iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: V Month of publication: May 2025

DOI: https://doi.org/10.22214/ijraset.2025.69868

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Integrated Deep Learning Framework for glaucoma detection, Optic Disk/Cup Segmentation, and CDR Calculation

Sarthak Mudaliar[1], Adibhatla Srinivasa Chakravarthi[2], Deebalakshmi R[3]
SRM Institute of Science and Technology Tiruchirappalli, India

Abstract:* The proposed system is a two stage deep learning framework for automated glaucoma detection and analysis of fundus images in this project. Once the image is processed, the system hands it off to a ResNet model to predict whether the image is positive for glaucoma or not. When it is a positive case, it segments the optic disc and cup using a YOLOv5 model and can then attempts to precisely calculate the cup to disc ratio (CDR), a key parameter in glaucoma risk determination. With combined classification and segmentation integration the proposed streamlines workflow greatly reducing manual examination-dependency and creates a more objective and accurate diagnostic support for ophthalmology. Clinicians can upload images, view segmentation results, and access CDR values in a user friendly system to help make appropriate clinical decisions. The proposed system is an efficient and accurate framework with the potential for implementation in real time for early glaucoma diagnosis in high demand or resource limited locations or situations or settings.
Keywords: glaucoma detection, deep learning, ResNet, YOLOv5, cup-to-disc ratio (CDR), optic disc segmentation.

I. INTRODUCTION

Glaucoma is a progressive eye disease, the leading cause of irreversible blindness that affects millions of people around the world. It mostly affects the optic nerve, which may be associated with high intraocular pressure (IOP) and can progress slowly until your vision starts to slip away. Glaucoma is a condition that is usually asymptomatic in its early stages so most often will not be detected until extensive damage has been done, because of this early detection is so critical, timely and efficient intervention becomes absolutely vital for slowing, or preventing vision loss, improving patient quality of life significantly..

Previous ways of diagnosing glaucoma involved the manual examination of fundus images to assess the size and shape of the optic disc and the cup regions, from which the cup to disc ratio (CDR) is calculated as a measure of glaucoma risk. An enlarged optic cup relative to the optic disc, or high CDR values, may indicate glaucoma. Manual CDR assessment, however, is time-consuming, subjective, and is highly dependent on how the clinician is familiar with it. However, when there is a high clinical need or limited access to qualified professionals, the subjective and time sensitive nature may result in diagnostic variability.

The advancements in recent years in deep learning gives rise to the possibility that glaucoma detection and diagnosis can be automated using medical image analysis. With high speed processing of large amounts of data, deep learning models can achieve precise classification and segmentation tasks for medical imaging. In this project, we take advantage of a two stage deep learning framework which combines classification and segmentation to try and simplify the glaucoma detection. This system automates the process of optic disc and cup segmentation and CDR calculation to create a rapid, objective, and reliable glaucoma assessment tool.

The first stage of the framework classifies fundus images as classes, glaucoma positive or negative with a given ResNet model. The Architecture is a deep layered and residual connected network, which works well to extract intricate features from images and also suits medical classification tasks. The system can segment glaucomatous patients from the rest with the help of ResNet, which greatly saves computational resources required to screen for the glaucoma.

The second stage of the framework for glaucoma positive cases extracts the optic disc and cup regions using YOLOv5, a fast and accurate object detector. YOLOv5 combines a feature extraction backbone, feature aggregation, and detection layers to process fundus images efficiently. Its real-time segmentation capabilities are crucial for delineating optic disc and cup regions, ensuring precise boundary detection even in challenging cases. The model's clinical applicability is improved by its capacity to manage changes in fundus image quality. The segmented areas are used to calculate the cup-to-disc ratio, a quantitative glaucoma risk diagnostic indicator..

The system is built to have a user friendly interface through Flask allowing clinicians to upload images, get results from segmentation, and access CDR calculation. This interface provides easy integration into clinical processes and improves usability through which ophthalmologists may rapidly analyze findings and make educated diagnostic decisions. It also decreases manual measurements calling for consistency and accuracy inside each diagnosis.

