

Model Outputs Report (test run on Google colab) and comparison with MEDMNIST benchmarks for blood cell classification

1. Dataset and Dataloader: K-Fold Splits and Number of Images

The dataset was split using 5-Fold Stratified Cross Validation to ensure a balanced distribution of samples across each fold. The class distribution is as follows:

- Total training images: 13,671
- Total testing images: 3,421
- Class distribution per fold is shown below:

```
Using device: cuda

Loading datasets...
Datasets loaded successfully in 35.83 seconds.

Setting up 5-Fold Stratified Cross Validation...
Preparing Fold 1/5...
  - Training samples: 10936
  - Validation samples: 2735
Preparing Fold 2/5...
  - Training samples: 10937
  - Validation samples: 2734
Preparing Fold 3/5...
  - Training samples: 10937
  - Validation samples: 2734
Preparing Fold 4/5...
  - Training samples: 10937
  - Validation samples: 2734
Preparing Fold 5/5...
  - Training samples: 10937
  - Validation samples: 2734

5-Fold Cross-validation splits created successfully!

Class distribution in Training set:
Basophil           : 974 images
Eosinophil         : 2493 images
Erythroblast       : 1240 images
Immature_granulocyte : 2316 images
Lymphocyte         : 971 images
Monocyte           : 1136 images
Neutrophil         : 2663 images
Thrombocyte        : 1878 images
Total images in Training set: 13671

Class distribution in Testing set:
Basophil           : 244 images
Eosinophil         : 624 images
Erythroblast       : 311 images
Immature_granulocyte : 579 images
Lymphocyte         : 243 images
Monocyte           : 284 images
Neutrophil         : 666 images
Thrombocyte        : 470 images
Total images in Testing set: 3421
```

