DETECTING MICROGLIA WITH AI

INTRODUCTION TO ARTIFICIAL INTELLIGENCE FOR NEUROSCIENCE

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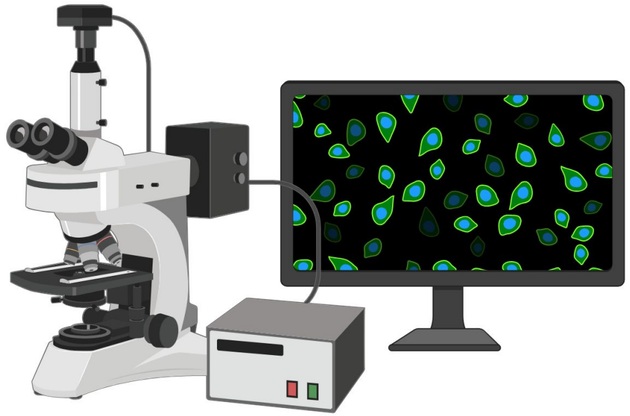
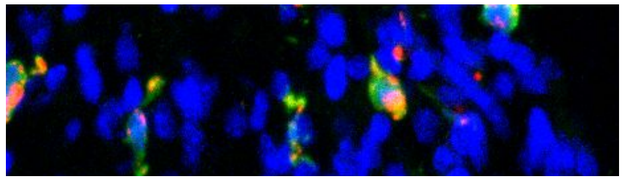
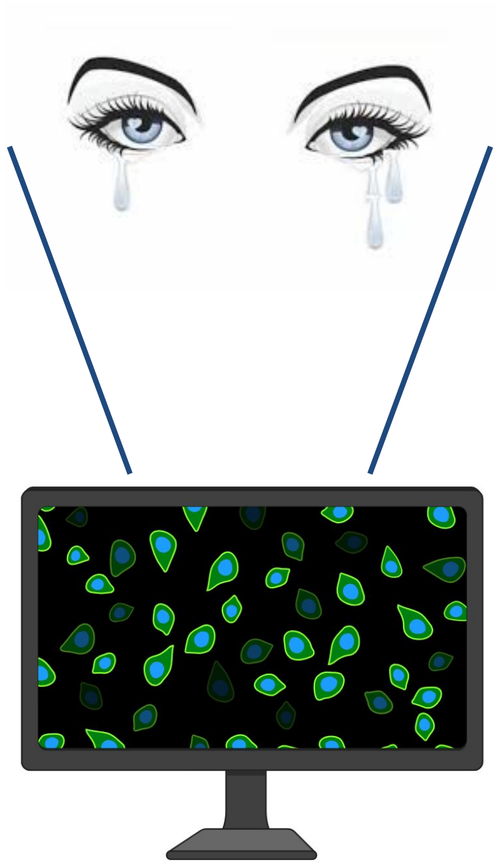
Concept





Understand the location of specific cells in the brain, and infer the significance of their existence in specific brain regions.



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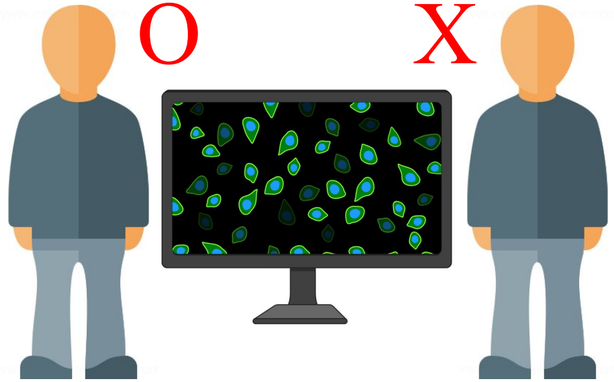
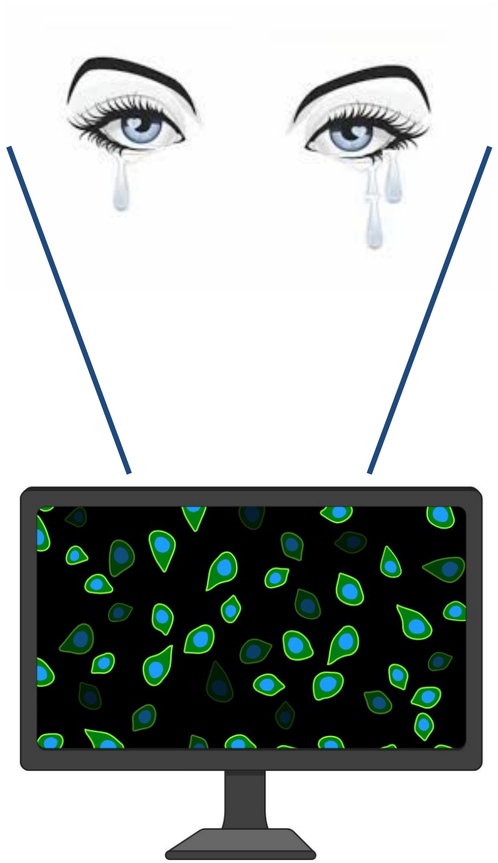
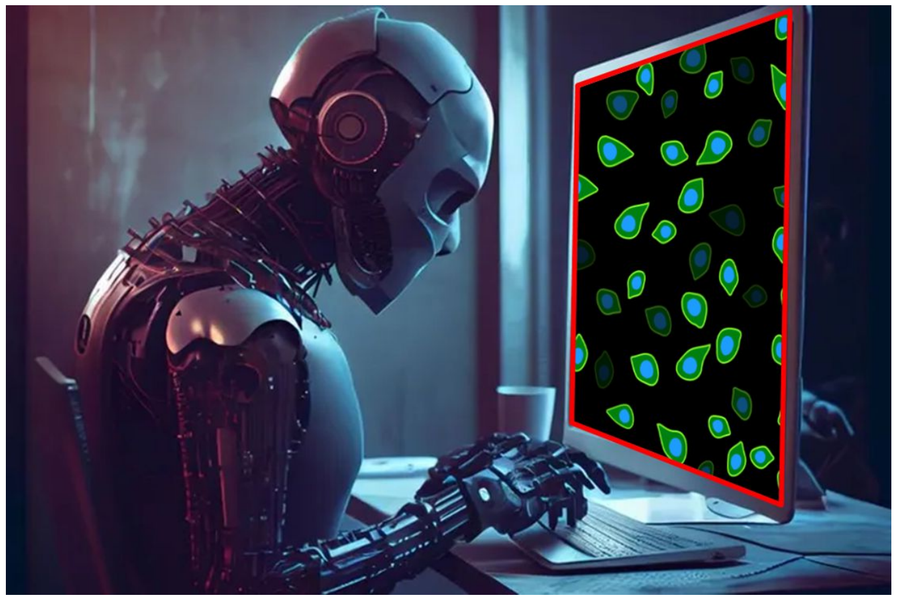
Cost a lot of time



Personal Equation

Aim



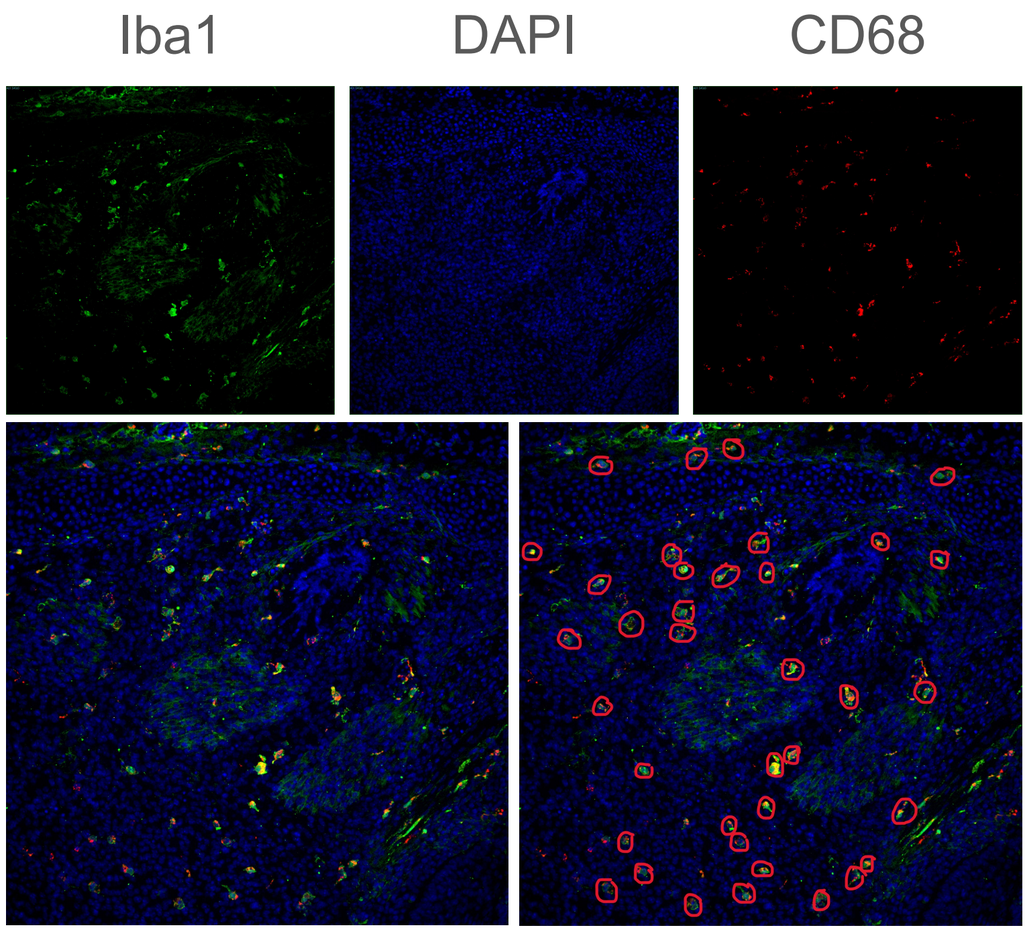


Train the model to assist us in interpreting the IF results

Our data set

When we identify the cell in IF staining, we will follow some rules. (this figure is staining for microglia)

1. Morphology (to distinguish amorphous cell debris)
   Cell like (round shape or size is correct)
2. DAPI nuclear marker (to find which one is cell)
   Blue color and round shape
3. Target cell marker (to find the target cell)
   Green color (Anti-Iba1) for microglia specific marker
4. Specific marker (our interesting marker)
   Red color (Anti-CD68)



Models

Support Vector Machine (SVM)

YOLOv5

Support Vector Machine (SVM)

Machine Learning Approach

What is SVM?

