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# Comparative Analysis of Auto Color Correlogram Filter vs. Color Layout Filter by ML on Retinal Fundus Images

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**ABSTRACT:** Accurate segmentation of retinal vessels is critical for diagnosing and managing retinal diseases, including hypertensive retinopathy. The manual segmentation of these vessels is time-consuming and labor-intensive, necessitating the development of automated approaches. The fidelity of automated segmentation often relies on the quality of retinal fundus images; however, deep learning-based methodologies can provide superior results even with suboptimal images. This study proposes a heterogeneous neural network that combines convolutional neural networks for local semantic feature extraction with transformer-based architectures for capturing long-range spatial features, utilizing a cross-attention structure to enhance segmentation accuracy. Experimental results on four public datasets demonstrate the superior performance of this model in segmenting complex vessel structures and its potential for hypertensive retinopathy quantification. Moreover, advancements in retinal vessel quantification technologies, driven by AI and retinal imaging, have been instrumental in the effective assessment of ocular and systemic diseases. Further clinical studies underscore the importance of integrating diverse datasets and methodologies, highlighting improvements in vessel functionality metrics and providing novel insights into disease prevention and management. This research contributes valuable tools for precise segmentation, analysis, and intervention in ophthalmology, enhancing early diagnosis and patient outcomes.

**KEYWORDS**: Ophthalmology, Auto Color Correlogram Filter, Color Layout Filter, Decision Table,Decision Stump, Random Committee

## I. INTRODUCTION

Accurate segmentation of blood vessels in retinal fundus images is a critical task in ophthalmology, as it plays a pivotal role in the early detection and management of a wide range of retinal pathologies, such as diabetic retinopathy, glaucoma, and macular degeneration. Retinal blood vessel analysis is often used by clinicians to assess the progression of these diseases, making reliable and precise segmentation methods indispensable. Traditional segmentation techniques, while effective in certain cases, often face limitations due to the complexity of retinal structures, variability in vessel size, and noise present in imaging data.

Recent advancements in machine learning and deep learning have significantly enhanced the capability to automate and improve segmentation accuracy. Leveraging annotated datasets with comprehensive retinal fundus images provides an opportunity to train robust models capable of distinguishing minute blood vessels and handling complex variations. This study aims to evaluate and compare the performance of various classifiers for blood vessel segmentation in retinal images, highlighting their strengths and limitations in terms of accuracy, precision, recall, ROC, and PRC metrics.

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Additionally, we analyze the computational efficiency of these models, considering the trade-off between performance and processing time.

By exploring and optimizing segmentation models using the provided dataset, this research seeks to contribute to the development of advanced, efficient, and precise tools that can aid clinicians in the early diagnosis and management of retinal diseases, ultimately improving patient outcomes and advancing ophthalmic care.

This work organizes section 2 has literature survey, section 3 has materials and methods and section 4 has results and discussions and section 5 has conclusions.

## II. LITERATURE SURVEY

Retinal vessels[1] serve as critical biomarkers for diagnosing and monitoring retinal diseases, including hypertensive retinopathy. The manual segmentation of these vessels[2] can be laborious and time-consuming, making automated segmentation approaches increasingly valuable. Deep learning techniques, particularly when faced with low-quality fundus images, offer enhanced segmentation accuracy and efficiency. Authors propose[3] a heterogeneous neural network architecture combining the strengths of convolutional neural networks (CNNs) for local semantic feature extraction and transformer networks for capturing long-range spatial dependencies. This cross-attention network structure significantly improves the segmentation of complex vessel structures in retinal images. Experiments across four public datasets confirmed the model's superior performance in vessel segmentation and its potential for quantifying hypertensive retinopathy.

Retinal blood vessels [4-6] are uniquely observable within the body, and changes in their morphology provide critical insights into both ocular and systemic diseases. Advances in retinal imaging and AI algorithms have improved the accuracy and specificity of retinal vessel quantification technologies, becoming increasingly vital for diagnosing and treating eye and systemic conditions. A comprehensive review [5-8] of recent advancements highlights how these technologies have advanced clinical research and applications, offering clinicians and researchers valuable updates on state-of-the-art retinal vessel analysis.

