

Report for Course Deep Learning 2024

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1. Approach

Diabetic Retinopathy, a diabetes-related complication, impacts the retina of the eye. Prolonged high blood sugar levels damage blood vessels, causing them to leak blood or fluid, leading to retinal swelling and blurred vision. In severe cases, it can result in permanent blindness [3].

Medical imaging often faces challenges with limited labeled datasets due to privacy, high annotation costs, and scarce expert knowledge [1] [6]. To address this, we use transfer learning with models like ResNet18, ResNet34, DenseNet201, VGG16, and EfficientNet, pre-trained on large datasets, to enhance performance on smaller ones. We approached diabetic retinopathy detection (DRT) in two ways:

- Using the DeepDRiD dataset, we applied pre-processing (e.g., augmentation, CLAHE, normalization), tuned models (ResNet34, ResNet18, VGG16, DenseNet201, EfficientNet), and enhanced performance with self-attention and spatial attention to evaluate pretrained models on a specific task shown in figure 1.
- Using the APTOS dataset, we fine-tuned ResNet34, DenseNet201, and EfficientNet by unfreezing pre-trained layers, further refined them on the DeepDRiD dataset, and applied ensemble methods (weighted, boosting, bagging) for improved results shown in figure 2.

2. Experiment and Discussion

2.1. Dataset

In this study, we utilized two distinct datasets for diabetic retinopathy detection. The first dataset, DeepDRiD (Diabetic Retinopathy Image Dataset), is a comprehensive resource designed to facilitate the diagnosis and grading of diabetic retinopathy [5]. It covers multiple stages: no apparent retinopathy, mild, moderate, severe, proliferative diabetic retinopathy (PDR), and cases where fundus images from both eyes are inadequate for assessment. The

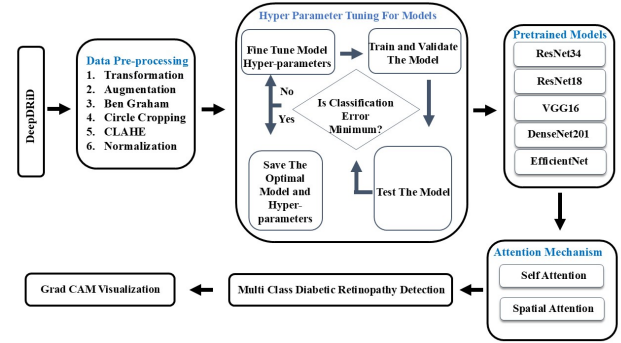


Figure 1. Diabetic Retinopathy Detection on DeepDRiD dataset

dataset contains 2,000 images, allocated as 1,200 for training, 400 for validation, and 400 for testing, collected from patients with diverse backgrounds. The images were captured under varying conditions, such as different camera angles and lighting environments. Each patient contributed four images—two from the left eye and two from the right eye—along with a detailed list of relevant features.

The second dataset, APTOS-2019 Blindness Detection, includes 3,662 samples obtained from participants in rural regions of India. These fundus photographs were taken under diverse environmental conditions over an extended timeframe. The dataset was curated by Aravind Eye Hospital, where a team of trained medical professionals labeled the images according to the International Clinical Diabetic Retinopathy Disease Severity Scale (ICDRSS).

2.2. Pre-trained Models with Transfer Learning

2.2.1 VGG16

The VGG (Visual Geometry Group) model is a widely recognized deep CNN architecture utilized for image recognition tasks. It comes in two main variants: VGG16 and VGG19, which consist of 16 and 19 layers, respectively. The architecture was initially trained on the ImageNet dataset, which contains over 14 million images spanning 1,000 distinct categories. Due to its remarkable perfor-

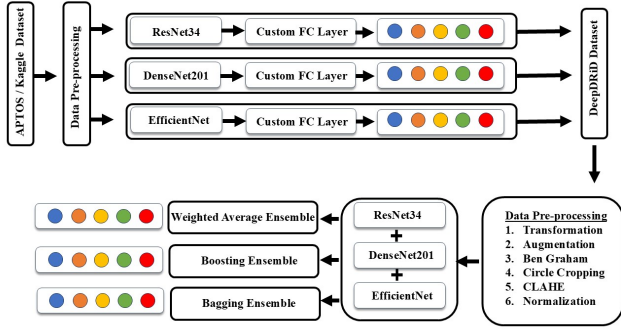


Figure 2. Diabetic Retinopathy Detection using Ensemble Learning

mance metrics, the pre-trained VGG16 model is extensively employed by researchers for image analysis across various applications. [4]

