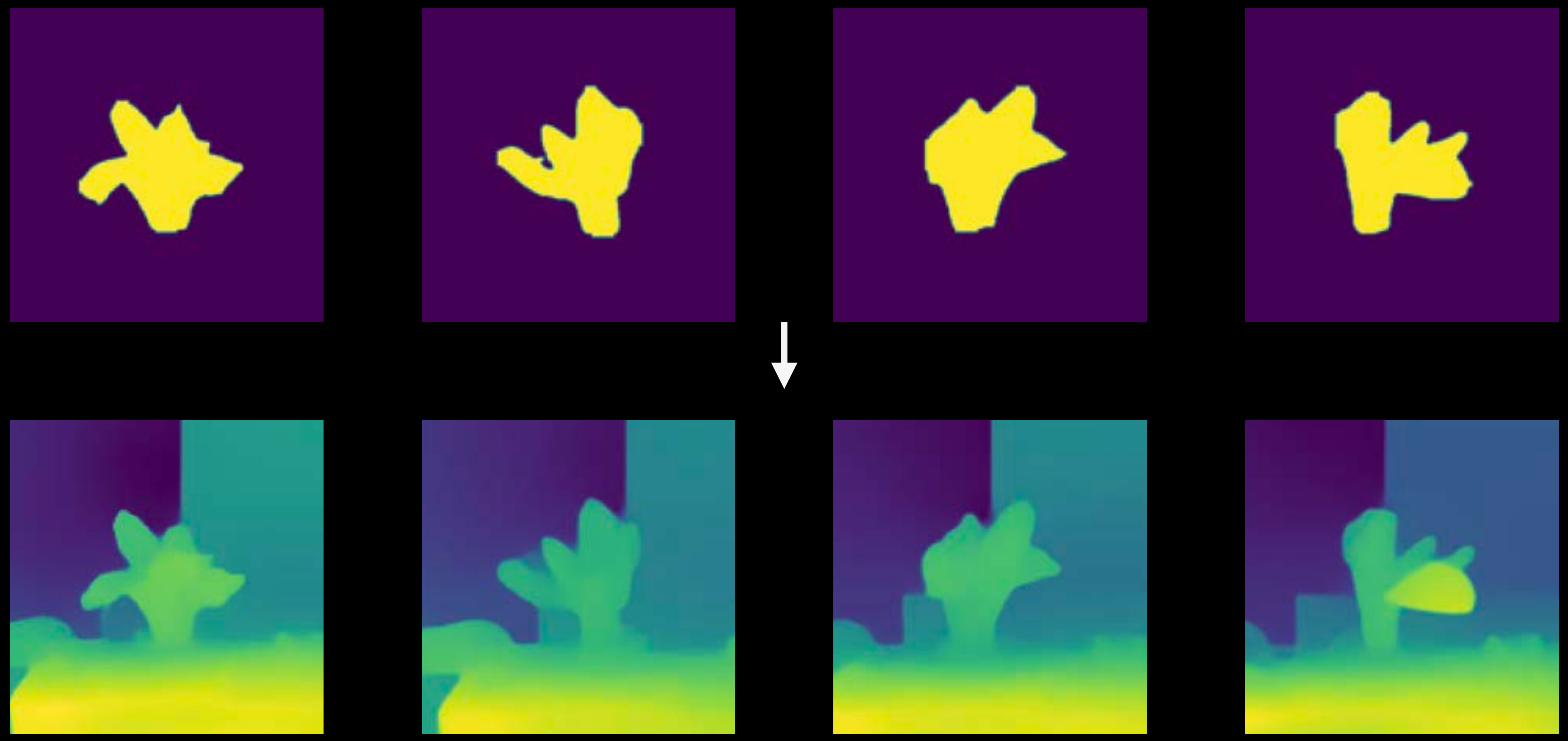
Segmentation mask

applied

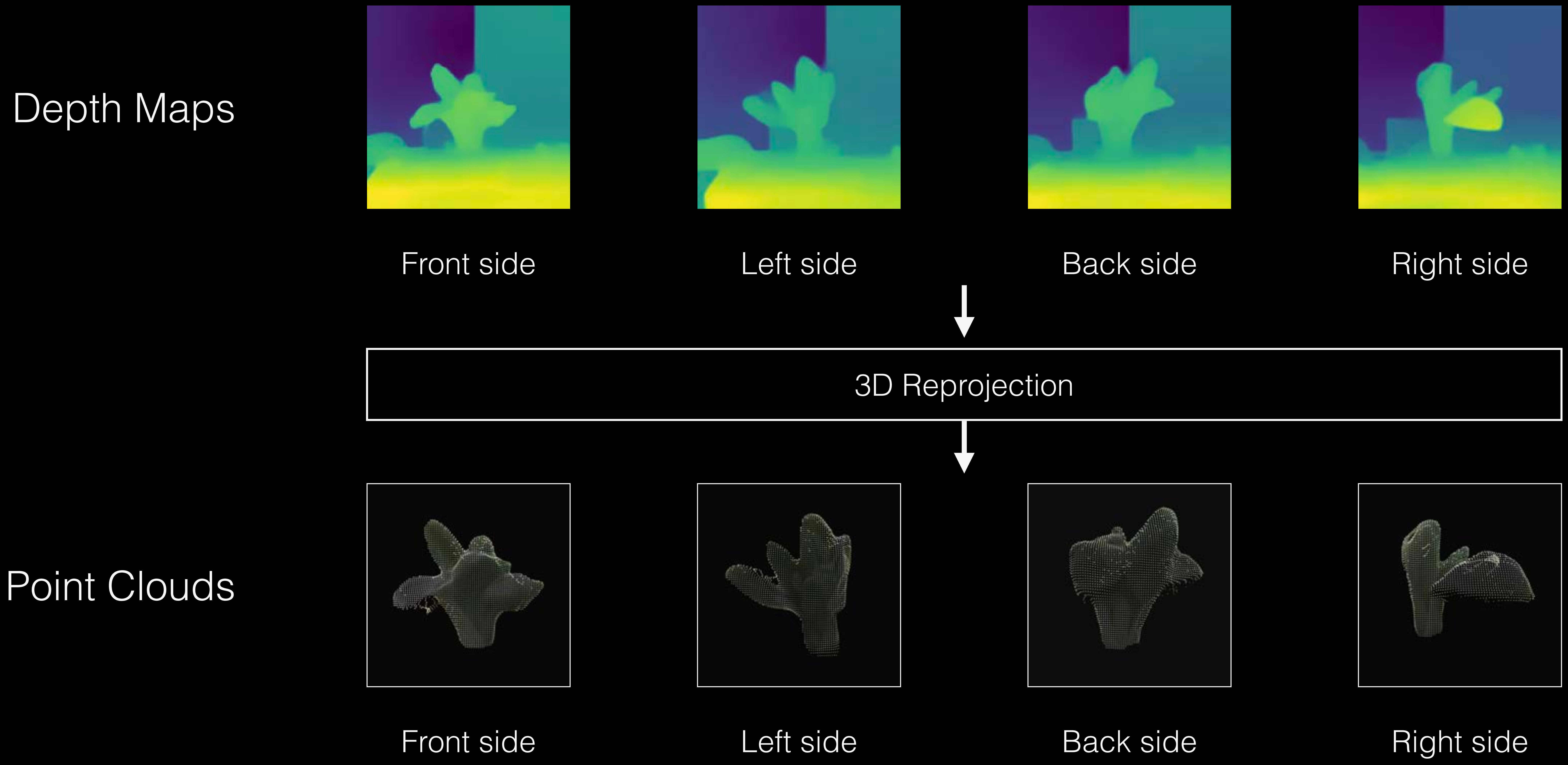
Depth Map

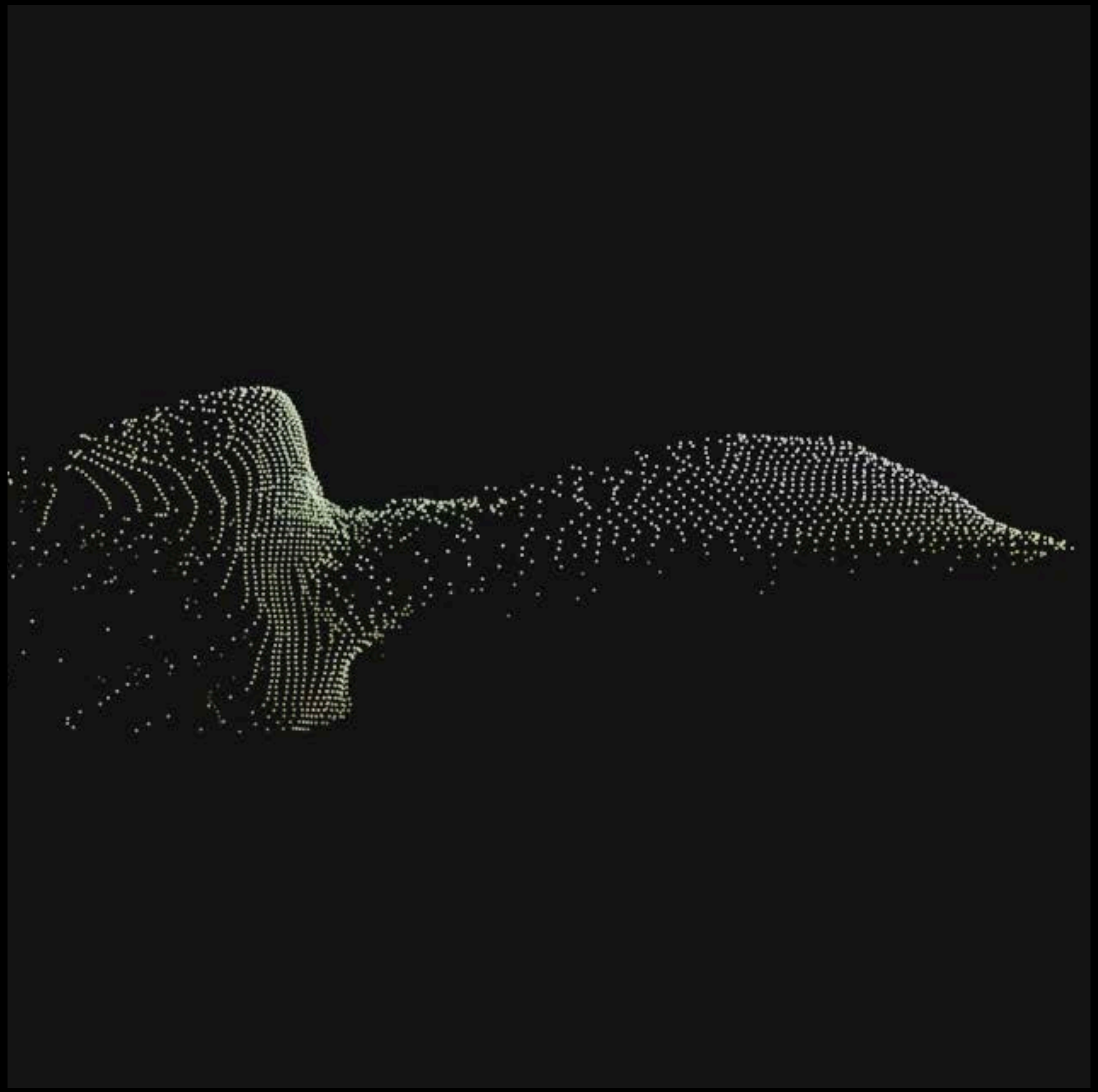
creates

Filtered Depth Map



POINT CLOUD GENERATION

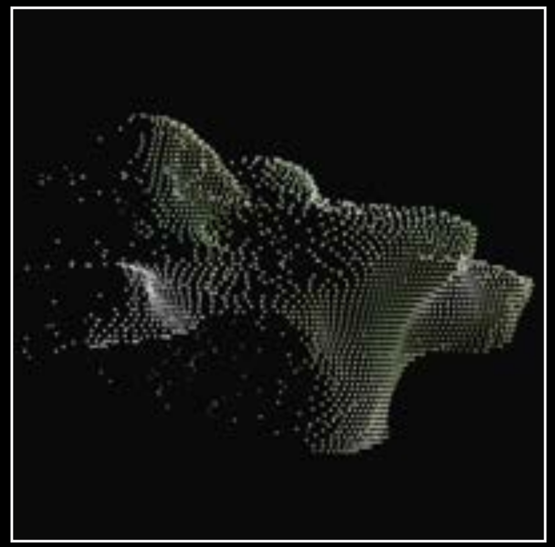




Warping problem