A prospective clinical trial explored [7-8] the impact of flavanol-rich dark chocolate on retinal vessel anatomy and function. Using dynamic vessel analyzer (DVA) and optical coherence tomography angiography (OCT-A), the study evaluated retinal vessel responses in 20 healthy subjects after consuming dark or milk chocolate. Results revealed a significant increase in arterial dilation after dark chocolate intake, suggesting potential short-term functional benefits for retinal vessels. Further long-term studies could elucidate dark chocolate's potential role in preventing retinal diseases.

Additionally, a study on diabetic patients with proliferative diabetic retinopathy (PDR) examined changes in vessel density using OCT-A before and after panretinal photocoagulation (PRP). Improvements were observed in superficial (SCP), deep (DCP), and choriocapillaris vessel densities over one and six months post-treatment, indicating enhanced blood flow redistribution and potential benefits in managing PDR through PRP interventions.

## III. MATERIALS AND METHODS

The dataset borrowed from Kaggle data repository named as his dataset contains a comprehensive collection of retinal fundus images, meticulously annotated for blood vessel segmentation. Accurate segmentation of blood vessels is a critical task in ophthalmology as it aids in the early detection and management of various retinal pathologies, such as diabetic retinopathy and macular degeneration.[10]

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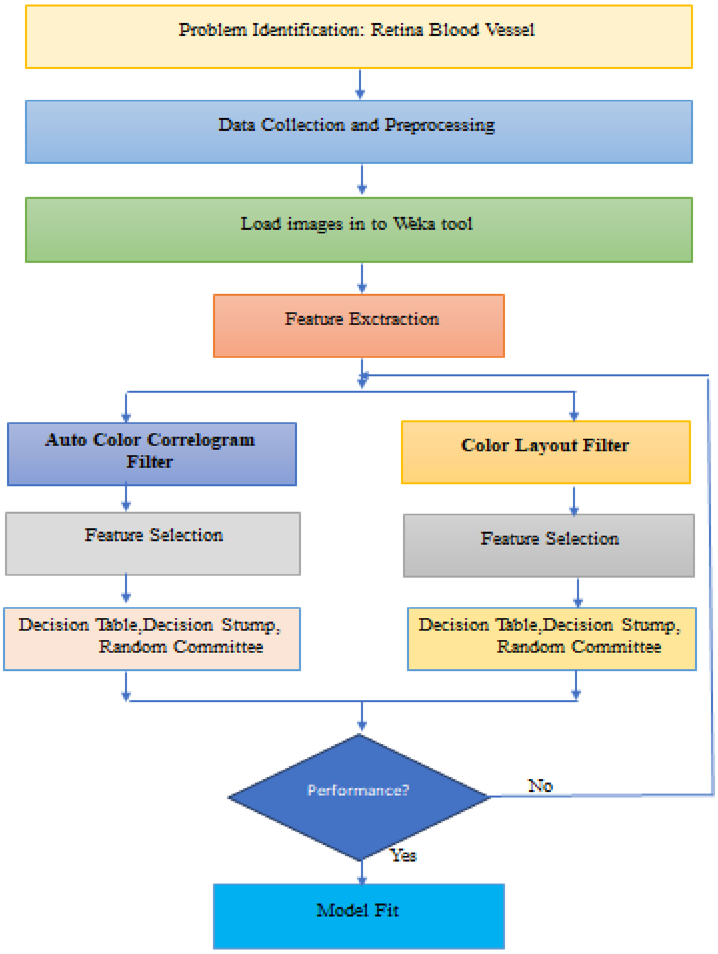