The project gives a possible complete solution for glaucoma detection which combines the classification power of ResNet and segmentation of image by YOLO v5. Reducing subjectivity and increasing diagnostic reliability, the automated CDR calculation of the system is an important tool in early glaucoma diagnosis. The framework is well suited to high volume clinical environments and environments with limited resources because of its potential for real-time processing and ease of deployment.

II. LITERATURE SURVEY

B. S. Abraham, D. G. Bhanu, A. Thomas, and J. Anitha (2023)

Abraham et al. (2023) explores the use of deep learning methods for optic disc and cup segmentation in glaucoma diagnosis. Critical for evaluating glaucoma risk, their research enhances cup-to-disc ratio (CDR) calculations using sophisticated segmentation models. This study shows how automated deep learning techniques may help ophthalmologists in glaucoma evaluation and stresses the need of exact segmentation in improving diagnostic reliability.

R. Krishnan, V. Sekhar, J. Sidharth, S. Gautham, and G. Gopakumar (2020)

Krishnan et al. (2020) focuses on detecting glaucoma through retinal fundus images using machine learning techniques. Their method uses feature extraction to categorize the presence of glaucoma, showing how machine learning can be used to detect glaucoma with a respectable level of accuracy. Nonetheless, the study emphasizes that integrating segmentation and classification could improve diagnostic value even more.

F. Z. Zulfira and S. Suyanto (2020)

Zulfira and Suyanto (2020) propose a multi-class glaucoma detection system utilizing Active Contour Snakes for segmentation and Support Vector Machine (SVM) for classification. The use of Active Contour Snakes enables effective segmentation of optic disc and cup regions. While successful in multi-class classification, the study underscores the limitations of extensive preprocessing, hinting that a streamlined approach could improve practical application.

J. K. Dewa, E. Rachmawati, and G. Kosala (2023)

Dewa et al. (2023) investigate self-attention mechanisms in the Swin-Unet model to enhance optic disc and cup segmentation. By leveraging self-attention, their model improves segmentation precision by focusing on crucial features within fundus images, which is essential for accurate CDR calculations in glaucoma detection. Despite the promising results, the study notes the computational demands of self-attention layers.

Y. Yang, G. Yang, D. Ding, and J. Zhao (2022)

Yang et al. (2022) introduce a Contour Offset Map technique designed to achieve smooth and robust segmentation of optic disc and cup contours. Their method improves the accuracy and consistency of CDR calculations, addressing common challenges in fundus image segmentation, such as boundary ambiguity. This approach provides a dependable way to deal with fundus image variability.

D. I. C. Wiguna, E. Rachmawati, and G. Kosala (2023)

Wiguna et al. (2023) utilizes a Dense Prediction Transformer for joint segmentation of the optic disc and cup regions, facilitating a streamlined glaucoma detection process. Their approach demonstrates that joint segmentation significantly enhances segmentation accuracy, directly influencing reliable CDR measurements. To make the model appropriate for real-time applications, the study does mention that optimization is necessary.

G.-R. Huang and T.-R. Hsiang (2020)

Huang and Hsiang (2020) present a simplified deep network for optic disc and cup segmentation, aiming to balance model accuracy with processing speed. Their streamlined architecture achieves effective segmentation while reducing computational complexity, making it viable for real-time deployment. This work suggests that efficient architectures can enhance scalability without compromising diagnostic quality.