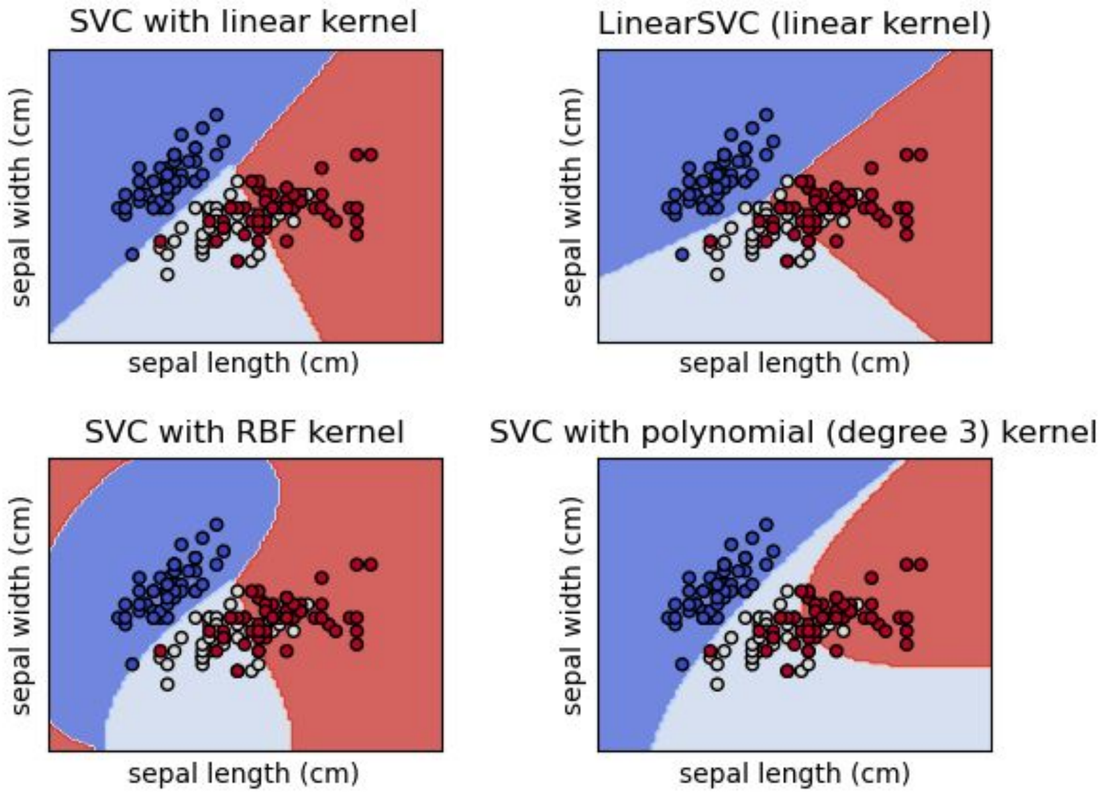
- Supervised machine learning algorithm used primarily for classification tasks
- Basically uses a function to separate the data and classify them
- Function can be linear or nonlinear

Why SVM?

- More efficient with smaller datasets
- Requires less computational resources

Training and Prediction

- Trained and predicted on the same dataset as the YOLOv5 model for fair comparison



SVM Model Training

01 Data Augmentation

02

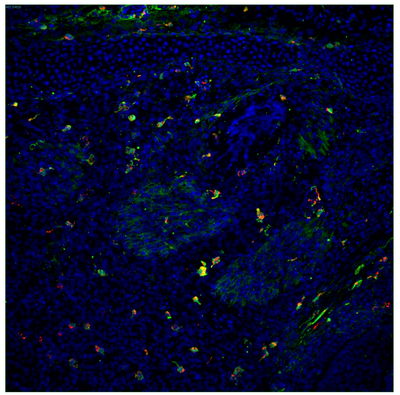
03

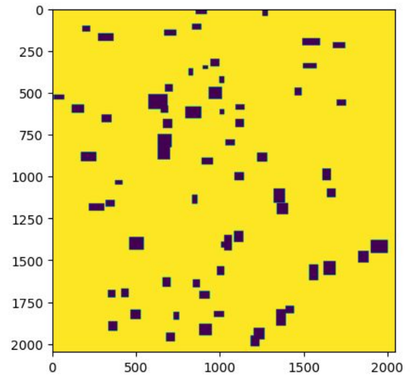
Dataset Size: 15 images (2048x2048)

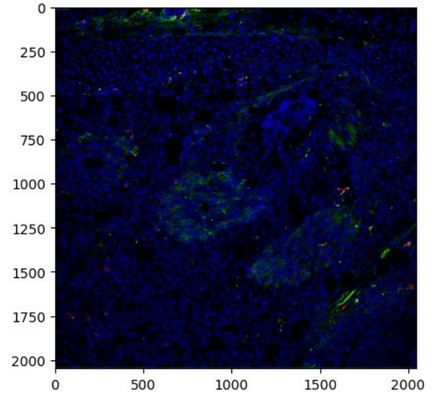
- Training: 13 images
- Prediction: 2 images

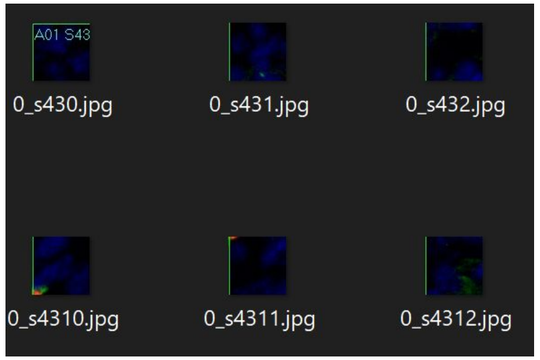
Data Augmentation:

1. Label microglia using MakeSense.ai tool
2. Use labels to get images of microglia in the size of 64x64 (Microglia dataset)
3. Create a mask and remove the microglia from the original images
4. Remove the microglia from the original dataset and segment the remaining images into 64x64 (Noise dataset)









SVM Model Training

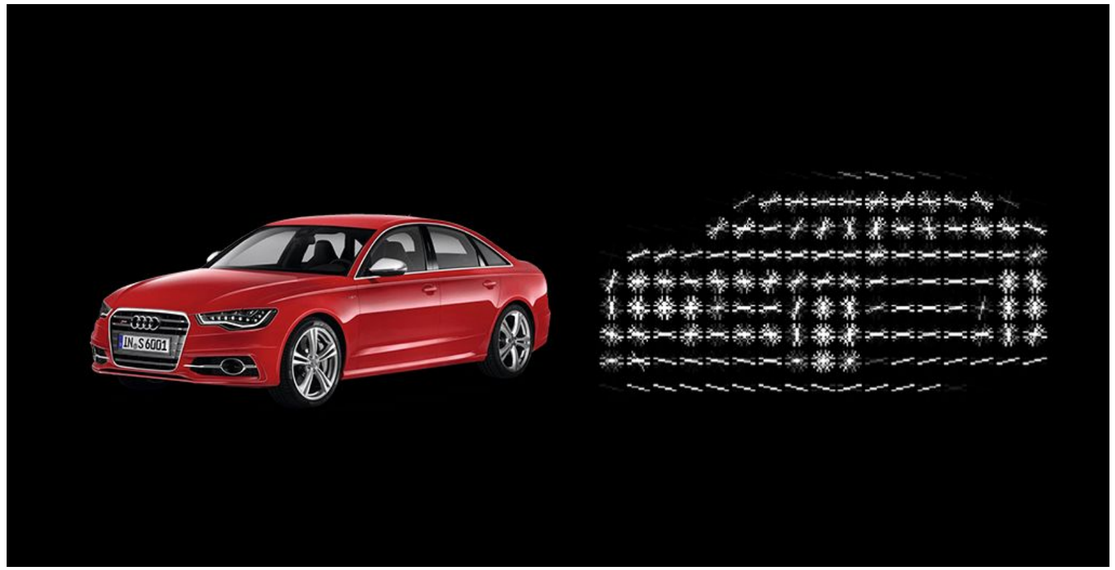
02 Training Process | 03 | 04

Features:

- HOG
- Colour Bins
- Colour Histogram

Libraries used:

1. OpenCV (for feature extraction, reading images, image pre-processing)
2. Scikit-learn (SVM)
3. Scikit-image (HOG)
4. Matplotlib (For showing images)
5. Numpy



SVM Model Training

03 Prediction Process

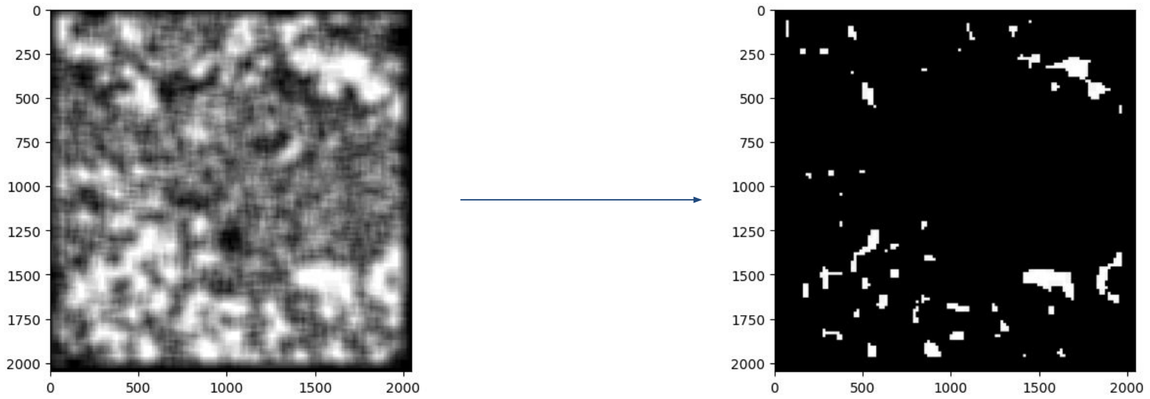
03 04

Prediction process:

1. Sliding windows (box size 8x8)
2. +1 in heatmap if recognized as microglia
3. Apply threshold in heatmap (if below threshold, change value to 0)
4. Draw boxes around predictions

Dynamic threshold:

- Captures top 5% values on the heatmap
- Converts values below threshold to be 0



SVM Model Training

Results:

- High rate of precision
- Low recall rate
- Poor accuracy, many microglia not detected

Evaluation:

To improve the accuracy of the model, we decided to create an ensemble model trained on images of different window sizes

Based on an analysis of the training data, around 95% of the labelled microglia were smaller than 100x100 pixels. Thus, we chose window sizes of 64, 80 and 100.

