Semantic Segmentation of CFRP Micrographs

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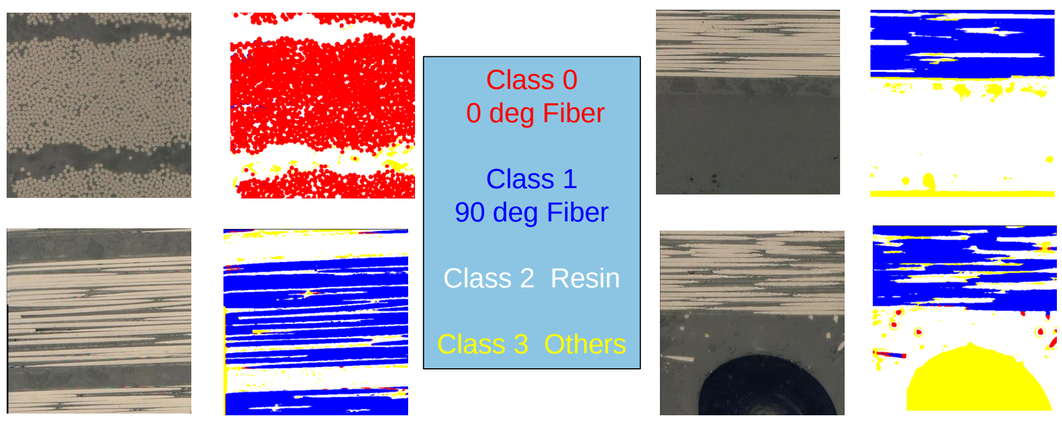
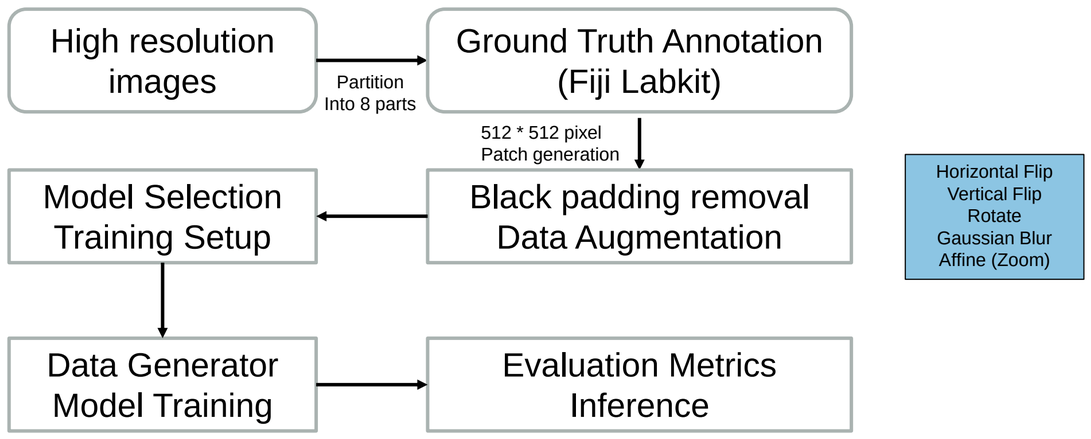
Motivation

- **Carbon Fiber Reinforced Polymers** (CFRP) play a vital role in aerospace and automotive industries.
- Develop a deep learning model for semantic segmentation of CFRP micrographs into 4 classes:



RGB Training patch and it's corresponding Ground Truth label

Methodology



Model Selection & Training Setup

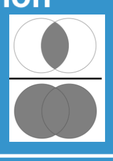
Architectures

i) U-Net ii) U-Net++

Evaluation Metrics

Intersection of Union

$$IoU = \frac{Area\ of\ Overlap}{Area\ of\ Union}$$



mean- Intersection of Union

$$mIoU = \frac{1}{C}\sum_{i=0}^{C} IoU_i$$

C: number of classes

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

Loss Functions

i) Focal Loss ii) Dice Loss iii) Cross-Entropy Loss

Fixed Hyperparameters Callbacks

- 200 Epochs
- Reduce On Plateau
- Early Stopping
- Batch Size = 4
- Adam Optimizer

Hyperparameters to tune

- With, Without Augmentation
- Learning Rate
- Number of Base Filter
- Dropout
- L2 Regularization

