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Accurate Classification of Acute Lymphoblastic Leukemia Subtypes Using Stacked Ensemble Learning on Peripheral Blood Smear Images

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INTRODUCTION & AIM

Acute Lymphoblastic Leukemia (ALL) is a rapidly progressing cancer affecting blood and bone marrow, primarily observed in children but also present in adults. Traditional diagnostic methods, such as blood tests and biopsies, are effective but time-intensive and reliant on skilled pathologists. The need for automated, efficient diagnostic tools has driven research in deep learning.

This study leverages a dataset of 3256 peripheral blood smear images from 89 patients, captured at 100x magnification. Using a stacked ensemble learning approach with DenseNet121, VGG16, and VGG19, we classify images into four categories: benign hematogones and malignant lymphoblast subtypes (Early Pre-B, Pre-B, and Pro-B).

Our aim is to enhance diagnostic precision and efficiency in ALL subtype classification using advanced machine learning techniques, paving the way for improved patient outcomes.

Methodology

We implemented a **stacked ensemble learning framework** to classify PBS images into four distinct categories.

Base Models:

DenseNet121: Employs dense connectivity to improve feature propagation, reduce parameters, and mitigate vanishing gradients.

VGG16: A 16-layer CNN known for its simplicity and strong performance in image classification tasks.

VGG19: An extended version of VGG16 with greater depth for more complex feature extraction.

All base models were pre-trained on ImageNet and fine-tuned on the ALL dataset to extract feature vectors from input image.

Meta-Model:

K-Nearest Neighbors (KNN): A simple yet effective classifier that makes predictions based on the majority class among the nearest data points in feature space.

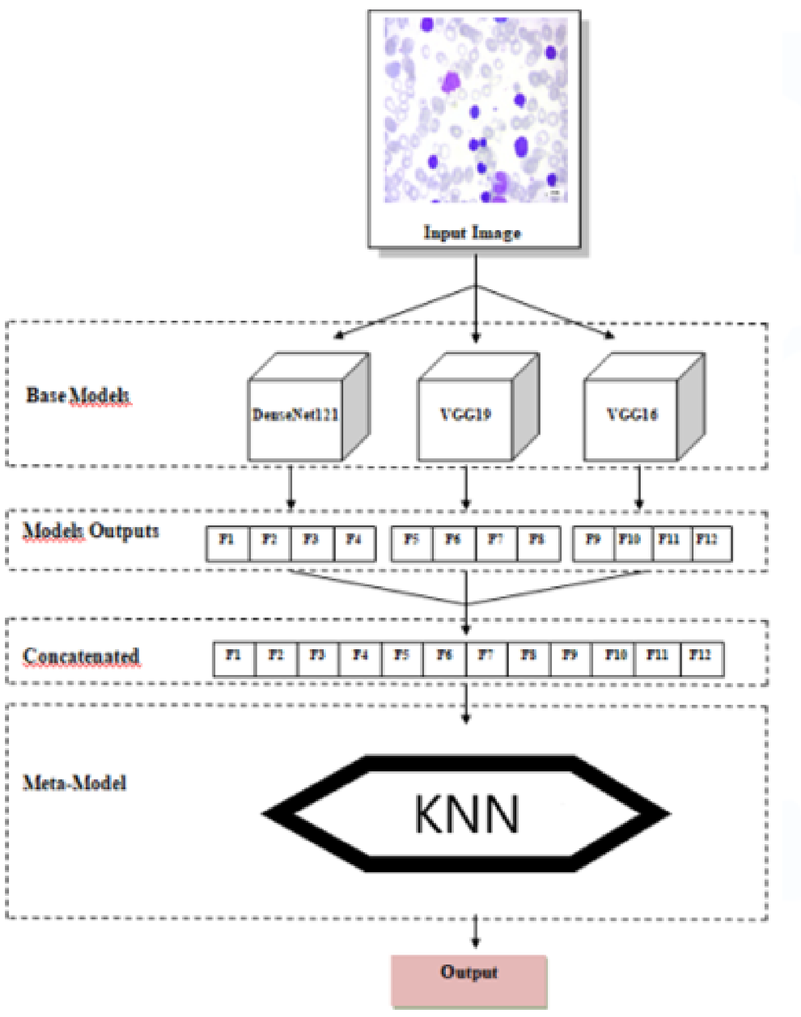

Figure 1. Our Stacked Ensemble Model.

Input: A 12-dimensional feature vector formed by concatenating feature vectors from DenseNet121, VGG16, and VGG19.

Output: Final predictions leveraging the strengths of all three base models.

This stacked ensemble approach optimally combines the unique features of each model, delivering enhanced classification performance.

RESULTS & DISCUSSION

The performance of the models was evaluated using the following metrics:

Accuracy: The proportion of correctly classified instances out of the total instances.

Confusion Matrix: A matrix used to visualize the performance of the classification model by comparing predicted and actual class labels.

Precision, Recall, and F1-Score: These metrics provide insights into the classification performance for each class.

Confusion Matrix Analysis:

The confusion matrix for the ensemble model is shown in Figure 1('Benign':0, 'Early':1,'Pre':2,'Pro':3). The matrix indicates that the model performed well across all classes, with the majority of misclassifications occurring between the malignant subtypes, which are inherently more challenging to distinguish.

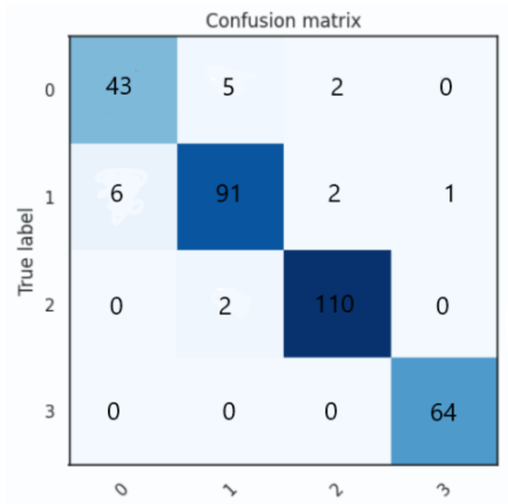

Figure 2. Confusion matrix

TABLE I. Results of our model

		Stacked Ensemble Model
	Test accuracy	94.48 %
Precision	for Benign Hematogones class	0.87
	for Early Pre-B ALL class	0.92
	for Pre-B ALL class	0.96
	for Pro-B ALL class	0.98
Recall	for Benign Hematogones class	0.86
	for Early Pre-B ALL class	0.91
	for Pre-B ALL class	0.98
	for Pro-B ALL class	1.00
F1 Score	for Benign Hematogones class	0.86
	for Early Pre-B ALL class	0.91
	for Pre-B ALL class	0.97
	for Pro-B ALL class	0.99

4. Precision, Recall, and F1-Score:

The precision, recall, and F1-score for each class were calculated to provide a more detailed evaluation of the model's performance:

CONCLUSION

THIS STUDY INTRODUCED AND EVALUATED A STACKED ENSEMBLE LEARNING APPROACH FOR THE ACCURATE CLASSIFICATION OF ACUTE LYMPHOBLASTIC LEUKEMIA (ALL) SUBTYPES USING PERIPHERAL BLOOD SMEAR IMAGES. BY COMBINING THE STRENGTHS OF DENSENET121, VGG16, AND VGG19, WE ACHIEVED ROBUST CLASSIFICATION PERFORMANCE.

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