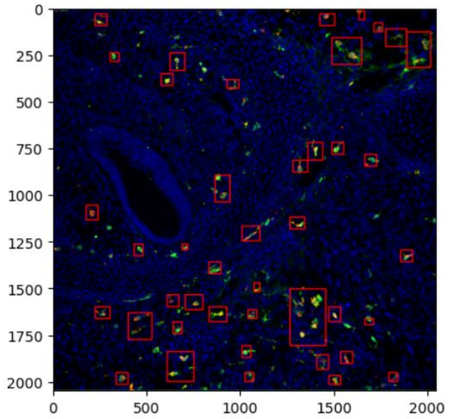


Figure 1: SVM prediction on test image 13

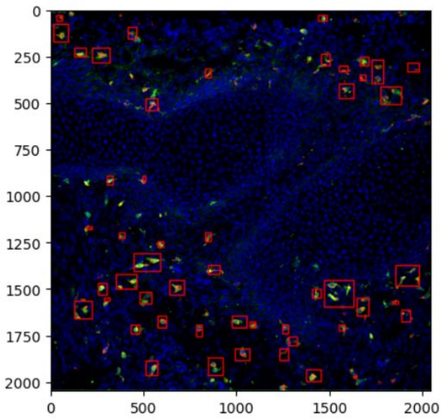


Figure 2: SVM prediction on test image 14

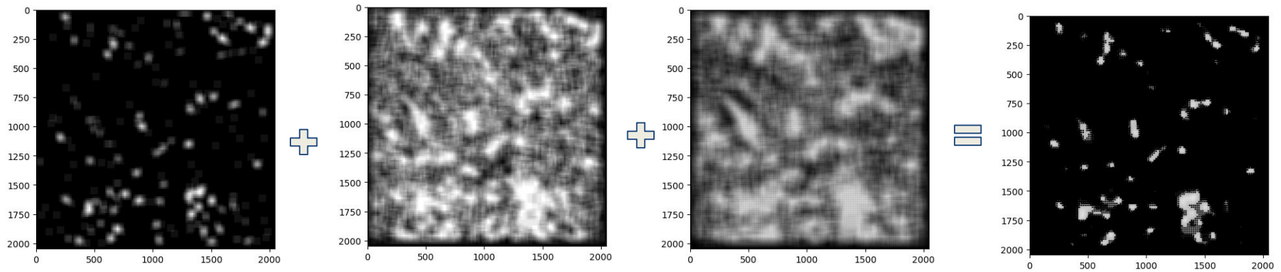
Metrics	Score
Precision	1.000
Recall	0.506
F1-Score	0.673

Table 1: Results of SVM model on test images 13 and 14

SVM Model Training

Improvements:

- Trained on different window sizes
- Used equal weights for all 3 heatmaps
- Ensemble heatmap created by averaging all 3 heatmaps and then getting the top 5% of highlighted intensity



64x64 80x80 100x100 Ensemble (After threshold)

Challenges:

- Window sizes of 80x80 and 100x100 resulted in a significant decrease of noise images for training
- Mitigated the issue by rotating the noise images (90, 180 and 270) degrees while keeping the microglia dataset the same size

Window Size	Precision	Recall	F1-Score
64	1.0	0.506	0.673
80	0.927	0.567	0.704
100	0.868	0.678	0.761
Ensemble	0.950	0.620	0.751

Table 2: Results of SVM model with different window sizes and the ensemble model

SVM Model Training

06 Other Attempts

07

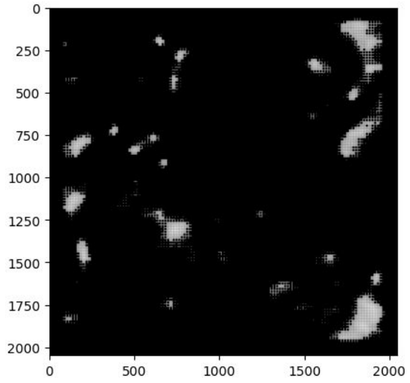
08

Hard Negative Mining:

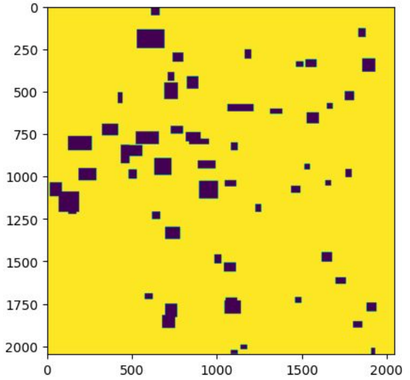
- Train with easy negatives first (E.g. noise images for a set of 10 images)
- Predict on next image in training set (E.g. 11)
- Combine heatmap of prediction and the inverse mask of labelled microglia to get areas that are false positives
- Crop out areas that are false positives and add them to the noise training set
- Continue until the end of training images

Challenges:

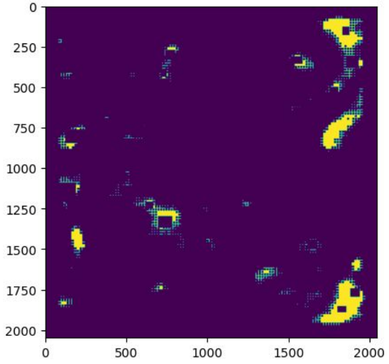
- Overall inaccurate, accuracy increases as set of easy negatives increases
- Computationally heavy



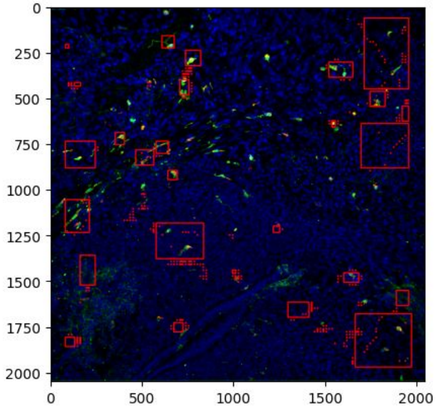
Heatmap



Inverse Mask



False Positives



Final Prediction Results

Resnet with SVM

To detect microglial cells in embryonic mouse brain images, we used a two-step approach

01

ResNet 50

Used a pre-trained ResNet-50 model for feature extraction

02

SVM

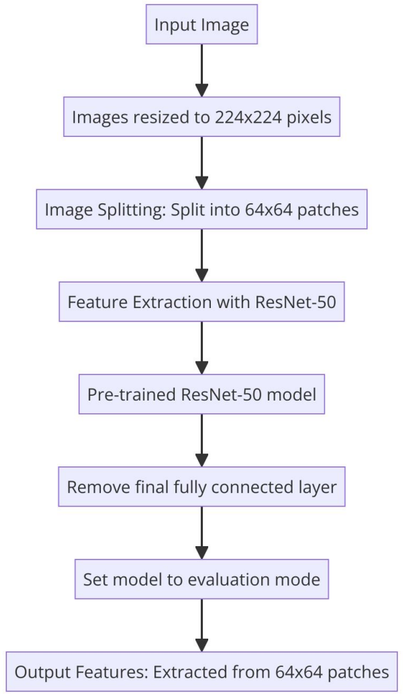
Features were classified using a Support Vector Machine (SVM)

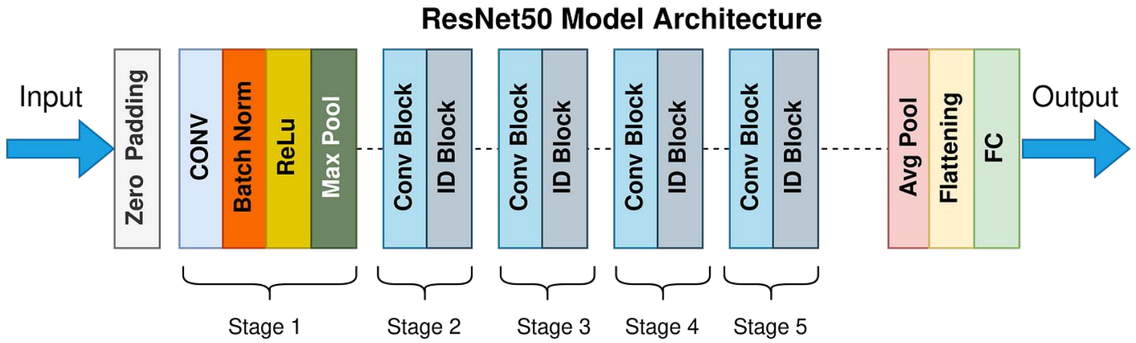
Feature Extraction with ResNet

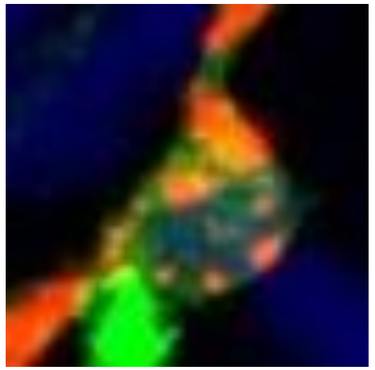
Overview of the Model

What is ResNet-50?

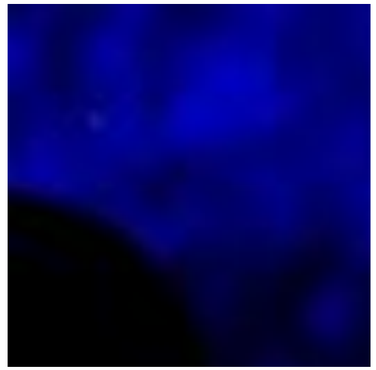
- ResNet-50 is a convolutional neural network pre-trained on the ImageNet dataset







Microglia
(64 by 64)



Noise
(64 by 64)