2.2.2 DenseNet201

The term "DenseNet" refers to a group of convolutional neural networks (CNNs) distinguished by their use of dense connections between layers. Variants within this family include DenseNet201 and DenseNet169. For instance, DenseNet201, when applied to process images with dimensions of 128×128 pixels, utilizes dense blocks that establish direct connections among all 201 layers. This design enables a seamless flow of information, allowing each layer to draw features from preceding layers while simultaneously passing its feature maps to subsequent layers, all while maintaining the network's feed-forward structure.

2.2.3 EfficientNet

The EfficientNet family includes eight models, from B0 to B7, offering improved accuracy with minimal increase in parameters. Unlike traditional CNNs, EfficientNet uses the Swish activation function instead of ReLU. Its core building block, MBConv, introduced in MobileNetV2, is more extensively utilized here due to a higher FLOPS budget. MBConv expands and compresses channels with direct connections between bottlenecks, reducing computation through depthwise separable convolutions. [2]

2.2.4 ResNet34

ResNet-34 is a convolutional neural network with 34 layers that is essential in a wide range of computer vision applications. Known as Residual Networks, ResNet has become a fundamental component in the design of neural networks. Originally presented in 2015, it has since evolved into a key tool in both academic research and commercial uses.

It is particularly valuable in fields like image recognition and medical research, where its deep learning features hold promise for diagnosing and treating various diseases.

2.3. Training

2.3.1 Task A

In this part, we utilized pre-trained Convolutional Neural Networks (CNNs) — ResNet38, VGG16, DenseNet201, and EfficientNet — to fine-tune their performance on the DeepDRiD dataset. Transfer learning was applied to these models using their ImageNet weights, and the fully connected layers were tailored for five-class diabetic retinopathy classification. To enhance model performance, we experimented with batch sizes of 24, learning rates of 0.001, and data augmentation techniques, as detailed in Table 1.

The highest Cohen Kappa scores were achieved using the optimal hyperparameters and augmentation strategies. Specifically, the best Kappa scores for ResNet38, VGG16, DenseNet201, and EfficientNet were 0.8170, 0.8547, 0.8127, and 0.8009, respectively.

Furthermore, Grad-CAM was employed to visualize the regions of importance identified by the models during classification. This method utilizes the gradients that flow into the final convolutional layer to produce a coarse localization map, highlighting critical areas in the input images that influence the predictions. The resulting heat maps provide insight into the model's focus during the decision-making process, as illustrated in Figure 4.

Table 1. Augmentation technique applied on DeepDRiD dataset.

Technique	Settings
Resize	(224, 224)
Random Horizontal Flip	p=0.5
Color Jitter	brightness=0.2, contrast=0.2, saturation=0.2, hue=0.1
Random Rotation	degrees=30
Random Affine	degrees=0, scale=(0.8, 1.2), translate=(0.1, 0.1)
Random Erasing	p=0.5, scale=(0.02, 0.1), ratio=(0.3, 3.3)
Normalize	mean=[0.5, 0.5, 0.5], std=[0.5, 0.5, 0.5]

2.3.2 Task B

In this part, we used five pre-trained models, namely VGG16, ResNet18, ResNet34, DenseNet121, and EfficientNet-B0. For image preprocessing, we applied CLAHE, Ben Graham transformation, image sharpening, Gaussian blur, random cropping, random rotation, random

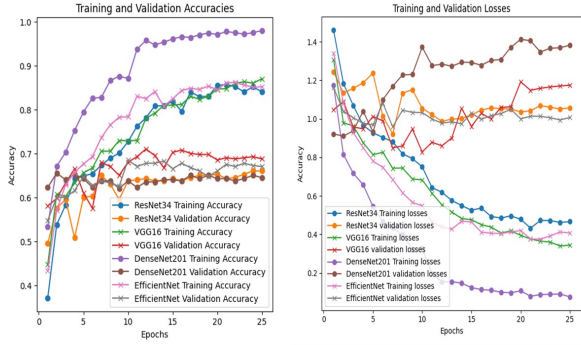


Figure 3. Training metrics of ResNet34, VGG16, DenseNet201, EfficientNet on DeepDRiD dataset