Figure 1: Stratified KFold and Class distribution for training and testing sets

2. Training Loop

The training loop was run for 10 epochs across each fold. The performance metrics such as accuracy, loss, and ROC AUC were tracked for each epoch.

```
===== Fold 1/5 =====
Epoch 1: Train Acc=0.8563, Train Loss=0.4840, Train ROC AUC=0.9849 | Val Acc=0.9199, Val Loss=0.2141, Val ROC AUC=0.9968
Epoch 2: Train Acc=0.9156, Train Loss=0.2660, Train ROC AUC=0.9940 | Val Acc=0.8830, Val Loss=0.3627, Val ROC AUC=0.9888
Epoch 3: Train Acc=0.9300, Train Loss=0.2164, Train ROC AUC=0.9959 | Val Acc=0.9049, Val Loss=0.2669, Val ROC AUC=0.9943
Epoch 4: Train Acc=0.9407, Train Loss=0.1810, Train ROC AUC=0.9972 | Val Acc=0.9590, Val Loss=0.1110, Val ROC AUC=0.9990
Epoch 5: Train Acc=0.9481, Train Loss=0.1599, Train ROC AUC=0.9976 | Val Acc=0.9642, Val Loss=0.1045, Val ROC AUC=0.9991
Epoch 6: Train Acc=0.9532, Train Loss=0.1406, Train ROC AUC=0.9983 | Val Acc=0.9594, Val Loss=0.1060, Val ROC AUC=0.9990
Epoch 7: Train Acc=0.9580, Train Loss=0.1287, Train ROC AUC=0.9985 | Val Acc=0.9594, Val Loss=0.1187, Val ROC AUC=0.9988
Epoch 8: Train Acc=0.9598, Train Loss=0.1241, Train ROC AUC=0.9986 | Val Acc=0.9601, Val Loss=0.1221, Val ROC AUC=0.9987
Epoch 9: Train Acc=0.9585, Train Loss=0.1287, Train ROC AUC=0.9984 | Val Acc=0.9631, Val Loss=0.1119, Val ROC AUC=0.9990
Epoch 10: Train Acc=0.9653, Train Loss=0.1056, Train ROC AUC=0.9990 | Val Acc=0.9770, Val Loss=0.0664, Val ROC AUC=0.9996

===== Fold 2/5 =====
Epoch 1: Train Acc=0.9641, Train Loss=0.1098, Train ROC AUC=0.9989 | Val Acc=0.9806, Val Loss=0.0519, Val ROC AUC=0.9998
Epoch 2: Train Acc=0.9644, Train Loss=0.1090, Train ROC AUC=0.9988 | Val Acc=0.9824, Val Loss=0.0554, Val ROC AUC=0.9997
Epoch 3: Train Acc=0.9685, Train Loss=0.0950, Train ROC AUC=0.9992 | Val Acc=0.9788, Val Loss=0.0616, Val ROC AUC=0.9996
Epoch 4: Train Acc=0.9671, Train Loss=0.0966, Train ROC AUC=0.9992 | Val Acc=0.9579, Val Loss=0.1072, Val ROC AUC=0.9990
Epoch 5: Train Acc=0.9672, Train Loss=0.0952, Train ROC AUC=0.9992 | Val Acc=0.9810, Val Loss=0.0603, Val ROC AUC=0.9996
Epoch 6: Train Acc=0.9737, Train Loss=0.0826, Train ROC AUC=0.9994 | Val Acc=0.9733, Val Loss=0.0772, Val ROC AUC=0.9995
Epoch 7: Train Acc=0.9738, Train Loss=0.0791, Train ROC AUC=0.9994 | Val Acc=0.9810, Val Loss=0.0524, Val ROC AUC=0.9998
Epoch 8: Train Acc=0.9813, Train Loss=0.0587, Train ROC AUC=0.9997 | Val Acc=0.9781, Val Loss=0.0639, Val ROC AUC=0.9996
Epoch 9: Train Acc=0.9732, Train Loss=0.0863, Train ROC AUC=0.9992 | Val Acc=0.9773, Val Loss=0.0729, Val ROC AUC=0.9994
Epoch 10: Train Acc=0.9728, Train Loss=0.0839, Train ROC AUC=0.9993 | Val Acc=0.9455, Val Loss=0.1511, Val ROC AUC=0.9984

===== Fold 3/5 =====
Epoch 1: Train Acc=0.9771, Train Loss=0.0728, Train ROC AUC=0.9995 | Val Acc=0.9854, Val Loss=0.0388, Val ROC AUC=0.9999
Epoch 2: Train Acc=0.9763, Train Loss=0.0750, Train ROC AUC=0.9994 | Val Acc=0.9689, Val Loss=0.0805, Val ROC AUC=0.9995
Epoch 3: Train Acc=0.9788, Train Loss=0.0646, Train ROC AUC=0.9996 | Val Acc=0.9792, Val Loss=0.0621, Val ROC AUC=0.9996
Epoch 4: Train Acc=0.9788, Train Loss=0.0635, Train ROC AUC=0.9996 | Val Acc=0.9623, Val Loss=0.1024, Val ROC AUC=0.9991