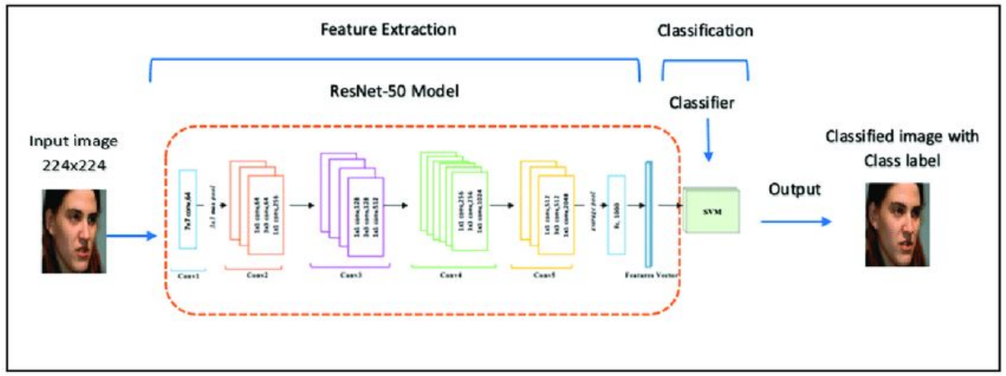
SVM Classifier

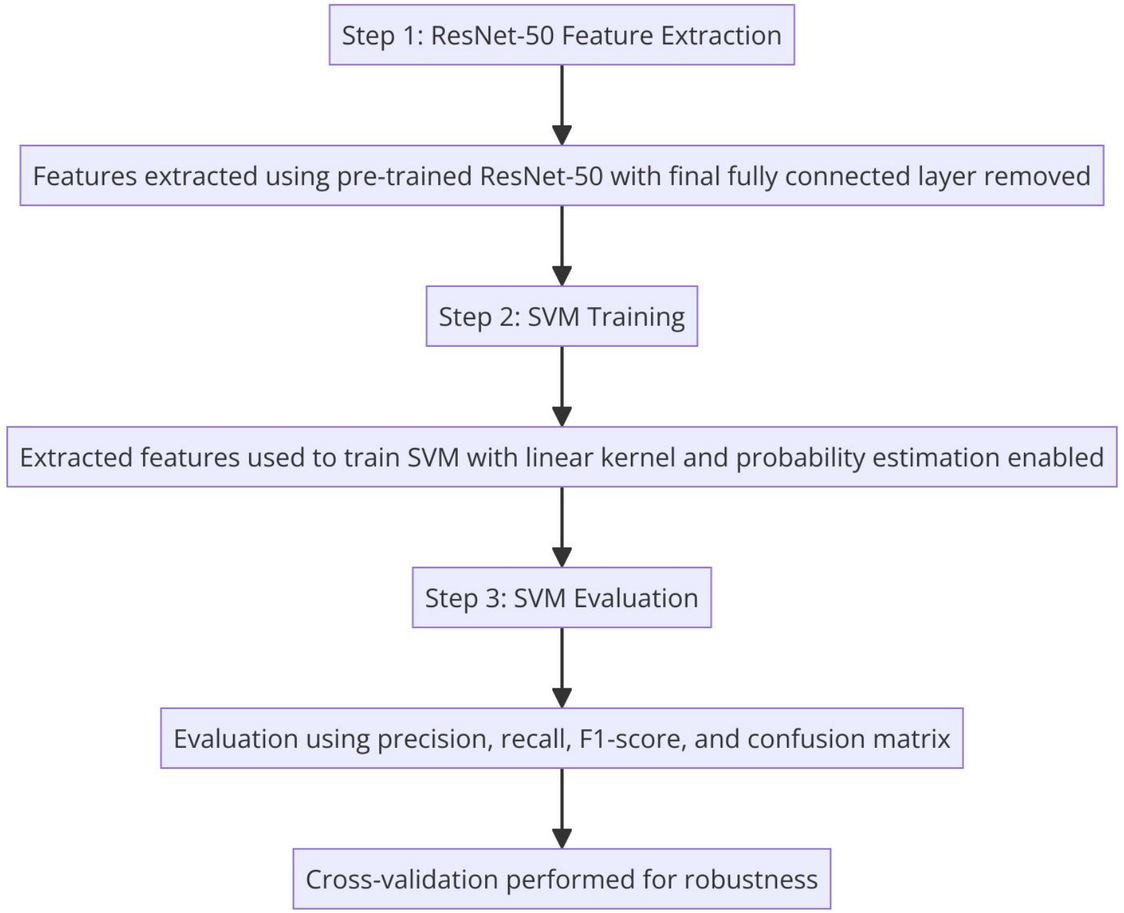
What is SVM?

- Supervised machine learning algorithm used primarily for classification tasks

What SVM?

- SVM was configured with a linear kernel, which is effective for high-dimensional data like our extracted features





Results and Evaluation

Patch Based Evaluation

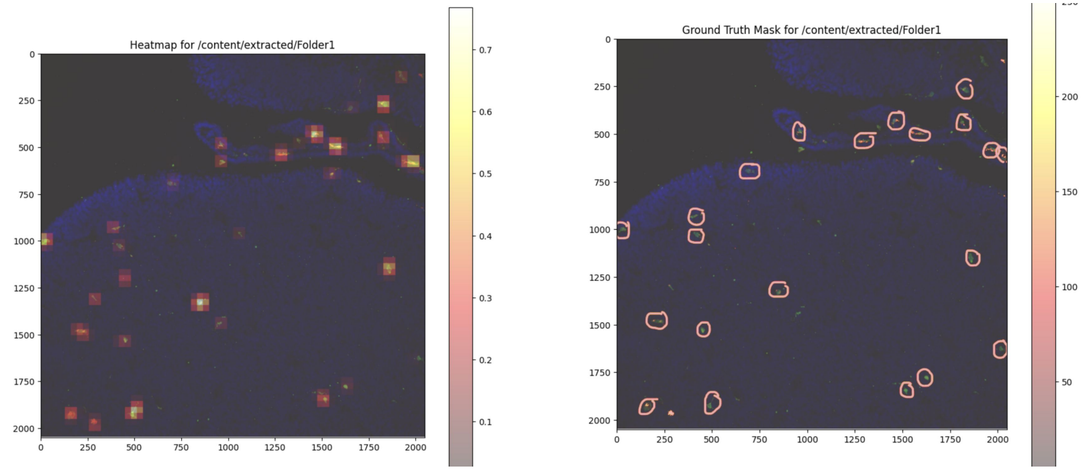
High accuracy in distinguishing microglia from noise.

- Precision: 1.00 (Noise), 0.95 (Microglia)
- Recall: 1.00 (Noise), 0.93 (Microglia)
- Overall Accuracy: 99%

Confusion Matrix:

- True Positives (Microglia correctly identified): 54
- True Negatives (Noise correctly identified): 1337
- False Positives (Noise incorrectly identified as Microglia): 3
- False Negatives (Microglia incorrectly identified as Noise): 4

Cross-Validation Scores: Average Accuracy: 98%



Full Image Evaluation

Performance significantly dropped when applied to full images.

Issues with thresholding and aligning ground truth masks.

Evaluation Metrics at Different Thresholds:

- Threshold 0.3: Precision: 0.21, Recall: 0.11, F1-Score: 0.15
- Threshold 0.4: Precision: 0.19, Recall: 0.06, F1-Score: 0.09
- Threshold 0.5: Precision: 0.14, Recall: 0.02, F1-Score: 0.03
- Threshold 0.6: Precision: 0.04, Recall: 0.003, F1-Score: 0.005
- Threshold 0.7: Precision: 0.01, Recall: 0.0002, F1-Score: 0.0003

YOLOv5 (You Only Look Once)

Deep Learning Approach

- Popular object detection model, known for its speed and accuracy.
- YOLOv5's structure consists of three main components: the Backbone, Neck, and Head.
  - Backbone: extracts essential features from the input image.
  - Neck: creates feature pyramids to help detect objects at different scales.
  - Head: an anchor-based detection mechanism that predicts bounding boxes, object classes, and confidence scores for each grid cell in the feature map, enabling efficient and accurate object detection.

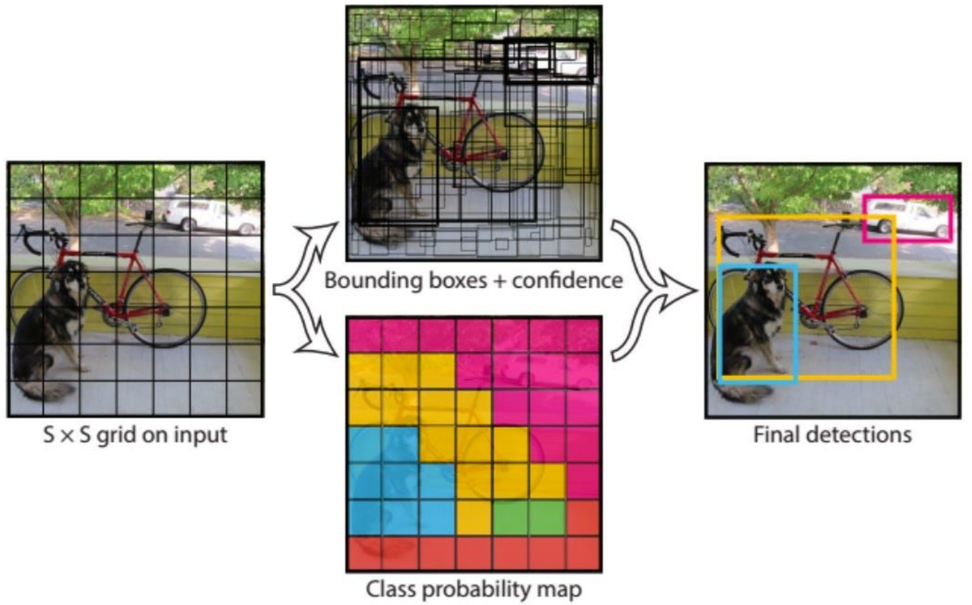


Figure 2: The Model. Our system models detection as a regression problem. It divides the image into an $S \times S$ grid and for each grid cell predicts B bounding boxes, confidence for those boxes, and C class probabilities. These predictions are encoded as an $S \times S \times (B * 5 + C)$ tensor.