I. D. S. Ubaidah, Y. Fu ‘Adah, S. Sa’ Idah, R. Magdalena, A. B. Wiratama, and R. B. J. Simanjuntak (2022)
Ubaidah et al. (2022) apply MobileNet, a lightweight CNN, for glaucoma classification using fundus images. MobileNet’s efficiency and low computational demands make it ideal for low-resource environments. The study does admit, though, that combining segmentation and classification would result in a more thorough evaluation of glaucoma

A. Septiarini, H. Hamdani, E. Setyaningsih, E. Arisandy, S. Suyanto, and E. Winarno (2021)
Septiarini et al. (2021) propose an automatic segmentation technique for the optic nerve head, using median filtering and clustering for initial segmentation. Although effective for basic segmentation, the study suggests that more advanced models, like CNNs, could enhance segmentation precision, making it better suited for detailed glaucoma diagnosis.

Preity, A. K. Bhandari, A. Jha, and S. Shahnawazuddin (2024)
Preity et al. (2024) introduce RD-Net, a Residual-Dense Network, for glaucoma prediction by focusing on optic nerve head structural features. The model’s dense connections and residual layers enhance feature extraction, achieving high classification accuracy. However, RD-Net lacks segmentation capabilities, which limits its application in comprehensive CDR-based glaucoma assessment.

III. PROPOSED METHODOLOGY

A. Data Collection and Preprocessing

1) Data Collection

A glaucoma diagnosis label and matching segmentation masks for the optic disc and cup regions are applied to each fundus image by skilled ophthalmologists. Both classification and segmentation models can be developed and trained using this annotated dataset.s.

.

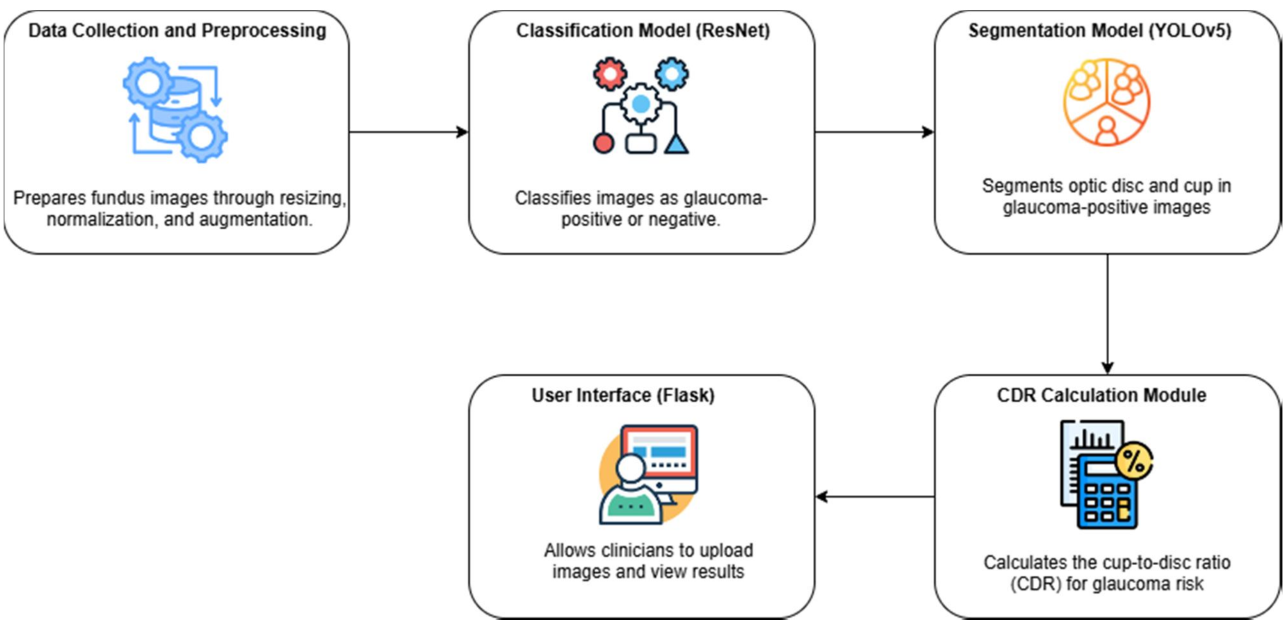


Fig 1 : System Architecture

2) Data Preprocessing

The raw images undergo several preprocessing steps to ensure consistency and improve model performance:
Resizing: For ResNet or YOLOv5, you resize all images to fixed dimension to meet their input requirements.
Normalization: The convergence of the model is improved by first normalizing the pixel values into a range (e.g. 0 to 1), and then feeding the normalized pixel values into the model.
Data Augmentation: In order to enhance the dataset variability, we do the rotation, flipping, zooming and adjusting brightness.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