Epoch 5: Train Acc=0.9780, Train Loss=0.0640, Train ROC AUC=0.9996 | Val Acc=0.9832, Val Loss=0.0515, Val ROC AUC=0.9997
Epoch 6: Train Acc=0.9795, Train Loss=0.0619, Train ROC AUC=0.9996 | Val Acc=0.9857, Val Loss=0.0385, Val ROC AUC=0.9999
Epoch 7: Train Acc=0.9792, Train Loss=0.0630, Train ROC AUC=0.9996 | Val Acc=0.9872, Val Loss=0.0401, Val ROC AUC=0.9998
Epoch 8: Train Acc=0.9820, Train Loss=0.0557, Train ROC AUC=0.9997 | Val Acc=0.9846, Val Loss=0.0487, Val ROC AUC=0.9998
Epoch 9: Train Acc=0.9809, Train Loss=0.0575, Train ROC AUC=0.9997 | Val Acc=0.9850, Val Loss=0.0460, Val ROC AUC=0.9998
Epoch 10: Train Acc=0.9815, Train Loss=0.0560, Train ROC AUC=0.9997 | Val Acc=0.9828, Val Loss=0.0463, Val ROC AUC=0.9998

===== Fold 4/5 =====
Epoch 1: Train Acc=0.9771, Train Loss=0.0667, Train ROC AUC=0.9996 | Val Acc=0.9784, Val Loss=0.0502, Val ROC AUC=0.9998
Epoch 2: Train Acc=0.9823, Train Loss=0.0580, Train ROC AUC=0.9997 | Val Acc=0.9865, Val Loss=0.0392, Val ROC AUC=0.9998
Epoch 3: Train Acc=0.9804, Train Loss=0.0590, Train ROC AUC=0.9997 | Val Acc=0.9857, Val Loss=0.0412, Val ROC AUC=0.9998
Epoch 4: Train Acc=0.9803, Train Loss=0.0596, Train ROC AUC=0.9996 | Val Acc=0.9879, Val Loss=0.0346, Val ROC AUC=0.9999
Epoch 5: Train Acc=0.9824, Train Loss=0.0525, Train ROC AUC=0.9997 | Val Acc=0.9920, Val Loss=0.0246, Val ROC AUC=0.9999
Epoch 6: Train Acc=0.9848, Train Loss=0.0502, Train ROC AUC=0.9997 | Val Acc=0.9872, Val Loss=0.0386, Val ROC AUC=0.9999
Epoch 7: Train Acc=0.9842, Train Loss=0.0502, Train ROC AUC=0.9997 | Val Acc=0.9887, Val Loss=0.0304, Val ROC AUC=0.9999
Epoch 8: Train Acc=0.9844, Train Loss=0.0447, Train ROC AUC=0.9998 | Val Acc=0.9817, Val Loss=0.0529, Val ROC AUC=0.9998
Epoch 9: Train Acc=0.9847, Train Loss=0.0453, Train ROC AUC=0.9998 | Val Acc=0.9898, Val Loss=0.0262, Val ROC AUC=0.9999
Epoch 10: Train Acc=0.9856, Train Loss=0.0413, Train ROC AUC=0.9998 | Val Acc=0.9821, Val Loss=0.0391, Val ROC AUC=0.9999

===== Fold 5/5 =====
Epoch 1: Train Acc=0.9803, Train Loss=0.0607, Train ROC AUC=0.9996 | Val Acc=0.9898, Val Loss=0.0307, Val ROC AUC=0.9999
Epoch 2: Train Acc=0.9858, Train Loss=0.0422, Train ROC AUC=0.9998 | Val Acc=0.9916, Val Loss=0.0243, Val ROC AUC=0.9999
Epoch 3: Train Acc=0.9888, Train Loss=0.0355, Train ROC AUC=0.9999 | Val Acc=0.9905, Val Loss=0.0298, Val ROC AUC=0.9999
Epoch 4: Train Acc=0.9834, Train Loss=0.0544, Train ROC AUC=0.9996 | Val Acc=0.9872, Val Loss=0.0387, Val ROC AUC=0.9999
Epoch 5: Train Acc=0.9869, Train Loss=0.0425, Train ROC AUC=0.9998 | Val Acc=0.9905, Val Loss=0.0281, Val ROC AUC=0.9999
Epoch 6: Train Acc=0.9866, Train Loss=0.0430, Train ROC AUC=0.9998 | Val Acc=0.9901, Val Loss=0.0321, Val ROC AUC=0.9999
Epoch 7: Train Acc=0.9867, Train Loss=0.0382, Train ROC AUC=0.9999 | Val Acc=0.9876, Val Loss=0.0395, Val ROC AUC=0.9998
Epoch 8: Train Acc=0.9861, Train Loss=0.0392, Train ROC AUC=0.9999 | Val Acc=0.9905, Val Loss=0.0274, Val ROC AUC=0.9999
Epoch 9: Train Acc=0.9865, Train Loss=0.0375, Train ROC AUC=0.9999 | Val Acc=0.9865, Val Loss=0.0335, Val ROC AUC=0.9999
Epoch 10: Train Acc=0.9891, Train Loss=0.0325, Train ROC AUC=0.9999 | Val Acc=0.9854, Val Loss=0.0450, Val ROC AUC=0.9999
```

