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Soft Computing Based Discriminator Model for Eye Disease

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Abstract: This paper presents a novel approach for glaucoma diagnosis using a lightweight convolutional neural network (CNN) architecture optimized for efficiency and accuracy. The model, designed to run effectively on resource-constrained devices, leverages depthwise separable convolutions and advanced image preprocessing to detect glaucomatous features in fundus images. Evaluated on benchmark datasets, the proposed method demonstrates high diagnostic accuracy and computational efficiency, indicating its potential for integration into real-time, accessible glaucoma screening tools, especially in underserved regions.
Keywords: Glaucoma diagnosis, fundus image processing, soft computing, support vector machine (SVM), feature extraction.

I. INTRODUCTION

Glaucoma is a progressive eye disease and the second leading cause of vision loss worldwide, projected to affect over 111 million people by 2040. It causes irreversible damage to the optic nerve, often without early symptoms, making timely diagnosis critical. This study proposes a soft computing-based Discriminator Model for Glaucoma Diagnosis (DMGD) that leverages advanced image preprocessing, feature extraction, and kernel-based classification techniques to accurately identify glaucomatous conditions from fundus images. The goal is to enhance early detection capabilities through automated and efficient image analysis.

A. Background

Glaucoma is a chronic and progressive eye disease that leads to irreversible damage of the optic nerve, often associated with elevated intraocular pressure (IOP). It is a leading cause of preventable blindness worldwide, and its early stages can remain asymptomatic, making timely diagnosis critical. Traditional diagnostic methods, though effective to an extent, often struggle with the variability and uncertainty inherent in clinical data.

B. Problem Statement

Early detection and diagnosis of retinal diseases such as diabetic retinopathy, glaucoma, and age-related macular degeneration are critical to preventing irreversible vision loss. Traditional manual examination of retinal images is time-consuming, subjective, and prone to inter-observer variability. Moreover, the increasing prevalence of eye-related diseases places a heavy burden on ophthalmologists and healthcare systems, especially in resource-limited settings.

Despite advancements in imaging modalities such as fundus photography and optical coherence tomography (OCT), accurate and automated analysis of retinal images remains a challenging task due to varying image quality, illumination artifacts, complex retinal structures, and the need for precise segmentation and feature extraction. There is a pressing need for robust, automated retinal image processing techniques that can enhance image quality, accurately segment anatomical structures and lesions, and support reliable disease detection and classification. Therefore, the core problem is to develop and optimize retinal image processing methods that can address these challenges, improve diagnostic accuracy, and enable scalable screening solutions for widespread clinical use.

C. Objectives

To improve diagnostic accuracy for glaucoma. To support ophthalmologists in early detection and clinical decision-making .To provide a robust framework capable of learning from data and handling variability in patient conditions

II. LITERATURE REVIEW

Extensive research has been conducted in the field of automated glaucoma diagnosis using fundus images. Early methods focused on statistical analysis and traditional image processing techniques to extract features like the cup-to-disc ratio. More recent studies have incorporated machine learning and deep learning approaches, including support vector machines (SVMs), convolutional neural

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networks (CNNs), and generative adversarial networks (GANs), to improve diagnostic accuracy. Researchers have explored both spatial and frequency domain features, including Local Binary Patterns (LBP) and LAWS textures, to capture critical patterns in optic disc regions. Despite advancements, challenges remain in segmenting noisy fundus images and ensuring generalizability across diverse datasets. The proposed DMGD system builds on these foundations by integrating soft computing techniques with kernel-based SVM classifiers to enhance glaucoma detection performance across multiple public databases.

III. METHODOLOGY

Retinal image processing involves a variety of methods to analyze images of the retina, typically captured by fundus cameras, fluorescein angiography, or Optical Coherence Tomography (OCT). These techniques are used to detect and assess various retinal conditions. The proposed Discriminator Model for Glaucoma Diagnosis (DMGD) is designed using a soft computing approach and is structured into three primary stages: preprocessing, feature extraction, and classification. The methodology treats glaucoma detection as a classification problem, where each fundus image is analyzed to determine whether it is normal or glaucomatous based on its attributes. The preprocessing stage is critical for enhancing image quality and extracting the region of interest (ROI), particularly the optic disc (OD).