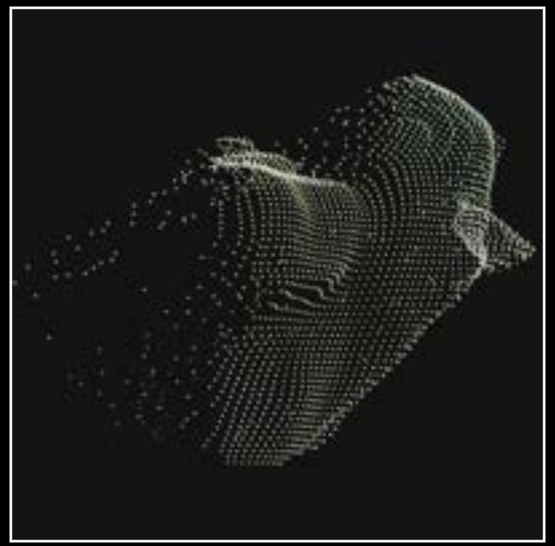
POINT CLOUD REFINEMENT

Fixing warping

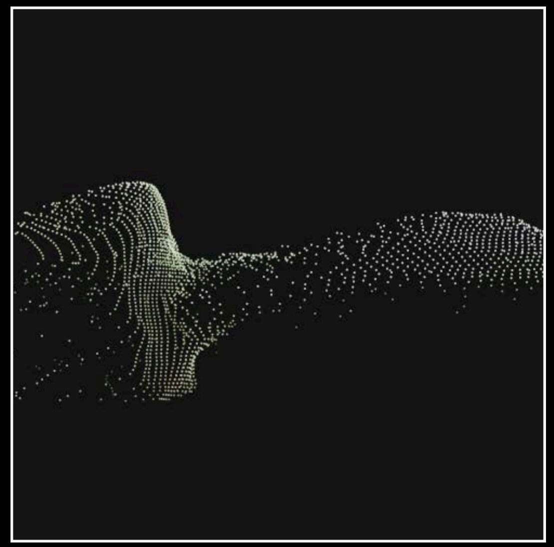


Front side

Left side

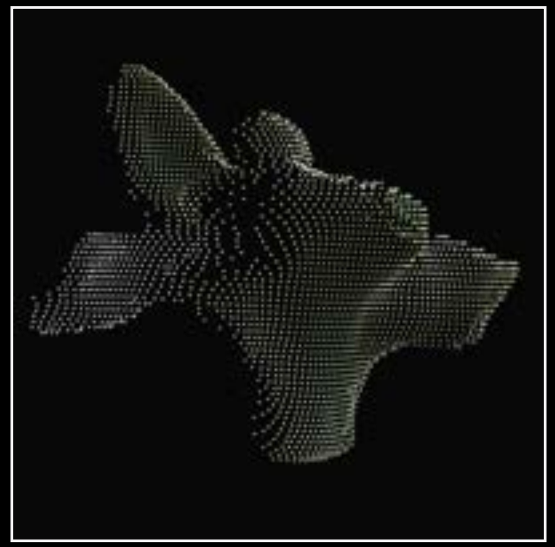


Back side

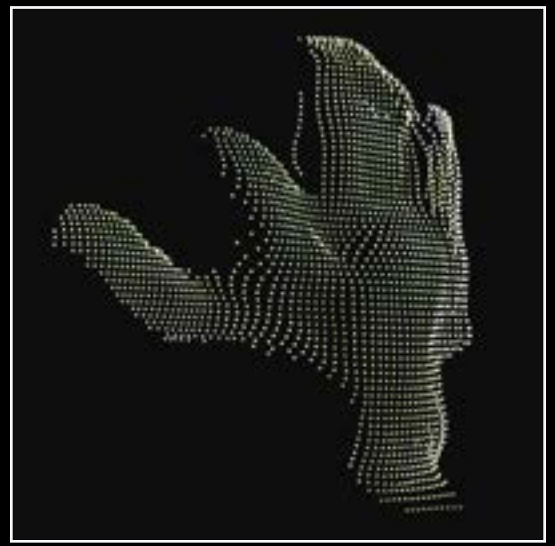


Right side