Figure 2: Fold and Epoch-wise training performance (accuracy, loss, and ROC AUC).

3. Validation ROC AUC Per Epoch Fold-Wise

The validation ROC AUC for each fold was tracked across all epochs. The plot below shows how the model generalizes across different folds during training.

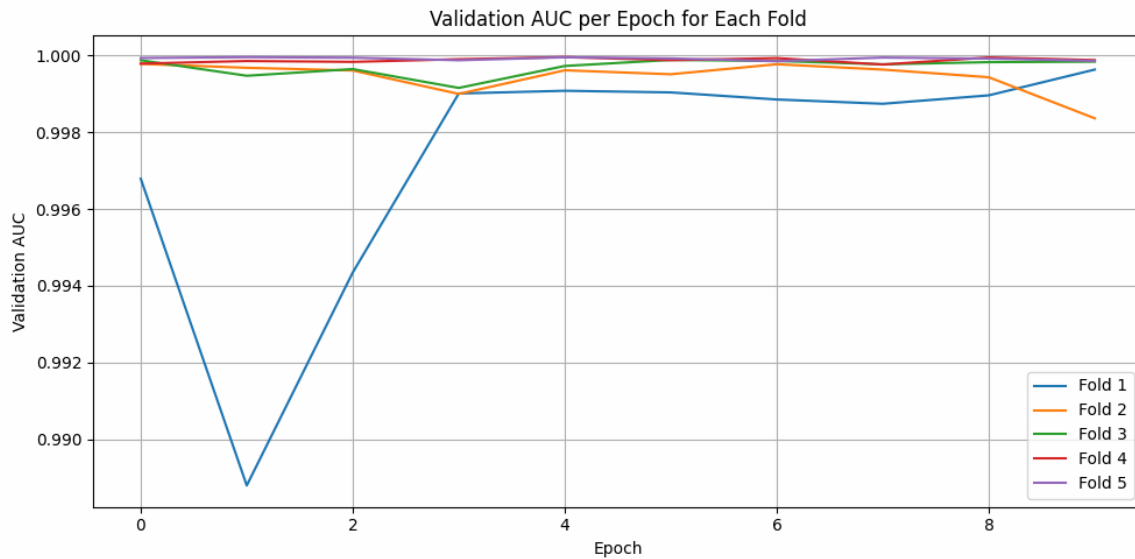


Figure 3: Validation ROC AUC for each epoch across all folds.

4. Accuracy Curve for Training and Validation (Best Fold)

The accuracy curve for the best fold (Fold 4) shows the progression of training and validation accuracy throughout the epochs.

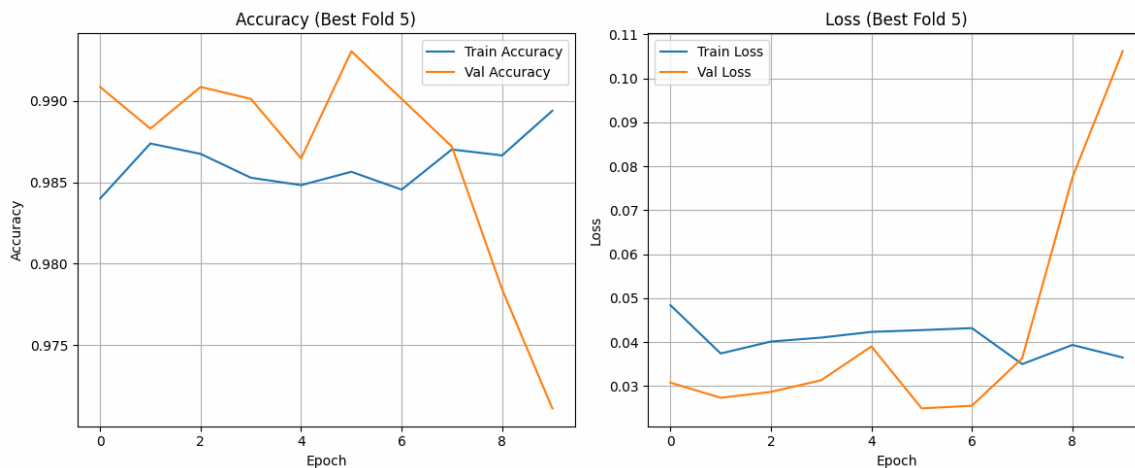


Figure 4: Accuracy curve for training and validation (Fold 4) – Mislabeled headings, supposed to be Fold 4

5. Prediction Metrics

The model performance on the test set for the best fold (Fold 4 is summarized with accuracy, precision, recall, and F1-score for each class.