B. Stage 1: ResNet: Classification of Glaucoma Detection

1) Model Selection

ResNet50 is chosen because of its exceptional capacity to extract complex features from medical images. The vanishing gradient issue is successfully resolved by its residual learning framework, ensuring steady learning in deep networks. This is essential for finding subtle structural changes in fundus images indicating glaucoma. Additionally, by leveraging transfer learning, ResNet50 adapts pre-trained weights to enhance performance with limited medical datasets, overcoming the challenge of data scarcity in ophthalmology

2) Model Training

Transfer learning is used to train the ResNet model on the preprocessed fundus image dataset, and the base layers of a pre-trained ResNet model are retrained on the new dataset.
Loss Function: Binary cross entropy loss is used as a classification accuracy measure.
Optimizer: The Adam optimiser is selected to reduce the loss function efficiently and achieve faster convergence.

3) Classification Inference

Inference: The ResNest model process each new image to classify them into glaucoma positive or negative. The positive cases are then segmented further in later steps.

C. Stage 2: YOLOv5 for Optic Disc and Cup Segmentation

1) Model Selection

YOLOv5, is a very advanced object detection model. It is known for its speed and precision in real-time segmentation. Its architecture combines feature extraction, feature aggregation, and detection layers to process fundus images efficiently. The challenge faced in fundus image segmentation is the variability in image quality and boundary ambiguity for optic disc and cup regions. YOLOv5 solves this challenge by using its robust detection mechanisms, enabling precise delineation of boundaries even in challenging cases. These precise outputs form the foundation for reliable CDR calculations.

2) Model Training

By manually identifying the optic disc and cup masks on glaucoma positive images, the YOLOv5 model is trained by using those images.
Loss Function: This results in a model that optimizes a combination of localization, confidence and classification losses to do accurate segmentation.
Bounding Box and Mask Generation: The bounding boxes and segmentation marks are generated by the YOLOv5 model for both optic disc and cup region.
Evaluation Metrics: The segmentation accuracy is evaluated with Dice coefficient and Intersection over Union (IoU).

3) Segmentation Inference

When in the case of glaucoma positive images, YOLOv5 model draws a segmentation to express precise masks that are required to estimate the CD ratio for the optic disc and cup regions.

D. Calculation of Cup to Disc Ratio (CDR)

1) CDR Calculation Process

The CDR is calculated using two approaches: area-based and diameter-based calculations. In the area-based method, the ratio of the optic cup area to the optic disc area is calculated. Similarly, the diameter-based calculation evaluates the vertical and horizontal diameters of the segmented regions. This gives a quantitative measurement of glaucoma risk.
A threshold is predefined, based on clinical standards, which determines glaucoma risk. Where CDR values higher than 0.6 indicate a significant likelihood of glaucoma.
These automated calculations and quantitative representations improve the consistency and reduce variability compared to manual methods.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

2) CDR Thresholding for glaucoma risk assessment

The CDR value of the fundus image is compared to the predefined threshold value to assess the risk of glaucoma. If the CDR value is larger than that of the threshold value is associated with greater probability of glaucoma, this represents a quantitative metric for diagnosis.

E. (Flask Application) User Interface

1) Interface Design

The Flask-based interface streamlines the diagnostic process by integrating the outputs of ResNet and YOLOv5 into a user-friendly platform. Clinicians can upload fundus images, view segmentation overlays, and access computed CDR values in real time. The interface also provides:

Visualization Features: Annotated overlays of segmentation results for easy interpretation.