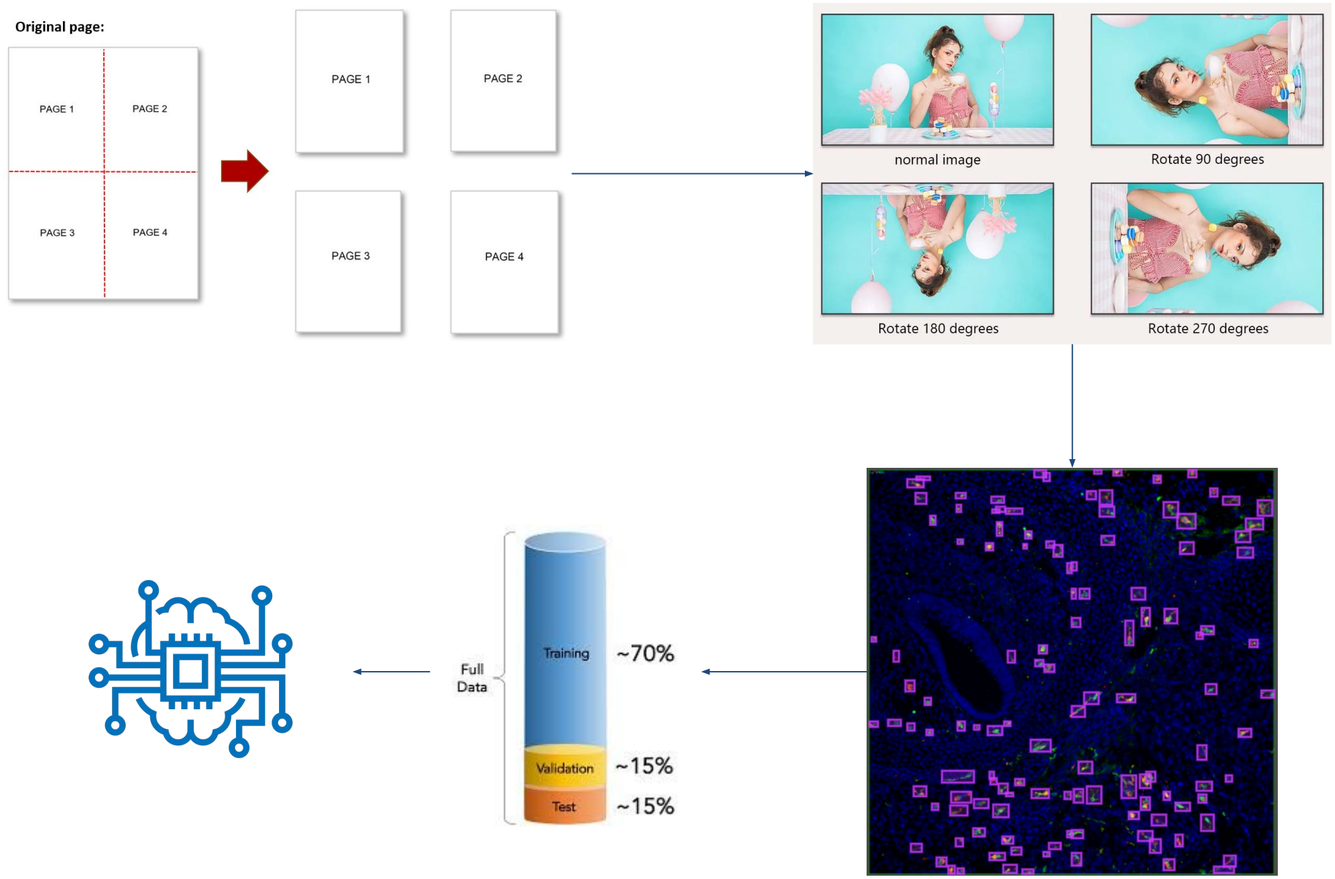
YOLOv5 Model Training

01 Data Augmentation + Training Process

02

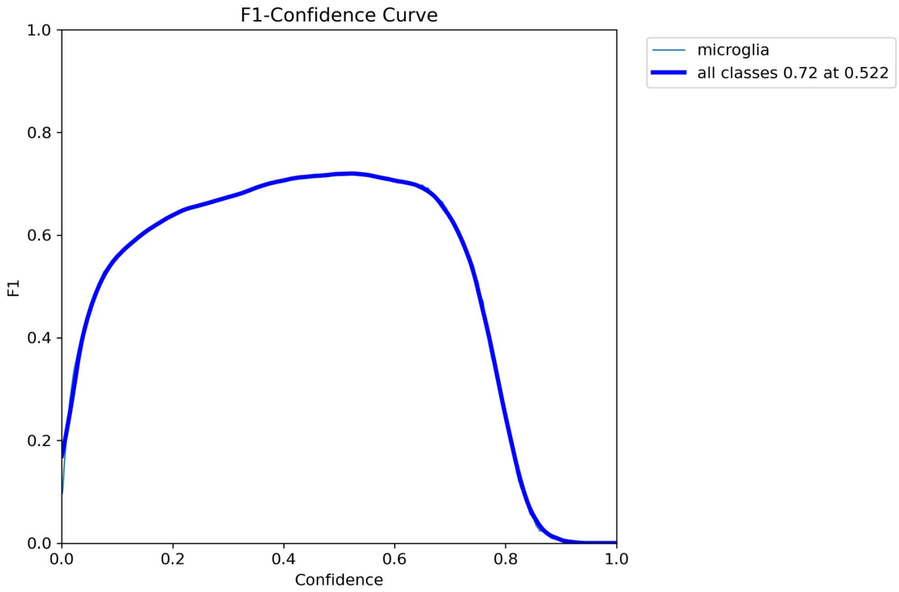
03

1. Segment original microglia images into 4 quadrants
2. Create multiple quadrants by rotating the original quadrant by 90, 180, 270 degrees.
3. Label each microglia in each quadrant using Make Sense AI (online tool for creating anotations for object detection)
4. Separate the dataset into train, validation and test sets.
5. Train the YOLOv5 model using the annotations created
6. Epochs = 50 (reduced from 300 to avoid overfitting)



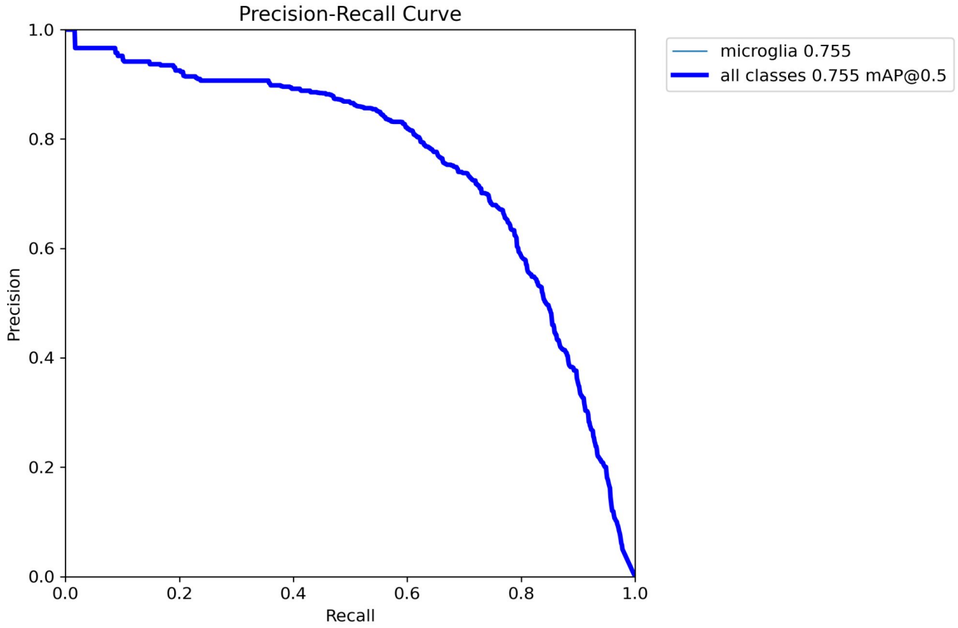
YOLOv5 Model Training

01 | 02 Model Training Performance | 03



The F1 Confidence Curve plots the F1 score against different confidence thresholds.

At the optimal confidence threshold of 0.522, the f1 score is 0.72.



The area under the curve (AUC) is a measure of how well the model is able to distinguish between classes.

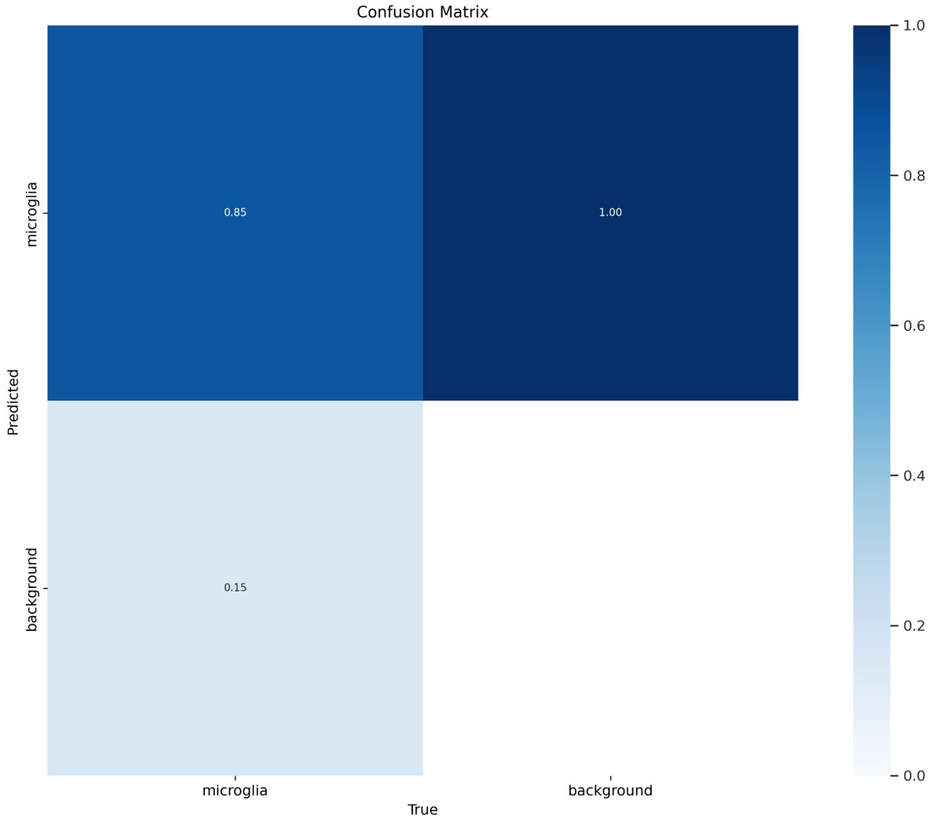
The closer the curve follows the top-right corner, the more accurate the model is.

