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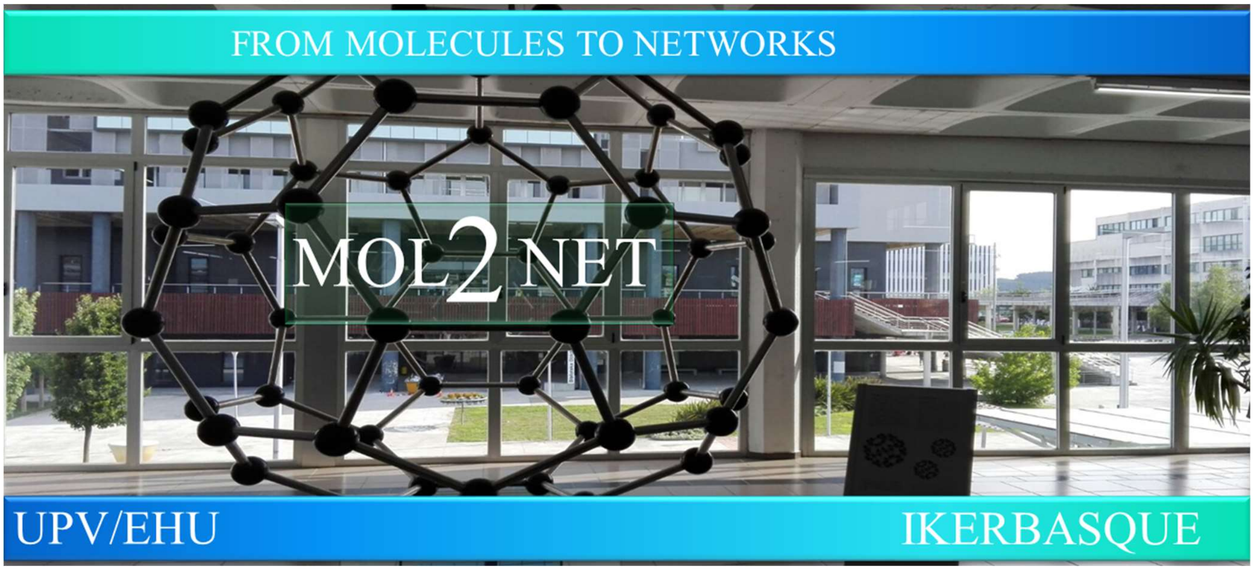


# Machine Learning-Based Automated Detection of Diabetic Retinopathy Using Retinal Fundus Images

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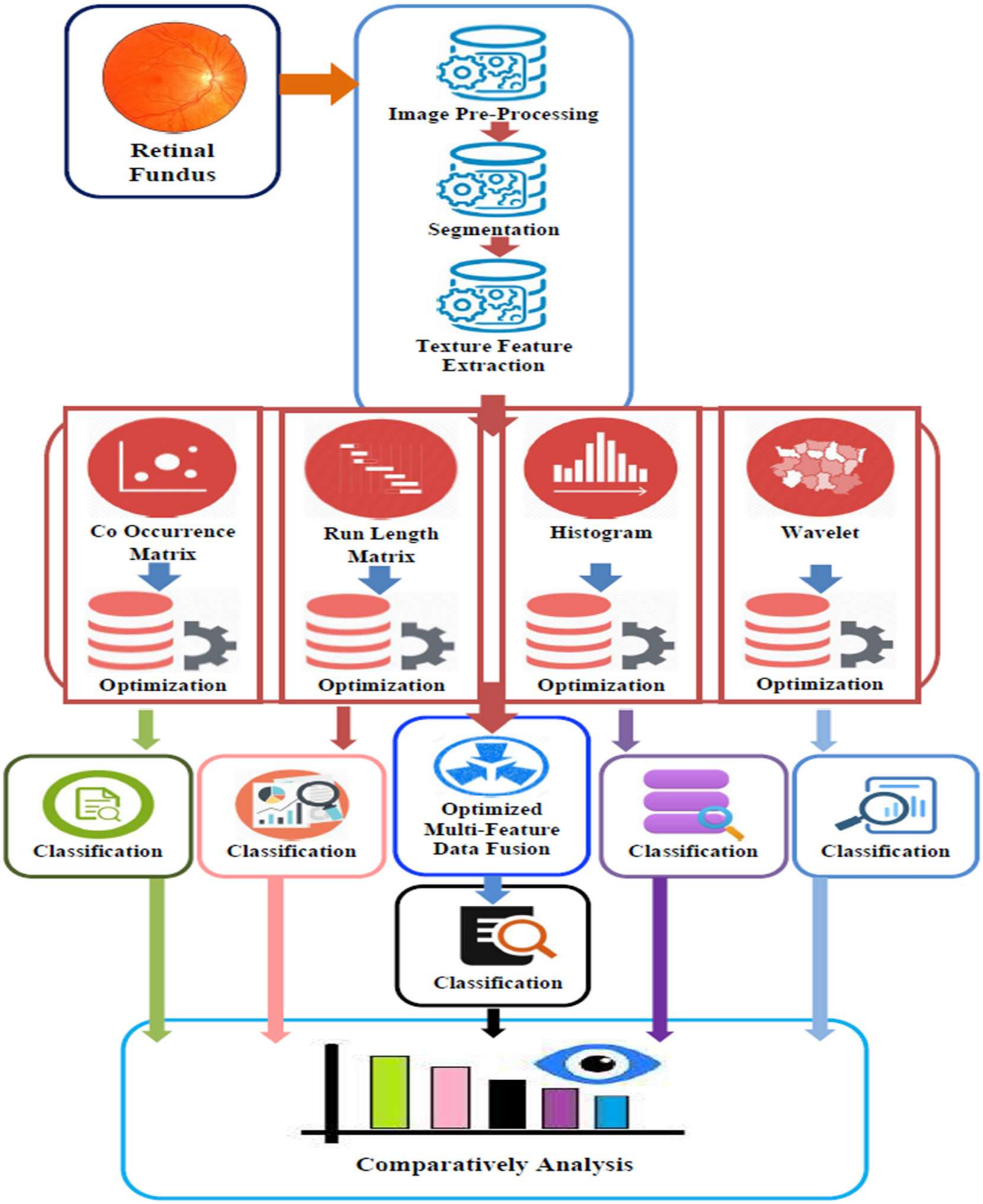
**Abstract.**