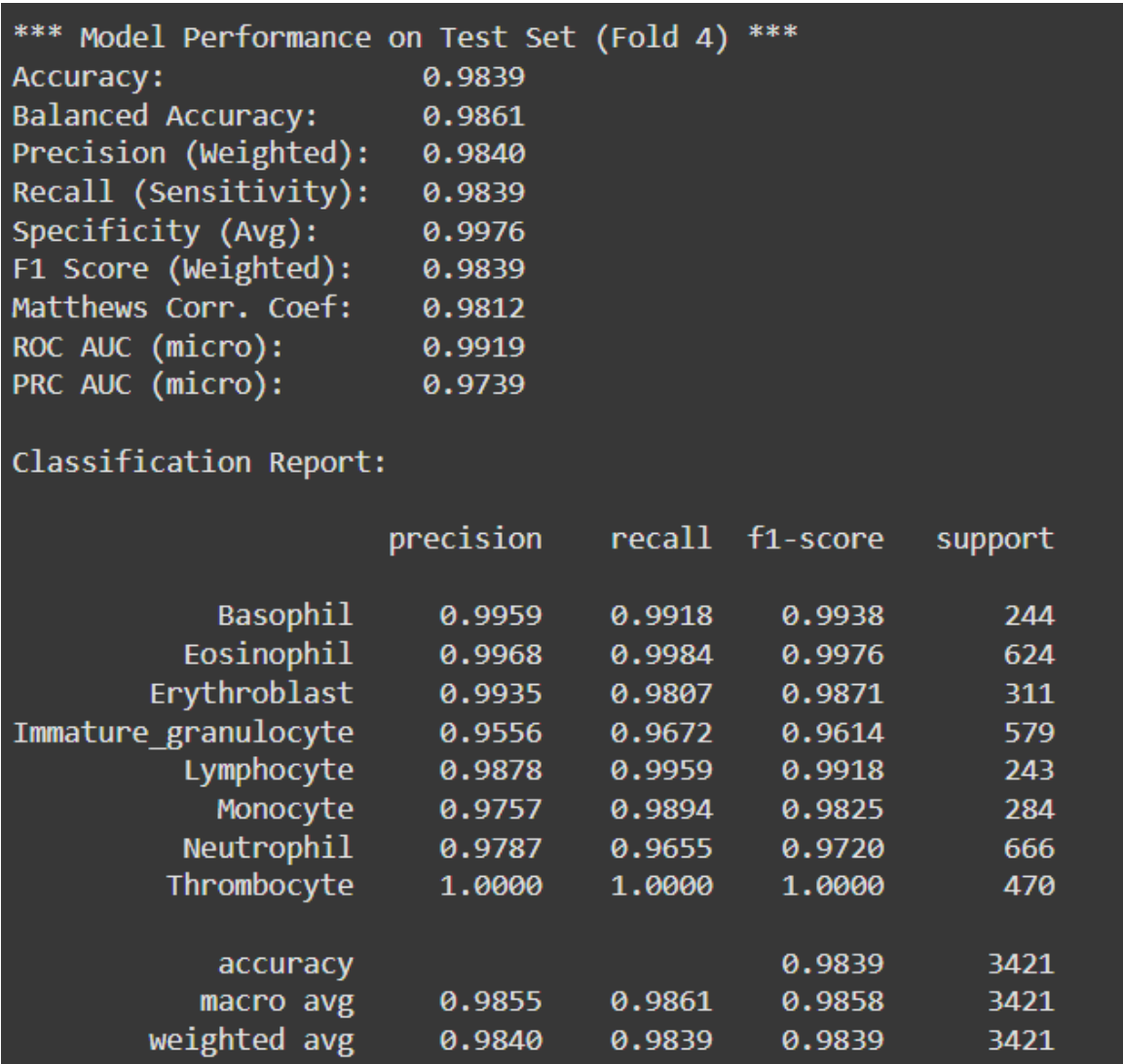


Figure 5: Prediction metrics for Fold 4 (best fold)

6. Confusion Matrix

The confusion matrix below shows the true vs. predicted labels for each class, providing insights into the model's classification performance.

