A Comparative Study of StarDist and Cellpose for 0–2 mm Oyster Seed Detection

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LSU Math

Motivation: Why 0–2 mm Is Challenging

Previous project phases achieved strong performance for larger oyster seeds, but the smallest size category remains more difficult.

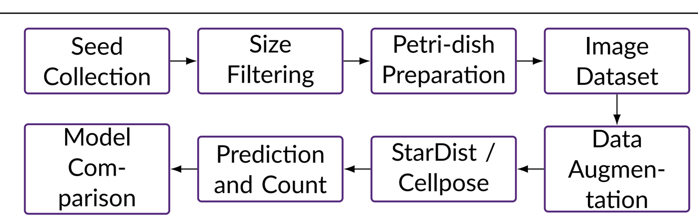
- Extremely small objects relative to image resolution
- Dense clusters and touching seeds
- Weak boundaries and low contrast
- Sensitivity to blur, lighting, and focus
- Higher risk of missed and merged detections

Representative 0–2 mm oyster seeds

Key Contributions

- Comparative evaluation of **StarDist** and **Cellpose/Cellpose-SAM** for 0–2 mm oyster seeds
- Evaluation of intermediate augmentation (90° Rotation)
- End-to-end workflow from seed collection to automated counting
- Error analysis for missed, merged, and false detections

End-to-End Pipeline



From oyster-seed collection to instance segmentation and counting

Dataset and Image Acquisition

Target size	0–2 mm	Total images	116
Training images	106	Test images	10
Epochs	500	IoU threshold	0.5
Resolution	4032 × 3024 pixels	Image format	JPG

StarDist vs. Cellpose

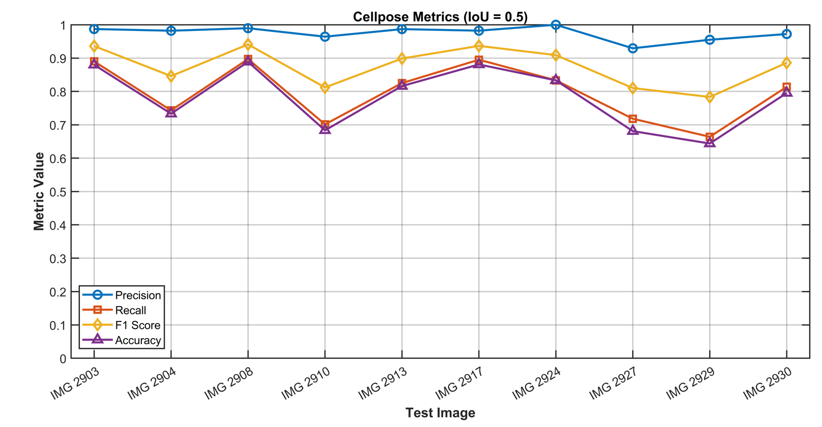
StarDist

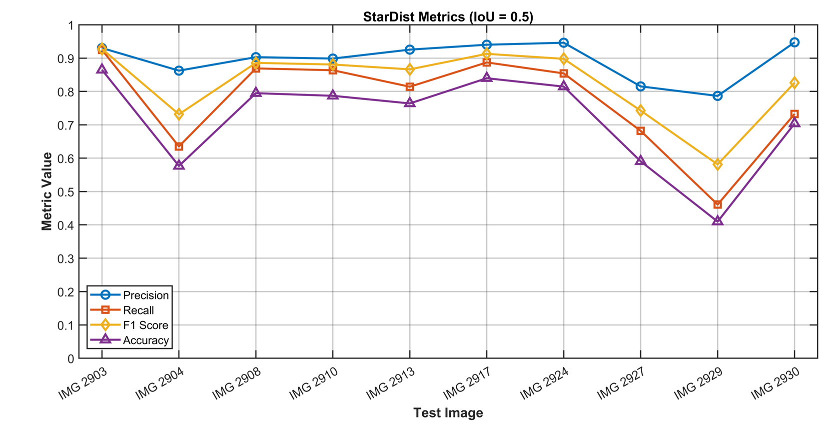
- U-Net-based model using star-convex polygon representation
- Best for compact, approximately convex oyster seeds
- Lightweight and efficient on CPU
- Custom model trained on our oyster dataset
- faster interface for simpler and more reglur-shaped object