YOLOv5 Model Training

01

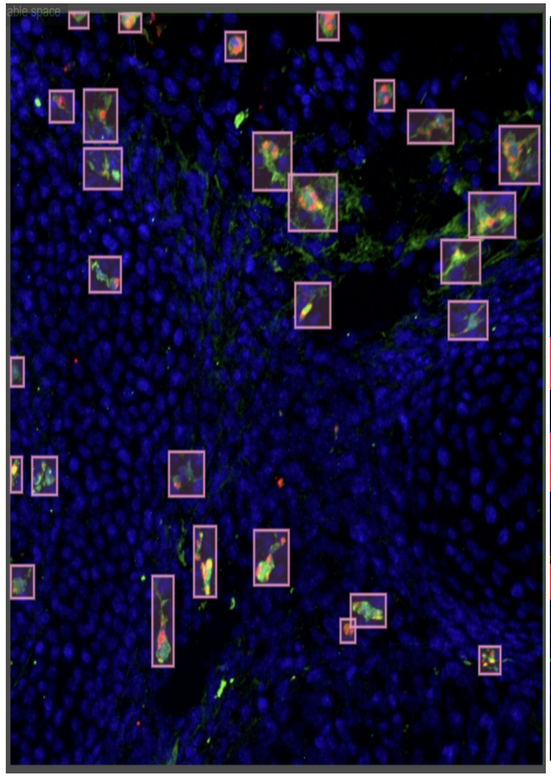
02 Model Training Performance

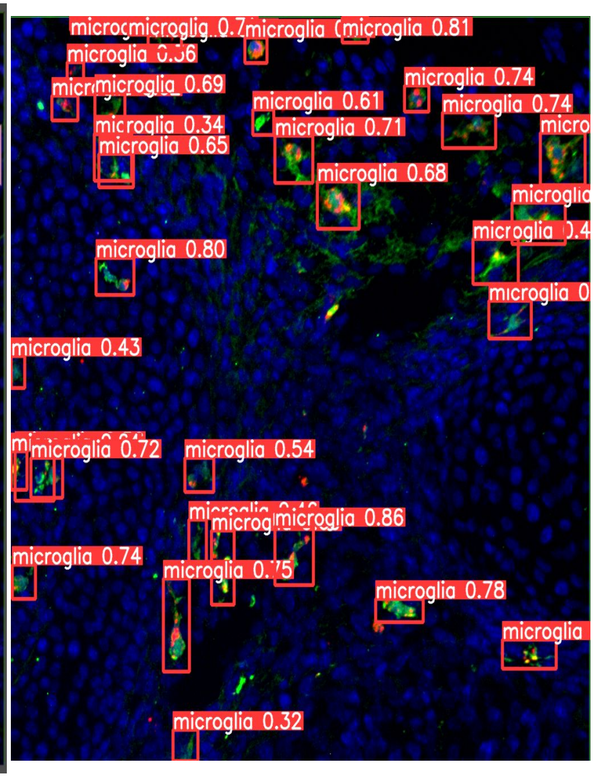
03

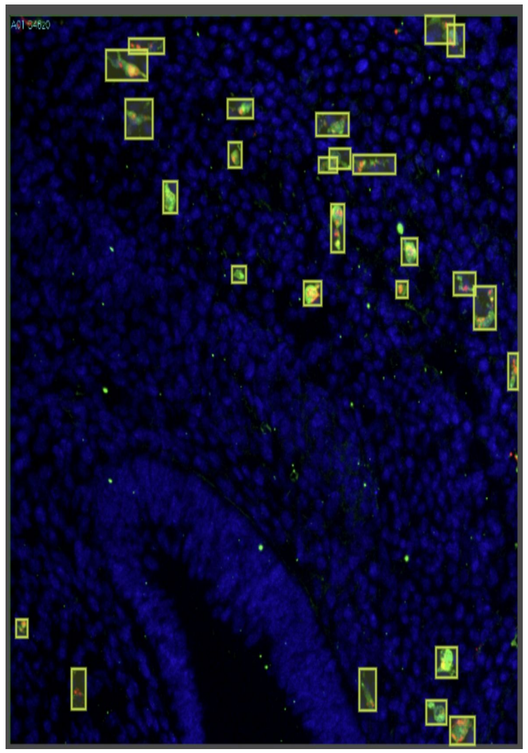


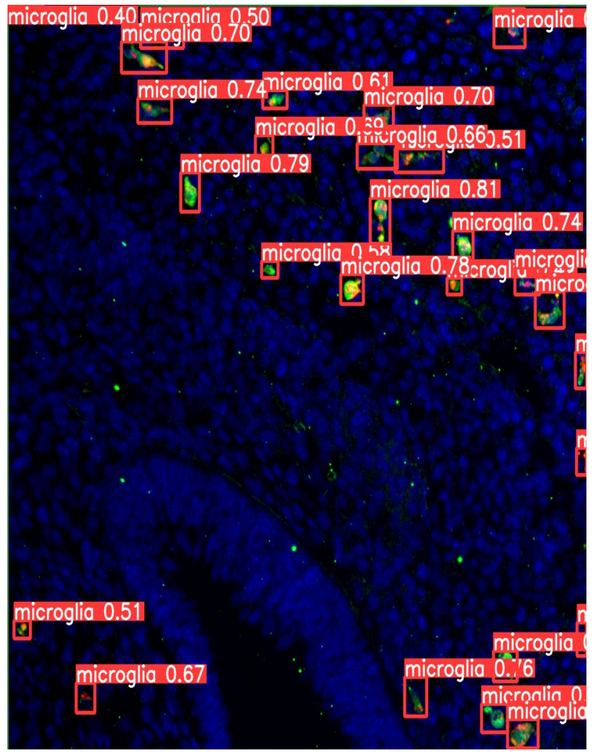
YOLOv5 Model Training

01 02 03 Model Performance on Test Images



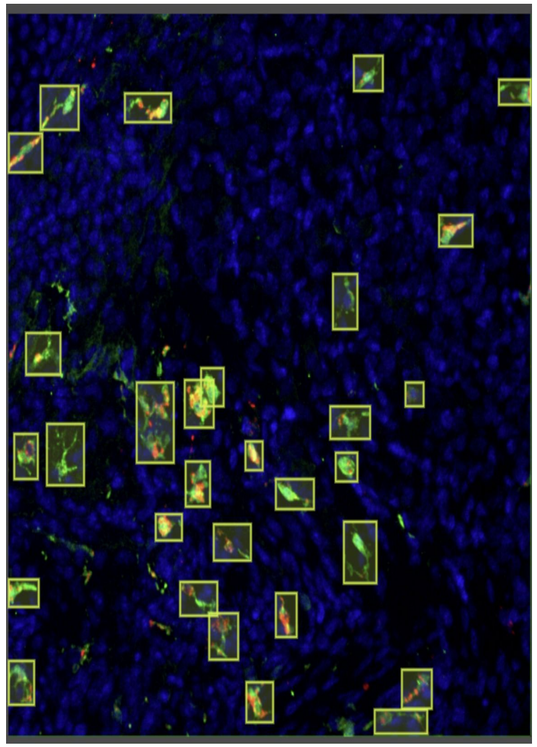


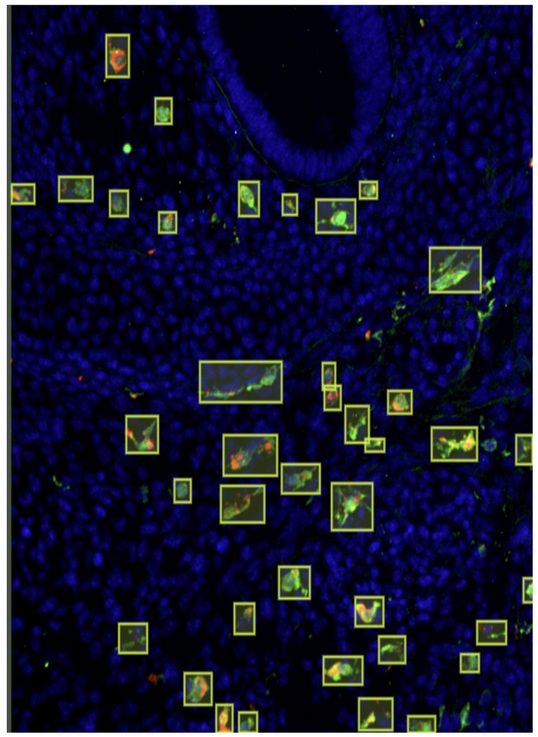


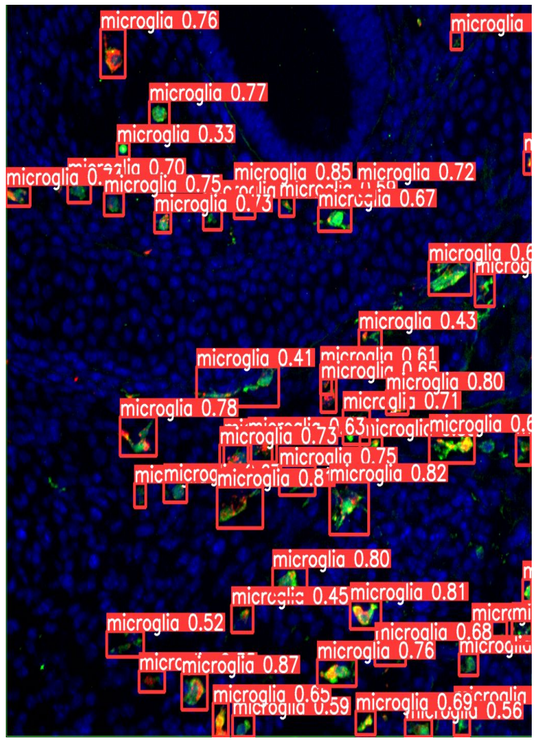


YOLOv5 Model Training

01 02 03 Model Performance on Test Images







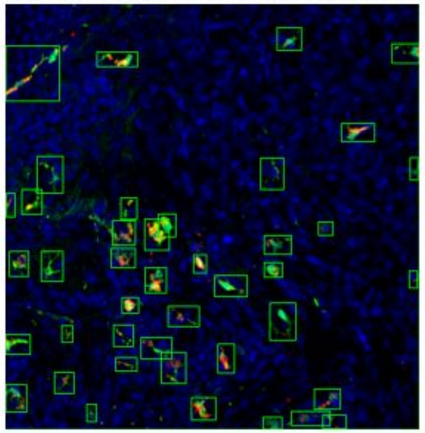
Model Performance Comparison

Metrics	SVM	YOLOv5
Precision	0.950	0.857
Recall	0.620	0.829
F1-Score	0.751	0.842

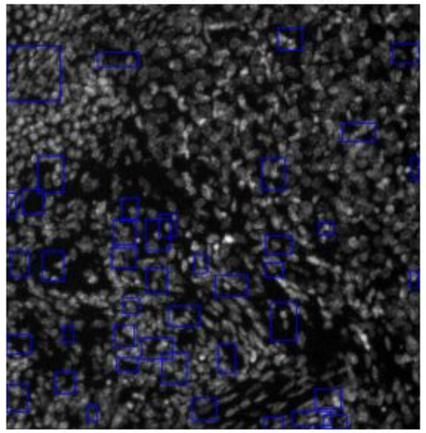
Denoising

Removing Noise from Microglia Images

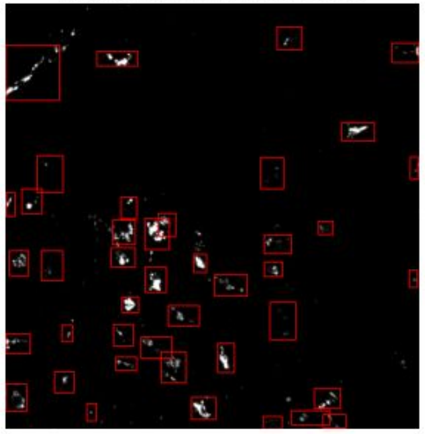
Original Image with Predicted Boxes



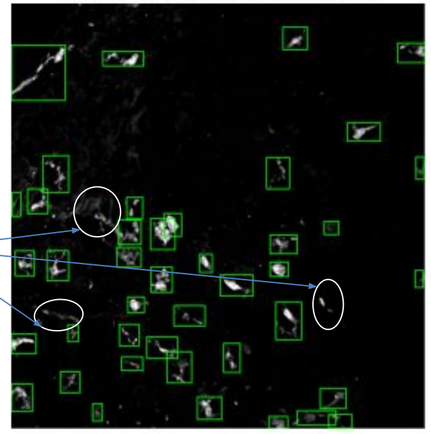
Blue Channel with Boxes



Red Channel with Boxes



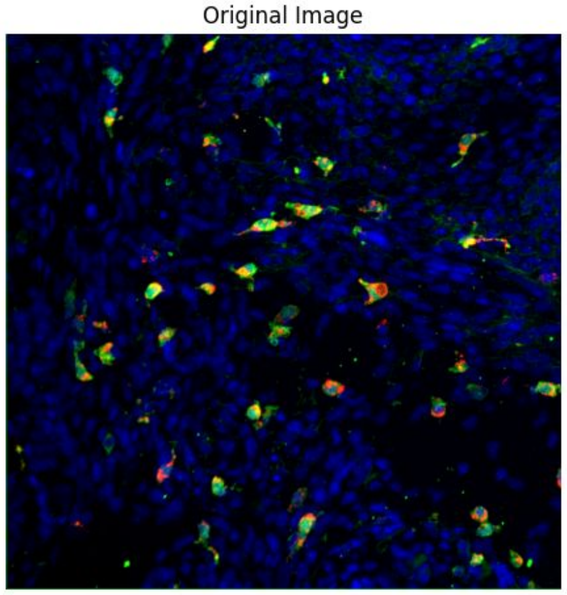
Green Channel with Boxes

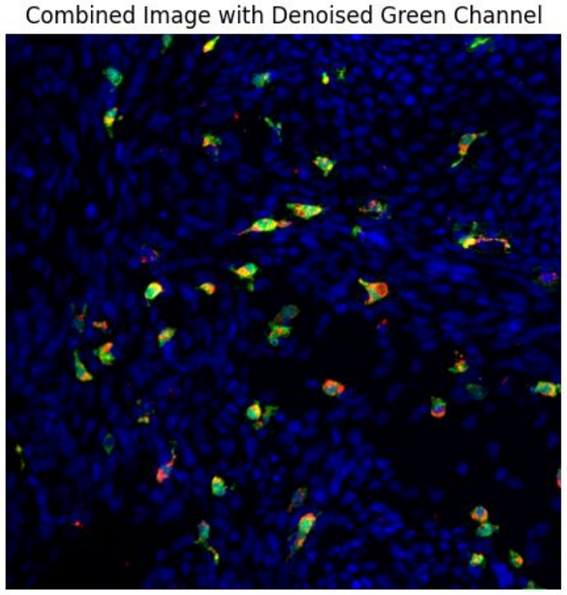


Out of the 3 layers (red, green, blue), the noises in the green layers are the clearest and easiest to recognise visually.