Downloadable Reports: The downloadable reports consist of Comprehensive diagnostic reports, including classification results, segmentation masks, and CDR values, to support clinical documentation.

2) User Feedback Integration

The User of the system (clinicians) can give feedback on the system outputs. They can be used to iteratively update and retrain the model with more data to make it even more accurate and increase its performance.

F. Evaluation and Testing

1) Performance Testing

The ResNet model achieved high performance metrics, including accuracy (92.5%), sensitivity (93.8%), specificity (91.3%), and F1-score (92.6%). These metrics validate the model's capability to distinguish glaucoma-positive cases with minimal false negatives, a critical factor in early detection. This addresses the challenge of ensuring diagnostic reliability in high-stakes medical scenarios. The YOLOv5 model achieved high segmentation accuracy, with Dice coefficients of 89.9% for optic disc and 86.5% for optic cup regions. These results ensure the precise delineation of optic structures, which is critical for calculating the CDR accurately. The model effectively addresses challenges such as boundary ambiguity and variability in fundus image quality, enhancing the reliability of glaucoma diagnostics. The calculated CDR values are validated against expert-annotated ground truth data, with an average deviation of only 2.3%, demonstrating the reliability of the framework for clinical use.

2) Cross-Validation

To make the model robust, it is cross validated across multiple data splits. This guarantees that the models generalize to the fundus images well. By doing so the model will become more reliable in clinical applications.

3) User Testing

The system is then tested for clinical usability to ensure the user interface is intuitive. The main objective of this is to fine tune user experience and optimize workflow for the clinical setup.

G. Dissemination

1) Interface and Models Integration

The model integrates ResNet and YOLOv5 models along with the CDR calculation module into an all inclusive system which is available through the Flask interface. The system is user ready as it provides smooth data flow from input to the resulting diagnostic output.

2) Deployment Model Optimization

The model should be compressed to deploy the system in resource constrained environments. Techniques like pruning and quantization are used to reduce the model size.

3) Real Time Processing Capabilities

Features like Parallel processing and hardware acceleration (GPU support) as well as an implementation to make the system feasible for high volume screening are applied, these enable real time analysis of fundus images in clinical environments.

IV. RESULTS AND DISCUSSION

This chapter presents the proposed glaucoma detection framework and the performance metrics for the classification and segmentation models of the proposed framework. The analysis of the model and applicability of these metrics in clinical environment and implications of system effectiveness is projected.

A. *Model Performance*

1) *Classification Model (ResNet)*

Various performance metrics were used to evaluate the ResNet model used for fundus image classification to class as glaucoma positive or negative.

Metric	Value (%)
Accuracy	92.5
Sensitivity	93.8
Specificity	91.3
F1-Score	92.6

The performance of this model in detecting glaucoma positive or negative cases is showcased here.

2) *Segmentation Model (YOLOv5)*

Intersection over Union (IoU) and Dice coefficient scores were used to calculate the YOLOv5 model's accuracy of segmentation optic disc and optic cup regions.

Table 1 : Segmentation Model

Segmentation Task	IoU (%)	Dice Coefficient (%)
Optic Disc	88.7	89.9
Optic Cup	85.4	86.5

These scores imply that there is a high degree of accuracy in segmentation of optic structures which is important step in computing cup to disc ratio (CDR).

B. *CDR Calculation Accuracy*

The accuracy of the system in giving reliable diagnosis was determined by comparing the integral calculated CDR with expert ground truth values.

Table 2 : CDR Calculation Accuracy

Metric	Value (%)
Average Deviation	2.3

A case is built by showing the reliability of the calculations through this low average deviation of the CDR calculations from values annotated by expert judges, and argue that the system is useful to glaucoma risk assessment.

C. *Visualization of Model Performance*

1) *Classification Metrics Visualization*

The below bar graph depicts the performance metrics of classification model which include accuracy, sensitivity, specificity and F1-score, as a percent.