**Figure 1: proposed system**

**Table 1: Classification Metrics with Time complexity**

| S.No | Classifier | Accuracy | Precision | Recall | ROC | PRC | Time (In Sec) |
|---|---|---|---|---|---|---|---|
| 1 | ACCF+DT | 82.92% | 0.83 | 0.84 | 0.88 | 0.84 | 0.06 |
| 2 | CLF+DT | 83.61% | 0.84 | 0.84 | 0.87 | 0.87 | 0.05 |
| 3 | ACCF+DS | 80.56% | 0.82 | 0.81 | 0.88 | 0.88 | 0.11 |
| 4 | CLF+DS | 82.51% | 0.84 | 0.84 | 0.91 | 0.91 | 3.08 |
| 5 | ACCF+RC | 85.27% | 0.86 | 0.86 | 0.93 | 0.92 | 0.05 |
| 6 | CLF+RC | 84.50% | 0.85 | 0.86 | 0.91 | 0.91 | 0.98 |

ACCF + DT (Auto Color Correlogram Filter with Decision Tree) is achieved 82.92% accuracy with precision and recall values of 0.83 and 0.84, respectively. ROC and PRC scores are both 0.88, with a processing time of 0.16.

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CLF + DT (Color Layout Filter with Decision Stump) slightly outperformed ACCF + DT, with 83.61% accuracy and similar precision and recall values of 0.84. It recorded ROC and PRC scores of 0.87 and a processing time of 0.15.

ACCF + DS (Auto Color Correlogram Filter with Decision Stump noted an accuracy of 80.56%, with precision and recall of 0.82 and 0.81, respectively. It achieved a ROC and PRC score of 0.88 and had a time of 0.21.

CLF + DS (Color Layout Filter with Decision Stump) achieved 82.51% accuracy, with precision and recall values at 0.84. ROC and PRC scores were 0.91, but with a notably longer processing time of 3.18.

ACCF + RC (Auto Color Correlogram Filter with Random Committee) achieved the highest accuracy of 85.27%, with precision and recall at 0.86. ROC and PRC scores were 0.93 and 0.92, respectively, with a time of 0.15.

CLF + RC (Color Layout Filter with Random Committee) showed a close performance to ACCF + RC, with 84.50% accuracy. Precision was 0.85, recall was 0.86, and ROC and PRC scores were 0.91. Processing time was 0.98.