This begins with color component separation, followed by initial cropping using the intensity of the green channel—leveraging the fact that the OD is the brightest region in fundus images. Spatially Weighted Fuzzy C-Means (SWFCM) clustering is then applied for precise OD segmentation, while a Gaussian Derivative Filter (GDF) is used to detect blood vessels within the OD region. These vessels are subsequently removed using a non-iterative inpainting algorithm based on transport equations, ensuring a clean ROI for further analysis. In the second stage, multiple features are extracted from the ROI, combining spatial and frequency domain characteristics. Color-based statistical features such as mean, standard deviation, skewness, and kurtosis are calculated across RGB channels. To improve robustness against illumination changes, Local Binary Patterns (LBP) are employed, while LAWS texture features are extracted to capture localized texture variations. These diverse features are integrated to form a comprehensive feature space. In the final stage, a Support Vector Machine (SVM) classifier with different kernel functions—Linear (LK), Polynomial (PK), Radial Basis Function (RBF), and Quadratic (QK)—is applied to categorize the images. The SVM's ability to construct optimal decision boundaries in high-dimensional feature spaces enables accurate classification of fundus images, with the RBF kernel demonstrating the highest performance across multiple datasets.

A. Machine Learning Algorithms

Various supervised and unsupervised learning methods are employed for classification and segmentation tasks.

IV. RESULTS AND ANALYSIS

The performance of the proposed Discriminator Model for Glaucoma Diagnosis (DMGD) was rigorously evaluated using cross-validation techniques across multiple fundus image databases, including HRF, DRISHTI-GS1, RIM-ONE, and ORIGA. The system was tested using a 10-fold cross-validation approach to ensure robustness and mitigate overfitting. The results indicate that the Radial Basis Function (RBF) kernel-based Support Vector Machine (SVM) consistently outperformed the Linear Kernel (LK), Polynomial Kernel (PK), and Quadratic Kernel (QK) classifiers. Specifically, the RBF-SVM achieved the highest classification accuracy across all databases, reaching up to 98.47% for RIM-ONE and 97.03% for DRISHTI-GS1, while maintaining a high specificity of 100% for HRF and sensitivity of 93.33%. In contrast, the PK-SVM exhibited the lowest performance, with accuracy dropping below 75% in all test cases. The Receiver Operating Characteristic (ROC) curves and confusion matrices further validated these findings, demonstrating the superior discriminative capability of the RBF-SVM. Overall, the combination of advanced preprocessing, robust feature extraction from spatial and frequency domains, and effective classification through soft computing techniques has enabled the DMGD system to reliably detect glaucomatous conditions, thereby showing promise as a second-opinion tool in clinical diagnostics.

A. Evaluation Methodology

The DMGD system was evaluated using a 10-fold cross-validation (CV) technique to ensure comprehensive testing and to prevent overfitting due to limited dataset size. In each iteration, a portion of the dataset was used for training, and the remainder was used for testing. The evaluation was conducted across multiple standard fundus image databases: HRF, DRISHTI-GS1, RIM-ONE, and ORIGA.

B. Classifier Performance Comparison

The classification was performed using Support Vector Machines (SVM) with four different kernel functions: Linear Kernel (LK), Polynomial Kernel (PK), Quadratic Kernel (QK), and Radial Basis Function Kernel (RBF). Among these, the RBF-SVM consistently achieved the highest accuracy across all databases. Specifically, it reached an accuracy of 98.47% on RIM-ONE and 97.03% on DRISHTI-GS1, with a perfect specificity (100%) on the HRF dataset and a sensitivity of 93.33%. In contrast, the PK-SVM showed the weakest performance, with accuracy consistently below 75%.

C. ROC and Confusion Matrix Insights

The confusion matrices for each classifier revealed the number of correctly and incorrectly classified instances, with RBF-SVM demonstrating the most balanced and precise results. The ROC curves confirmed this observation, as the RBF kernel consistently exhibited a higher area under the curve (AUC), reflecting its superior diagnostic capability in distinguishing between glaucomatous and normal cases.

D. Overall System Effectiveness

The integration of preprocessing, including optic disc segmentation and vessel removal, followed by multi-domain feature extraction (color, LBP, LAWS), and advanced SVM-based classification, contributed to the DMGD system's high accuracy. These results highlight the potential of soft computing techniques in enhancing computer-aided glaucoma diagnosis, offering a reliable second-opinion tool in clinical settings.