Diabetic retinopathy is the most well-known side effect of diabetes (DR). People with diabetes experience it and can observe how it affects human sight. Patients with DR have damaged blood vessels in the retina, the delicate layer at the back of the eyes. Even though it may not initially show symptoms or cause mild vision problems, DR can cause blindness if not treated. In this study, the classification of the retina based on texture analysis is used to examine the various phases of DR, including mild, moderate, non-proliferative, proliferative, and regular human eye. Stages of DR show misunderstandings about the body. As a result, it might be difficult for a doctor to tell which stage of DR a patient is going through. In order to recognize and classify DR phases, this work suggests an automated approach that combines machine learning (ML) and image processing (IP) techniques. The m has been created for texture analysis utilizing a data fusion approach. A multi-feature dataset and an ML classifier were used to create the model (using cross-validation 10). The multi-layer perceptron (MLP) has shown an extremely high degree of performance with a classification accuracy of 98.53%.

**Graphical Abstract**




## Introduction

The most common diabetic consequence is diabetic retinopathy (DR). Diabetes people are more likely to have it, which can affect either eye. Patients who suffer from retinopathy have blood vessels in the retina, the sensitivity layer found in the back of the eye, that is damaged. In the beginning, DR will either not create any symptoms or cause modest difficulties with vision. At the very end, the cause of blindness manifests itself [1]. You have had diabetes for a long time and are not controlling your blood sugar level. You promote these visual complications. DR slowly progresses over the years. If you have diabetes, you must check your eyes regularly. A good blood sugar level can help control retinopathy or delay in development. However, if you have retinopathy, there is a cure to improve your vision [2].

DR is one of the foremost causes of sightlessness, and valuable behaviors hold back the development of the disease, provided that it is identified in the early stage. However, DR is usually non-democratic in its early stage. Therefore, diabetes patients do not have to wait for any eye exam that is already too late for possible treatment and brutal radial Due to damages [3]. Average retinal assessment of diabetic patients guarantees an early identification of DR, which considerably reduces the occurrence of blindness. As for the massive occurrence of diabetes, mass screening is time-consuming, and it needs many qualified graders to scrutinize the fundus photographs probing the retinal lesions [2].