Cellpose / Cellpose-SAM

- Vector flow-field based instance segmentation
- Better for irregular, overlapping, and touching oyster seeds
- Higher accuracy but GPU recommended for efficient inference
- Pretrained models available and can be fine-tuned

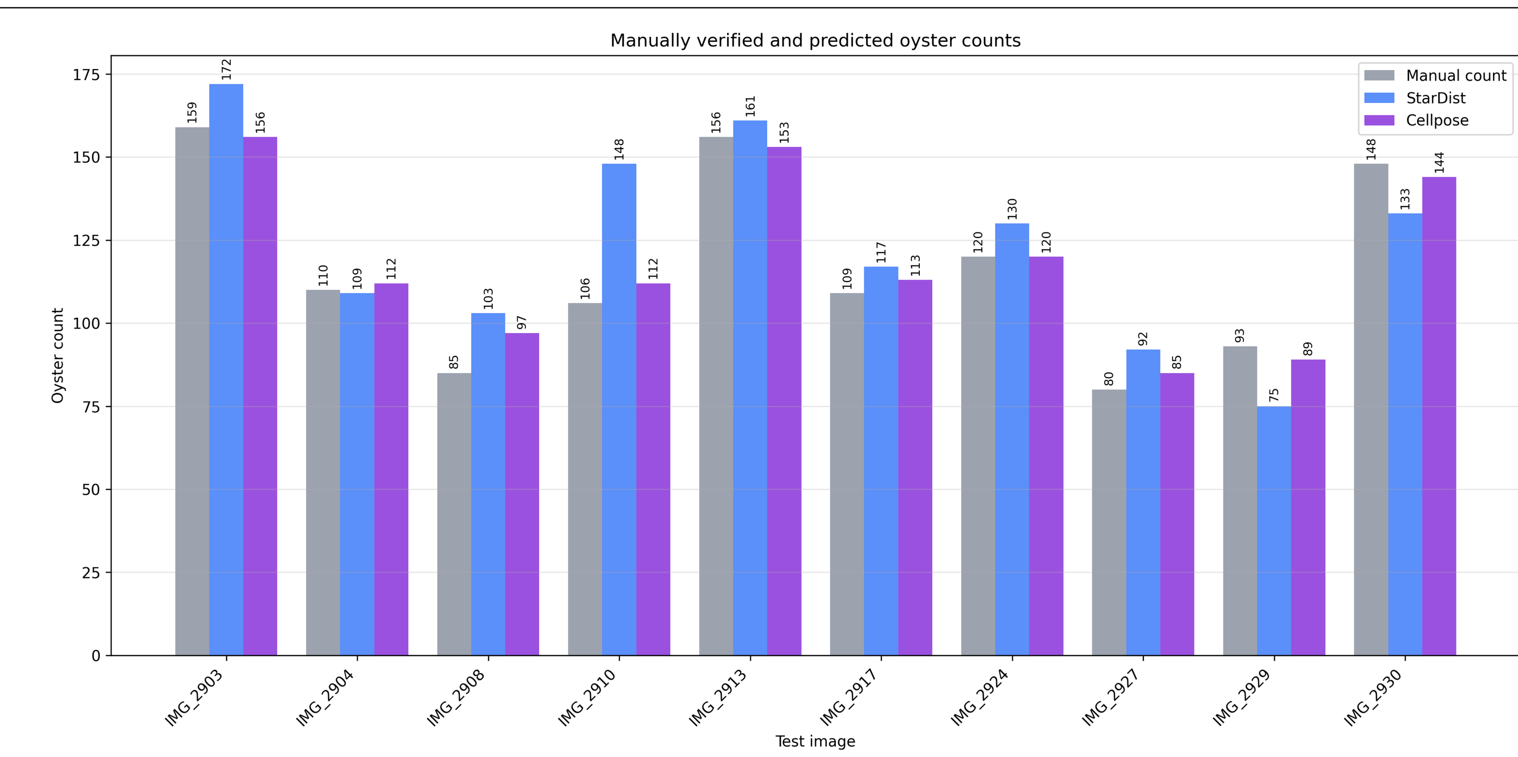
Evaluation Metrics on the Test Set





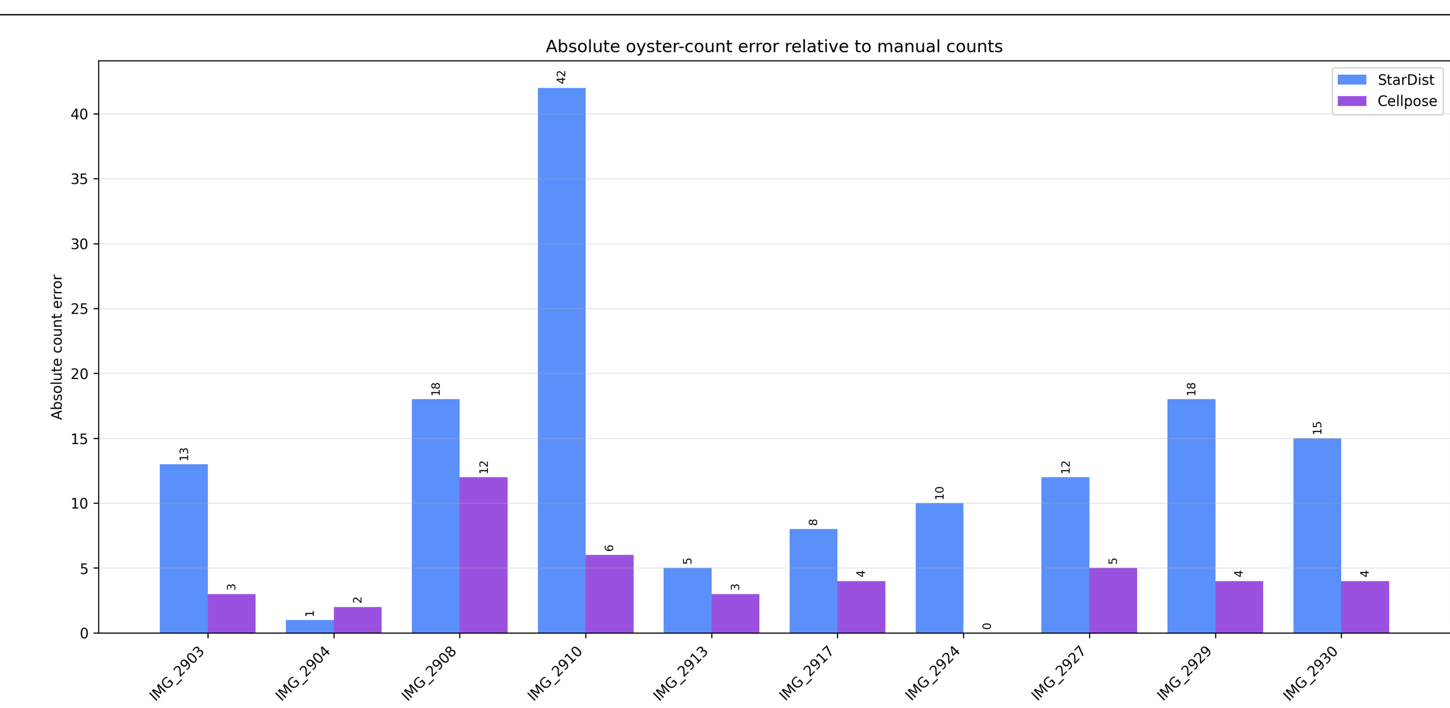
Both models achieved strong precision, recall, F1 score, and instance accuracy across the test set.