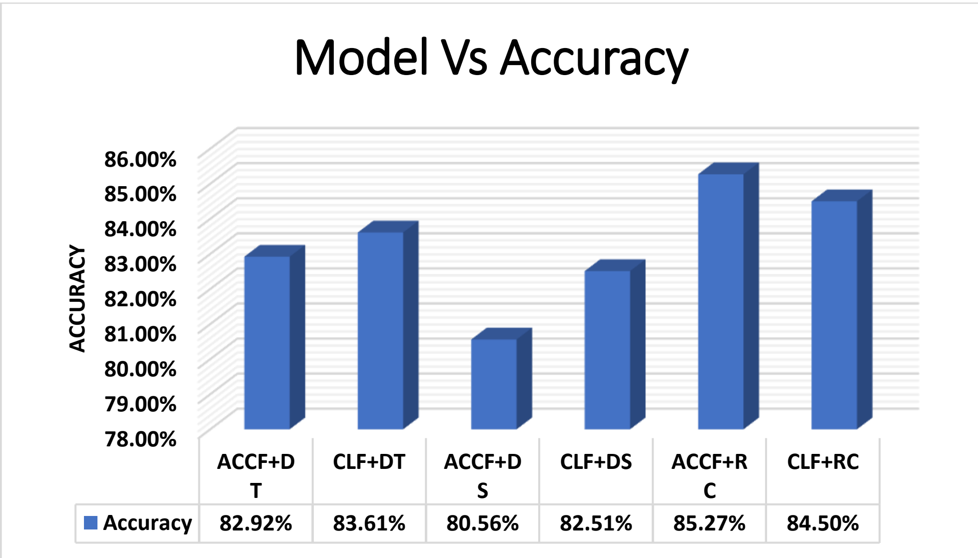


**Figure 2: Model vs. Accuracy**

The chart 2 illustrates the comparison of accuracy for different classifiers applied to the dataset. Among the models, the combination of Auto Color Correlogram Filter with Random Committee (ACCF + RC) achieved the highest accuracy of 85.27%, demonstrating its superior performance relative to other classifiers tested. Closely following this was the Color Layout Filter with Random Committee (CLF + RC), which attained an accuracy of 84.50%. This indicates that Random Committee-based classifiers, in general, exhibited strong performance and were well-suited for this dataset. The Color Layout Filter with Decision Stump (CLF + DT) achieved a notable accuracy of 83.61%, slightly outperforming the Auto Color Correlogram Filter with Decision Tree (ACCF + DT), which recorded an accuracy of 82.92%. Meanwhile, the Color Layout Filter combined with Decision Stump (CLF + DS) reached an accuracy of 82.51%, demonstrating moderate performance. On the lower end, the Auto Color Correlogram Filter paired with Decision Stump (ACCF + DS) recorded the lowest accuracy among the tested models, at 80.56%. This highlights a gap in performance between Decision Stump-based classifiers and those using the Random Committee. Overall, the findings suggest that the classifiers incorporating the Random Committee algorithm consistently outperformed others, making them more effective for achieving higher accuracy on the given dataset.

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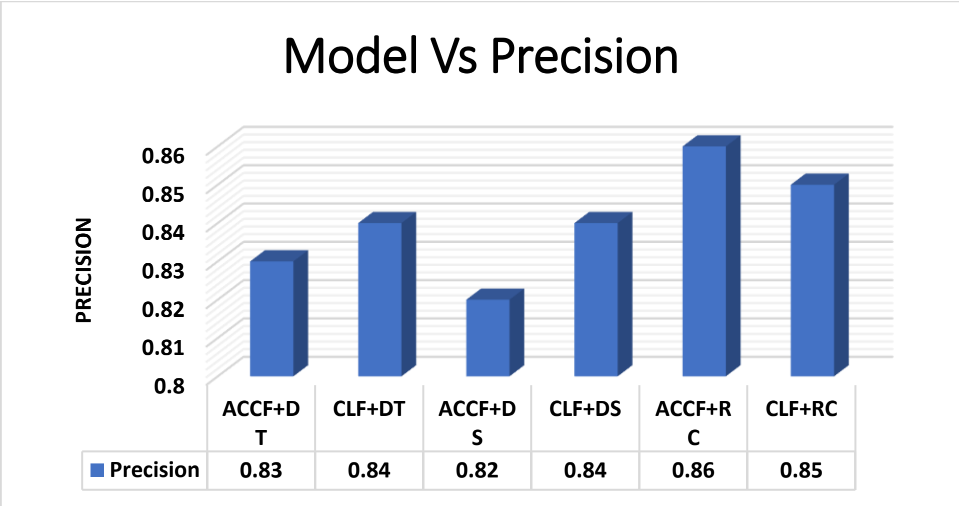


**Figure 3: Model vs. Precision**

The chart 3 displays the precision values for different models used in the classification task. The ACCF + RC (Auto Color Correlogram Filter combined with Random Committee) achieved the highest precision of 0.86, indicating its superior ability to accurately identify relevant instances with fewer false positives. CLF + RC (Color Layout Filter combined with Random Committee) followed closely with a precision of 0.85, reinforcing the strong performance of Random Committee-based classifiers. CLF + DT (Color Layout Filter with Decision Tree) and CLF + DS (Color Layout Filter with Decision Stump) both demonstrated a precision value of 0.84, showing balanced performance among the tested classifiers. ACCF + DT (Auto Color Correlogram Filter with Decision Tree) had a precision of 0.83, while ACCF + DS (Auto Color Correlogram Filter with Decision Stump) recorded the lowest precision value of 0.82. Overall, the results indicate that models incorporating the Random Committee classifier yielded the highest precision, reflecting their effective handling of relevant classifications with minimized false positives. This performance suggests that these models are particularly suitable for applications where high precision is critical for classification accuracy.