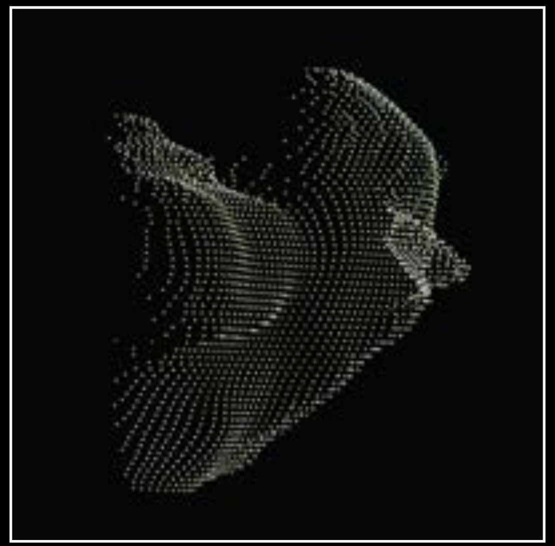
`.transform`



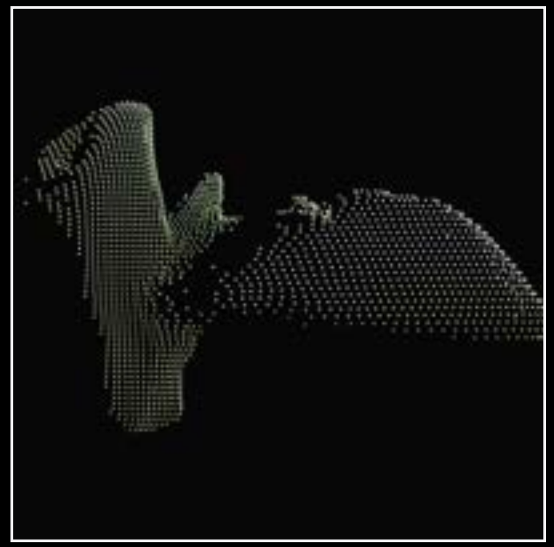
Front side



Left side

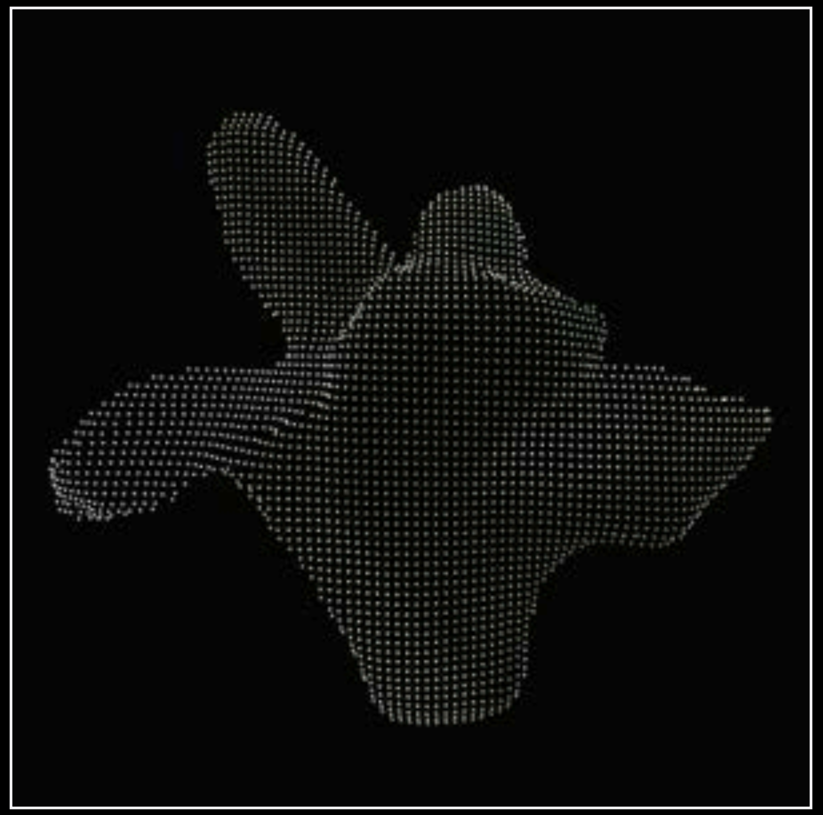


Back side

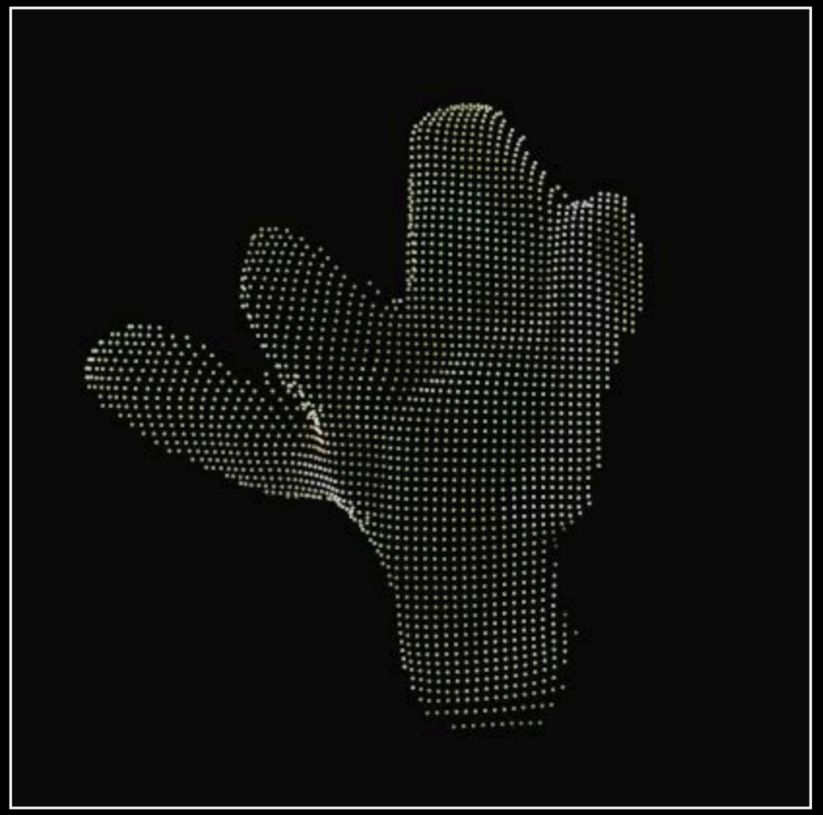


Right side

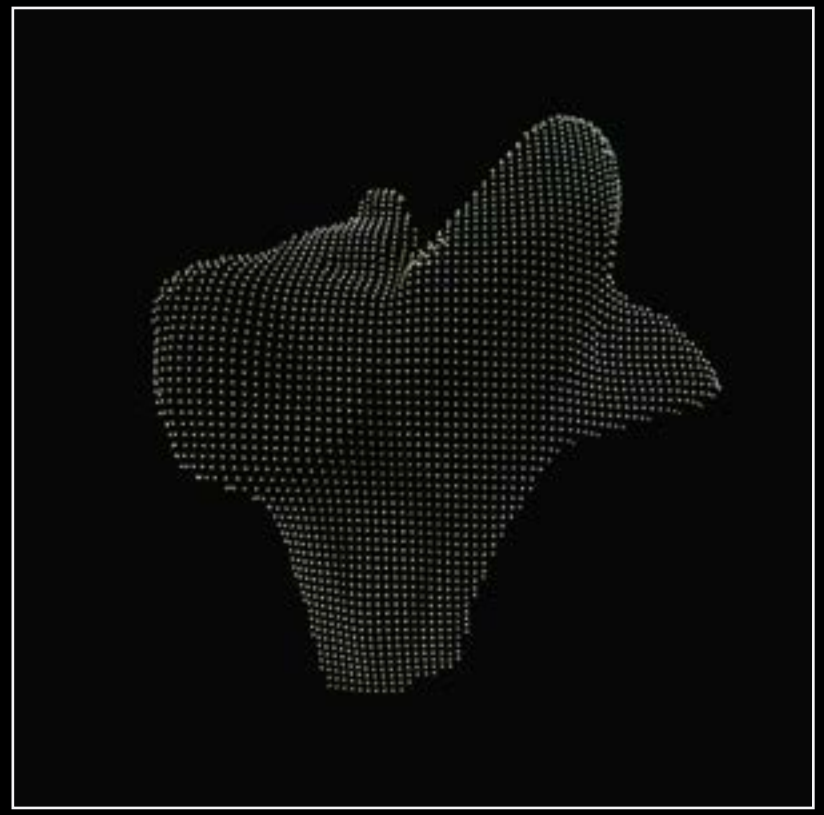
POINT CLOUD REGISTRATION