Denoising

Removing Noise from Microglia Images





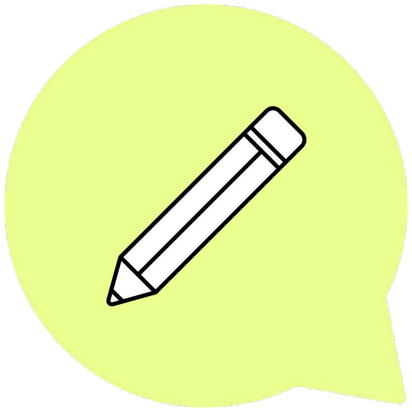
1. Use the model to identify microglia cells on test images
2. Split those images into the 3 RGB layers
3. Remove the noise from the green layer ('black out' everything other than the microglia cells the model identified
4. Recombine the 3 layers

Final product: Denoised image with microglia cells identified by the models

THANK YOU

THANK YOU...

JOB ROLES & REQUIREMENTS



During this recruitment stage, we outline job roles and qualifications required for each position in our organization.

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OUR HIRING PHILOSOPHY

01 02 03

DIVERSITY

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INCLUSION

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CAREER DEVELOPMENT

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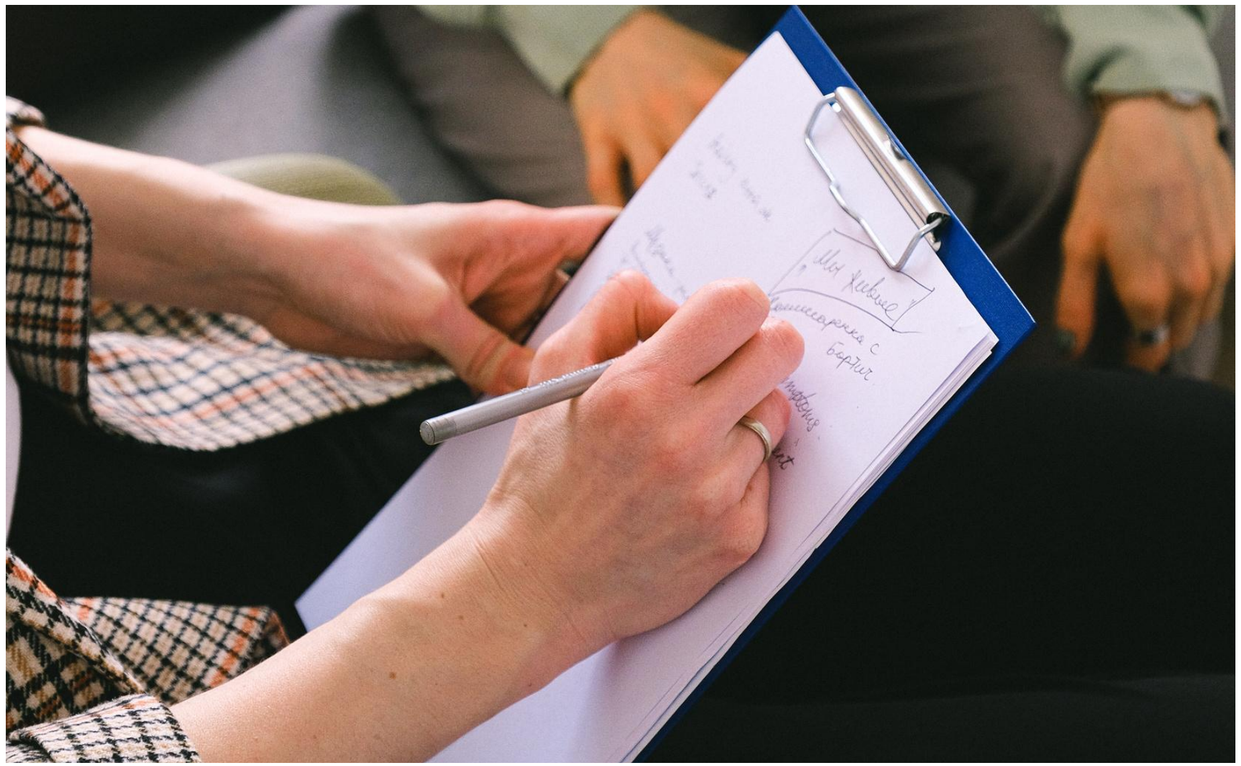
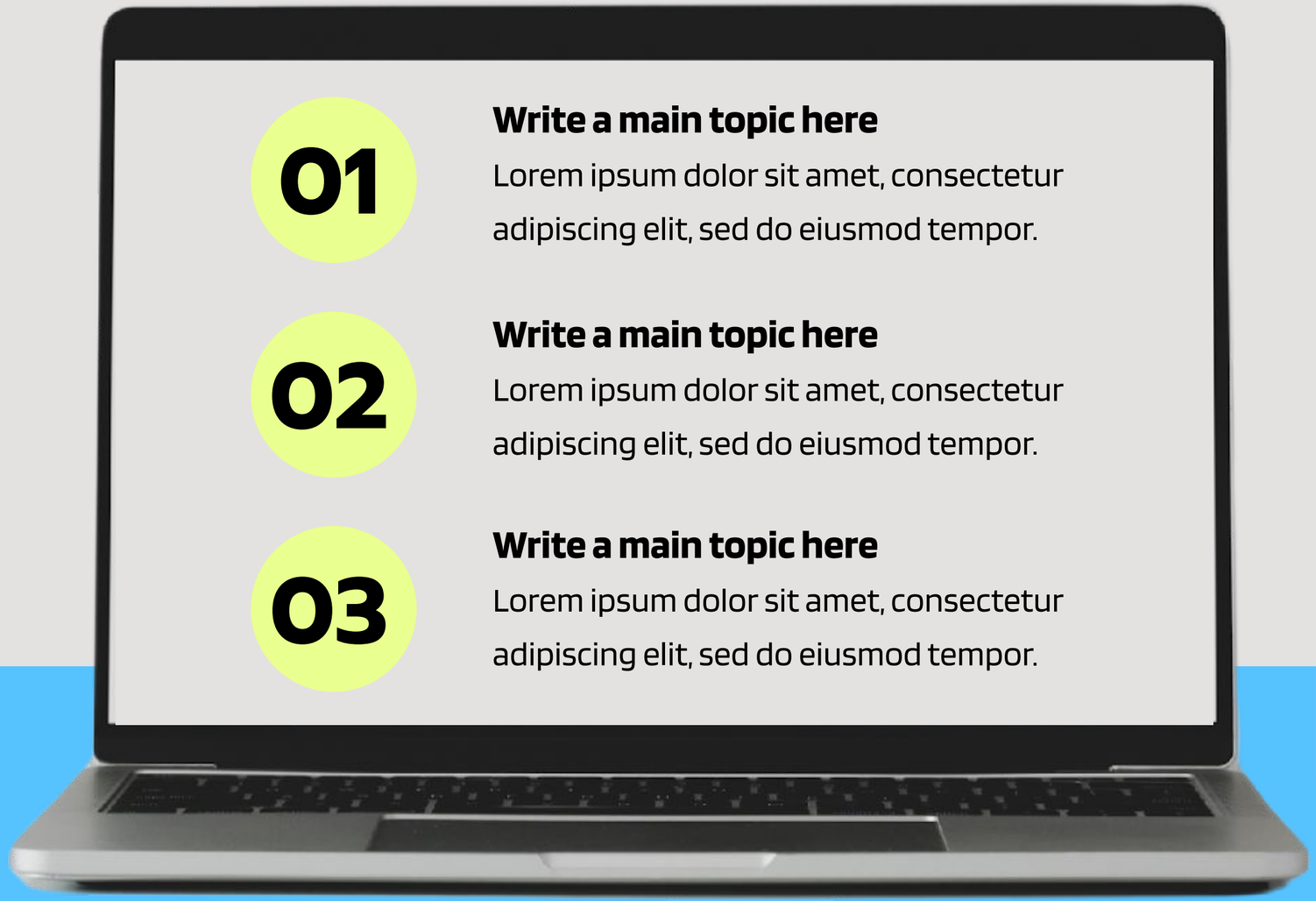


APPLICATION SUBMISSION



“

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John Doe

DIVERSITY & INCLUSION

Discussion of your company's commitment to diversity, equity, and inclusion.