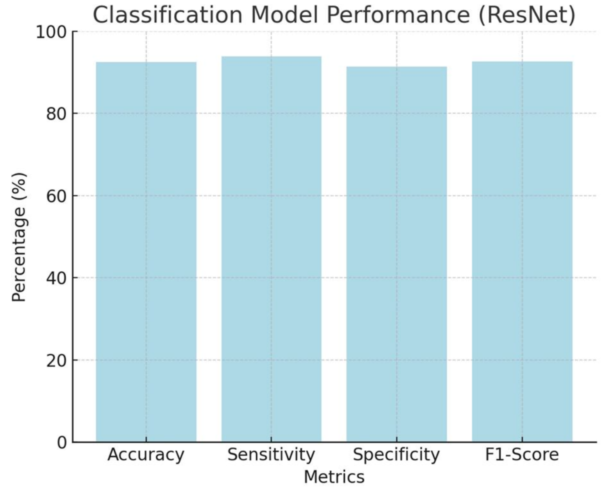


Fig 2 : Classification Metrics Visualization

2) Segmentation Metrics Visualization

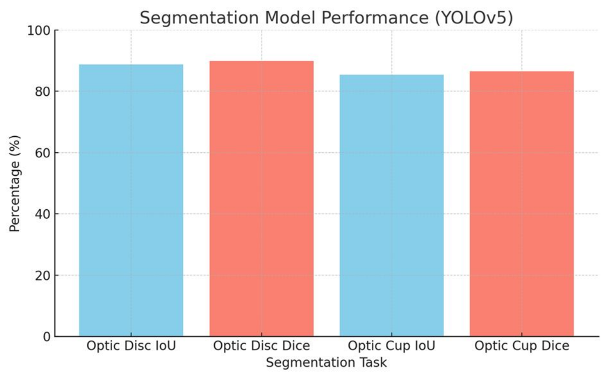


Fig 3: Segmentation Metrics Visualization

The segmentation performance of the YOLOv5 model is visualized through a bar graph representing IoU and Dice coefficient values for the optic disc and cup segmentation.

D. Discussion

The proposed system's results show that it is accurate and objective in glaucoma detection and assessment. The ResNet model is a suitable performer for screening tasks capable of detecting glaucoma positive cases. The YOLOv5 model has very accurate segmentation which results in low deviation of the CDR calculations from the ground truth value. It has a very intuitive user experience making it very feasible in clinical environment and the potential to decrease manual examinations while increasing glaucoma diagnosis efficiency.

V. CONCLUSION

The two stage deep learning framework designed for automated glaucoma detection using a combination of ResNet and YOLOv5 for the classification stage and optic disc and cup segmentation stage is presented in this study. This system aims to make the diagnosis of glaucoma more accessible and also enable early and fast detection by classification, segmentation and cup to disc ratio (CDR) calculation.

High sensitivity and specificity in classifying were shown in the ResNet model for screening purposes, and the YOLOv5 model accurately segmented the optic disc and cup regions, critically needed for accurate CDR measurement. Subsequent analysis demonstrates that the system can provide an objective diagnostic metric for risk assessment in glaucoma with an average deviation from expert CDR values of only 2.3 percent, mitigating both subjectivity and variability of manual assessment.

The clinical applicability of the framework is further enhanced by the integration of a user-friendly interface that will allow ophthalmologists to upload images, view results, and make speedy decisions. This high accuracy, low cost and low logistics framework offers a valuable tool for the glaucoma diagnosis and particularly in high demand in less resource rich settings.