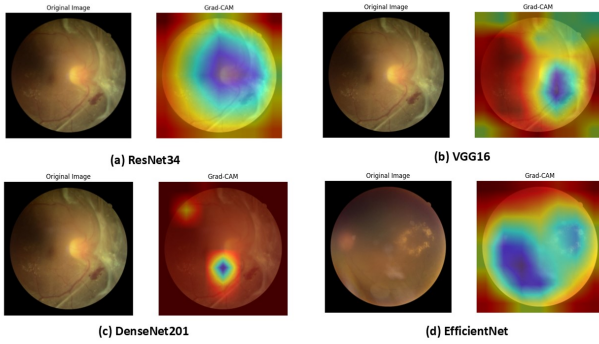


Figure 4. Grad-CAM visualization of ResNet34, VGG16, DenseNet201, EfficientNet on DeepDRiD dataset.

vertical flipping, random horizontal flipping, and color jitter.

The architecture of the VGG16 model is shown in Figure [2]. We trained this model using five preprocessing methods. Initially, we used the default preprocessing method provided in the template code. Then, we combined CLAHE and sharpening in one method, referred to as `custom_transform_train1`. Next, we used Ben Graham transformation and sharpening in another method, called `custom_transform_train2`. In `custom_transform_train3`, we applied both CLAHE and Ben Graham transformation. In `custom_transform_train4`, we combined CLAHE with the default method.

For `custom_transform_train1`, `custom_transform_train2`, and `custom_transform_train3`, the results were unsatisfactory due to class imbalance. The model performed well for the first class but poorly for the last class. However, when trained with the default augmentation method, the model performed significantly better. The training and validation accuracies and losses are shown in the figure below.

The architecture of ResNet18 is shown in Figure [2]. We loaded the pre-trained weights into the model and trained it on the DeepDRiD dataset. For this model, we used a learn-

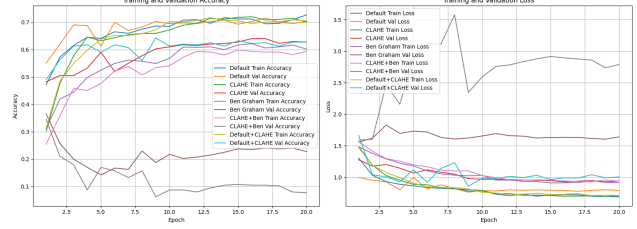


Figure 5. Training metrics of VGG16 using different augmentation techniques

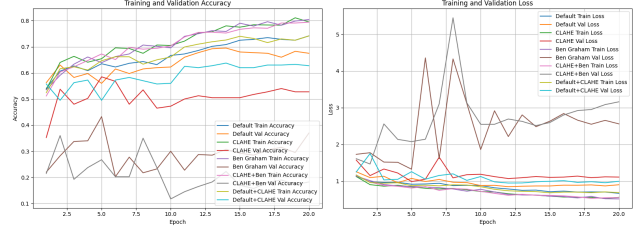


Figure 6. Training metrics of Resnet18 using different augmentation techniques

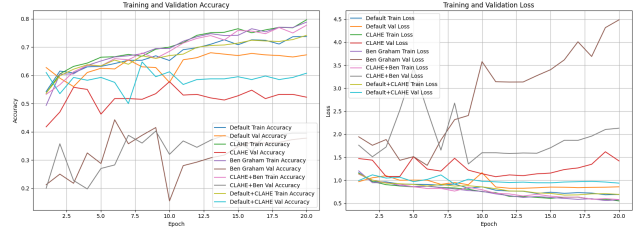


Figure 7. Training metrics of Resnet34 using different augmentation techniques

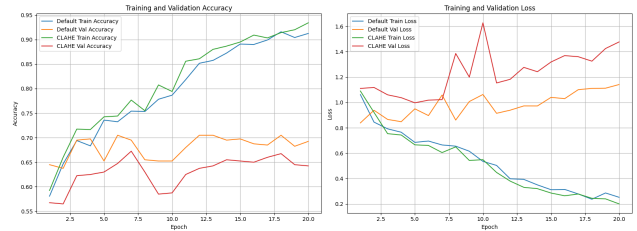


Figure 8. Training metrics of Efficientnet using different augmentation techniques

ing rate of 0.001 and a dropout rate of 0.35. We trained the model using all five augmentation methods. Among them, the most effective method was the EfficientNet method.

