

## TABLE OF CONTENTS

TABLE OF CONTENTS.....	2
LIST OF IMAGES.....	4
LIST OF TABLES.....	6
LIST OF EQUATIONS.....	7
ABSTRACT.....	8
CHAPTER I. INTRODUCTION.....	9
1.1. Research Background.....	9
1.2. Research Problem.....	11
1.3. Research Objective.....	11
1.4. Research Scope.....	12
1.5. Research Advantage.....	12
1.6. Research Schematic.....	13
CHAPTER II. LITERATURE REVIEW.....	14
CHAPTER III. FUNDAMENTAL THEORY.....	17
3.1. Diabetic Retinopathy.....	17
3.2. Deep Learning and Convolutional Neural Network (CNN).....	19
3.3. ResNet Architecture.....	21
3.4. Network Training Fundamentals.....	22
3.4.1. Parameters vs. Hyperparameters.....	22
3.4.2. Loss Function.....	23
3.4.3. Optimization Algorithms.....	23
3.4.4. Learning Rate.....	24
3.4.5. Batch Size and Epochs.....	24
3.5. Semantic Segmentation.....	25
3.6. U-Net.....	27
3.7. DeepLabV3.....	28
3.7.1. Atrous (Dilated) Convolution.....	29
3.7.2. Atrous Spatial Pyramid Pooling (ASPP).....	30
3.8. Evaluation Metrics.....	31
3.8.1. Pixel Accuracy (PA).....	31
3.8.2. Intersection over Union (IoU).....	32
3.8.3. Dice Coefficient (Dice).....	32
3.8.4. Precision and Recall.....	32
3.8.5. Area Under the Precision-Recall Curve (AUPR).....	34
CHAPTER IV. RESEARCH METHODOLOGY.....	35

4.1. Research Framework.....	35
4.2. Dataset Selection and Preparation.....	36
4.3. Data Preprocessing.....	37
4.4. Model Implementation.....	38
4.5. Training Process.....	38
4.6. Comparative Analysis and Evaluation.....	39
4.6.1. Quantitative Performance Assessment.....	39
4.6.2. Architectural and Qualitative Analysis.....	40
CHAPTER V. IMPLEMENTATION.....	42
5.1. Computing Environment.....	42
5.2. Software Implementation.....	43
5.2.1. Library Preparation and Dependencies.....	43
5.2.2. Hyperparameter Configuration.....	44
5.2.3. Image Preprocessing and Augmentation.....	44
5.2.4. Architecture Initialization and Checkpointing.....	45
5.2.5. Training Loop and Loss Calculation.....	46
5.2.6. Evaluation and Metric Calculation.....	47
5.2.7. Per-Class Precision-Recall (PR) Curve Comparison.....	48
5.2.8. Training and Validation Loss Monitoring.....	49
5.2.9. Per-Class Evaluation Scores.....	50
5.2.10. Qualitative Mask Visualization and Legend.....	51
CHAPTER VI. RESULTS AND DISCUSSION.....	52
6.1. Macro Performance Analysis.....	52
6.2. Comparative Analysis of Architectures.....	53
6.3. Per-Class Lesion Segmentation Performance.....	54
6.4. Computational Efficiency.....	55
6.5. Training Loss Convergence Analysis.....	55
6.6. Impact of Encoder Depth.....	56
6.7. Stability and Overfitting Assessment.....	57
6.8. Per-Class Precision-Recall Curve Analysis.....	57
6.9. Comparative Performance in Pathological Detection.....	60
6.10. Final Qualitative Results and Error Legends.....	61
CHAPTER VII. CONCLUSION AND RECOMMENDATIONS.....	63
7.1. Conclusion.....	63
7.2. Recommendations.....	64
REFERENCES.....	66

## LIST OF IMAGES

Figure 2.1 Showing severity level in DR classification.....	14
Figure 2.2 Showing sample annotated images in DR datasets: (top) image-level grading [Grade 0 to 4] (bottom) feature segmentation.....	15
Figure 3.1 Illustration of retinal image (in center) by highlighting normal structures (blood vessels, optic disc and fovea center) and abnormalities associated with DR: Enlarged regions (in left) MAs, and HEs and (in right) SEs, and EXs (Porwal et al., 2018).....	18
Figure 3.2 Overview of a typical CNN architecture (Munir et al., 2024).....	20
Figure 3.3 Shortcut connection within ResNet (He et al., 2015).....	22
Figure 3.4 Left: a building block for ResNet34. Right: a “bottleneck” building block for ResNet-50/101/152 (He et al., 2015).....	22
Figure 3.5 Evolution of object recognition or scene understanding from coarse-grained to fine-grained inference: classification, detection or localization, semantic segmentation, and instance segmentation (Garcia-Garcia et al., 2017).....	26
Figure 3.6 U-net architecture (Ronneberger et al., 2015).....	27
Figure 3.7 Different use of rates in atrous convolution with a kernel size of 3x3 (Chen et al., 2017).....	29
Figure 3.8 DeepLabV3 Architecture with ASPP (Chen et al., 2017).....	30
Figure 3.9 Example of AUPR measured using Positive Predictive Value (a.k.a. Precision) and Sensitivity (a.k.a. Recall) (Porwal et al., 2018).....	34
Figure 4.1 Flowchart of the Research Framework.....	35
Figure 4.2 Sample of DR with its lesions, top-left: original image, top-right: SE, middle-left: MAs, middle-right: HEs, bottom-left: EXs, bottom-right: Optic Disc.....	37
Figure 5.1 Showing libraries initialized for the code.....	44
Figure 5.2 Showing hyperparameters used for all the models.....	44
Figure 5.3 Augmentation includes contrast enhancement, flipping, rotating, and normalizing the images.....	45
Figure 5.4 Initializing models that were provided by the segmentation_models_pytorch library and creating model checkpointing.....	46
Figure 5.5 Showing the training implementation and loss per epoch.....	47
Figure 5.6 Showing evaluation metrics implementation.....	48
Figure 5.7 Showing the implementation of precision and recall curve calculations and the visualization of the curve.....	49
Figure 5.8 Showing implementation of loss logs saved into a csv and plotting them on a graph.....	50
Figure 5.9 Showing per-class evaluation metrics implementation.....	51
Figure 5.10 Showing implementation of segmentation mask visualization using different colors to indicate different samples.....	51
Figure 6.1 Showing the loss progression after each epoch.....	56

Figure 6.2 Showing PR Curves for every lesion performed by U-Net ResNet-50.....	58
Figure 6.3 Showing PR Curves for every lesion performed by U-Net ResNet-50.....	58
Figure 6.4 Showing PR Curves for every lesion performed by DeepLabV3 ResNet-50.....	59
Figure 6.5 Showing PR Curves for every lesion performed by DeepLabV3 ResNet-101.....	59
Figure 6.6 Showing Segmentation mask for all models indicated by the coloring.....	62
Figure 7.1 Sample retina scan from the APTOS 2019 dataset representing the proposed target for future generalization and classification testing.....	64

## LIST OF TABLES

Table 5.1 Showing the computing environment.....	42
Table 6.1 Showing the macro evaluation scores for every model.....	52
Table 6.2 Showing AUPR scores for every lesion type performed by each model.....	54
Table 6.3 Showing the loss difference from the first epoch with the last epoch.....	56

## LIST OF EQUATIONS

Equation 3.1 Showing formula of Pixel Accuracy.....	31
Equation 3.2 Showing formula of Intersection over Union.....	32
Equation 3.3 Showing formula of Dice coefficient.....	32
Equation 3.4 Showing formula of Recal.....	33
Equation 3.5 Showing formula of Precision.....	33