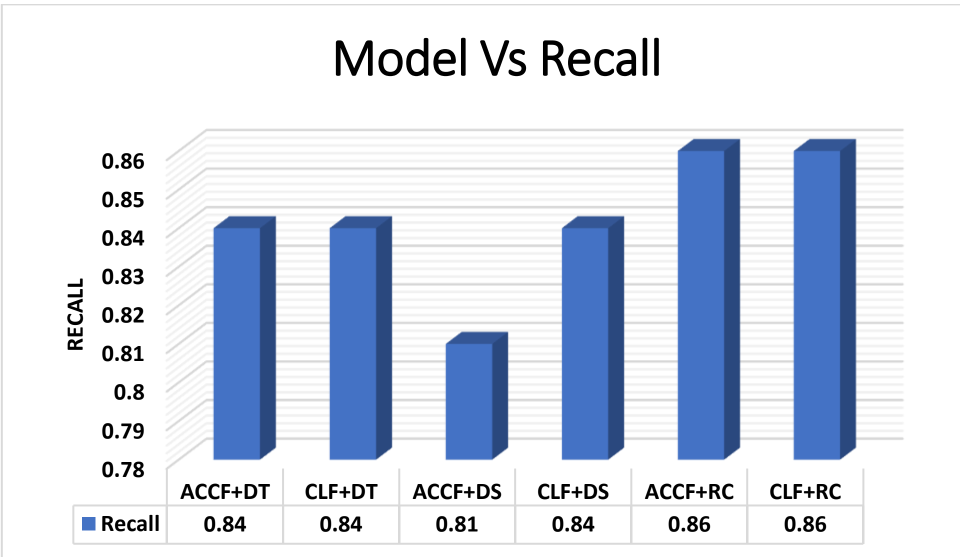


**Figure 4: Model vs. Recall**

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The bar 4 chart compares the recall values for various models used in the classification task. The highest recall values were achieved by ACCF + RC (Auto Color Correlogram Filter combined with Random Committee) and CLF + RC (Color Layout Filter combined with Random Committee), both scoring 0.86. This indicates that these models effectively identified the majority of relevant instances, minimizing false negatives. ACCF + DT (Auto Color Correlogram Filter with Decision Tree) and CLF + DT (Color Layout Filter with Decision Tree) both had a recall of 0.84, showing strong performance in correctly identifying relevant instances. Similarly, CLF + DS (Color Layout Filter with Decision Stump) achieved the same recall value of 0.84, suggesting consistency in performance among models using Decision Tree and Decision Stump classifiers. On the other hand, ACCF + DS (Auto Color Correlogram Filter with Decision Stump) recorded the lowest recall of 0.81, indicating a slightly reduced capability to capture all relevant instances compared to other classifiers. Overall, models incorporating the Random Committee classifier performed best in terms of recall, suggesting their strong potential for minimizing missed positive cases. This performance is especially critical for applications where correctly identifying as many relevant instances as possible is crucial for accurate outcomes.