There has been an improvement in diseases related to age and society, Like diabetes. Eye-related issues can be divided into two main modules, for example, first eye disease, cataract, glaucoma, blepharitis, and conjunctivitis [1]. The second set is classified as lifestyle-associated diseases, for example, hypertension, arteriosclerosis, and diabetes. Diabetes can hurt the eyes by affecting the blood vessels of the eye retina, which consecutively can be the basis for loss of vision. When retina-based diabetes is artificially performed, this kind of disease is termed DR. Early treatment and evaluation have been recognized as a treatment for reducing the processing ratio by DR with, more importantly, regular medical examination for monitoring of this disease [4]. During this procedure, retina images are cautiously processed using a medical image camera. Screeners and ophthalmologists physically hunt them for the occurrence of DR objects [2]. Assessment of the hazards for the development of Age-Related Macular Deterioration (ARMD) needs consistent recognition and quantitative planning of the retinal deviations that are measured as the originator of the disease [2]. Distinctive signs for the second one is the so-called drusen that emerge as irregular white-yellow drops on the retina. Color retinal images are currently utilized to recognize the occurrence of drusens visually. Classification of these features and utilizing the conventional image analysis techniques are quite complex, mainly owing to the non-uniform elucidation and thein consistency of the pigmentation of the environment tissue [4]. Automated recognition and examination can offer essential information concerning the quantity and worth of the drusens.

Image Processing (IP) is a form of processing that is captured as either images or frames, for which the input is given as a and is also a picture attached to the IP output image. IP is related to digital IP, but visual and analog processing is also imaginable. Medical Image Processing is when the images generated from the human body for medical purposes are subjected to processing. It helps quickly to detect and identify the disease. In a complicated image dispensation scheme, the processing techniques must be efficient enough to relate the exact image processing method to the regions of interest [5]. The application of image processing (IP) and machine vision is increasing rapidly in engineering and science. The current progress of such techniques in the medical capacity is primarily reducing the time to diagnose the disease to prevent early diagnosis of medical diseases. Development has been successful in processing them, such as auto investigative systems. This system is based on algorithm verification that diagnoses diseases in less time [5]. For example, various automatic systems have been presented in medical imaging science. The following short background information is about the retina and DR.

## Materials and Methods

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This research aims to propose an intelligent classification model for DR stages using RF images. Four stages in DR, Mild, Moderate, non-proliferative, and proliferative, will be used for classification and the normal retinal case as shown in Figure 1.


**Figure 1:** Fundus Images of DR Stages and Normal Retina **[4]**

**This process is defined into eight basic steps.**

- The first step is the collection of image data. In this step, RF images of regular Patients and DR Patients are collected from Bahawal Victoria hospital Bahawalpur, Pakistan.
- The second step is image preprocessing. In this step, image enhancement using various filters, noise removal, and data cleaning is done for data standardization [6].
- The segmentation of the DR image, which takes place in the third stage, helps to eliminate unnecessary objects, identify the lesion's precise location, and smooth out its texture. This will make it easier to assess the qualitative character of the data and relevant information for the current investigation.
- The extraction of texture features is the fourth stage. Four features are retrieved from a standardized RF picture collection in this step: the histogram feature, "co-occurrence matrix" feature, "run length matrix" feature, and wavelet feature [7].

- Optimization comes in at step five. Choose the most valuable property from the retrieved feature dataset in this stage.
- The sixth step is classification. After completing the above step, the optimized texture feature dataset is prepared. Now different ML algorithms are implemented for classification accuracy.
- The seventh step is multi-feature data fusion. In this step, four different types of features are fused. After the fusion of multi-feature, the worth of the dataset was increased, and the previous step of optimization and classification was implemented on the optimized fused dataset [8-9].
- The eighth and last step is comparative analysis. In this step, analysis of the ML algorithm classification accuracy. Which feature gives the more reliable and efficient result, and fusion of multi-feature is helpful to improve the classification accuracy inside of the individual.

## Results and Discussion

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- Classification model: Multi-Layer Perceptron (MLP).
- Time taken to build the model: 0.23 seconds
- Test mode: 10-fold cross-validation

**Table 1:** MLP Classifier Summary

| | | |
|---|---|---|
| **Total Number of Instances** | 1500 | |
| **Correctly Classified Instances** | 1478 | **98.5333 %** |
| **Incorrectly Classified Instances** | 22 | 1.4667% |
| **Kappa statistic** | 0.9817 | |
| **Mean absolute error** | 0.2406 | |
| **Root mean squared error** | 0.3172 | |
| **Relative absolute error** | 75.1833 % | |
| **Root relative squared error** | 79.2885 % | |

**Table 2:** MLP Classifier Detailed Accuracy

| TP Rate | FP Rate | Precision | Recall | F-Measure | MCC | ROC Area | Class |
|---|---|---|---|---|---|---|---|
| 1.000 | 0.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | **Healthy** |
| 0.970 | 0.003 | 0.986 | 0.970 | 0.978 | 0.973 | 0.997 | **Mild** |
| 1.000 | 0.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | **Moderate** |
| 0.973 | 0.001 | 0.997 | 0.973 | 0.985 | 0.981 | 0.996 | **NonProliferative** |
| 0.983 | 0.014 | 0.946 | 0.983 | 0.964 | 0.955 | 0.989 | **Proliferative** |
| 0.985 | 0.004 | 0.986 | 0.985 | 0.985 | 0.982 | 0.996 | **Weighted Avg.** |