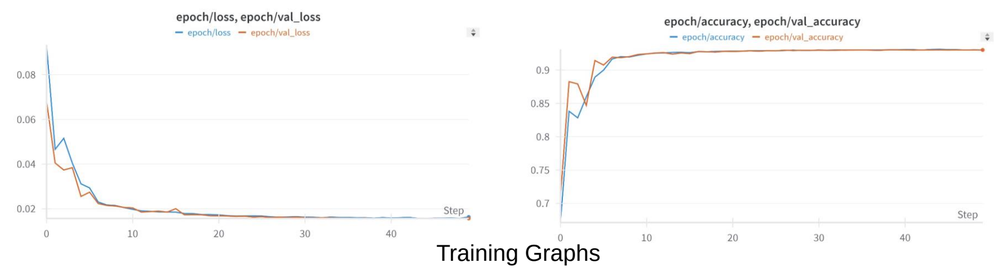
- Grid Search for initial model selection based on val accuracy and mIoU.
- Top models refined via Hyperparameter tuning using Keras Hyperband.

Model Training

Model 1

U-Net (Focal Loss): Includes data augmentation, Adam optimizer, batch size 4, early stopping, ReduceLROnPlateau. Training starts at LR = 0.01, reducing as needed.

Training Pixel Accuracy : 93.13 %	Validation Pixel accuracy : 93.03 %
Training *mIoU* : 73.83 %	Validation *mIoU* : 75.14 %

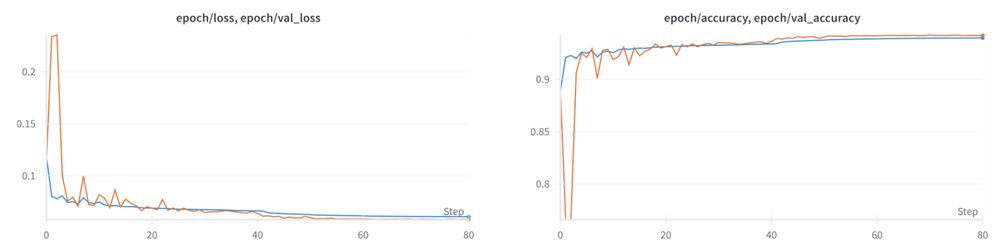


Training Graphs

Model 2

U-Net++ (Dice Loss): Includes data augmentation, Adam optimizer, batch size 4, early stopping, ReduceLROnPlateau. Training starts at LR = 0.001, reducing as needed.

Training Pixel Accuracy : 93.44 %	Validation Pixel accuracy : 93.45 %
Training *mIoU* : 86.61 %	Validation *mIoU* : 86.52%



Training Graphs

Results and Conclusion

- **Model 1** generalizes well

Test image CFM_1

Test image CFM_2

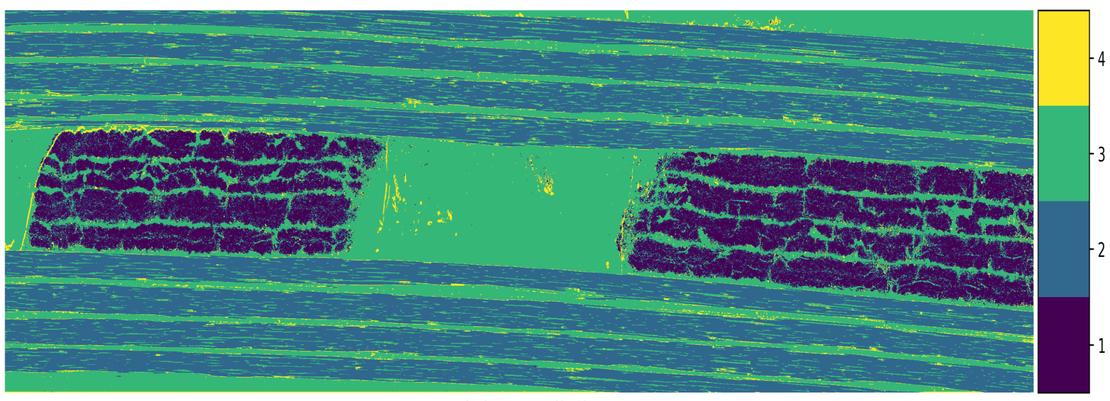
Test Pixel Accuracy : 89.29 %
Jaccard (*mIoU*) : 64.17 %

- **Model 2** did not generalize well

Test image CFM_1

Test image CFM_2

Test Pixel Accuracy : 67.51 %
Jaccard (*mIoU*) : 51.43 %



Model 1 prediction

- Possible causes for not generalizing for all classes are,
  1. Overfitting 2. Improper annotation 3. Class imbalance