Predicted Counts Generally Follow the Manual Reference Counts



Both models produced reasonable count estimates, with Cellpose generally closer to the manual counts.

Cellpose Produces Lower Absolute Count Error on Most Test Images



Lower absolute error indicates more reliable counting performance, and Cellpose achieved lower absolute errors across most test images.

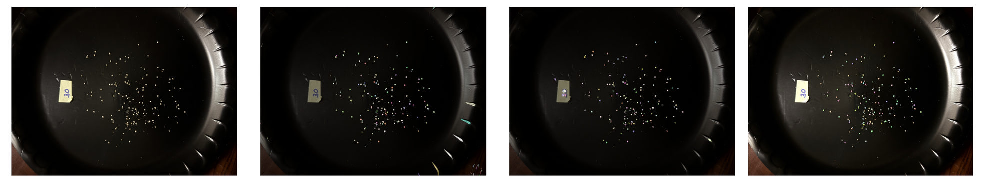
Quantitative Results

Model	Precision	Recall	F1	Instance Acc.	MAE
StarDist	0.895	0.772	0.825	0.715	14.2
Cellpose	**0.975**	**0.798**	**0.876**	**0.782**	**4.3**

Overall, Cellpose demonstrated superior detection and counting performance compared with StarDist

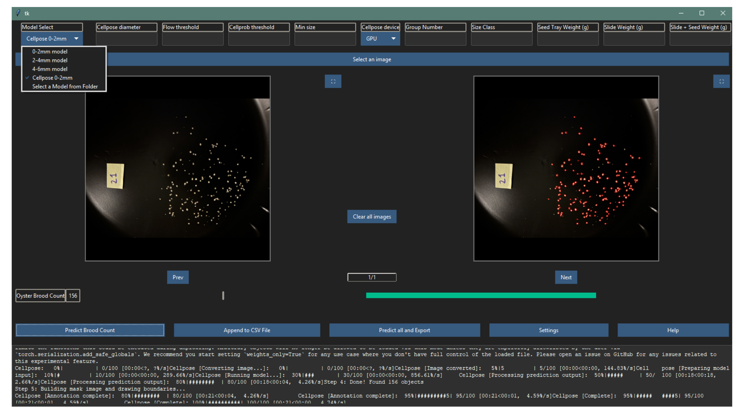
Qualitative Prediction Comparison

Input | Ground Truth | StarDist | Cellpose



Representative input, ground-truth, StarDist, and Cellpose outputs (IMG_2930), chosen as the frame whose F1-score for both methods is closest to their respective test-set means.

GUI Prediction Example



- Cellpose and StarDist 0–2 mm models added
- Models load automatically
- NVIDIA CUDA GPU support with CPU/GPU switching
- Live progress bar during prediction
- Results export directly to CSV

Future Work

- Increase the 0–2 mm dataset size and evaluate robustness under less-controlled imaging conditions
- Testing the GUI with the models in Grand Isle Lab
- Integrate the best-performing model with the Raspberry Pi setup

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References

1. Schmidt, U., Weigert, M., Broaddus, C., and Myers, G. (2018). Cell Detection with Star-Convex Polygons. MICCAI 2018.
2. Weigert, M., Schmidt, U., Haase, R., Sugawara, K., and Myers, G. (2020). Star-convex polyhedra for 3D object detection and segmentation in microscopy.
3. StarDist examples: `https://nbviewer.org/github/stardist/stardist/blob/master/examples/other2D/multiclass.ipynb`
4. LSU DeVision repository: `https://github.com/LSU-Devision/Summer-2024`