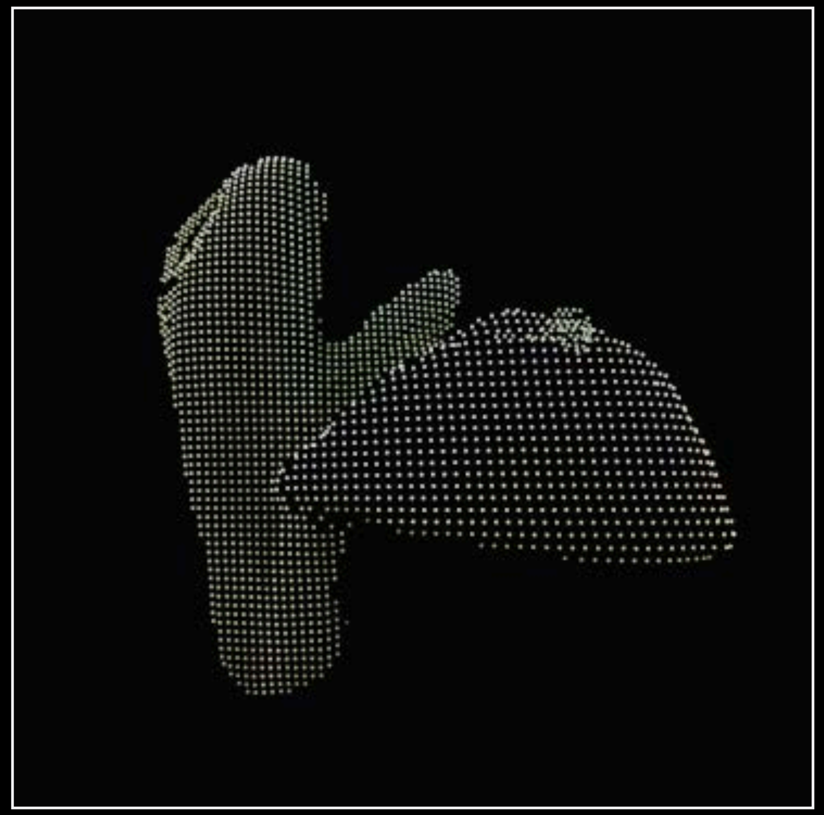
Front side



Left side



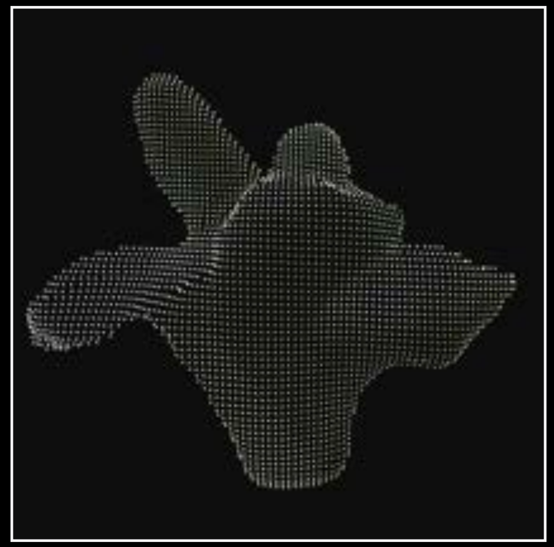
Back side



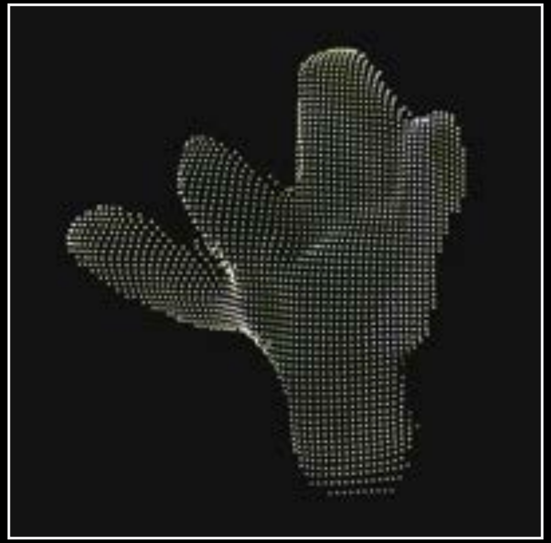
Right side

Disconnected point clouds

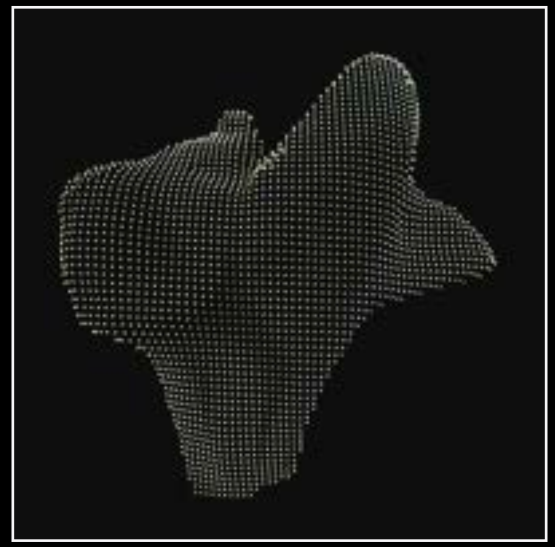
POINT CLOUD REGISTRATION