**Table 3:** Confusion Matrix using MLP Classifier

| Classified as | A | B | C | D | E |
|---|---|---|---|---|---|
| A = Healthy | **300** | 0 | 0 | 0 | 0 |
| B = Mild | 0 | **291** | 0 | 0 | 9 |
| C = Moderate | 0 | 0 | **300** | 0 | 0 |
| D = Non-Proliferative | 0 | 0 | 0 | **292** | 8 |
| E = Proliferative | 0 | 4 | 0 | 1 | **295** |

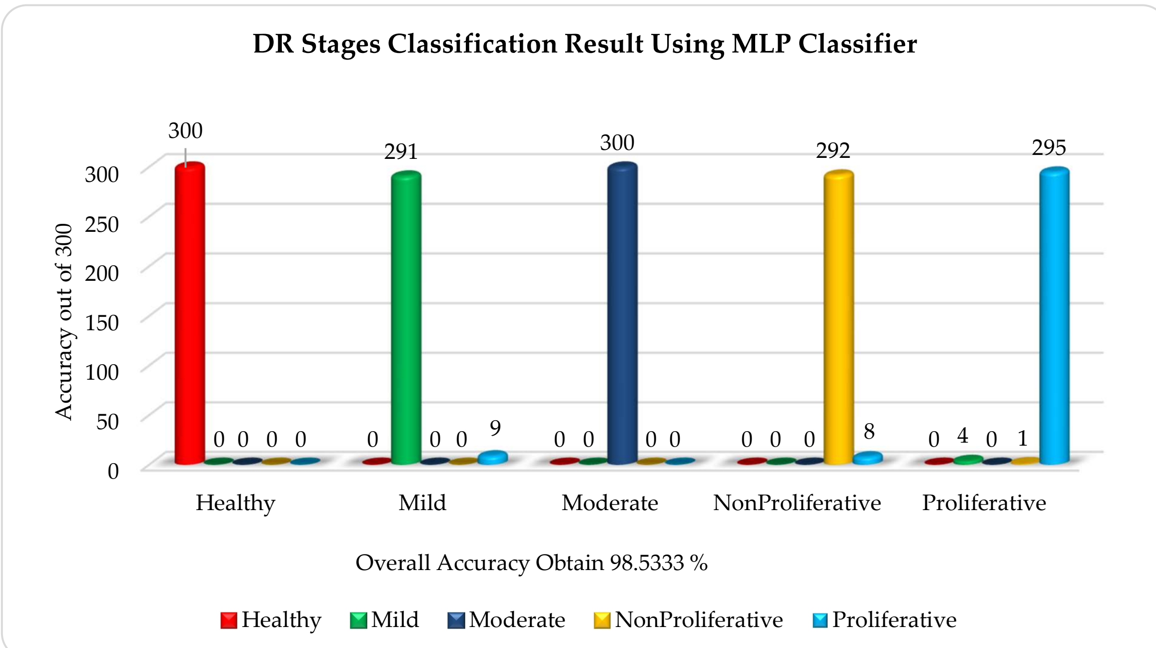


**Figure 2:** Accuracy of Dataset using MLP Classifier (10-Fold)

## Conclusions

Through fundus images and texture analysis, this study attempts to provide an intelligent system that employs ML classifiers to categorize DR stages. The objectives of this work were to create and choose suitable ideal features and identify suitable classifiers for efficient classification. This study examines the classification and feature extraction techniques for the four DR stages. The results differ because different modalities of texture analysis have been employed. The extracted characteristics are run-length, co-occurrence, wavelet, and histogram. The extracted feature mentioned above was eventually combined with the multi-feature dataset made using a data fusion approach to produce a multi-feature dataset. An ML classifier has been used to categorize each observation, and a comparative analysis has also been performed. As a result, optimized feature datasets and the optimization process have received the most attention. A large number of characteristics might raise the overall execution time and decrease classification accuracy. The study also links feature extraction, IP strategies, segmentation, and reduction strategies. The classification of DR required all of these processes. According to this study, using MLP classifiers to data sets created by combining several features might generate conclusions that are more exact and accurate (histogram, wavelet, co-occurrence, and run-length).

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