



***APPLICATION OF ALEXNET, EFFICIENTNETV2B0, AND  
VGG19 WITH EXPLAINABLE AI FOR CATARACT AND  
GLAUCOMA IMAGE CLASSIFICATION***

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Diajukan Sebagai Salah Satu Syarat  
untuk Memperoleh Gelar Sarjana Komputer pada  
Program Studi Sistem Informasi

Oleh:



**MUHAMMAD FAUZI FAYYAD**  
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**FAKULTAS SAINS DAN TEKNOLOGI**  
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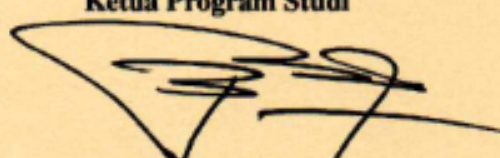
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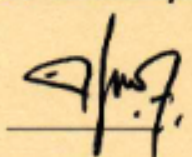

**DEWAN PENGUJI:**

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**Sekretaris : Mustakim, ST., M.Kom.**

**Anggota 1 : Dr. Rice Novita, S.Kom., M.Kom.**

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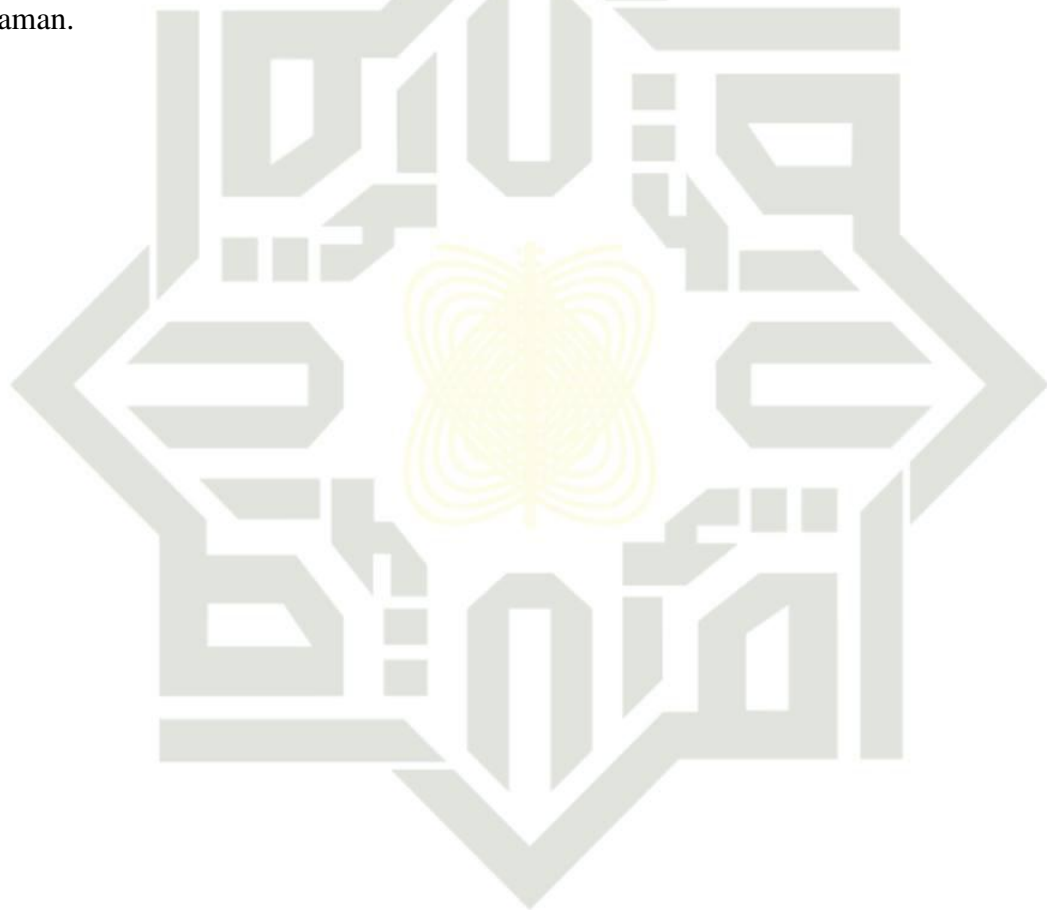
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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

*Dengan menyebut nama Allah yang maha pengasih lagi maha penyayang*

*Assalamu'alaikum Warahmatullahi Wabarakatuh*

*Alhamdulillah Rabbil 'Alamiin, segala puji bagi Allah Subhanahu Wa Ta'ala sebagai bentuk rasa syukur atas segala nikmat yang telah diberikan tanpa ada kekurangan sedikitpun. Shalawat beserta salam tak lupa pula kita ucapkan kepada Nabi Muhammad Shallallahu 'Alaihi Wa Sallam dengan mengucapkan "Al-lahumma Sholli'ala Sayyidina Muhammad Wa'ala Ali Sayyidina Muhammad". Semoga kita semua selalu senantiasa mendapat syafaat-Nya di dunia maupun di akhirat, aamiin ya rabbal'aalamiin.*

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*Wassalamu'alaikum Warahmatullahi Wabarakatuh*

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## KATA PENGANTAR

*Alhamdulillah Rabbil 'Alamin*, bersyukur kehadiran Allah *Subhanahu Wa Ta'ala* atas segala rahmat dan karunia-Nya sehingga peneliti dapat menyelesaikan Tugas Akhir ini. *Shalawat* serta salam kita ucapkan kepada Nabi Muhammad *Shalallahu 'Alaihi Wa Sallam* dengan mengucapkan *Allahumma Sholli'Ala Sayyidina Muhammad Wa'Ala Ali Sayyidina Muhammad*. Tugas Akhir ini dibuat sebagai salah satu syarat untuk mendapatkan gelar Sarjana Komputer di Program Studi Sistem Informasi Universitas Islam Negeri Sultan Syarif Kasim Riau.

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Bapak Dr. Hartono, M.Pd sebagai Dekan Fakultas Sains dan Teknologi.

Bapak Eki Saputra, S.Kom., M.Kom sebagai Ketua Program Studi Sistem Informasi.

4. Ibu Siti Monalisa, ST., M.Kom sebagai Sekretaris Program Studi Sistem Informasi.

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dapat peneliti amalkan dan menjadi amal jariyah.