V. CONCLUSIONS

This study introduces a soft computing-based Discriminator Model for Glaucoma Diagnosis (DMGD) that effectively combines advanced image preprocessing, multi-domain feature extraction, and kernel-based SVM classification. By accurately segmenting the region of interest and removing irrelevant structures, the system enhances the reliability of glaucoma detection. Among various kernel classifiers tested, the RBF-SVM consistently demonstrated the highest accuracy across multiple fundus image datasets. The results indicate that the DMGD system offers a promising tool for supporting clinical diagnosis and could serve as a reliable second opinion in glaucoma screening.

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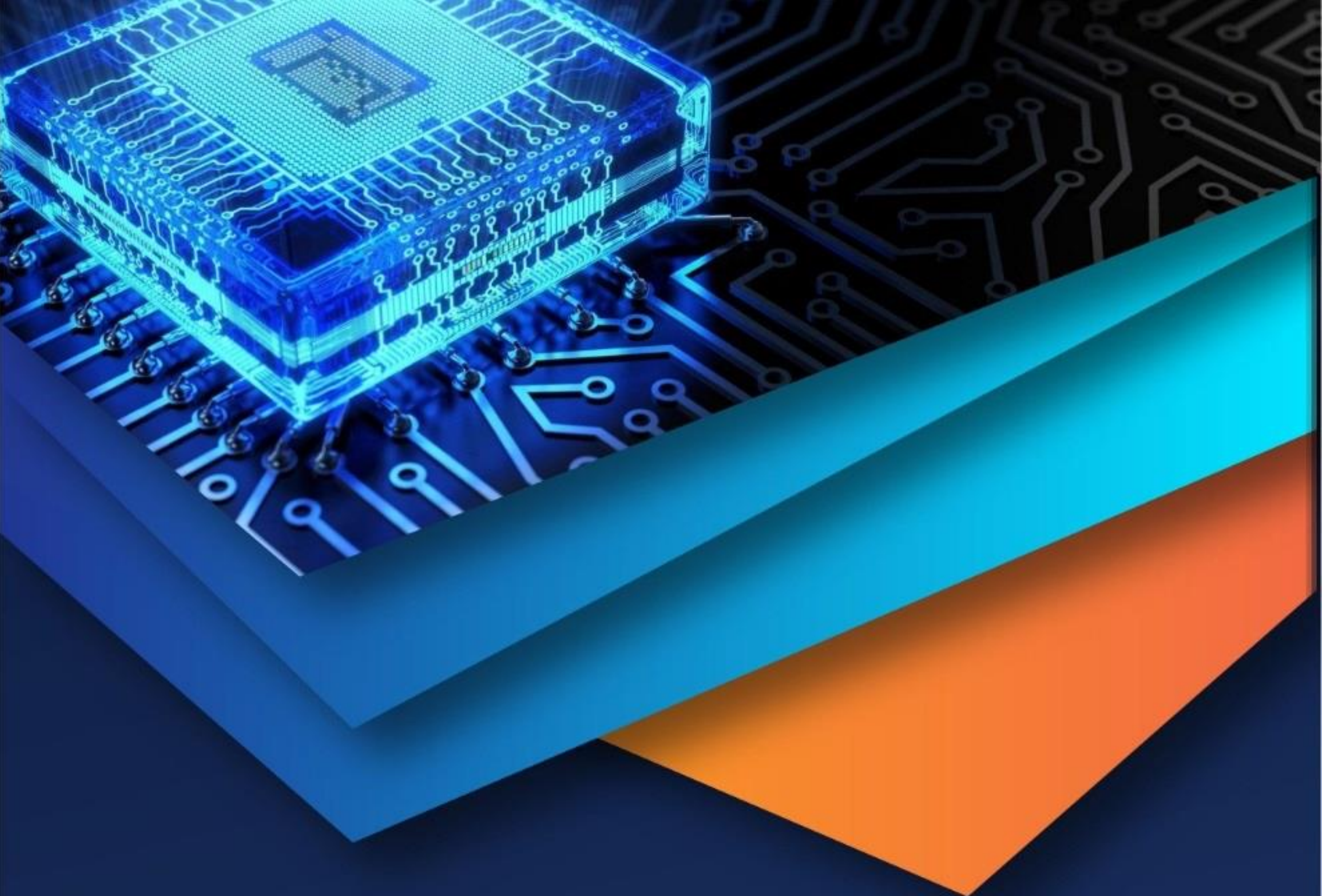

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