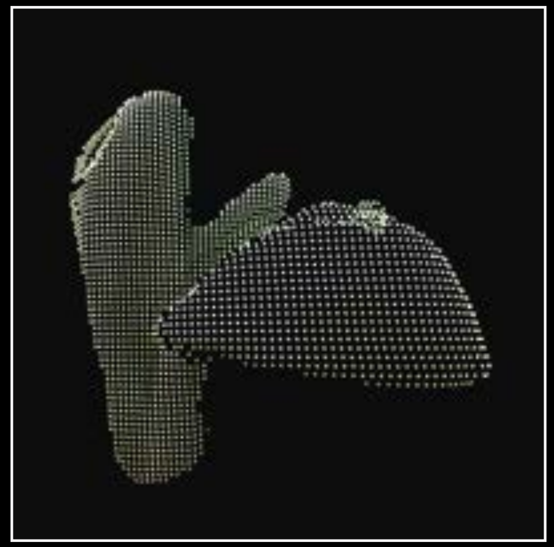
Front side



Left side

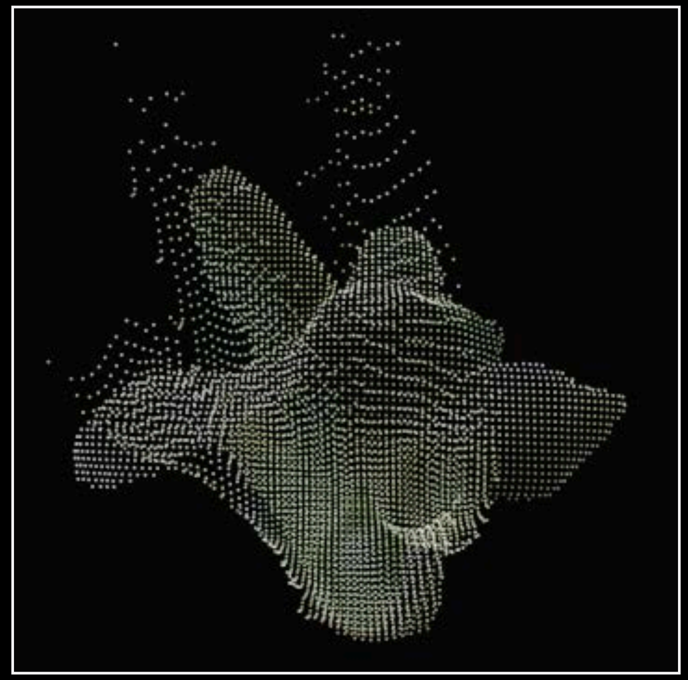


Back side

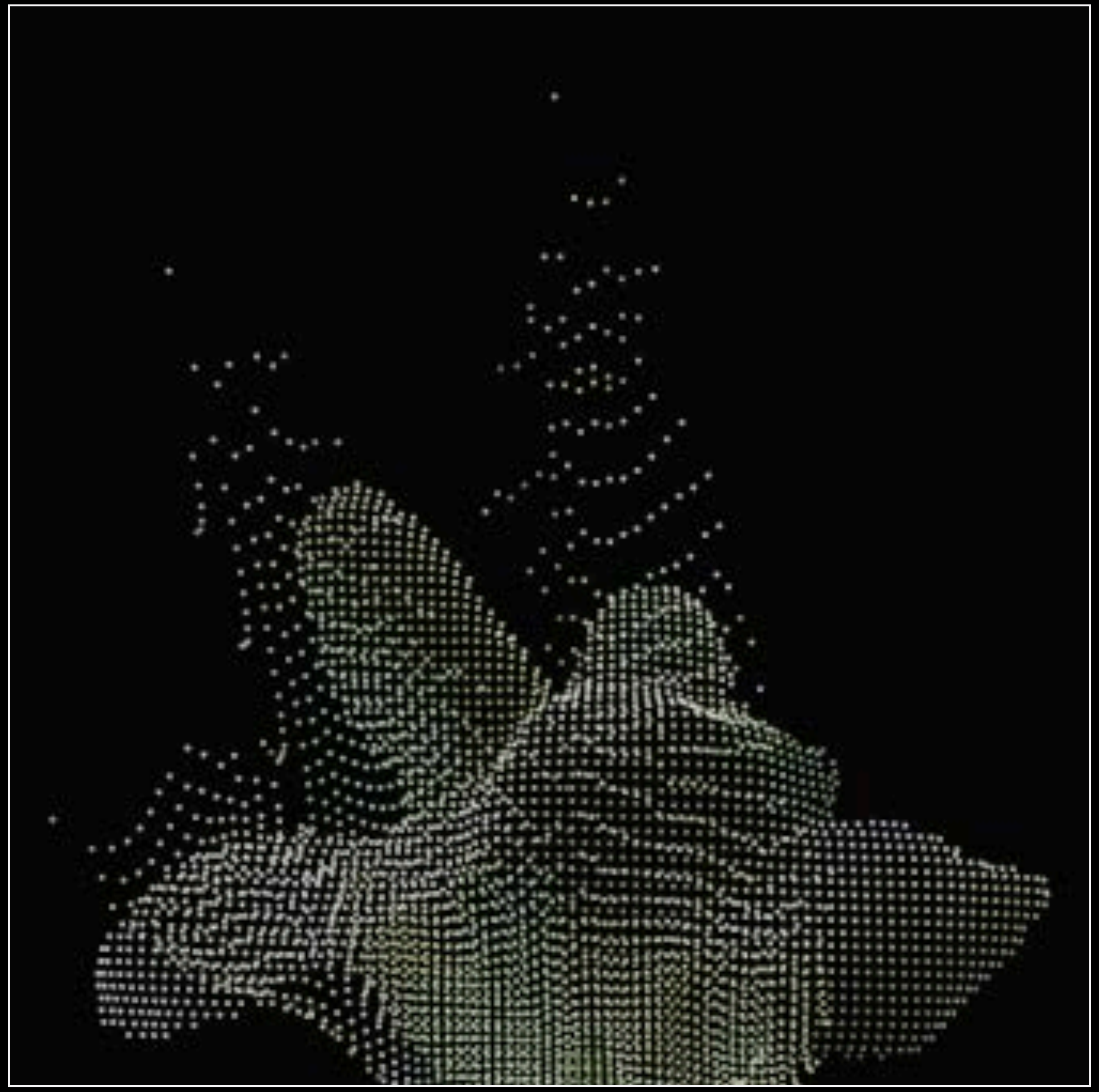


Right side

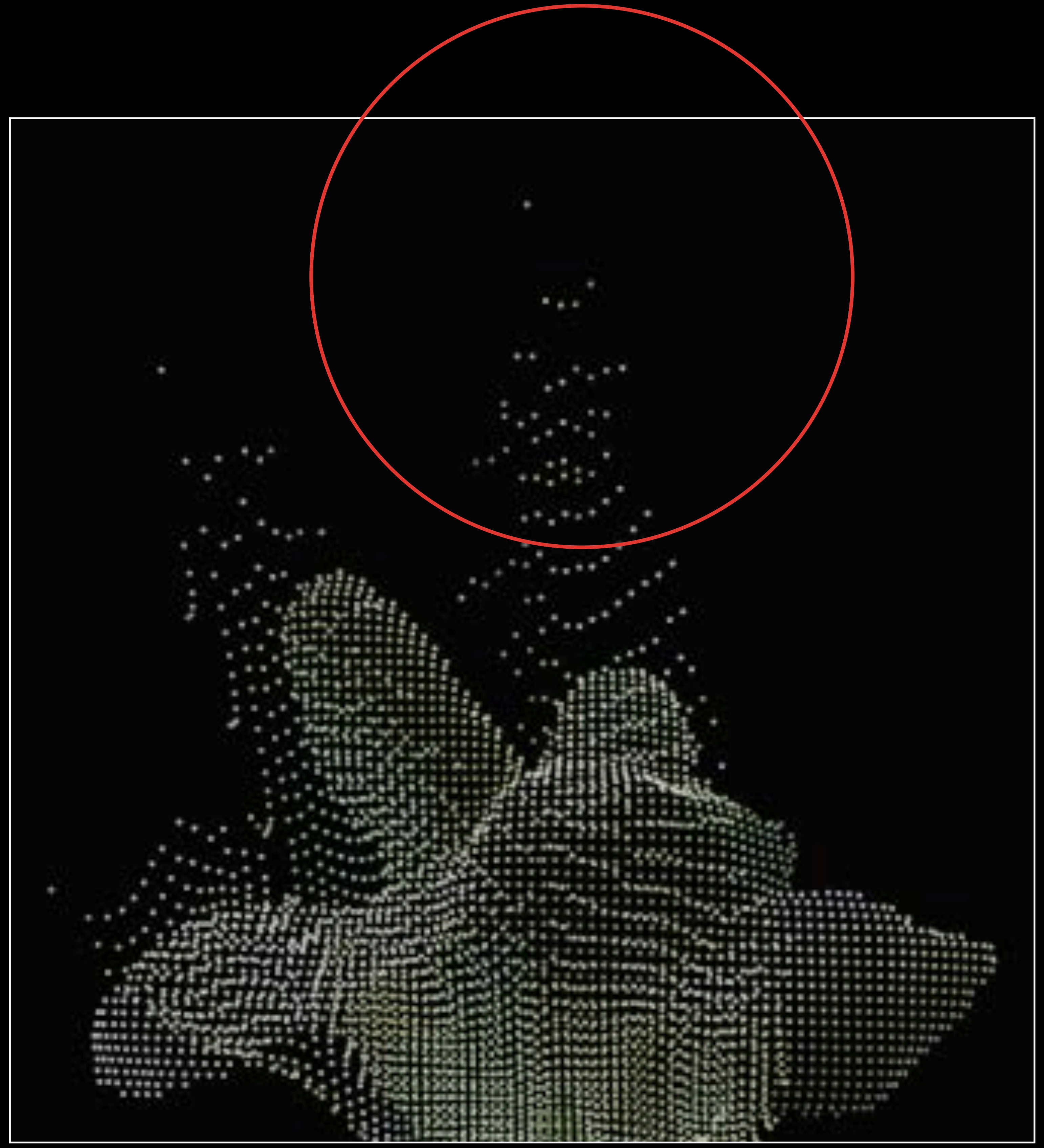
`.translate` `.rotate` `.scale` `.transform`