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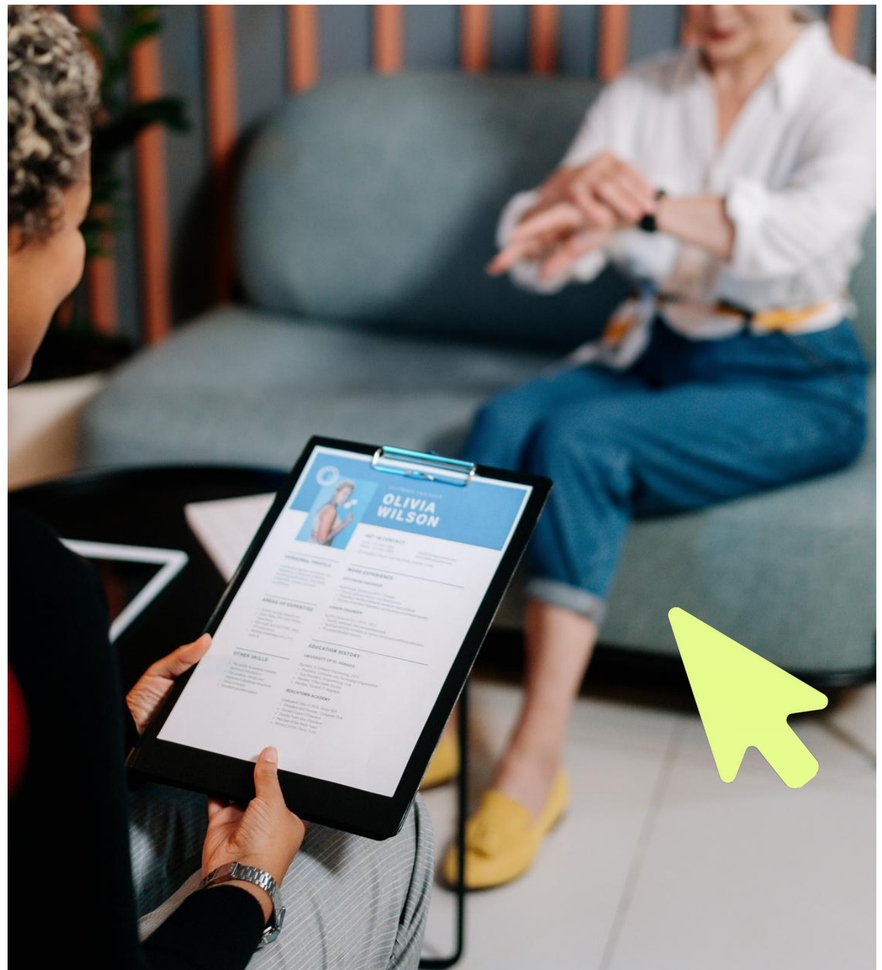
RESUME SCREENING



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TIP 1

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TIP 2

INITIAL INTERVIEW

Explanation of what candidates can expect during the initial interview stage.

Explanation of what candidates can expect during the initial interview stage.

SKILLS ASSESSMENT

Skill 01 | Skill 02 | Skill 03

Technical assessments

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Writing samples or presentations

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Evaluation Criteria

Accuracy

Assess candidates' ability to produce accurate and error-free work, particularly in technical or data-driven tasks.

Efficiency

Evaluate candidates' efficiency in completing tasks within the allotted time frame and meeting deadlines.

Problem-solving skills

Evaluate candidates' efficiency in completing tasks within the allotted time frame and meeting deadlines.

Communication skills

Evaluate candidates' communication and presentation abilities through their writing samples, verbal responses, or presentation delivery.

SECOND INTERVIEW

Write down information about the second interview phase and its purpose.

Write down information about the second interview phase and its purpose.

REFERENCE CHECKS

01

Write a main idea here

Explanation of how reference checks are conducted and their significance.

02

Write a main idea here

Explanation of how reference checks are conducted and their significance.

03

Write a main idea here

Explanation of how reference checks are conducted and their significance.

FINAL DECISION

DESCRIPTION OF HOW THE FINAL DECISION IS MADE AND COMMUNICATED TO CANDIDATES.

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FINAL

BENEFITS OF JOINING OUR TEAM

EMPLOYEE BENEFITS

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EMPLOYEE PERKS

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COMPETITIVE SALARY

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WORK-LIFE BALANCE

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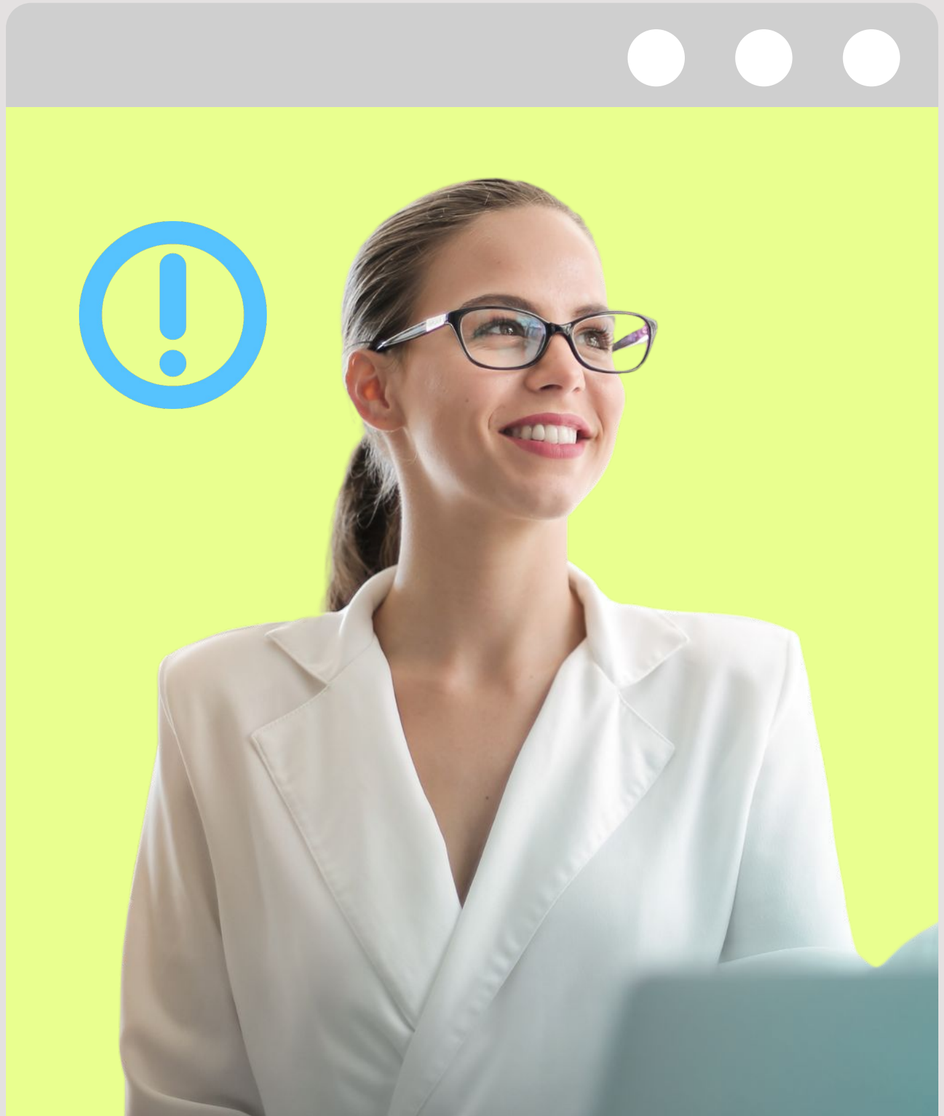
EMPLOYEE TESTIMONIALS



Jane Doe

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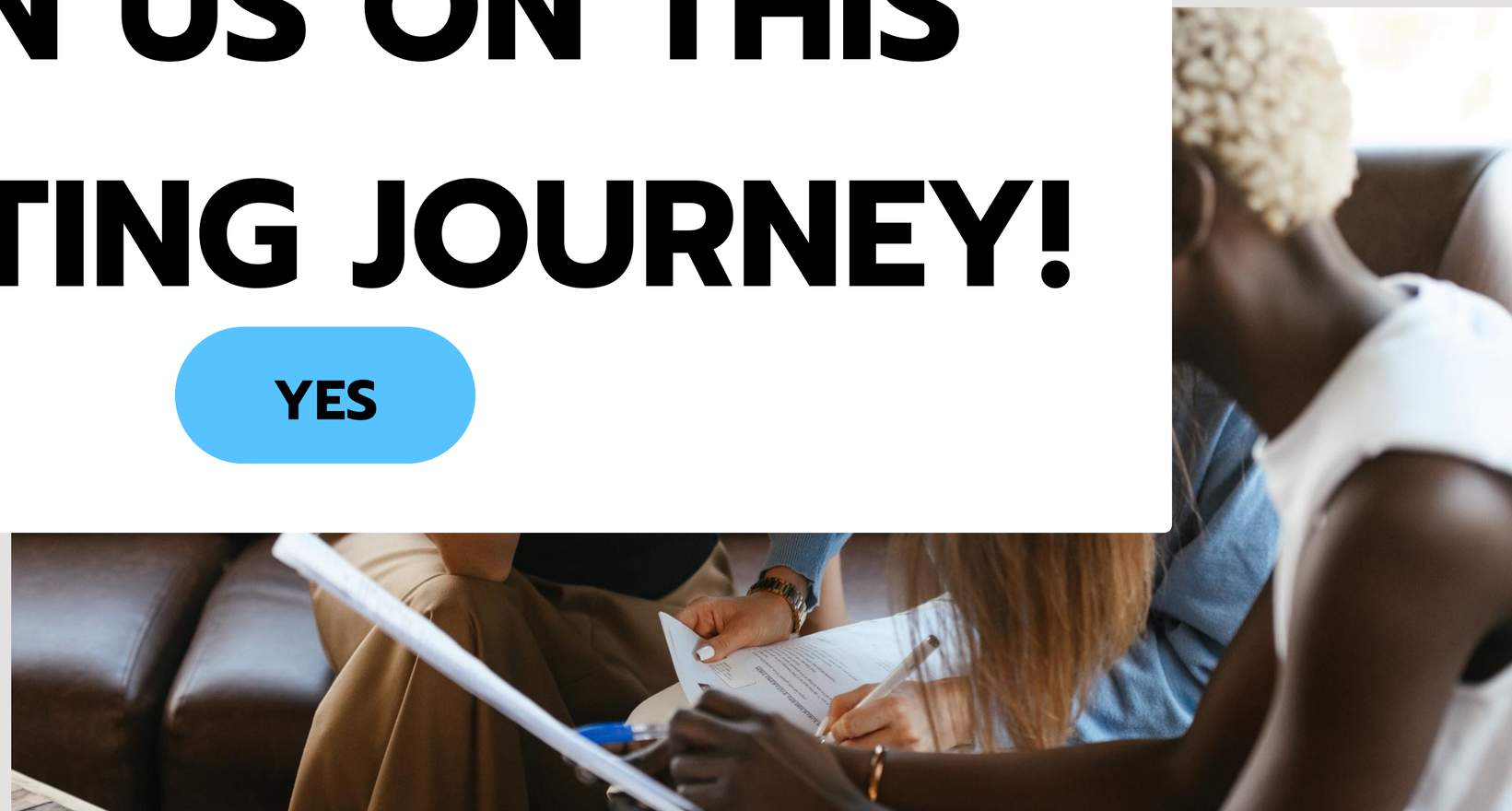
JOIN US ON THIS EXCITING JOURNEY!

YES



FAQ

Question 01

How long does the recruitment process typically take?

SUBMIT

Answer 01

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OK

Question 02

How many rounds of interviews are there?

SUBMIT

Answer 02

2 rounds of interviews

OK

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OKAY