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16. Keluarga besar Sistem Informasi 20 khususnya teman-teman dari SIF A Class, KKN Desa Kijang Rejo 2023, serta teman-teman seperbimbingan Tugas Akhir ini.
17. Kakak-kakak dan Abang-Abang Alumni Sistem Informasi yang memberikan ilmu dan bimbingan selama proses perkuliahan.
18. Semua pihak yang namanya tidak dapat disebutkan satu persatu, yang telah banyak membantu dalam pelaksanaan serta penyelesaian Tugas Akhir ini. Peneliti menyadari bahwa penulisan Tugas Akhir ini masih banyak terdapat kekurangan dan jauh dari kata sempurna. Untuk itu kritik dan saran yang membangun sangat diharapkan untuk kesempurnaan Tugas Akhir ini. Kritik dan saran atau pertanyaannya dapat diajukan *email* peneliti 12050314864@students.uin-suska.ac.id. Semoga laporan ini bermanfaat bagi kita semua. Akhir kata peneliti ucapkan terima kasih.

Pekanbaru, 26 Juni 2024

Peneliti,

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Dear Mr. Muhammad Fayyad:

Congratulations - We are pleased to inform you that your manuscript #1571024685 ('Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification') has now been ACCEPTED by 2024 International Electronics Symposium (IES).

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We, IES 2024 organizer, are now planning the detail program and will inform you in coming weeks the information related to IES 2024.

We look forward to seeing you in Bali, Indonesia, or joining us virtually, on August 6-8, 2024.

Sincerely Yours,

Regard,  
Akhdar Alimudin, Ph.D  
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\*pilih salah satu sesuai jenis karya tulis

# Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification

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**Abstract**—The rapid integration of Artificial Intelligence (AI) has significantly improved healthcare outcomes, especially in ophthalmology. However, Deep learning algorithms are often called to as 'black-box' models, making interpreting decision processes difficult. The Explainable AI approach helps understand AI model predictions by explaining the decision-making process based on features. The research objective is to find the best model for classifying eye disease images through experiments using AlexNet, EfficientNetV2, and VGG19 architectures. The selected best model will be analyzed using Grad-CAM, enhancing transparency and interpretability in healthcare AI models. This study employs multi-class classification using AlexNet, EfficientNetV2B0, and VGG19 architectures to classify cataract, glaucoma, and normal fundus. Different holdout-validation techniques (70:30, 80:20, 90:10) and optimization strategies (Adam, AdamW, RMSProp, SGDM) are studied for effective disease classification. The experimental results found that the best-performing model, EfficientNetV2B0 with holdout 90:10 and RMSProp optimizer, outperformed other models in accurately classifying fundus images. The model demonstrated strong performance with high recall, precision, F1-score of 0.8969, 0.8970, 0.8969, and an accuracy rate of 89.77%. Grad-CAM analysis also identified unique features of each eye disease class, for example, cataracts. AI model is capable of detecting cataract characteristics through the level of opacity in the eye lens, underscoring its robust classification capabilities in eye disease diagnosis.

**Keywords**—cataract, deep learning, glaucoma, grad-cam, XAI

## I. INTRODUCTION

Artificial Intelligence (AI), machine learning, and deep learning are transforming many areas of healthcare, especially ophthalmology. Deep learning, a subset of machine learning, shows promising potential for enhancing clinical examination outcomes [1], [2]. Computer-Aided Diagnosis (CAD) is one such application in healthcare [3], with Convolutional Neural Networks (CNN) being the prominent choice for image analysis [4]. CNNs demonstrate high prediction accuracy, but their analogy as 'black-box models' makes decision interpretation challenging [5], [6], [7]. This lack of transparency hinders user trust and credibility in the model's decisions [8], [9]. Enhancing transparency and explainability in CNN decision-making can improve trust levels among healthcare professionals [3], [10].

The Explainable Artificial Intelligence (XAI) approach aids in understanding AI model predictions by explaining the decision-making process based on features [11], [12]. Critical aspects of XAI include ease of use, validity, robustness,

computational cost, the necessity of fine-tuning, and open-source availability [6]. Gradient-weighted Class Activation Mapping (Grad-CAM) is an effective XAI technique that visually highlights image regions contributing to AI model decisions [12]. According to Velden et al., Grad-CAM meets all critical aspects of XAI better than other methods [6]. Using XAI can assist in the decision-making process of AI models [13]. the impacts of eye diseases on eye health must be considered.

The eye is a sensory organ that transmits visual stimuli to the brain [14]. Among the numerous eye diseases, cataracts and glaucoma are the significant causes of blindness [15], [16]. Cataract is characterised by the opacity of the lens [17]. Meanwhile glaucoma is attributed to the gradual degeneration of retinal ganglion cells, resulting in optic nerve damage [18], [19]. Cataracts are associated with glaucoma. Both diseases tend to appear with the aging process [20], [21] and are correlated with some aetiological and iatrogenic factors [22].

The World Health Organization (WHO) reports that over two billion people globally suffer from near or distant visual impairment and one billion experiencing visual impairment from cataracts (94 million) and glaucoma (7.7 million) [23]. In Indonesia, the recent RAAB survey (2014-2016) found untreated cataracts as the primary cause of blindness and visual impairment in those over 50, accounting for 77.7% of cases [24]. The shortage of ophthalmologists, with only one doctor per 1000 people in 45% of WHO member countries, is a significant concern [1]. In 2019, Indonesia had 1152 ophthalmologists [25], far below the recommended ratio of 1:250000 population according to The Roadmap for Overcoming Visual Impairment in Indonesia 2017-2030 by the Indonesian Ministry of Health [26]. It puts pressure on doctors, impacting the quality and accessibility of eye care services.

Previous research by Arias-Serrano et al. (2023) achieved 92.06% accuracy in glaucoma and diabetic retinopathy detection using AlexNet with SGDM optimizer [27]. Imran et al. (2020) achieved 95.65% accuracy in cataract classification using an ensemble of CNN architectures and SVM [28]. De Zarzà et al. (2022) obtained F1-Scores of 96.6 (EfficientNet-B0) and 95.7 (EfficientNetV2-B3) in binary glaucoma detection with EfficientNet and Adam optimizer [29]. Gomez-Valverde et al. (2019) reported VGG19 with transfer learning as the best model for glaucoma and normal fundus classification, achieving a sensitivity of 87.01%, and specificity of 89.01% [18]. Junayed et al. (2021) developed

CataractNet for binary classification of cataracts and normal disease, outperforming Inception-V3, MobileNet, ResNet-50, VGG16, and VGG19 with an accuracy of 99.13% and f1-score of 99.07%[30].

Based on previous research described by the authors, many studies only perform binary classification. Therefore the authors propose modeling AlexNet, EfficientNetV2B0 and VGG19 with multi-class classification consisting of 3 classes namely cataract, glaucoma and normal. It implements a diverse range of Holdout-Validation techniques, including splits like 70:30, 80:20, and 90:10, to assess model robustness across different data partitions. Furthermore, it delves into the impact of multiple optimizers such as Adam, Adam with Weight Decay (AdamW), RMSProp and Stochastic Gradient Descent with Momentum (SGDM) on model performance, aiming to identify the most effective optimization strategies for accurate disease classification. This research uses Google Colab Pro and Python programming with Tesla T4 GPU.

## II. RESEARCH METHODOLOGY

A flowchart depicts the procedural framework outlining the research process from data collection to interpreting AI models for eye disease diagnosis. It aims to establish a clear structure and direction to achieve the stated objectives. Figure 1 illustrates the sequential stages of this research

### A. Data Collection

The dataset of fundus images was collected from a publicly available dataset on Kaggle called eye disease classification [31]. The dataset contains four labels: cataract, glaucoma, normal, and diabetic retinopathy. However, due to unique severity levels associated with diabetic retinopathy, only the cataract, glaucoma, and normal labels were used in this study. Previous research has classified diabetic retinopathy into five severity levels, ranging from 0 to 4 [4], [32]. This dataset consists of 3119 eye image data, with 1007 glaucoma eyes, 1038 cataract eyes, and 1074 normal eyes. The visualization of dataset images used in this research is depicted in Figure 2.

### B. Data Preprocessing

The preprocessing of fundus images involves two key steps, image normalization and augmentation. Image normalization adjusts pixel values to a standardized range between 0 and 1 [28], [33]. This process provides faster convergence during training and improves overall model generalization [34]. Moreover, image data augmentation is aimed at adding variation to the dataset while preserving essential image features [28], [35], [36], [37].

### C. Holdout Method

Holdout is a popular method for evaluating machine learning models [38]. It entails dividing the data into two sets: the testing and the training datasets [38], [39]. In this research, the holdout data division is based on ratios of 70:30, 80:20, and 90:10. This method is chosen for its simplicity and ability to provide less biased model estimation than other techniques[38].

### D. AlexNet

The AlexNet architecture was the pioneer of CNN algorithm introduced during the ImageNet Challenge competition in 2012 [35]. It is structured with 8 layers, including 5 convolutional layers and 3 fully-connected layers [40]. AlexNet introduced two significant innovations, using

the ReLU activation function and the inclusion of dropout layers to mitigate overfitting risks commonly encountered in deep learning architectures [35].



Fig. 1. Research Methodology



Fig. 2. Eye Fundus Images Dataset Visualization

### E. EfficientNetV2B0

EfficientNetV2 is a CNN architecture designed to improve training speed and parameter efficiency [32], [41], [42]. It is an enhanced version of EfficientNetV1, achieving accelerated model training through the utilization of Fused-MBConv and MBConv blocks [42]. The MBConv layer is the foundational structure of MobileNetV2 based on the inverted residual blocks [41]. EfficientNetV2 comprises 44 layers, consisting of 1 convolution layer, 10 Fused-MBConv layers, 30 MBConv layers, 1 convolution layer with max pool 2x2 layer and 1 fully-connected layer [42].

### F. VGG19

The VGG19 architecture was developed in 2014 by researchers at the Oxford Visual Geometry Group [4], [35]. The primary difference between VGG16 and VGG19 is the number of convolution layers; VGG16 comprises 16 convolution layers, while VGG19 incorporates 19 convolution layers [4]. The advantage of VGG19 lies in its sequential block design, where convolution layers are arranged in a sequential manner to minimize spatial information loss [4]. VGG19 consists of 19 layers, including 16 convolutional layers and 2 fully-connected layers [43].

### G. Optimizers

The optimizer is crucial in increasing the model's accuracy [44]. Its main task is updating the weights to reduce the loss function's value [44], [45]. Optimizers significantly impact convergence during training, particularly in transfer learning settings [4]. The optimizers applied in this research are Adam, SGDM, RMSProp and AdamW.

## H. Evaluation Metrics

According to Nauta et al. (2023), evaluation metrics are used to estimate the performance of predictive models [46]. Furthermore, the models will be evaluated with the confusion matrix technique. The confusion matrix provides insights into the classifier's performance on the designated testing dataset [47]. Moreover, the efficiency of the modeling process will be estimated based on the duration of model training. The performance evaluation of classification models can be calculated using various metrics, such as accuracy, precision, recall, and F1-score, which can be formulated using the Eq. (1), Eq. (2), Eq. (3), and Eq. (4) [14], [35], [48], [49]:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

$$F1\ Score = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (4)$$

Accuracy validates correct model classifications [28], [35]. Precision measures true positive predictions out of actual positive instances [28], while recall quantifies correctly classified data with true positive values [28]. F1-score represents the harmonic mean of precision and recall [35].

### I. Grad-CAM

The Grad-CAM method is an advancement of the original Class Activation Mapping (CAM) method [11]. Also, it is a saliency method that calculates the sensitivity level based on gradient [9]. This procedure generates weighted gradient activation maps using the gradient concept as it progresses towards the last convolutional layer [3]. According to Velden et al, Grad-CAM complies with all the important aspects of the XAI approach when compared to other XAI approaches [6]. Eq. (5) and Eq. (6) define the Grad-CAM process [5]:

$$w_k^c = \frac{1}{s} \sum_i \sum_j \frac{\partial y^c}{\partial A_{ij}^k} \quad (5)$$

$$L_{Grad-CAM}^c = \sigma(w_k^c * A^k) \quad (6)$$

## III. RESULTS AND DISCUSSION

Based on the data collection phase, the total data for the three classes is 3119 fundus images. In the deep learning framework, the dataset is separated into three parts: training, validation and testing. Furthermore, data division was performed using the holdout technique with ratios of 70:30, 80:20, and 90:10, detailed in Table I.

Afterward, the data preprocessing process starts with image normalization. Followed by augmentation to enrich data diversity. In this research, two transformation techniques were used: rotating the images by 45° and flipping the images vertically. The composition of augmentation data described in Table II, the data augmentation process began by rotating the images by 45 degrees. Next the images were flipped vertically, these transformations were applied to both the original training data and the 45-degree rotated images. Finally, the results from all four sources the original training data, 45-degree rotated images, vertically flipped images, and

combined 45-degree rotated and vertically flipped images were merged. Furthermore, the detailed hyperparameter settings for the CNN architecture modelling process are provided in Table III.

The models will then be evaluated using the confusion matrix technique described in Table IV, V and VI. In Table IV, AlexNet's precision, recall, and F1-score averaged 0.7764 at holdout ratios of 70:30 and 80:20 but improved to 0.8300 using holdout 90:10. Table V shows VGG19's consistent performance at 0.8450 across all optimizers, with optimal results using the Adam optimizer and holdout 90:10.

TABLE I. DATASET DISTRIBUTION USING HOLDOUT TECHNIQUES

Holdout	Class	80:20		Data Testing
		Data Training	Data Validation	
70:30	Cataract	580	146	312
	Glaucoma	563	141	303
	Normal	600	151	323
80:20	Cataract	664	166	208
	Glaucoma	644	161	202
	Normal	687	172	215
90:10	Cataract	747	187	104
	Glaucoma	724	182	101
	Normal	772	194	108

TABLE II. AUGMENTATION COMPOSITION ON TRAINING DATASET

Holdout	Class	Before Augmentation	After Augmentation	Total
70:30	Cataract	580	2320	6972
	Glaucoma	563	2252	
	Normal	600	2400	
80:20	Cataract	664	2656	7980
	Glaucoma	644	2576	
	Normal	687	2748	
90:10	Cataract	747	2988	8972
	Glaucoma	724	2896	
	Normal	772	3088	

TABLE III. HYPERPARAMETER SETTINGS

Parameter Name	Parameter Setting	Value
Adam	Learning rate	0.0001
AdamW	Learning rate	0.0001
	Weight decay	0.0001
RMSProp	Learning rate	0.0001
SGDM	Learning rate	0.0001
	Momentum	0.99
	Nesterov momentum	True
EarlyStopping	Patience	10
ModelCheckpoint	Save best only	True
	Save weights only	True
ReduceLROnPlateau	Factor	0.3
	Patience	4
	Min_lr	0.00001

TABLE IV. PERFORMANCE EVALUATION OF ALEXNET ARCHITECTURES

Holdout	Optimizers	Recall	Precision	F1-Score
70:30	RMSProp	0.7872	0.7857	0.7855
	SGDM	0.7909	0.7914	0.7905
	Adam	0.7882	0.7879	0.7879
	AdamW	0.7894	0.7885	0.7888
80:20	RMSProp	0.7806	0.7854	0.7801
	SGDM	0.7777	0.7820	0.7778

Holdout	Optimizers	Recall	Precision	F1-Score
90:10	Adam	0.7822	0.7869	0.7817
	AdamW	0.7775	0.7824	0.7775
	RMSProp	0.8293	0.8332	0.8297
	SGDM	0.8264	0.8268	0.8261
	Adam	0.8304	0.8297	0.8299
	AdamW	<b>0.8331</b>	<b>0.8331</b>	<b>0.8329</b>

TABLE V. PERFORMANCE EVALUATION OF VGG19 ARCHITECTURES

Holdout	Optimizers	Recall	Precision	F1-Score
70:30	RMSProp	0.8404	0.8394	0.8390
	SGDM	0.8386	0.8392	0.8373
	Adam	0.8398	0.8406	0.8385
	AdamW	0.8496	0.8500	0.8483
80:20	RMSProp	0.8549	0.8563	0.8551
	SGDM	0.8485	0.8494	0.8485
	Adam	0.8501	0.8514	0.8503
	AdamW	0.8514	0.8550	0.8518
90:10	RMSProp	0.8482	0.8534	0.8504
	SGDM	0.8452	0.8460	0.8445
	Adam	<b>0.8772</b>	<b>0.8795</b>	<b>0.8773</b>
	AdamW	0.8546	0.8571	0.8538

TABLE VI. PERFORMANCE EVALUATION OF EFFICIENTNETV2B0 ARCHITECTURE

Holdout	Optimizers	Recall	Precision	F1-Score
70:30	RMSProp	0.8746	0.8749	0.8748
	SGDM	0.8852	0.8855	0.8852
	Adam	0.8836	0.8840	0.8837
	AdamW	0.8857	0.8855	0.8856
80:20	RMSProp	0.8731	0.8761	0.8740
	SGDM	0.8807	0.8821	0.8811
	Adam	0.8774	0.8807	0.8782
	AdamW	0.8826	0.8856	0.8835
90:10	RMSProp	<b>0.8969</b>	<b>0.8970</b>	<b>0.8969</b>
	SGDM	0.8875	0.8878	0.8876
	Adam	0.8869	0.8874	0.8865
	AdamW	0.8937	0.8944	0.8939

Table VI demonstrates EfficientNetV2B0's excellent performance at 0.8833, outperforming other models. The best model is EfficientNetV2B0 with RMSProp and holdout 90:10, which attains recall, precision, and f1-score of 0.8969, 0.8970, and 0.8969. These results show the importance of data distribution in model evaluation

In Table VII, model training times are presented. AlexNet had the shortest training time due to its simpler CNN layer structure. EfficientNetV2B0 trained efficiently with holdout 70:30 using RMSProp, completing training in 3409.674 seconds. Comparatively, the best model, EfficientNetV2B0 with holdout ratio 90:10 using RMSProp, took a total of 6045.734 seconds, indicating an additional 2636.06 seconds compared to the 70:30 Holdout ratio, 1.77 times longer duration for training.

TABLE VII. TRAINING TIME DURATION OF CNN ARCHITECTURES

Model	Optimizer	Training Time (s)		
		70:30	80:20	90:10
AlexNet	RMSProp	3793.204	5678.458	5945.515
	SGDM	3124.730	5714.298	6114.709
	Adam	3707.632	4664.140	5845.171
	AdamW	<b>2499.415</b>	5150.772	4360.151

Model	Optimizer	Training Time (s)		
		70:30	80:20	90:10
VGG19	RMSProp	5603.105	6194.264	6384.201
	SGDM	5970.255	6377.984	6495.860
	Adam	3426.189	5637.703	6377.040
	AdamW	4660.264	5751.001	6485.122
EfficientNetV2B0	RMSProp	<b>3409.674</b>	5907.824	<b>6045.734</b>
	SGDM	5602.670	6045.904	6105.276
	Adam	3692.476	5482.753	6270.904
	AdamW	3612.532	5810.205	5856.201

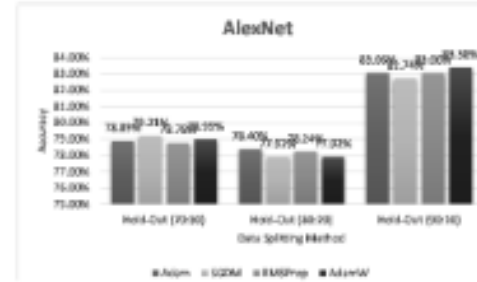


Fig. 3. Accuracy Bar Chart of AlexNet Variants

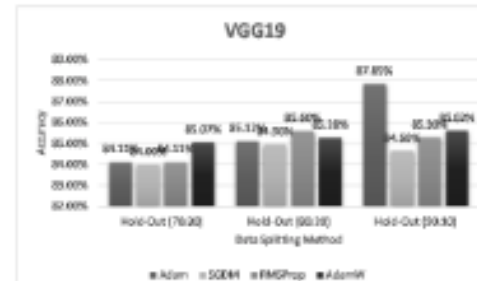


Fig. 4. Accuracy Bar Chart of VGG19 Variants

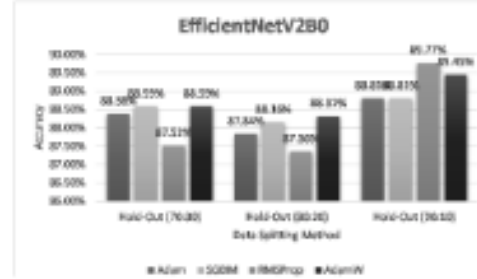


Fig. 5. Accuracy Bar Chart of EfficientNetV2B0 Variants

The evaluation results of deep learning modelling, assessed using accuracy metrics, are depicted in Figures 3, 4, and 5. Figure 5 specifically illustrates the outcomes of the EfficientNetV2B0 experiment, revealing that the optimal model was achieved using the holdout 90:10 and the RMSProp optimizer, with an accuracy of 89.77%.

Moreover, Figure 6 explains the confusion matrix analysis of EfficientNetV2B0 using the holdout 90:10 and RMSProp optimizer, revealing notable discrepancies in performance across different classes. The model demonstrates high performance for cataract and normal cases, it shows lower performance in identifying glaucoma cases, with 10 cases (9.90%) misclassified as normal and 6 cases (5.94%) misclassified as cataract. Moreover, The model classification performance of each class measured by Recall values are

84.16% for glaucoma, 93.27% for cataract, and 91.67% for Normal.

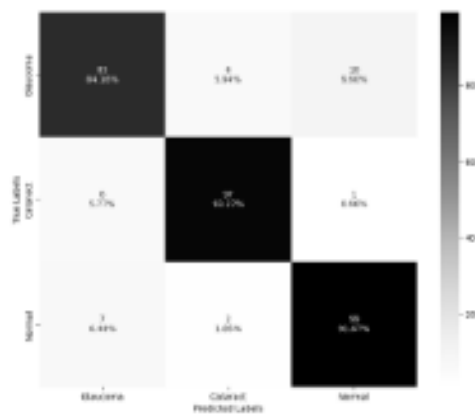


Fig. 6. Confusion Matrix of EfficientNetV2B0 with RMSProp.

Furthermore, We implement the EfficientNetV2B0 as the best model with an XAI approach. Using Grad-CAM for explainability, we identify critical areas for diagnosing cataracts, glaucoma, and normal eye conditions. A method for evaluating XAI techniques is required to assess the quality of AI interpretation. We used a function-based evaluation method, which assesses explanation quality without human assistance, but with validated proxies [6], [9]. These proxies might encompass metrics confirmed by human users [6]. Firstly, we sought validated proxies from previous research that are relevant to cataracts and glaucoma. Subsequently, we identified several studies that define validated proxies from reputable sources as the standard for evaluating XAI [17], [16], [18]. We then applied these proxies to evaluate the model using an XAI approach.

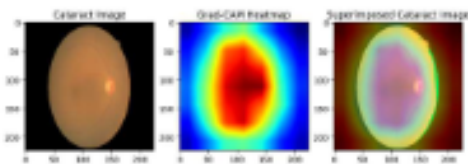


Fig. 7. Explainable Cataract Region Analysis

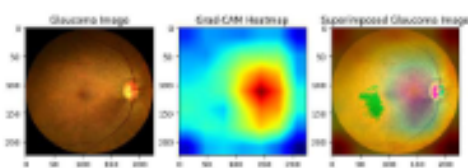


Fig. 8. Explainable Glaucoma Region Analysis

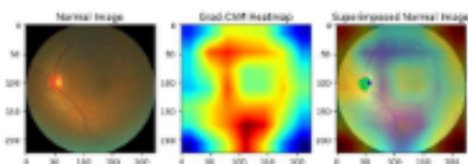


Fig. 9. Explainable Normal Region Analysis

Figures 7, 8, and 9 demonstrate the critical areas for diagnosis highlighted by our XAI techniques. These regions, marked in red on the Grad-CAM heatmap correspond to areas of interest identified for cataract, glaucoma, and normal eye conditions, respectively. The superimposed image is a

composite image created by overlaying the Grad-CAM heatmap onto the original class image. This superimposition serves important purposes in our XAI approach namely visual clarity, contextual relevance, and enhanced interpretability. The superimposed heatmaps highlight regions of the fundus images that are critical for diagnosis.

Tongren Hospital introduced a direct method for cataract detection, estimating opacity in fundus images [17]. In Figure 7, the AI model demonstrates its ability to identify cataracts by analysing the blurriness in fundus images, aligning with these critical features for cataract detection. Moreover, to diagnose glaucoma involves assessing cupping changes in fundus images, measured by the Cup-to-Disk Ratio (CDR) and Reduction in the Neuro-Retinal Rim (NRR) [16]. First, The value of CDR is 0.3 for a healthy eye, 0.4 to 0.7 for mild glaucoma, and above 0.7 for moderate/severe glaucoma [16]. Second, The NRR area refers to the region between the Optic Disc (OD) and the Optic Cup (OC) [16]. It is verified with Inferior being thicker than Superior, thicker than Nasal, and thicker than Temporal, known as the ISNT Rule [16], [18]. The thickness levels in each region of the NRR area should follow a decreasing order, as seen in Eq. (7) [16]:

$$I > S > N > T \quad (7)$$

In Figure 8, the AI model focuses on the enlarged OC area, implying a high CDR value. This can be observed through the superimposed glaucoma image, which highlights the OC and OD areas, with OC marked in red and enlarged. The method to determine the ISNT size in the eye is as follows: Inferior is located below the OC, Superior is above the OC, Nasal is to the right of the OC, and Temporal is to the left of the OC. Referring to these ISNT rules, the inferior region below the OC appears smaller, contradicting the ISNT rule. This observations underscore the AI model's capacity to discern intricate features crucial for detecting glaucoma. In Figure 9, the AI model annotates the OC is smaller compared to the OD, along with the NRR area adhering to the ISNT Rule, signifying a healthy eye. In addition, the model recognizes other features like arteries and veins since these elements are prominently visible in the normal fundus image.

#### IV. CONCLUSION

From the findings of the research experiment, the AlexNet, EfficientNetV2B0, and VGG19 architectures work effectively in classifying images of cataract and glaucoma eye diseases. The data distribution technique significantly affects model evaluation, emphasizing the advantages of using larger training datasets. Among these architectures, the best-performing model obtained EfficientNetV2B0 with holdout 90:10 and RMSProp. It attained a recall, precision, f1-score of 0.8969, 0.8970, 0.8969, an accuracy of 89.77%, and a training time of 6045.734 seconds. Moreover, the best model identifies unique features for each eye disease class using Grad-CAM analysis, indicating strong performance in eye disease classification.

Future research should focus the accuracy and reliability of eye disease classification models by exploring ensemble techniques like CNN stacking and incorporating robust architectures such as XGBoost, LightGBM, and CatBoost in the final classification layer. We can also using high-quality hospital datasets and advanced healthcare equipment to improve model generalization and clinical applicability. Additionally, implementing preprocessing techniques like

Adaptive Histogram Equalization (AHE), Contrast Limited Adaptive Histogram Equalization (CLAHE), and Vessel Segmentation are beneficial for enhancing image quality and facilitating precise feature extraction.

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## LAMPIRAN A

### HASIL WAWANCARA

Wawancara dilakukan pada tanggal 3 Mei 2024 di Poli Mata Rumah Sakit Umum Daerah (RSUD) Arifin Achmad Provinsi Riau kepada salah satu dokter spesialis mata dengan profil sebagai berikut :

Nama: dr. Yulia Wardany, Sp.M

Riwayat Pendidikan:

- Pendidikan Kedokteran Umum Universitas Diponegoro, Tahun 2005.
- Pendidikan Spesialis Mata Universitas Gadjah Mada, Tahun 2015.

Pengalaman Praktek: 9 Tahun

Transkrip wawancara:

1. Penyakit apa yang sering dialami pasien? Dan keluhan seperti apa yang sering disampaikan pasien?

Jawab: Kelainan refraksi, rabun jauh, rabun dekat, infeksi, katarak, diabetik retinopati, dan glaukoma.

2. Pasien usia berapa yang sering berobat ke poli mata dan biasanya mengidap penyakit apa?

Jawab: Bervariasi tergantung kasus penyakit yang diidap pasien.

3. Apa itu penyakit Katarak dan Glaukoma?

Jawab:

Katarak: Penurunan tajamnya penglihatan di bagian media refraktor, harus dibersihkan media refraktornya dengan lensa buatan.

Glaukoma: Kerusakan syaraf sehingga tidak dapat disembuhkan.

4. Apa saja gejala/ciri-ciri penderita penyakit Katarak dan Glaukoma?

Jawab:

Gejala-gejala pasien penderita penyakit katarak:

- Penglihatan kabur seperti melihat di dalam asap/kabut
- Terjadi pada pasien berusia tua
- Mata tidak merah dan tidak nyeri

Gejala-gejala pasien penderita penyakit Glaukoma:

- Penglihatan kabur seperti melihat di dalam terowongan (sempit)



- Umum terjadi pada pasien berusia 40 tahun ke atas
- Mata terang

Glaukoma akut: Mata merah dan tidak bisa menggunakan foto fundus (penyakit berat)

Bagaimana cara dokter melakukan diagnosis bahwa penyakit yang dialami pasien adalah Glaukoma dan Katarak?

Jawab:

Cara diagnosis pasien pengidap penyakit katarak:

- Mengukur ketajaman penglihatan mata menggunakan Snellen Chart
- Melihat struktur bola mata (Slit-lamp)
- Mengukur lensa buatan (IOL Master)

Cara diagnosis pasien pengidap penyakit Glaukoma:

- Mengukur ketajaman penglihatan mata menggunakan Snellen Chart
- Melihat struktur bola mata (Slit-lamp)
- Melihat citra fundus retina (DRS Non-Mydriatic Digital Fundus Camera)

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## LAMPIRAN B

### FOTO DOKUMENTASI

#### B.1 Dokumentasi Wawancara Kepada Dokter



#### B.2 Dokumentasi Alat Digital Fundus Camera



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## LAMPIRAN C

## SURAT PENGANTAR IZIN ETIK PENELITIAN



UIN SUSKA RIAU

KEMENTERIAN AGAMA REPUBLIK INDONESIA  
UNIVERSITAS ISLAM NEGERI SULTAN SYARIF KASIM RIAU  
FAKULTAS SAINS DAN TEKNOLOGI

كلية العلوم و التكنولوجيا

FACULTY OF SCIENCES AND TECHNOLOGY

Jl. H.R. Soebrandas No. 155 KM. 15 Tuah Madani - Pekanbaru 28293 PO.Box. 1004 Telp.(0761) 589026 - 589027  
Fax. (0761) 589 025 Web. www.uin-suska.ac.id, Email : faste@uin-suska.ac.id

Nomor : B- 10539 /F.V/PP.00.9/ 11/2023  
Sifat : Penting  
Hal : Permohonan Pengantar Izin Etik Penelitian

Pekanbaru, 16 November 2023

Kepada Yth.  
Pimpinan Sekolah Tinggi Ilmu Kesehatan  
Payung Negeri Pekanbaru  
Jl. Tamtama No.6 Labuh Baru, Pekanbaru

*Assalamu 'alaikum Wr. Wb.*

Dengan hormat, sehubungan telah dimulainya mata kuliah Tugas Akhir pada Fakultas Sains dan Teknologi UIN Suska Riau, Kami bermaksud mengirimkan mahasiswa :

Nama : Muhammad Fauzi Fayyad  
NIM : 12050314864  
Fakultas : Sains dan Teknologi  
Program Studi / Smt : Sistim Informasi/7  
No. HP / E-mail : 08127607065/12050314864@students.uin-suska.ac.id

untuk pengambilan data yang sangat dibutuhkan dalam Tugas Akhir mahasiswa tersebut yang berjudul "**Penerapan Arsitektur Deep Learning Alex Net, VGG19 dan EfficientNetV2 Untuk Klasifikasi Citra Penyakit Katarak dan Glaukoma**". Kami mohon kiranya Saudara berkenan memberikan **pengantar izin etik penelitian ke Rumah Sakit Umum Daerah Arifin Ahmad Pekanbaru** demi kelancaran Tugas Akhir mahasiswa yang bersangkutan.

Demikian surat ini Kami sampaikan, atas bantuan dan kerjasama Saudara kami ucapkan terima kasih.

Wassalam  
Dekan.  
  
Dr. D.S. Hartono, M.Pd  
NIP. 196403011992031003

Tembusan :  
Yth. Rektor UIN Suska Riau.

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 • S1 ILMU KESEHATAN MASYARAKAT • S1 KEBIDANAN • S1 INFORMATIKA KESEHATAN  
 • D.III KEPERAWATAN • D.III KEBIDANAN

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**KETERANGAN LAYAK ETIK**  
*DESCRIPTION OF ETHICAL EXEMPTION*  
 "ETHICAL EXEMPTION"

No.013/IKES PN/KEPK/II/2024

Protokol penelitian versi 1 yang diusulkan oleh :  
*The research protocol proposed by*

**Peneliti utama** : Muhammad Fauzi Fayyad  
*Principal In Investigator*

**Nama Institusi** : Universitas Islam Negeri Sultan Syarif  
 Kasim Riau  
*Name of the Institution*

Dengan judul:  
*Title*

**"Penerapan Arsitektur Deep Learning AlexNet, VGG19 dan EffciennetV2 Untuk Klasifikasi Citra Penyakit Katarak dan Glaukoma"**

*"Application of Deep Learning Architectures AlexNet, VGG19 and EffciennetV2 for Cataract and Glaucoma Image Classification"*

Dinyatakan layak etik sesuai 7 (tujuh) Standar WHO 2011, yaitu 1) Nilai Sosial, 2) Nilai Ilmiah, 3) Pemerataan Beban dan Manfaat, 4) Risiko, 5) Bujukan/Eksploitasi, 6) Kerahasiaan dan Privacy, dan 7) Persetujuan Setelah Penjelasan, yang merujuk pada Pedoman CIOMS 2016. Hal ini seperti yang ditunjukkan oleh terpenuhinya indikator setiap standar.

*Declared to be ethically appropriate in accordance to 7 (seven) WHO 2011 Standards, 1) Social Values, 2) Scientific Values, 3) Equitable Assessment and Benefits, 4) Risks, 5) Persuasion/Exploitation, 6) Confidentiality and Privacy, and 7) Informed Consent, referring to the 2016 CIOMS Guidelines. This is as indicated by the fulfillment of the indicators of each standard.*

Pernyataan Laik Etik ini berlaku selama kurun waktu tanggal 06 Februari 2024 sampai dengan tanggal 06 Februari 2025.

*This declaration of ethics applies during the period February 06, 2024 until February 06, 2025*



*Professor and Chairperson,*



Dr. Ezalina, Skep, Ns, Mkes



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SURAT IZIN PENELITIAN RSUD ARIFIN ACHMAD  
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PEMERINTAH PROVINSI RIAU  
RSUD ARIFIN ACHMAD

Jl. Diponegoro No. 2 Telp. (0761) - 23418, 21618, 21657, Fax (0761) - 20253  
Pekanbaru



Pekanbaru, 27 Februari 2024

Nomor : 071/Diklit-Litbangpus/22  
Sifat : Biasa  
Lampiran : -  
Hal : Izin Penelitian

Kepada Yth : Kepala Instalasi Rawat Jalan ( Ruang Poli Mata)

di  
Pekanbaru

Dengan Hormat

Menindaklanjuti surat dari Dekan Fakultas Sains dan Teknologi Universitas Islam Negeri Sultan Syarif Kasim Riau Nomor: B-9217/F.V/ PP.00.9/09/2023 tanggal 26 September 2023 perihal Permohonan Rekomendasi Izin Penelitian/Riset bersama ini disampaikan bahwa mahasiswa/i dibawah ini :

Nama : Muhammad Fauzi Fayyad  
NIM : 12050314864  
Program Studi : S1. Sistim Informasi

Berdasarkan persetujuan dari Bagian/Bidang, KJF/KSM, Instalasi dan Komite dilingkungan RSUD Arifin Achmad dapat diberikan Izin Penelitian dengan Judul **"Penerapan Arsitektur Deep Learning AlexNet, VGG19 dan EfficientNetV2 Untuk Klasifikasi Citra Penyakit Katarak dan Glaukoma"** dengan ketentuan sebagai berikut :

1. Tidak diperkenankan melakukan tindakan menyimpang selama kegiatan penelitian berlangsung.
2. Tidak diperkenankan melakukan tindakan medis secara langsung kepada pasien.
3. Wajib menjalankan prosedur *informed consent* bagi penelitian yang bersubjek pasien (manusia).
4. Tidak diperkenankan melakukan kegiatan selain penelitian
5. Izin penelitian berlaku selama 3 (tiga) bulan terhitung dari tanggal terbitnya surat ini.

Untuk itu diminta kepada Bidang/Bagian, KJF/KSM, Instalasi dan Komite dilingkungan RSUD Arifin Achmad untuk dapat memfasilitasi kegiatan penelitian yang dilakukan oleh mahasiswa/i tersebut sesuai dengan ketentuan yang berlaku.

Demikian disampaikan untuk dapat dilaksanakan sebagaimana mestinya

DIREKTUR RSUD ARIFIN ACHMAD  
PROVINSI RIAU,



drg. Wan Fajriatul Mamnunah., Sp.KG  
Pembina Tk.I  
Nip. 19780618 200903 2 001



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**LAMPIRAN F**

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**Keynote Speakers**  
Prof. Naoki Uchiyama (ToyoHashi University of Technology)  
Prof. Dedid Cahya Happyanto (Politeknik Elektronika Negeri Surabaya)  
Josephine Chitra (PT. GoTo Gojek Tokopedia)

**Important Dates**

Deadline of Paper Submission	April 28, 2024
Notification of Paper Acceptance	May 17, 2024
Extended Deadline of Paper Submission	June 9, 2024
Final Notification of Paper Acceptance	July 12, 2024
Early Bird Payment	May 27, 2024
Deadline Registration & Payment	July 15, 2024
Final Manuscript (Camera Ready)	July 18, 2024
Main Conference	August 6 - 8, 2024

All accepted and presented papers :  
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## LAMPIRAN G

## BUKTI PENDAFTARAN CONFERENCE IES 2024



MUHAMMAD FAUZI FAYYAD Sistem Informasi &lt;12050314864@students.uin-suska.ac.id&gt;

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26 April 2024 pukul 18.48

Kepada: Muhammad Fauzi Fayyad &lt;12050314864@students.uin-suska.ac.id&gt;, Mustakim Mustakim &lt;mustakim@uin-suska.ac.id&gt;

Dear Mr. Muhammad Fayyad:

Thank you for uploading your review manuscript for paper 1571024685 (*Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification*) to **2024 International Electronics Symposium (IES)**. The paper is of type application/pdf and has a length of 624701 bytes.

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Regards,  
Akhmad Alimudin, Ph.D  
General Chair  
2024 International Electronics Symposium (IES)  
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Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification

Mr. Muhammad Fauzi Fayyad and Mr. Mustakim Mustakim

2024 International Electronics Symposium (IES)

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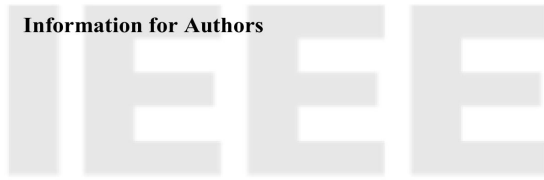
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## H.2 Email Accepted Paper



6/5/24, 11:31 AM

Email Universitas Islam Negeri Sultan Syarif Kasim Riau - [IES 2024] Congratulation Your paper #1571024685 ('Application of...



MUHAMMAD FAUZI FAYYAD Sistem Informasi &lt;12050314864@students.uin-suska.ac.id&gt;

### [IES 2024] Congratulation Your paper #1571024685 ('Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification') - Accepted

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17 Mei 2024 pukul 14.00

Kepada: Muhammad Fauzi Fayyad &lt;12050314864@students.uin-suska.ac.id&gt;, Mustakim Mustakim &lt;mustakim@uin-suska.ac.id&gt;

Dear Mr. Muhammad Fayyad:

Congratulations - We are pleased to inform you that your manuscript #1571024685 ('Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification') has now been ACCEPTED by 2024 International Electronics Symposium (IES).

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We, IES 2024 organizer, are now planning the detail program and will inform you in coming weeks the information related to IES 2024.

We look forward to seeing you in Bali, Indonesia, or joining us virtually, on August 6-8, 2024.

Sincerely Yours,

Regards,  
Akhmad Alimudin, Ph.D  
General Chair  
2024 International Electronics Symposium (IES)  
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Reviews/Comments:  
===== Review 1 =====

> \*\*\* Originality: Uniqueness and originality in the presented paper  
Average (3)

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> \*\*\* Literature: Adequacy of references to literature  
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> \*\*\* Technical Discussion: Technical Discussion  
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> \*\*\* Contribution: Potential impact and contribution  
Good (4)

> \*\*\* Comment to Author: e.g. Major reasons of your overall recommendation

- In the Results and Discussion section, you state that you utilize function-based evaluation methods to evaluate XAI techniques. Please describe how you implemented this approach in your study.
- In each figure 7, 8, and 9 it is possible to show through figures the parts referred to as critical areas for diagnosis.
- How does the Superimposed Normal Image function on images 7, 8, and 9? I didn't find an explanation of Superimposed Normal Image and its relation to XAI.
- In Glaucoma cases, it is still necessary to assess cupping changes on fundus images by measuring CDR and NRR. How can the CDR ratio be identified from Figure 8? including the NRR ratio.
- Finally, in the abstract you state that "Grad-CAM analysis also effectively identified unique features for each eye disease class", how do you get this statement from the explanation of your paper? Do you also carry out effectiveness tests?

=====  
Review 2  
=====

> \*\*\* Originality: Uniqueness and originality in the presented paper  
Average (3)

> \*\*\* Literature: Adequacy of references to literature  
Good (4)

> \*\*\* Technical Discussion: Technical Discussion  
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Table II presents the augmentation composition on training dataset for each holdout validation and class. It seems that the dataset 4 times increasing compared to before augmentation. However, the authors stated they used two transformation techniques, namely rotating image by 45 degree and flipping the image horizontally. Could you please to describe the augmentation clearer?

Numerical values in Figure 6 are too small. It is difficult to see.

Please add a future plan or sugesstion in the conclusion section.

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Saya yang bertanda tangan dibawah ini:

Nama : Muhammad Fauzi Fayyad  
NIM : 12050314864  
Program Studi : Sistem Informasi  
Judul Tugas Akhir : *Application of AlexNet, EfficientNetV2B0 and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification*

Menyatakan bahwa akan melengkapi seluruh kelengkapan administrasi Tugas Akhir Program Studi Sistem Informasi Fakultas Sains dan Teknologi Universitas Islam Negeri Sultan Syarif Kasim Riau berupa **bukti pelaksanaan conference secara lengkap**. Demikian yang dapat saya sampaikan dengan sungguh-sungguh. Atas perhatiannya, saya ucapkan terima kasih.

Pekanbaru, 26 Juni 2024

Hormat Saya,



**Muhammad Fauzi Fayyad**

NIM. 12050314864



## DAFTAR RIWAYAT HIDUP



Muhammad Fauzi Fayyad lahir di Bengkulu, pada tanggal 19 Desember 1999. Saya merupakan anak dari Bapak Budi Hidayat, S.P., M.M dan Ibu Ir. Tri Esti Indrarwati M.Si, Saya adalah Anak Pertama dari dua bersaudara. Saya memulai pendidikan formal saya di TK Kartini di Kota Pekanbaru, dan menyelesaikan pendidikan pada tahun 2007. Selanjutnya, saya melanjutkan ke Sekolah Dasar di SDN 036 di Kota Pekanbaru. Saya menyelesaikan pendidikan Sekolah Dasar pada tahun 2013. Setelah menyelesaikan pendidikan dasar, saya melanjutkan ke tingkat SLTP di SMPN 4 di Kota Pekanbaru, dan menyelesaikan pendidikan pada tahun 2016. Selanjutnya, saya melanjutkan ke tingkat SLTA di MAN 2 Model di Kota Pekanbaru, dan menyelesaikan pendidikan pada tahun 2019. Saat ini, saya sedang menempuh pendidikan tingkat sarjana di Universitas Islam Negeri Sultan Syarif Kasim Riau, Program Studi Sistem Informasi di Fakultas Sains dan Teknologi. Saya mulai kuliah pada tahun 2020 dan diharapkan dapat menyelesaikan studi pada tahun 2024. Selama masa kuliah, saya telah menyelesaikan kerja praktek yang bertempat di Dinas Komunikasi, Informatika dan Statistika Provinsi Riau, yang memberi saya pengalaman praktis dalam analisis kualitas website menggunakan WebQual 4.0 dengan SPSS. Selanjutnya, saya juga telah menyelesaikan Kuliah Kerja Nyata (KKN) di Desa Kijang Rejo, Kabupaten Kampar, dimana saya terlibat dalam Pembuatan Peta Desa Kijang Rejo dengan Citra Satelit menggunakan QGIS dan SASPlanet. Sebagai bagian dari tugas akhir saya di universitas, saya sedang mengerjakan proyek mengenai “*Application of AlexNet, EfficientNetV2B0, and VGG19 with Explainable AI for Cataract and Glaucoma Image Classification*”, yang bertujuan untuk mengklasifikasi citra fundus penyakit katarak dan glaukoma menggunakan Algoritma Deep Learning dan Pendekatan XAI. Saya berharap dapat menyelesaikan proyek ini pada tahun 2024.

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