Unified point cloud



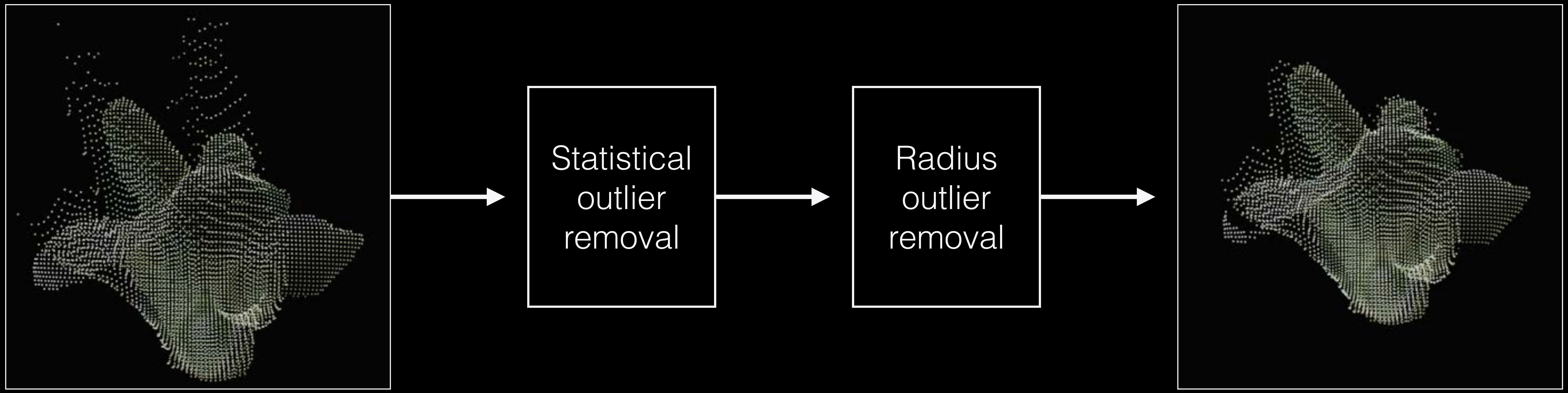
Outlier problem

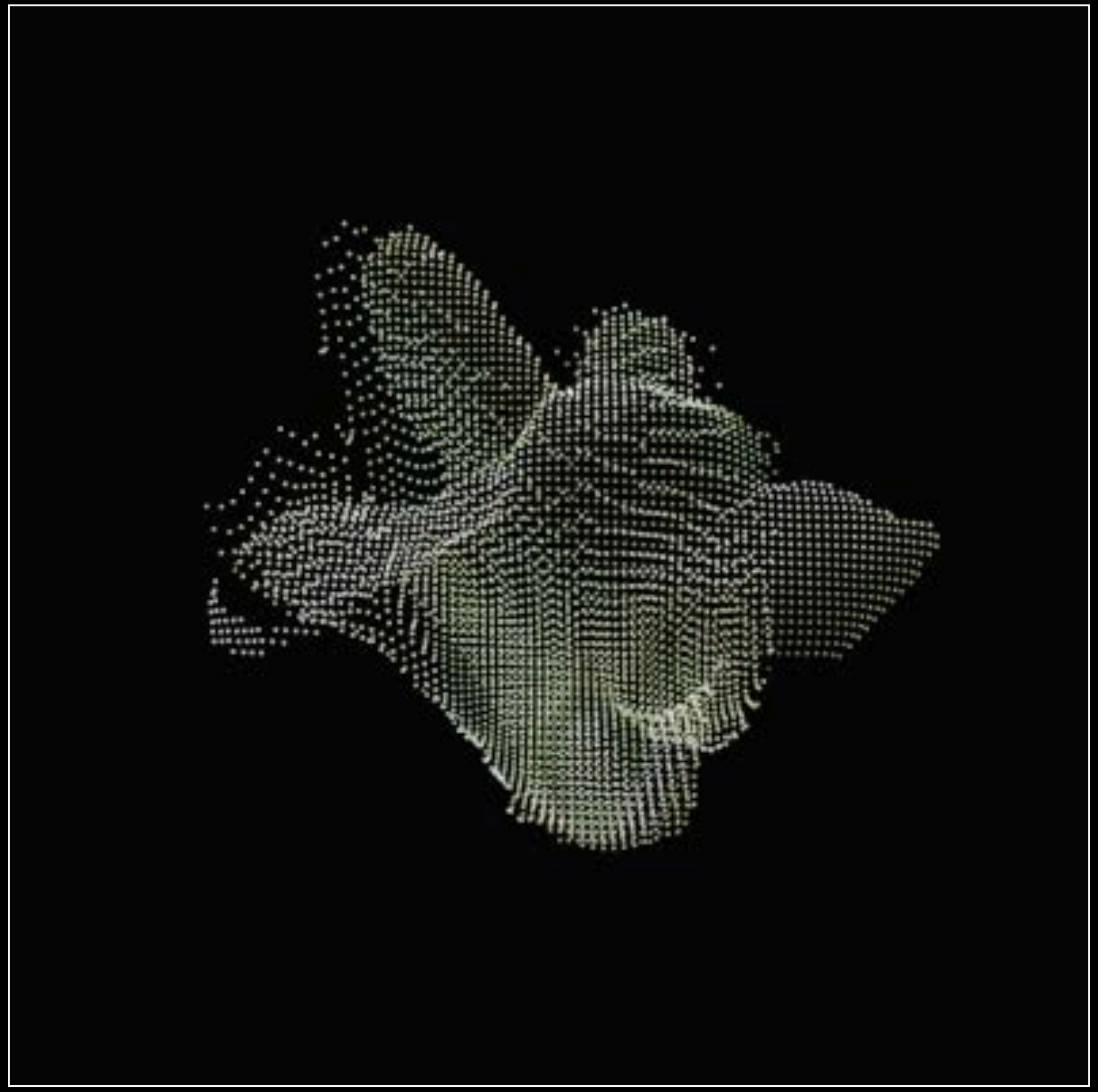


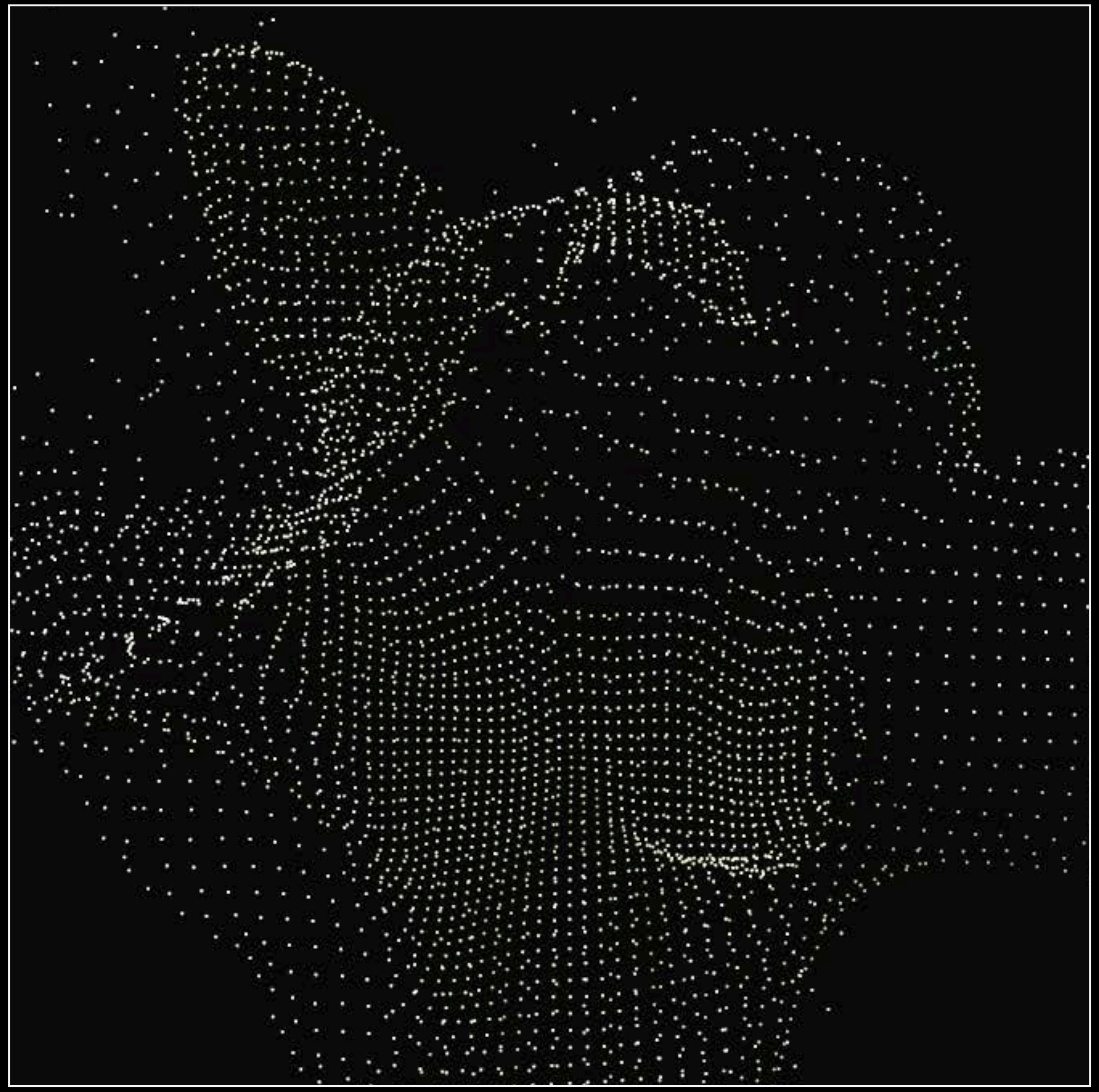
Outlier problem

POINT CLOUD REFINEMENT

Fixing excess point clouds

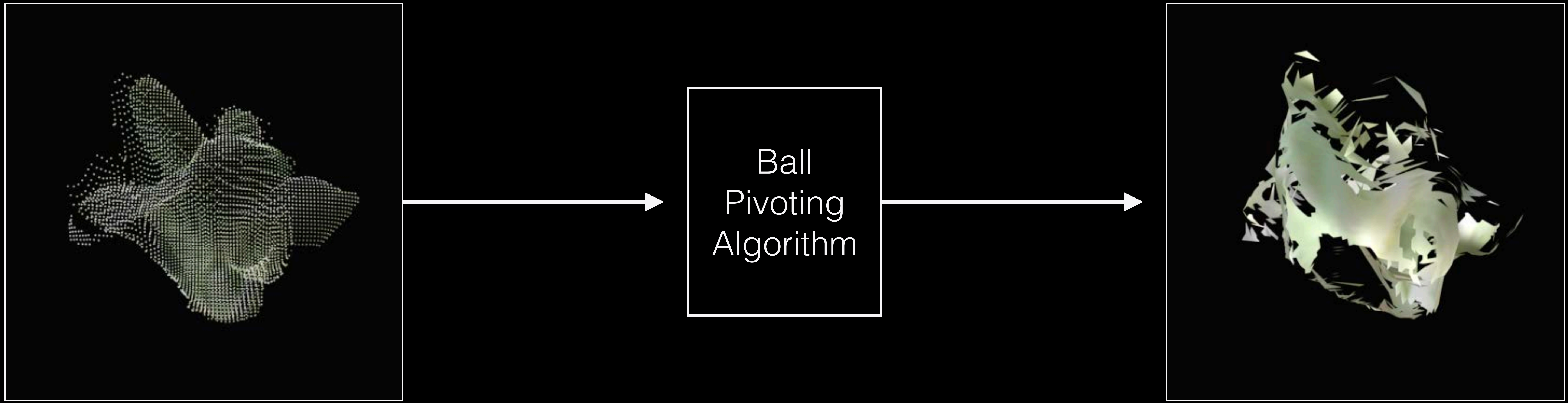




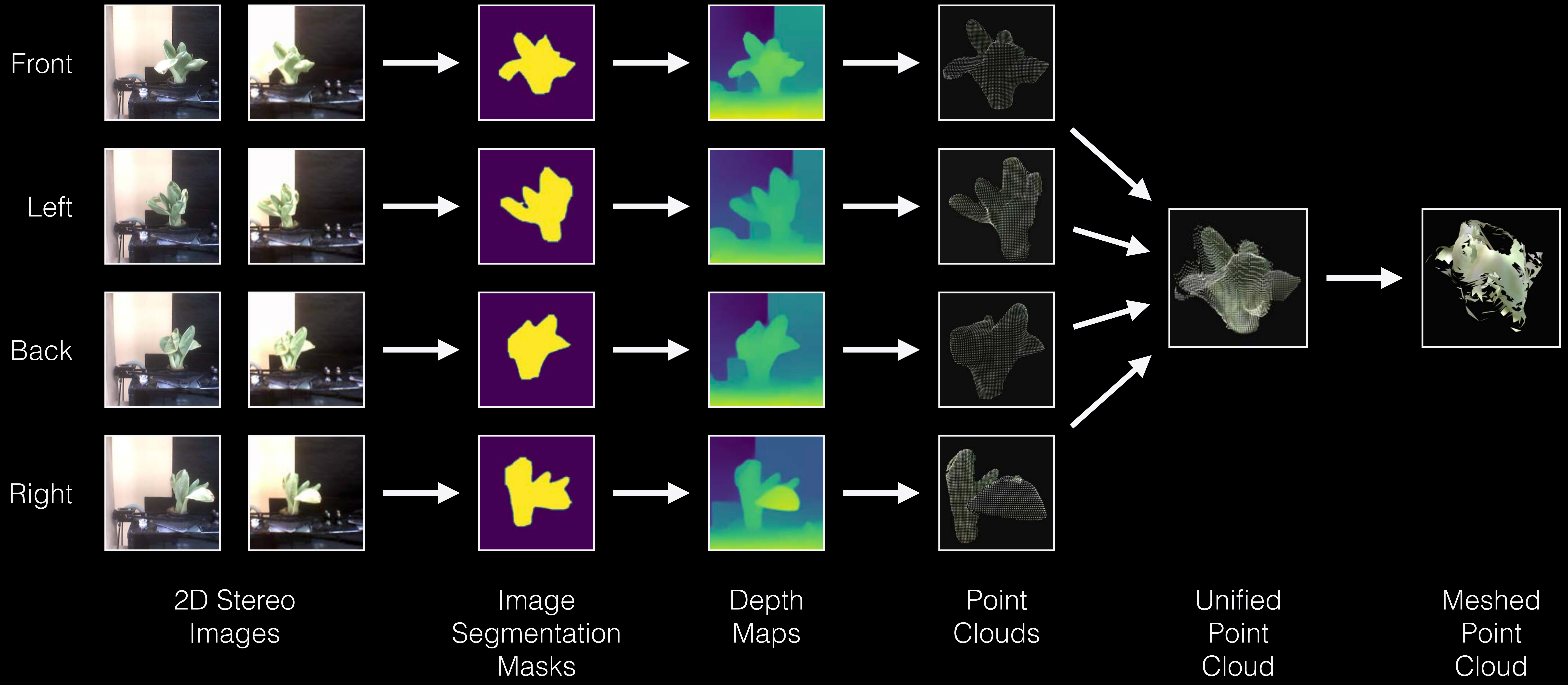


Discontinuous surface

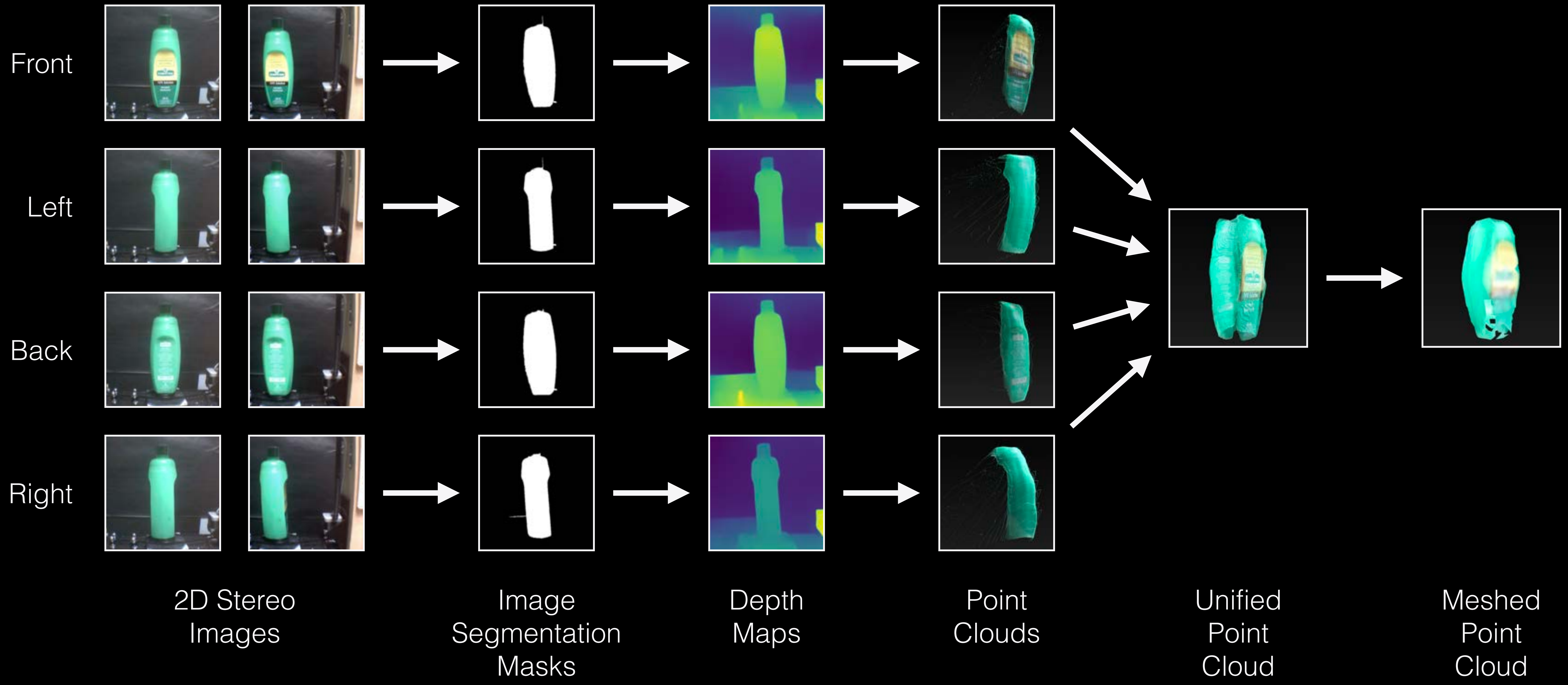
MESH GENERATION



Summary


Front
Left
Back
Right
2D Stereo Images
Image Segmentation Masks
Depth Maps
Point Clouds
Unified Point Cloud
Meshed Point Cloud

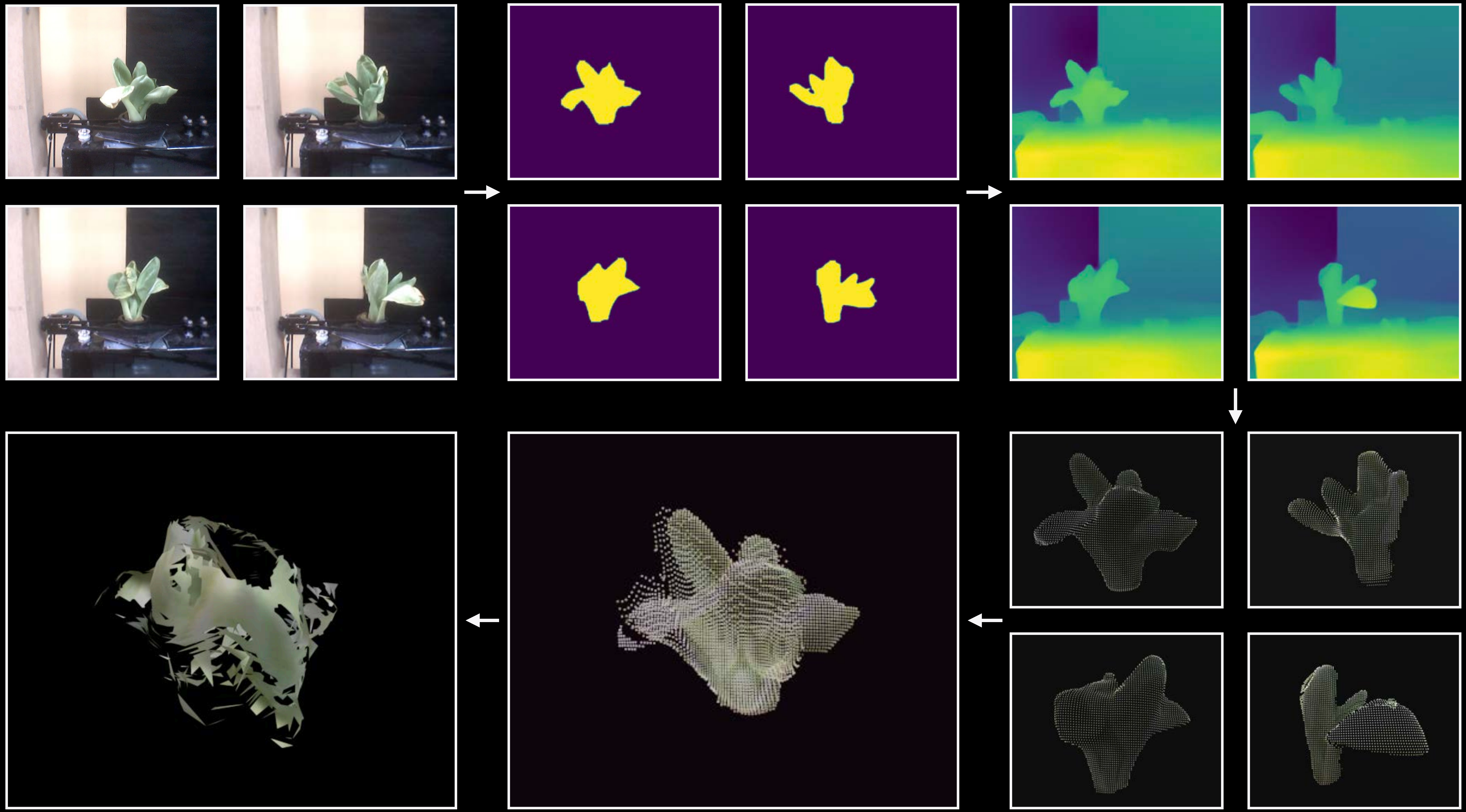
Testing other objects



LIMITATIONS

Evaluation in the 3D reconstruction process is limited to visual inspection, with no quantitative assessment.

The 3D reconstruction process focuses solely on the front, left, back, and right sides of the object, **excluding the top and bottom views**.



CONCLUSIONS

CONCLUSIONS

Comparing YOLOv8 and Detectron2 for Plant Class Segmentation

In plant class segmentation,

YOLOv8 trains faster with lower Train Times,

Detectron2 provides better segmentation with higher Box and Mask Average Precisions, and lower Box and Mask Losses,

Detectron2 is more RAM-efficient with lower System RAM and GPU RAM consumptions.

CONCLUSIONS

Comparing YOLOv8 and Detectron2 for Plant Class Segmentation

		Hyperparameters	
		Decreasing	Increasing
YOLOv8	Segmentation Accuracy	Worsens (in small decrements)	Improves (in small increments)
	Training Speed	Improves	Worsens
	Memory Consumption	Improves (with respect to GPU RAM)	Worsens (with respect to GPU RAM)
Detectron2	Segmentation Accuracy	Worsens (in large decrements)	Improves (in large increments)
	Training Speed	Worsens	Improves
	Memory Consumption	Improves (with respect to GPU RAM)	Worsens (with respect to GPU RAM)

CONCLUSIONS

Comparing YOLOv8 and Detectron2 for Plant Class Segmentation

YOLOv8 is ideal

When you want faster training times and can accept slightly lower accuracy, with GPU RAM usage not being a concern.

Detectron2 is ideal

When you need better segmentation accuracy or have lower GPU RAM requirements, even if it means longer training times.

CONCLUSIONS

Comparing YOLOv8 and Detectron2 for Plant Class Segmentation

For YOLOv8,

Use lower hyperparameters if you want faster training and lower GPU RAM usage, with a slight trade-off in segmentation accuracy.

Use higher hyperparameters if you aim to improve segmentation accuracy and are okay with slower training and higher GPU RAM usage.

CONCLUSIONS

Comparing YOLOv8 and Detectron2 for Plant Class Segmentation

For Detectron2,

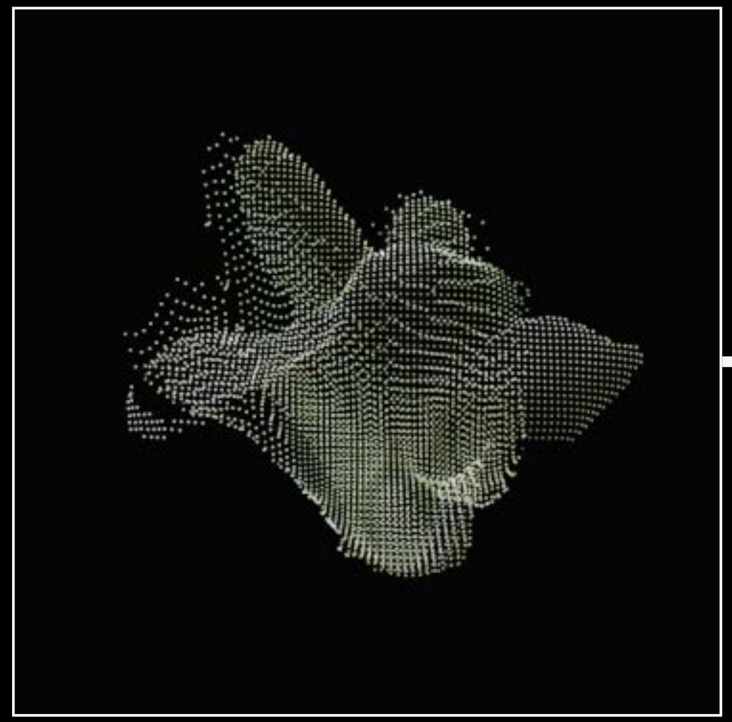
Use lower hyperparameters if you have limited GPU RAM and can accept slight compromises in segmentation accuracy and training speed.

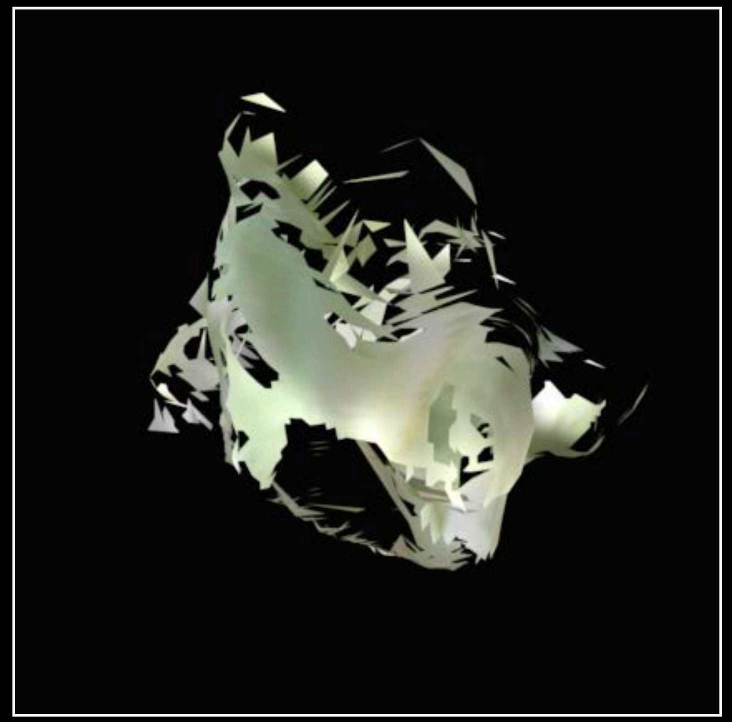
Use higher hyperparameters if you want to maximize segmentation accuracy and training speed, and GPU RAM usage is not a concern.

CONCLUSIONS

3D Reconstruction process from 2D Stereoscopic Plant Images

Combining existing computer vision technologies to reconstruct a 3D model from 2D stereoscopic plant images is theoretically possible. However, the visual inspection of the result does not meet expectations, as the plant's (or object's) structure or form is hardly distinguishable.





CONCLUSIONS

3D Reconstruction process from 2D Stereoscopic Plant Images

Firstly, the point cloud density is very low, resulting in a blurry mesh with points that are spaced too far apart, preventing a smooth, continuous surface from forming.

Secondly, the process of merging the point clouds through manual transformations, while functional, is inefficient. It is time-consuming, and achieving good merging results often requires countless trials and errors.

CONCLUSIONS

3D Reconstruction process from 2D Stereoscopic Plant Images

To improve point cloud quality, we recommend using high-resolution stereo cameras to produce higher-resolution point clouds, leading to more accurate disparity and depth mapping.

Another suggestion is to explore alternative techniques for capturing images with stereo cameras that may result in denser point clouds.

Lastly, we recommend implementing an automatic point cloud merging technique to replace the current manual process.

Investigating 3D Model Reconstruction from 2D Stereoscopic Plant Images with Investigation between YOLOv8 and Detectron2 AI Architectures for Plant Class Segmentation

John Ivan Diaz, Craig Joseph Goc-ong, Kaye Louise Manilong
Alvin Joseph Macapagal, Philip Virgil Astillo*