VI. FUTURE WORK

The glaucoma detection framework can be improved by feeding more data with more diverse cases and higher quality data and combining it with Optical Coherence Tomography (OCT) to provide multi modal approach. Techniques as advanced as segmentation techniques and attention mechanisms might result in improved level of precision in detection of the optic disc and cup boundaries. Real-time mobile use could add access to resource limited settings, and could be optimized to achieve this. CDR tracking over time can be used to detect the progression of disease treatment. Usability could be clinical validated and further refined or semi supervised learning could continue improving. Linking the system to Electronic Health Records (EHR) will make management of health of the individual easier and also management of data which will help better treat the patients in future. Such advancements would add up to others to create a more accurate, tractable and scalable glaucoma detection solution.

REFERENCES

[1] B. S. Abraham, D. G. Bhanu, A. Thomas and J. Anitha, "A Deep Dive into Optic Disc and Cup Segmentation for Glaucoma Diagnosis with Deep Learning," 2023 International Conference on Emerging Research in Computational Science (ICERCS), Coimbatore, India, 2023, pp. 1-6, doi: 10.1109/ICERCS57948.2023.10434051.

[2] R. Krishnan, V. Sekhar, J. Sidharth, S. Gautham and G. Gopakumar, "Glaucoma Detection from Retinal Fundus Images," 2020 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2020, pp. 0628-0631, doi: 10.1109/ICCSP48568.2020.9182388.

[3] F. Z. Zulfira and S. Suyanto, "Detection of Multi-Class Glaucoma Using Active Contour Snakes and Support Vector Machine," 2020 3rd International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), Yogyakarta, Indonesia, 2020, pp. 650-654, doi: 10.1109/ISRITI51436.2020.9315372.

[4] J. K. Dewa, E. Rachmawati and G. Kosala, "Investigating Self-Attention in Swin-Unet Model for Disc and Cup Segmentation," 2023 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), Semarang, Indonesia, 2023, pp. 401-406, doi: 10.1109/ICITACEE58587.2023.10276855.

[5] Y. Yang, G. Yang, D. Ding and J. Zhao, "Contour Offset Map: A New Component Designed for Smooth and Robust Optic Disc/Cup Contour Detection," 2022 IEEE International Conference on Bioinformatics and Biomedicine (BIBM), Las Vegas, NV, USA, 2022, pp. 1773-1776, doi: 10.1109/BIBM55620.2022.9995691

