Multi-Class Quantification of Frog Embryos using Deep Learning

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Introduction

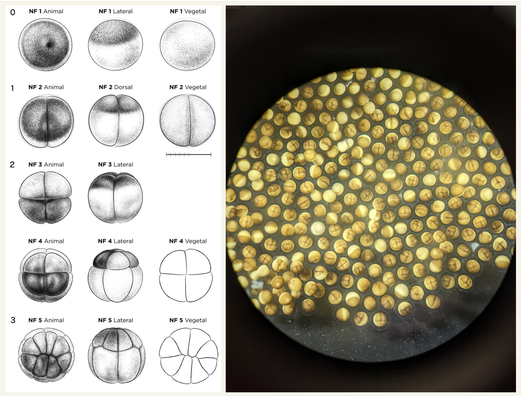

Figure 1. *Xenopus* embryos and their stages of development

- In previous semesters, participants in the capstone course developed a program for multi-class quantification using a machine learning algorithm based on the StarDist model.
- This semester, our project serves a similar purpose. This ongoing project is being conducted in collaboration with the Aquatic Germplasm Genetic Research Center (AGGRC) and the Marine Biological Laboratory (MBL).

Objectives

- Our goal is to develop a multiclass machine learning model using StarDist to accurately classify different stages of *Xenopus* frog embryos.
- Our classifications are based on Nieuwkoop and Faber (NF) stages 2, 3, 4 of *Xenopus laevis*.

VGG Image Annotator

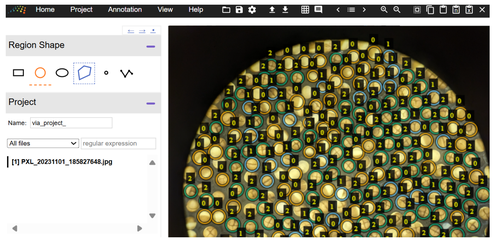

Figure 2. VGG Image Annotator (VIA) tool

- We utilized VGG Image Annotator (VIA) to identify and classify each embryo in the dataset.
- 0 - Unfertilized/abnormal, 1 - two cells, 2 - four cells, 3 - eight cells

Metrics of F1 score, Precision, Accuracy and Recall over Epochs

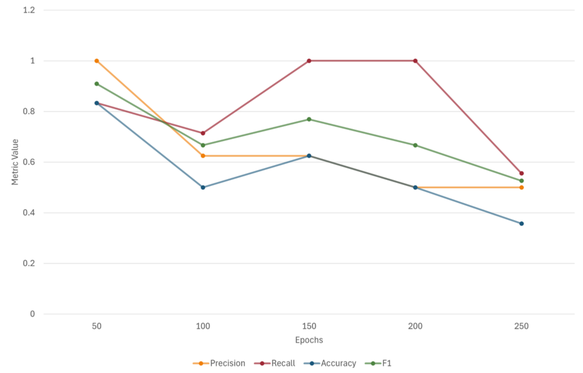

Figure 3. Illustration of the metrics - F1 score, Precision, Accuracy, and Recall on Epochs 50 to 250

- The graph depicts the variations in f1 score, accuracy, recall, and precision for varying epochs during the training of U-Net CNN architecture and StarDist.
- The dataset was split into 85 percent training and 15 percent testing and model was evaluated using an Intersection over Union (IoU) threshold equal to 0.4.
- Evaluating the model across different epochs showed an early improvement in metrics, followed by a gradual decline, highlighting the importance of recognizing training saturation to increase overall performance.

Distance and Probability Loss on 250 Epochs

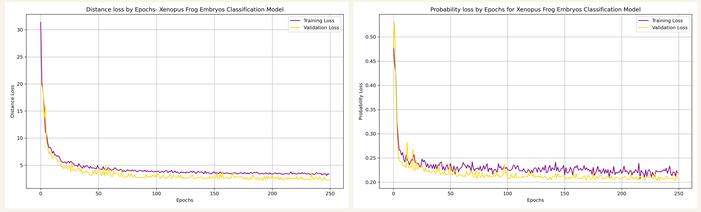

Figure 4. Distance and Probability Loss

- The first graph shows that the Distance Loss for both training and validation losses started around 30 and decreased to 5 by epochs 50, 100, 150, 200, 250.
- The second graph shows that the Probability Loss for training and validation started at .5 and dropped sharply to around 0.25 by epoch 10.
- The training and validation curves for both losses progressed closely across all epochs, representing the model's consistent learning without major overfitting.

GUI

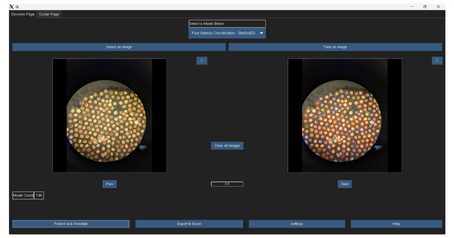

Figure 5. Graphical User Interface (GUI) Tool

- Our user-friendly graphical user interface (GUI) lets users upload images, receive annotated results and embryo counts, and export the data.

Multiclass Prediction

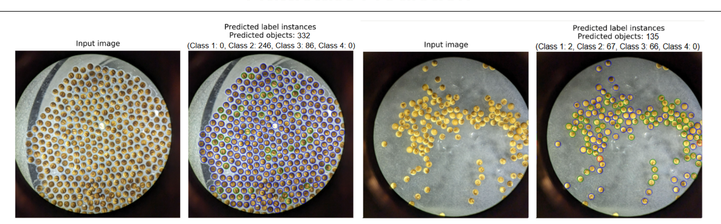

Figure 6. Predictions on Different Classes and Counts

Future work

- For future work, we would like to create a synthetic data set oversampling the less prevalent classes in order to address class imbalances.
- Additionally, we aim to apply geometric and color augmentations to create a larger, more diverse dataset, improving the model's performance.
- We also would like compose an article regarding StarDist and this specific model.

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References

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