



**SKRIPSI**

**KLASIFIKASI TINGKAT KEPARAHAN RETINOPATI  
DIABETIK MENGGUNAKAN STACKING  
ENSEMBLE DENGAN EFFICIENTNET V2-S,  
RESNET50, DAN DENSENET121**

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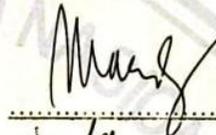
## LEMBAR PENGESAHAN

### KLASIFIKASI TINGKAT KEPARAHAN RETINOPATI DIABETIK MENGUNAKAN STACKING ENSEMBLE DENGAN EFFICIENTNET V2-S, RESNET50, DAN DENSENET121

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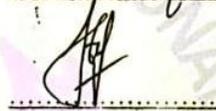
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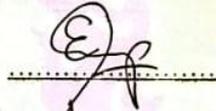
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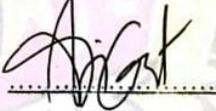
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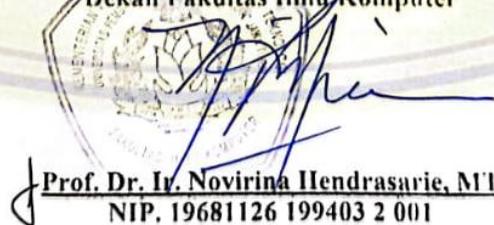
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## LEMBAR PERSETUJUAN

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RESNET50, DAN DENSENET121**

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dengan ini menyatakan bahwa isi sebagian maupun keseluruhan skripsi dengan judul:

**KLASIFIKASI TINGKAT KEPARAHAN RETINOPATI DIABETIK  
MENGUNAKAN STACKING ENSEMBLE DENGAN EFFICIENTNET V2-S,  
RESNET50, DAN DENSENET121**

adalah benar-benar hasil karya intelektual mandiri, diselesaikan tanpa menggunakan bahan-bahan yang tidak diizinkan dan bukan merupakan karya pihak lain yang saya akui sebagai karya sendiri. Semua referensi yang dikutip maupun dirujuk telah ditulis secara lengkap pada daftar pustaka. Apabila ternyata pernyataan ini tidak benar, saya bersedia menerima sanksi sesuai peraturan yang berlaku.



Surabaya, 08 Januari 2026  
Yang Membuat Pernyataan,



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## ABSTRAK

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Judul Skripsi : Klasifikasi tingkat keparahan Retinopati Diabetik menggunakan Stacking Ensemble dengan EfficientNet V2-S, ResNet50, dan DenseNet121  
Dosen Pembimbing : 1. Dr. Ir. I Gede Susrama Mas Diyasa, ST. MT. IPU  
2. Hendra Maulana, S.Kom., M.Kom

Retinopati diabetik merupakan komplikasi mikrovaskuler diabetes melitus yang dapat menyebabkan kebutaan permanen jika tidak terdeteksi dan ditangani secara dini. Deteksi manual memerlukan waktu lama dan terbatas pada ketersediaan tenaga ahli, sehingga sistem Computer-Aided Diagnosis (CAD) berbasis deep learning menjadi solusi penting untuk skrining massal. Penelitian ini bertujuan mengembangkan sistem klasifikasi tingkat keparahan Retinopati diabetik menggunakan Stacking Ensemble yang mengintegrasikan tiga arsitektur CNN pre-trained: EfficientNetV2-S, ResNet50, dan DenseNet121 sebagai base learners dengan Gradient Boosting Classifier sebagai meta-learner. Dataset merupakan gabungan dari APTOS 2019, IDRiD, dan Messidor-2 dengan total 5.922 citra fundus retina yang melalui tahap pra-pemrosesan ROI Extraction, Gamma correction, CLAHE, dan Resizing. Setiap base learner dilatih pada tiga skenario pembagian dataset (80:10:10, 70:15:15, dan 60:20:20) dengan tiga metode sampling (Random sampling, Undersampling, dan No Augmentation), menghasilkan total 36 model. Hasil evaluasi menunjukkan bahwa EfficientNetV2-S mencapai performa terbaik pada skenario 70:15:15 dengan Random sampling, mencapai akurasi 83,11%, Precision 0,8304, recall 0,8311, F1-Score 0,8289, dan QWK 0,9298. Metode Stacking Ensemble pada konfigurasi yang sama mencapai akurasi 82,78% dan QWK 0,9293. Penelitian ini membuktikan bahwa pendekatan Ensemble learning dengan meta-learner Gradient Boosting mampu mengatasi penurunan performa model saat jumlah Data latih berkurang. Hal ini dilakukan dengan memanfaatkan pola-pola yang saling melengkapi dari tiga arsitektur model yang digunakan.

**Kata kunci :** Klasifikasi, Retinopati Diabetik, Citra Fundus, Stacking Ensemble, Deep Learning

## ABSTRACT

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Thesis Title : Classification of Diabetic Retinopathy Severity Levels using Stacking Ensemble with EfficientNet V2-S, ResNet50, and DenseNet121  
Advisor : 1. Dr. Ir. I Gede Susrama Mas Diyasa, ST. MT. IPU  
2. Hendra Maulana, S.Kom., M.Kom