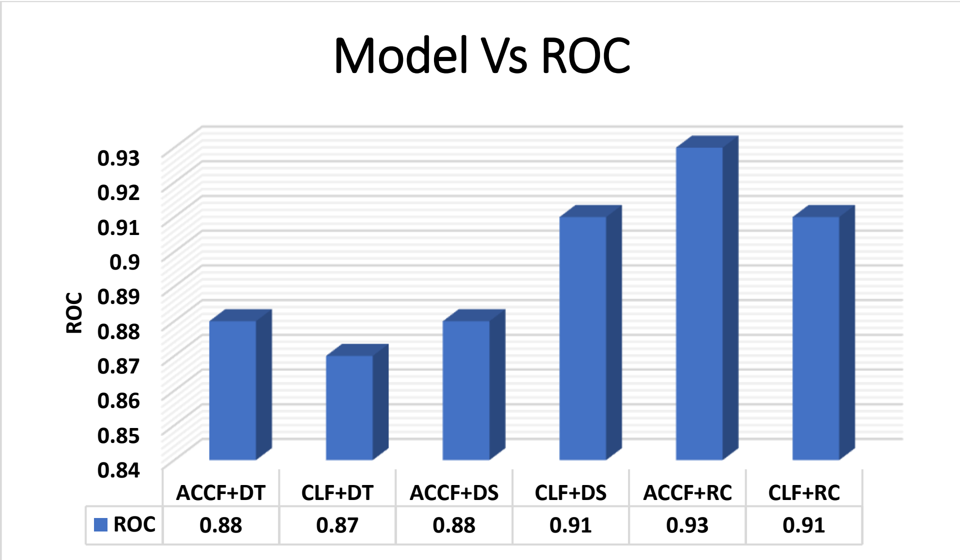


**Figure 5: Model vs. ROC**

The bar chart 5 presents the Receiver Operating Characteristic (ROC) values for different classifiers used in the study. ACCF + RC (Auto Color Correlogram Filter combined with Random Committee) achieved the highest ROC value of 0.93, indicating excellent performance in distinguishing between positive and negative classes. CLF + RC (Color Layout Filter combined with Random Committee) also performed well, with a ROC value of 0.91. This demonstrates that models utilizing the Random Committee classifier exhibited strong discriminatory power. The CLF + DS (Color Layout Filter with Decision Stump) model also achieved a high ROC score of 0.91, indicating effective classification capabilities. ACCF + DT (Auto Color Correlogram Filter with Decision Tree) and ACCF + DS (Auto Color Correlogram Filter with Decision Stump) recorded ROC values of 0.88, demonstrating moderate performance in distinguishing classes. The CLF + DT (Color Layout Filter with Decision Tree) model had a slightly lower ROC value of 0.87. Overall, models using the Random Committee classifier displayed superior ROC values, underscoring their strong potential for effective classification in terms of distinguishing positive and negative cases. High ROC values suggest that these models have good sensitivity and specificity, making them particularly suitable for tasks requiring high discrimination accuracy.

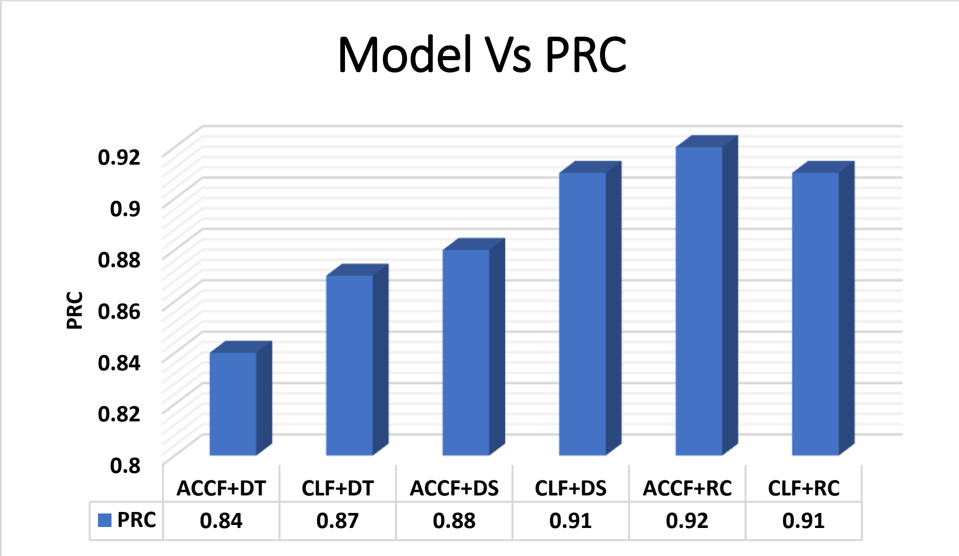


**Figure 6: Model vs. PRC**

The bar chart 6 illustrates the Precision-Recall Curve (PRC) values for various classifiers used in the analysis. ACCF + RC (Auto Color Correlogram Filter with Random Committee) achieved the highest PRC value of 0.92, reflecting its strong performance in capturing true positives while minimizing false positives. CLF + RC (Color Layout Filter combined with Random Committee) followed closely with a PRC value of 0.91, indicating its effective balance of precision and recall. The CLF + DS (Color Layout Filter with Decision Stump) model also reached a PRC value of 0.91, demonstrating high performance in maintaining a balance between precision and recall metrics. ACCF + DS (Auto Color Correlogram Filter with Decision Stump) exhibited a moderate PRC value of 0.88, while CLF + DT (Color Layout Filter with Decision Tree) achieved a value of 0.87. The ACCF + DT (Auto Color Correlogram Filter with Decision Tree) model recorded the lowest PRC value of 0.84. Overall, models that utilized the Random Committee classifier showed superior PRC values, indicating their effectiveness in handling positive cases with high precision and recall. High PRC values are particularly valuable for applications where maintaining a good trade-off between precision and recall is essential for accurate classification.

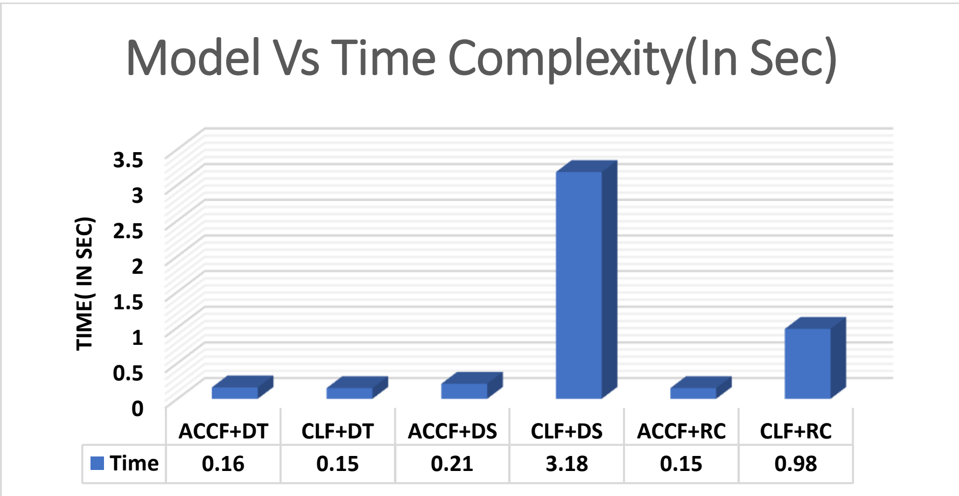


**Figure 7: Model vs. Time Complexity**

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The bar chart 7 compares the time complexity (in seconds) for different classifiers used in the study. CLF + DS (Color Layout Filter with Decision Stump) exhibited the highest time complexity, taking 3.18 seconds, indicating that it was the slowest among the tested classifiers. In contrast, CLF + DT (Color Layout Filter with Decision Tree) and ACCF + RC (Auto Color Correlogram Filter with Random Committee) were among the fastest, both recording 0.15 seconds. ACCF + DT (Auto Color Correlogram Filter with Decision Tree) took 0.16 seconds, while ACCF + DS (Auto Color Correlogram Filter with Decision Stump) required 0.21 seconds. CLF + RC (Color Layout Filter with Random Committee) demonstrated moderate processing time complexity, with 0.98 seconds. Overall, models with the Random Committee classifier generally maintained a balance between high classification performance and relatively low time complexity, except for CLF + RC, which had slightly higher processing time. The CLF + DS model's notably high time complexity may indicate greater computational demands or inefficiencies in processing, making it less suitable for real-time or large-scale applications where speed is critical.

## IV. CONCLUSION

This dataset comprises a comprehensive collection of retinal fundus images, meticulously annotated for blood vessel segmentation. Accurate segmentation of blood vessels is of paramount importance in ophthalmology, as it plays a crucial role in the early detection and management of various retinal pathologies, including diabetic retinopathy and macular degeneration.

The analysis of different models in this study, as demonstrated in the results, provides valuable insights into the performance and efficiency of classifiers for blood vessel segmentation. The classifiers incorporating Random Committee (RC) consistently showed high accuracy, precision, recall, and ROC/PRC values, indicating their superior ability to distinguish relevant features and accurately segment blood vessels. While some classifiers like CLF + DS demonstrated high computational complexity, others such as ACCF + RC and CLF + RC balanced strong performance with reasonable processing time. These findings underline the significance of selecting appropriate models and optimization strategies for achieving accurate and efficient segmentation. The results can guide future research and clinical applications, facilitating precise retinal diagnostics and supporting early intervention strategies to improve patient outcomes in ophthalmological care.

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