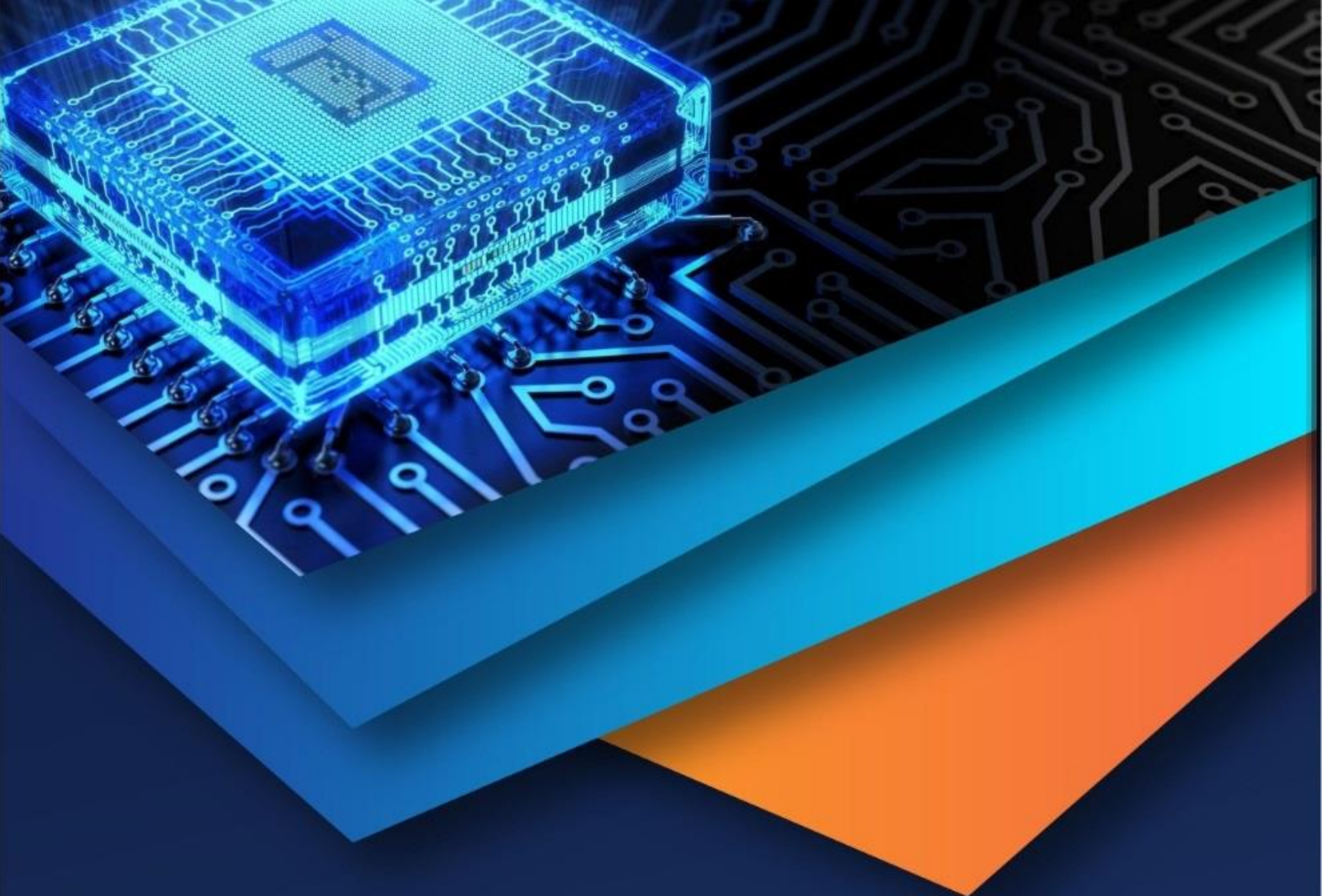
[6] D. I. C. Wiguna, E. Rachmawati and G. Kosala, "Glaucoma Detection Based on Joint Optic Disc and Cup Segmentation Using Dense Prediction Transformer," 2023 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), Semarang, Indonesia, 2023, pp. 407-412, doi: 10.1109/ICITACEE58587.2023.10277656.

[7] G. -R. Huang and T. -R. Hsiang, "A Simplified Deep Network Architecture on Optic Cup and Disc Segmentation," 2020 International Joint Conference on Neural Networks (IJCNN), Glasgow, UK, 2020, pp. 1-7, doi: 10.1109/IJCNN48605.2020.9206670.

[8] I. D. S. Ubaidah, Y. Fu'Adah, S. Sa'Idah, R. Magdalena, A. B. Wiratama and R. B. J. Simanjuntak, "Classification of Glaucoma in Fundus Images Using Convolutional Neural Network with MobileNet Architecture," 2022 1st International Conference on Information System & Information Technology (ICISIT), Yogyakarta, Indonesia, 2022, pp. 198-203, doi: 10.1109/ICISIT54091.2022.9872945.

[9] A. Septiarini, H. Hamdani, E. Setyaningsih, E. Arisandy, S. Suyanto and E. Winarno, "Automatic Segmentation of Optic Nerve Head by Median Filtering and Clustering Approach," 2021 13th International Conference on Information & Communication Technology and System (ICTS), Surabaya, Indonesia, 2021, pp. 118-122, doi: 10.1109/ICTS52701.2021.9608854.

[10] Preity, A. K. Bhandari, A. Jha and S. Shahnawazuddin, "RD-Net: Residual-Dense Network for Glaucoma Prediction Using Structural Features of Optic Nerve Head," in IEEE Transactions on Artificial Intelligence, doi: 10.1109/TAI.2024.3447578.



doi crossref

10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

ISI

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY