

Automated Blood Cell Classification for Hematological Disorders Using Convolutional Neural Networks (CNN's)

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Introduction

- Affecting millions of people a year, Hematological disorders encompass a diverse array of conditions affecting the blood and its cellular components, including red blood cells, white blood cells (WBCs), and platelets.
- These disorders can arise from various genetic, environmental, and acquired factors, resulting in abnormalities in blood cell production, function, or regulation.
- Hematological disorders range widely in severity from benign to life-threatening ailments that have significant effects on the health and quality of life of the patient.
- When left untreated, malignancies like acute leukemias can advance quickly and cause organ infiltration, bone marrow failure, and other potentially fatal consequences. Even less aggressive diseases require constant and proper patient care to slow the disease progression.
- Studies find that **Myelodysplastic Syndromes** have a 20% misdiagnosis rate as they are frequently confused for cancer emphasizing the urgency for a more accurate diagnostic protocol.
- In order to identify and characterize hematological illnesses affecting blood cells, classification diagnosis processes are essential. This helps healthcare workers develop effective treatment plans and improve patient care.
- However current process's are labor-intensive, time-consuming, and vulnerable to subjective interpretation. Traditional diagnostic techniques like
 - manual blood cell counting
 - microscopycan result in inconsistent results and errors in diagnosis.
- The focus of this study is on the classification of blood cells, which play a crucial role in immune function and are indicative of various hematological disorders.

Model

- Convolutional Neural Networks (CNN's) are a powerful tool that excel at feature extraction by automatically extracting relevant features from images through convolutional layers.
- Implementing deep learning techniques such as CNN's to the Hematological disorder field allows healthcare workers to leverage machine learning into improving patient care, prognosis, and treatment plans.
- The MobileNetV2 deep learning model was trained and evaluated on a dataset of 4 subtypes of white blood cells.
- After evaluation on the test dataset containing around 700 images for each subtype, the model reached an overall accuracy of 99.4%, precision of 99%, and recall of 99%.

Figure 1. Microscopic blood smear image of Anemia

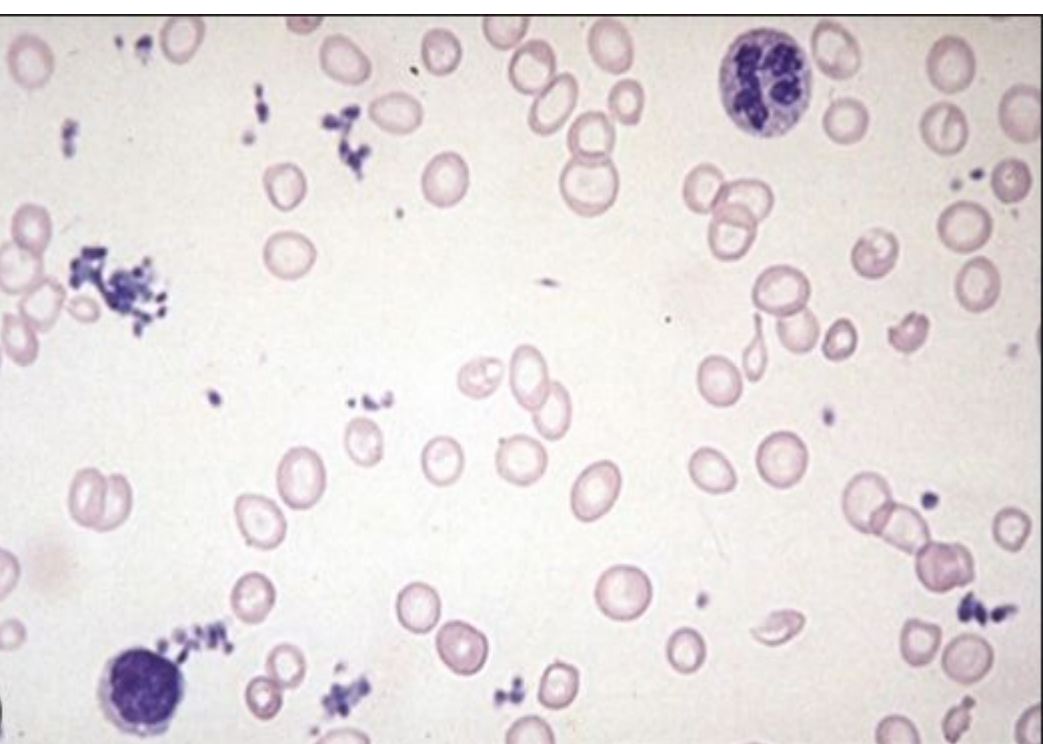
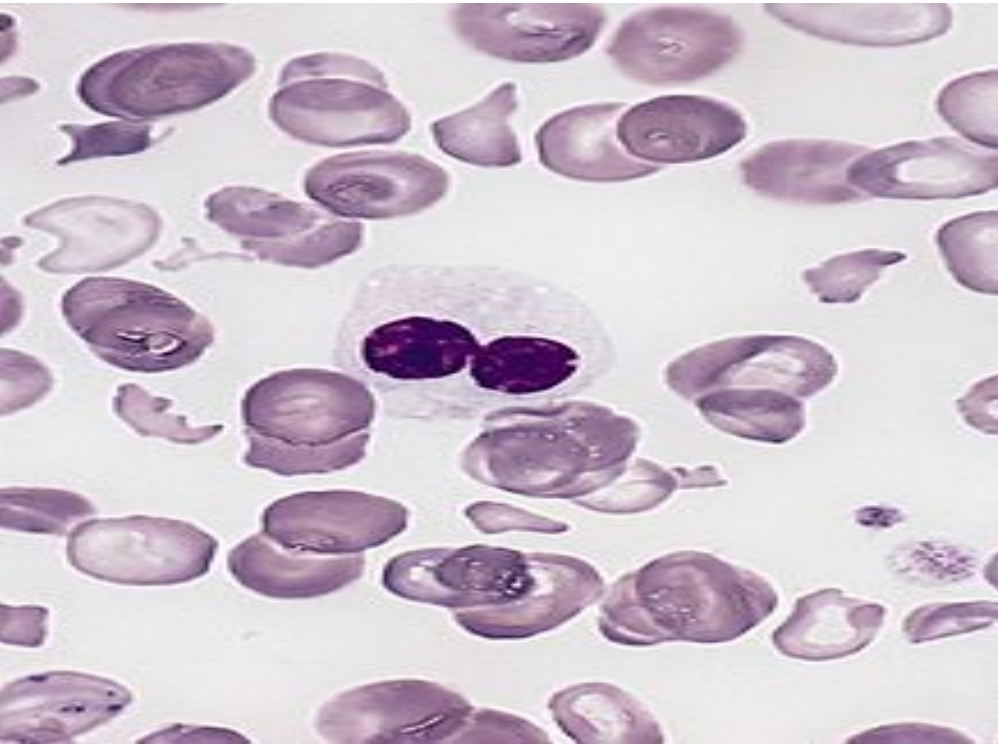


Figure 2. Microscopic blood smear image of Myelodysplastic Syndromes



Engineering Objectives

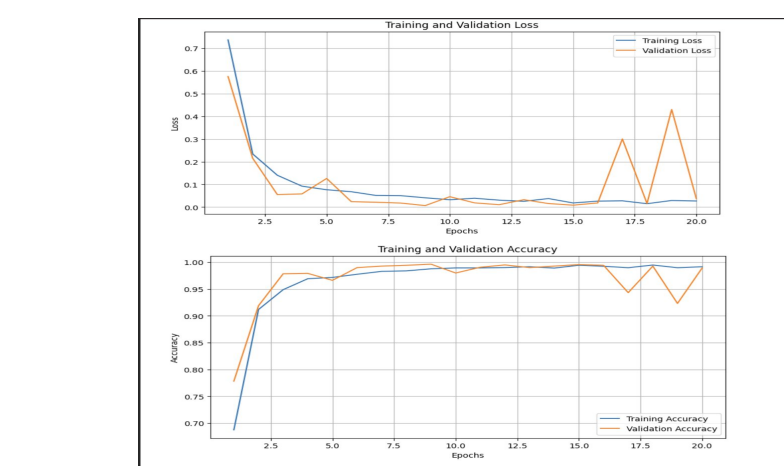
Research Question: How accurately can a Convolutional Neural Network (CNN) classify blood cells for hematological disorder detection?

Engineering Goal:

- Develop an accurate CNN-based model for automated blood cell classification.
- Achieve good precision and recall rates in identifying individual white blood cell types.
- Investigate the potential use of deep learning for early detection of hematological disorders.

Methodology

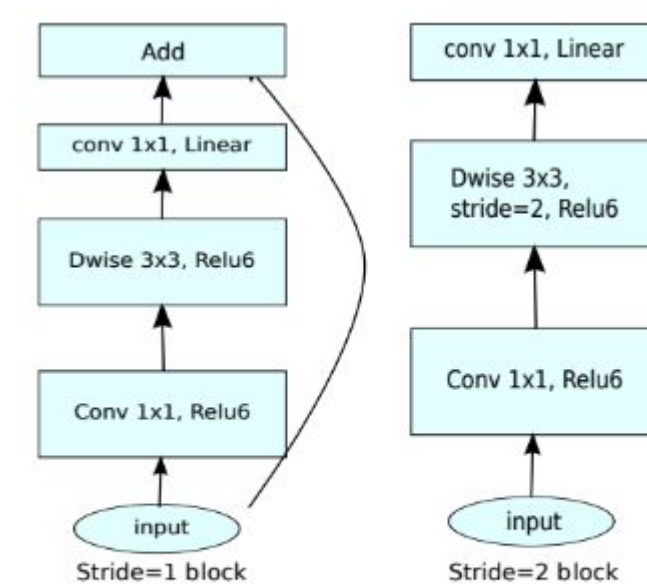
- The project was carried out using a Kaggle Dataset containing 4 classes of blood cells.
- 4 different models were trained and evaluated:
 - Resnet50: **84%** base accuracy
 - Custom Sequential CNN: **89% base** accuracy
 - InceptionV3: **87%** base accuracy
 - MobileNetV2: **96%** base accuracy
- Given that it performed the best, The MobileNetV2 deep learning model was adjusted, re-trained, and evaluated on a dataset of 4 subtypes of white blood cells:
 - Lymphocytes, approx. 2500 training images
 - Monocytes, approx 2500 training images
 - Eosinophils, approx 2500 training images
 - Neutrophils, approx 2500 training images



Graph 1. Training and Validation Acc./Loss Curves for MobileNetV2 Model

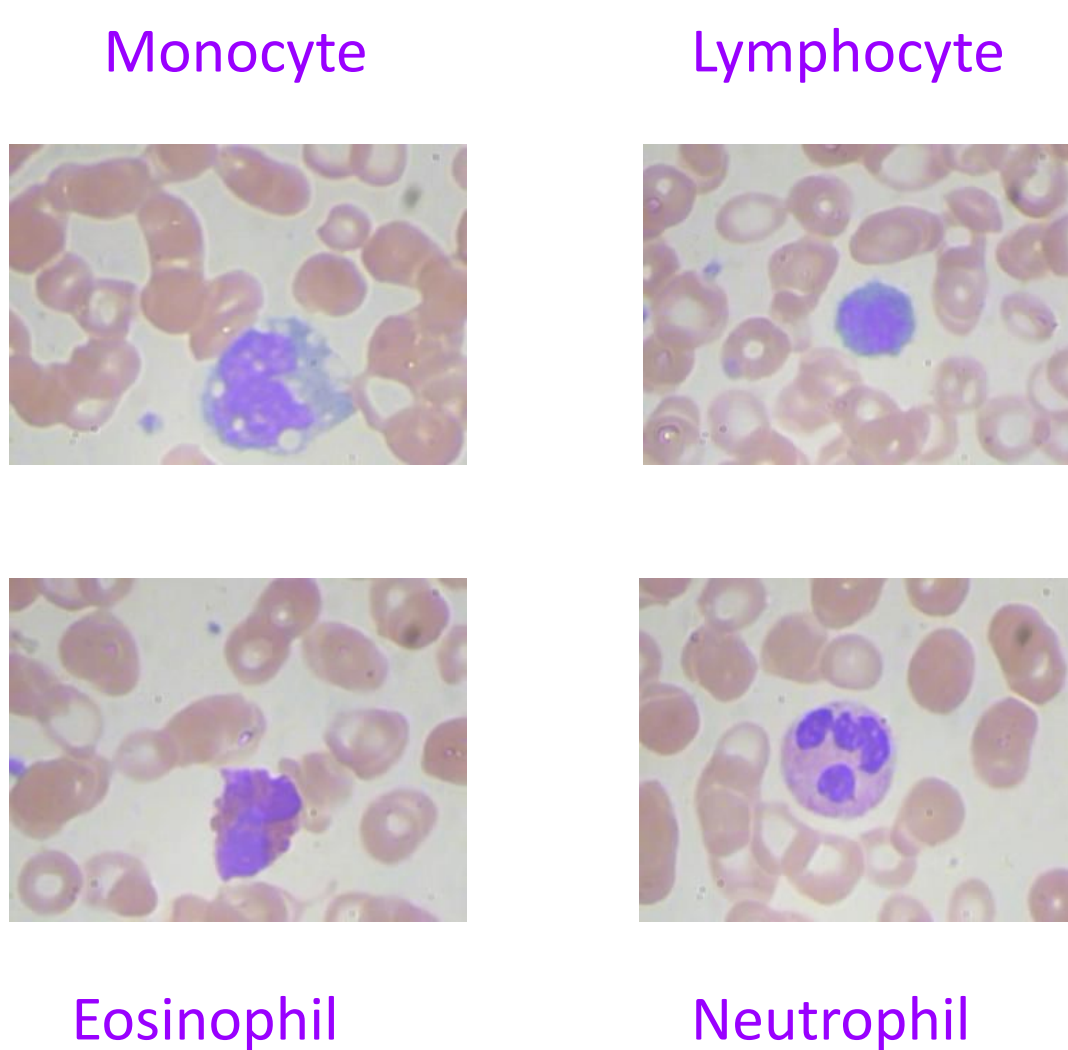
- 6 augmentation techniques were applied to only the training dataset in order to model real world conditions more accurately:
 - Rotation Range: 20 degrees
 - Width Shift Range: 0.1 (fraction of total width)
 - Height Shift Range: 0.1 (fraction of total height)
 - Zoom Range: 0.1 (random zoom in the range [-0.1, 0.1])
 - Horizontal Flip: True (random horizontal flipping)
 - Vertical Flip: True (random vertical flipping)
- The models training process was monitored using the un-augmented validation dataset. The curves indicate that the model is learning the training data well. (*Refer to Graph 1*)
- Post training, the best performing model would be evaluated on a un-augmented test set of approx. 700 images for each class using:
 - Classification Report:** Provides model statistics.
 - Confusion Matrix:** Displays model predictions.

Figure 3. General structure of MobileNetV2 model.



(d) Mobilenet V2

Figure 4. Dataset Samples



Results

Table 1. Classification Report of MobileNetV2 Model

Classification Report:	precision	recall	f1-score	support
EOSINOPHIL	0.98	0.99	0.99	781
LYMPHOCYTE	1.00	1.00	1.00	764
MONOCYTE	1.00	0.99	0.99	729
NEUTROPHIL	0.98	0.99	0.99	714
accuracy			0.99	2988
macro avg	0.99	0.99	0.99	2988
weighted avg	0.99	0.99	0.99	2988

Figure 5. Confusion Matrix of MobileNetV2 Model

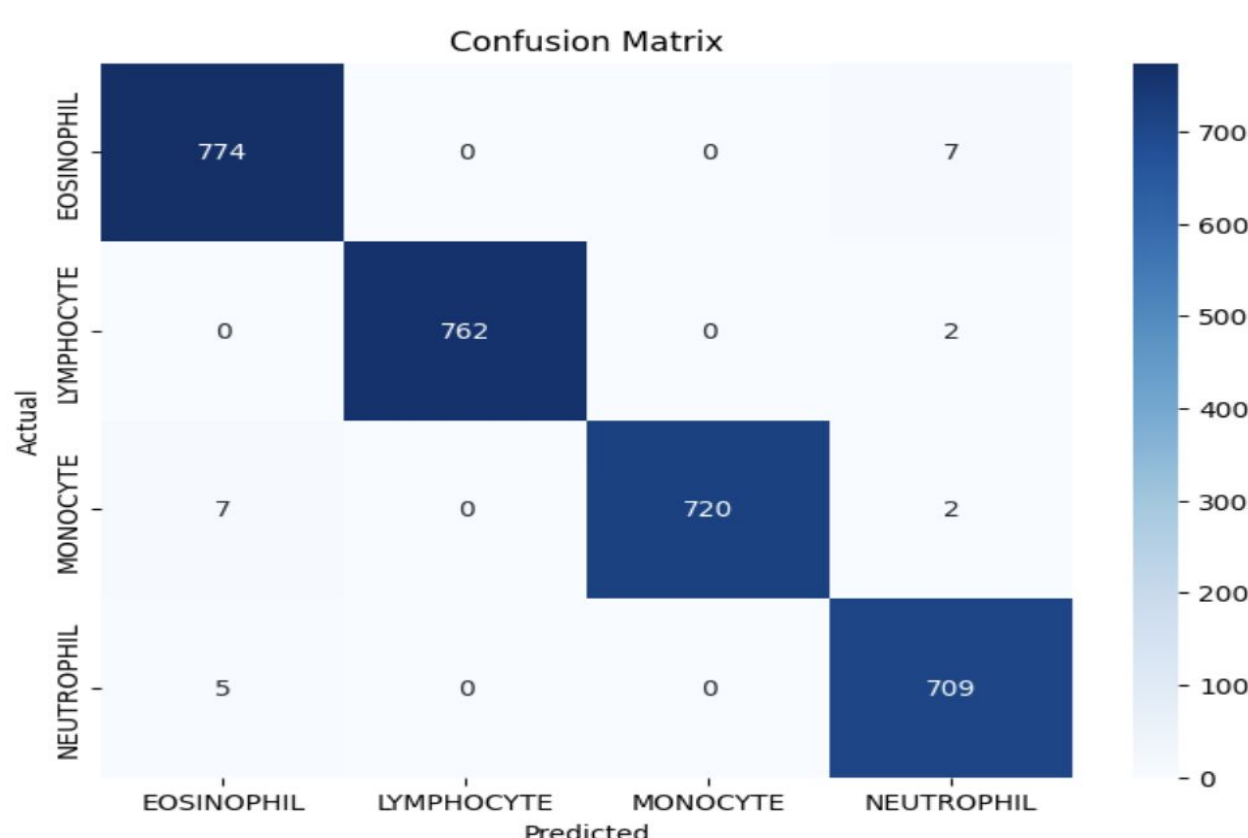
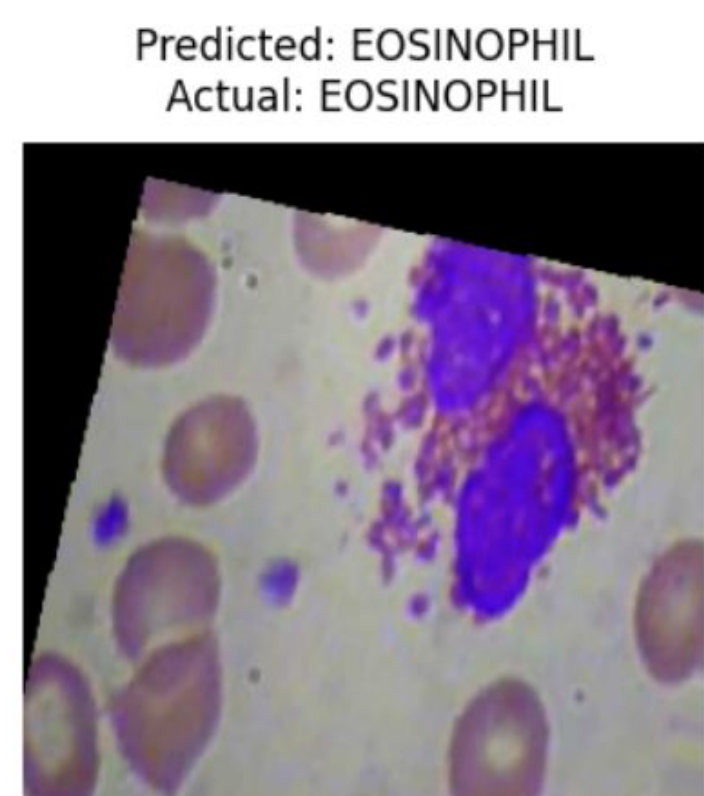


Table 2. Performance Comparison of the Proposed Model with Prior Studies

Study Name	Accuracy	F1 Score	Recall
White Blood Cell Classification: Convolutional Neural Network (CNN) and Vision Transformer (ViT) under Medical Microscope	98.8%	97.5%	96.8%
Classification of White blood Cell using Convolution Neural Network	97%	97%	97%
WBC image classification and generative models based on convolutional neural network	98.55%	98%	98.3%

Sample 1. Example of model prediction



Conclusion

- Although the dataset was restricted to white blood cells, the project shows the power of feature extraction that CNN's possess as the model reached a peak accuracy of 99%.
- High Precision, Recall, and F1-score:
 - Precision, recall, and F1-score are metrics for evaluating the performance of a classification model.
 - Precision measures the accuracy of positive predictions, indicating how often the model correctly identifies instances of a class among all instances it predicts as that class.
 - Recall measures the ability of the model to correctly identify all positive instances of a class, capturing the proportion of actual positives that the model correctly identifies.
 - F1-score is the harmonic mean of precision and recall, providing a balanced measure of a model's performance.
 - The model achieved values of 0.98 and above for all classes indicating an exceptional level of precision, recall, and overall performance of correctly classifying instances across all classes.**
- Confusion Matrix:
 - The confusion matrix provides a visual representation of the model's performance by comparing predicted labels with true labels across different classes.
 - Minimal deviation observed in the confusion matrix indicates that the model has made very few misclassifications.**
 - A well-organized confusion matrix with high values along the diagonal (true positives) and low off-diagonal values (false positives and false negatives) demonstrates the model's ability to accurately classify instances into their respective classes.

Discussion/Future Studies

- This project explores the application of advanced artificial intelligence techniques to automate the analysis of white blood cells, a crucial aspect of diagnosing various hematological conditions.
- By harnessing deep learning algorithms, our model accurately identifies different types of white blood cells from microscopic images, offering a fast and reliable alternative to manual examination, which can be time-consuming and prone to human error.
- This advancement in automated diagnosis not only accelerates the diagnostic process but also ensures greater accuracy, paving the way for more effective treatment strategies and improved patient care.

- Next Steps:
 - explore the integration of multimodal data sources
 - expand the models classification abilities into different types of blood cells
 - explore more advanced neural networks for classifying blood cells

References

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