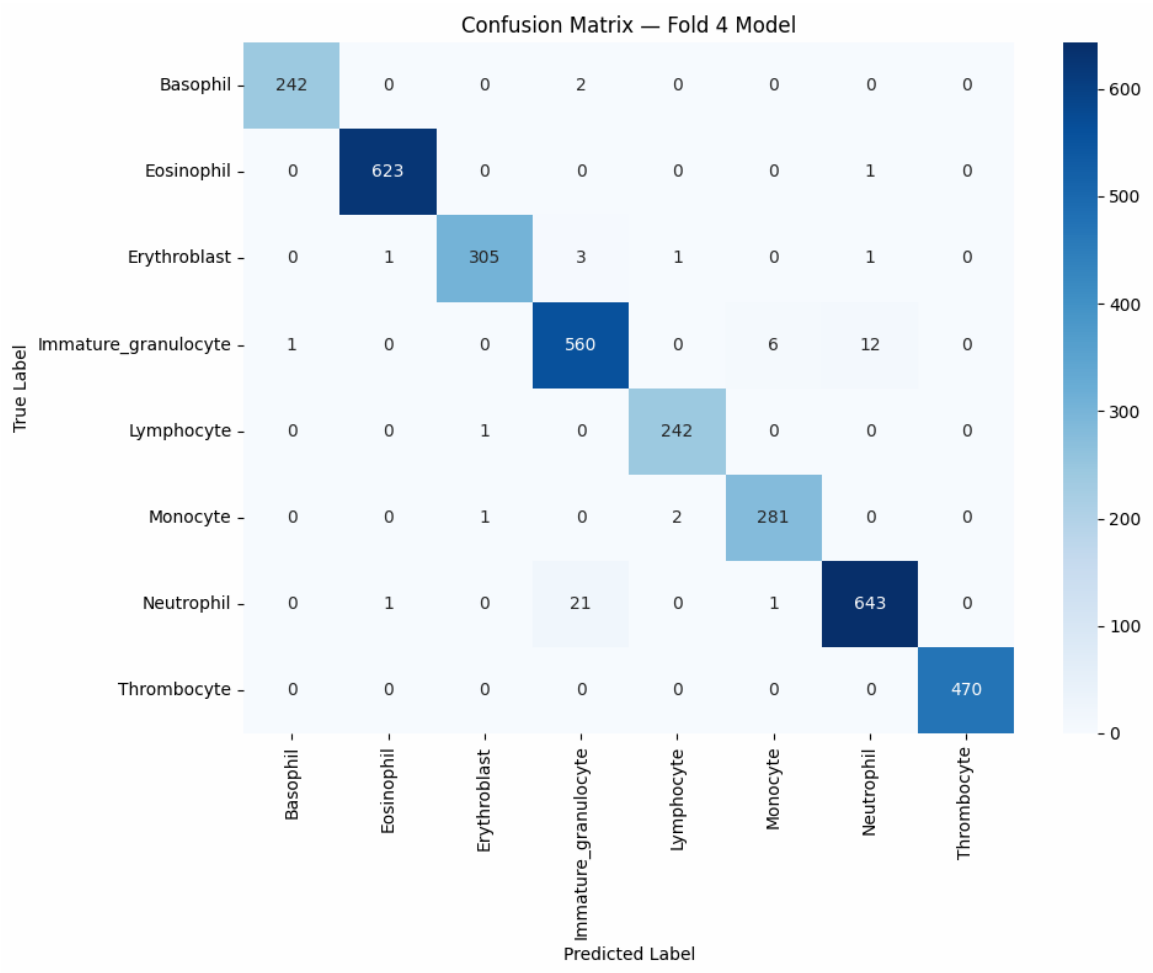


Figure 6: Confusion matrix for Fold 4 (best fold)

7. Comparison of results with MEDMNIST benchmarks for Blood cell classification:

Model	Test accuracy	Test AUC (ROC AUC)
ResNet-18 (224x224)	0.963	0.998
ResNet-18 (28x28)	0.958	0.998
ResNet-50 (224x224)	0.95	0.997
ResNet-50 (28x28)	0.956	0.997
auto-sklearn	0.878	0.984
AutoKeras	0.961	0.998
Google AutoML Vision	0.966	0.998
My classifier CNN model	0.9839	0.992

Check out results of different models here:

<https://medmnist.com/>

GitHub repo link of my project:

https://github.com/rdk004/project_rishabh_kulkarni