ResNet34, DenseNet121, and EfficientNet-B0 were trained in a similar manner using all the augmentation techniques.

Oversampling: There is a class imbalance in the dataset. We used an oversampling method to balance the dataset.

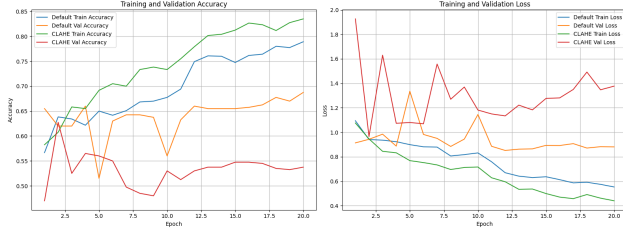


Figure 9. Training metrics of Densenet121 using different augmentation techniques

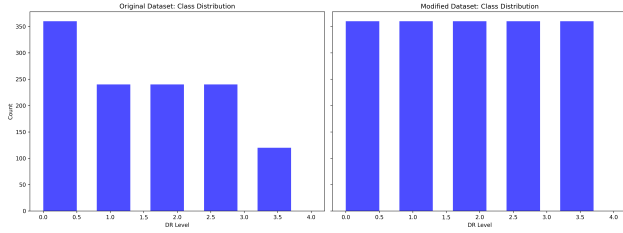


Figure 10. Class Distribution after oversampling

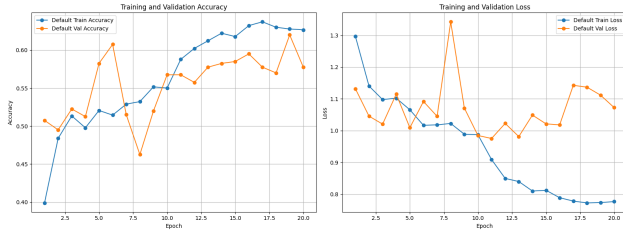


Figure 11. VGG16 training matrices—trained on oversampled data

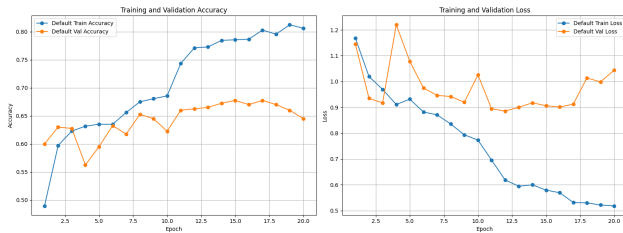


Figure 12. Resnet18 training matrices—trained on oversampled data

The number of samples per class is shown in . After oversampling, all classes had the same number of samples. While implementing the oversampling method, we sampled at the patient level rather than the individual image level. Class distribution after oversampling is given in figure-10.

When we trained the five models using the oversampled dataset, we obtained the following results in Figure - 11, 12, 13, 14 and 15.

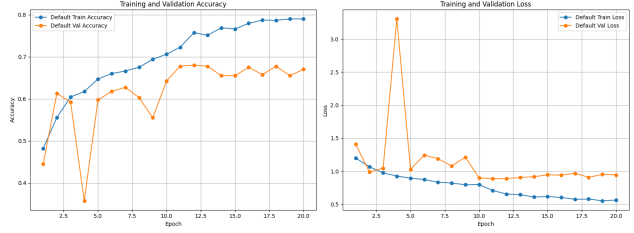


Figure 13. Resnet34 training matrices—trained on oversampled data

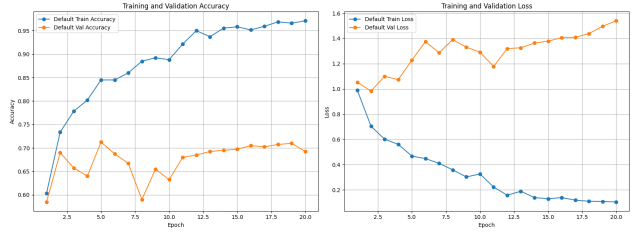


Figure 14. EfficientNet training matrices—trained on oversampled data

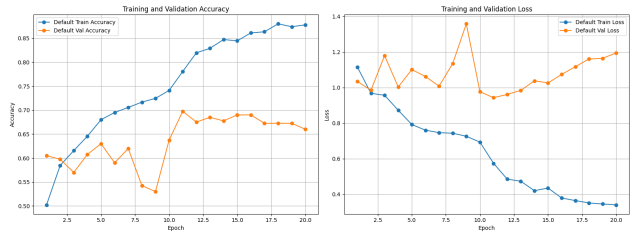


Figure 15. DenseNet training matrices—trained on oversampled data

2.3.3 Task C

In this part, we have applied self-attention and spatial attention mechanisms to ResNet34, VGG16, DenseNet201, and EfficientNet. Self-attention captures global dependencies, while spatial attention highlights key regions, enhancing feature representation, and improving the models' overall performance. For DenseNet201 by applying spatial attention mechanism has improved it overall best kappa from 0.8127 to 0.8494. However, for the other models, the attention mechanisms resulted in only marginal changes in kappa scores.

2.3.4 Task D

For this part, we used three pre-trained models: ResNet34, DenseNet121, and EfficientNet. We implemented three ensemble techniques: weighted average, bagging, and boosting.

Weighted Average: In this method, we assigned arbitrary

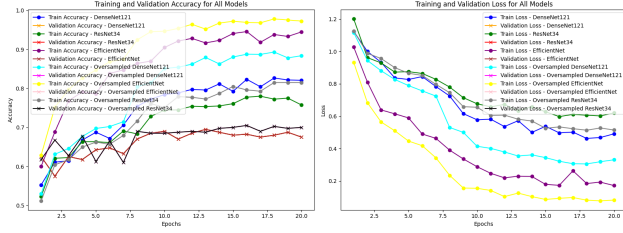


Figure 16. Training and Validation plots all models used in beg ensemble method

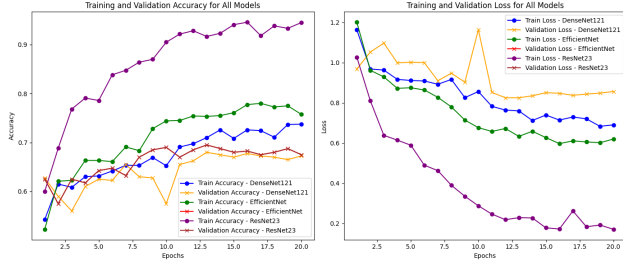


Figure 17. Training and Validation plots all models used in boost ensemble method

weights to each model during the testing phase. The predictions generated by each model were multiplied by their respective weights and summed up to produce the final prediction. This method improved the testing accuracy of the models when tested on Kaggle.

Bagging: In this method, we used bootstrapping to create multiple datasets and trained each model separately. During the aggregation phase, we used a majority voting method to generate the final predictions.

Boosting: For this method, the models were trained sequentially, with weights assigned to emphasize the data with higher errors. At the prediction stage, we applied a majority voting system for the final predictions.

3. Conclusion

In this project, we performed multistage diabetic retinopathy detection based on transfer learning using the available datasets of DeepDRiD and APTOS. For Task-A, we fine-tuned the ImageNet pre-trained CNN models of ResNet34, VGG16, DenseNet201, and EfficientNet. We tried different image augmentation techniques with hyperparameter tuning to boost the evaluation metrics. After training these models, we achieved the best kappa scores of 0.8170, 0.8548, 0.8127, and 0.8007, respectively. To further enhance the models' classification performance, we applied self-attention and spatial-attention mechanisms. However, the overall performance of the models did not show much improvement, except for the DenseNet201 model, where the kappa score improved from 0.8127 to 0.8494.

In Task-B, we used the 'Kaggle DR Resized' pretrained weights to train these models on the DeepDRiD dataset. We performed all the tests using different augmentation techniques together with sampled and unsampled data. From this task, we observed that EfficientNet, DenseNet, and ResNet18 had the best performance compared to VGG16 and ResNet34. We used CLAHE, Ben Graham transformation, image sharpening, and Gaussian blur. However, the default augmentation method achieved the highest score.

In Task-D, we used EfficientNet, DenseNet, and ResNet34 for ensembling. We tried weighted average, bagging, and boosting methods. The weighted average method achieved the highest score with 87.90% accuracy.

We used GradCAM for each model to visualize and understand where the model focuses on the image while making predictions. This technique helped identify the regions of the image that contributed the most to the model's decisions.

Contribution: Task A, Task C, Task E has been done by Md Rabiul Hasan and Task B, Task D and Task E has been done by Abu Taher.

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