Diabetic retinopathy is a microvascular complication of diabetes mellitus that can cause permanent blindness if Not detected and treated early. Manual detection requires considerable time and is limited by the availability of expert personnel, making Computer-Aided Diagnosis (CAD) systems based on deep learning an important solution for mass screening. This research aims to develop a Diabetic retinopathy severity classification system using Stacking Ensemble that integrates three pre-trained CNN architectures: EfficientNetV2-S, ResNet50, and DenseNet121 as base learners with Gradient Boosting Classifier as the meta-learner. The dataset is a combination of APTOS 2019, IDRiD, and Messidor-2 with a total of 5,922 retinal fundus images that underwent preprocessing Stages of ROI Extraction, Gamma correction, CLAHE, and Resizing. Each base learner was trained on three dataset split scenarios (80:10:10, 70:15:15, and 60:20:20) with three sampling methods (Random sampling, Undersampling, and No Augmentation), resulting in a total of 36 models. Evaluation results show that EfficientNetV2-S achieved the best performance in the 70:15:15 scenario with Random sampling, achieving an Accuracy of 83.11%, Precision of 0.8304, recall of 0.8311, F1-Score of 0.8289, and QWK of 0.9298. The Stacking Ensemble method with the same configuration achieved an Accuracy of 82.78% and QWK of 0.9293. This research demonstrates that the Ensemble learning approach with Gradient Boosting meta-learner is capable of overcoming model performance degradation when the amount of training Data is reduced. This is achieved by leveraging complementary patterns from the three model architectures used.

**Keywords** : Classification, Diabetic Retinopathy, Fundus Image, Stacking Ensemble, Deep Learning

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## DAFTAR NOTASI

<b>Simbol/Singkatan</b>	<b>Keterangan</b>
<b>AI</b>	<i>Artificial Intelligence</i>
<b>APTOS</b>	<i>Asia Pacific Tele-Ophthalmology Society</i>
<b>BGR</b>	<i>Blue-Green-Red (format warna)</i>
<b>CAD</b>	<i>Computer-Aided Diagnosis</i>
<b>CLAHE</b>	<i>Contrast Limited Adaptive Histogram Equalization</i>
<b>CNN</b>	<i>Convolutional Neural Network</i>
<b>CORAL</b>	<i>Consistent Rank Logits</i>
<b>CORN</b>	<i>Conditional Ordinal Regression for Neural Networks</i>
<b>CSV</b>	<i>Comma-Separated Values</i>
<b>CUDA</b>	<i>Compute Unified Device Architecture</i>
<b>DDR</b>	<i>Diabetic Retinopathy Dataset</i>
<b>DME</b>	<i>Diabetic Macular Edema</i>
<b>DNN</b>	<i>Deep Neural Network</i>
<b>DR</b>	<i>Diabetic RetiNopathy</i>
<b>DRF</b>	<i>Distributed Random Forest</i>
<b>DRIVE</b>	<i>Digital Retinal Images for Vessel Extraction</i>
<b>DXA</b>	<i>Twentieths of a point (satuan pengukuran)</i>
<b>EHR</b>	<i>Electronic Health Record</i>
<b>FN</b>	<i>False Negative</i>

<b>Simbol/Singkatan</b>	<b>Keterangan</b>
<b>FP</b>	<i>False Positive</i>
<b>GB</b>	<i>Gradient Boosting</i>
<b>GLM</b>	<i>Generalized Linear Model</i>
<b>GPU</b>	<i>Graphics Processing Unit</i>
<b>HE</b>	<i>Hemorrhages</i>
<b>ICDR</b>	<i>Indian Diabetic Retinopathy</i>
<b>IDF</b>	<i>International Diabetes Federation</i>
<b>IDRiD</b>	<i>Indian Diabetic Retinopathy Image Dataset</i>
<b>IRMA</b>	<i>Intraretinal Microvascular Abnormalities</i>
<b>KNN</b>	<i>K-Nearest Neighbors</i>
<b>LUT</b>	<i>Look-Up Table</i>
<b>MA</b>	<i>Microaneurysms</i>
<b>NPDR</b>	<i>Non-Proliferative Diabetic Retinopathy</i>
<b>NVD</b>	<i>Neovascularization of the Disc</i>
<b>NVE</b>	<i>Neovascularization Elsewhere</i>
<b>OCT</b>	<i>Optical Coherence Tomography</i>
<b>PDR</b>	<i>Proliferative Diabetic Retinopathy</i>
<b>PNG</b>	<i>Portable Network Graphics</i>
<b>QWK</b>	<i>Quadratic Weighted Kappa</i>
<b>RAM</b>	<i>Random Access Memory</i>

<b>Simbol/Singkatan</b>	<b>Keterangan</b>
<b>RF</b>	<i>Random Forest</i>
<b>RGB</b>	<i>Red-Green-Blue</i>
<b>RMSE</b>	<i>Root Mean Square Error</i>
<b>ROI</b>	<i>Region of Interest</i>
<b>RTX</b>	<i>Ray Tracing Texel eXtreme (NVIDIA GPU)</i>
<b>SDGs</b>	<i>Sustainable Development Goals</i>
<b>SE</b>	<i>Squeeze-and-Excitation</i>
<b>SGD</b>	<i>Stochastic Gradient descent</i>
<b>SMOTE</b>	<i>Synthetic Minority Over-sampling Technique</i>
<b>SSD</b>	<i>Solid State Drive</i>
<b>SVM</b>	<i>Support Vector Machine</i>
<b>T1DM</b>	<i>Type 1 Diabetes Mellitus</i>
<b>T2DM</b>	<i>Type 2 Diabetes Mellitus</i>
<b>TIFF</b>	<i>Tagged Image File Format</i>
<b>TN</b>	<i>True Negative</i>
<b>TP</b>	<i>True Positive</i>
<b>VRAM</b>	<i>Video Random Access Memory</i>
<b>VTDR</b>	<i>Vision-Threatening Diabetic Retinopathy</i>