



Prediction of Diabetic Retinopathy Using Health Records With Machine Learning Classifiers and Data Science

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ABSTRACT

Diabetes is a rapidly spreading disease. It occurs when the pancreas produces insufficient insulin or the body cannot utilise it effectively. Diabetic retinopathy (DR) and blindness are two major issues for diabetics. Diabetes patients increase the amount of data collected about DR. To extract important information and undiscovered knowledge from data, data mining techniques are required. DM is necessary in DR to improve society's health. The study focuses on the early detection of diabetic retinopathy using patient information. DM approaches are used to extract information from these numeric records. The dataset was used to forecast DR using logistic regression, KNN, SVM, bagged tree, and boosted tree classifiers. Two cross-validations are used to find the best features and avoid overfitting. The dataset includes 900 diabetes patients. The boosted tree produced the best classification accuracy (90.1%) with 10% hold-out validation. KNN also achieved 88.9% accuracy, which is impressive. As a result, the research suggests that bagged trees and KNN are good classifiers for DR.

KEYWORDS

Bagged Tree, Boosted Tree, Cross Validation, Data Mining, Data Science, Diabetic Retinopathy, KNN, Logistic Regression, SVM

INTRODUCTION

Diabetes is a very widely spread illness everywhere in the world. This disease falls in the category of continual and persistent infection. It occurs when our bodies cease producing enough insulin. Insulin is a hormone that aids the cells in our bodies' cells utilizing glucose obtained from the diet. The body's glucose level rises as a result of insufficient insulin synthesis. A person develops diabetes as a result of this. The disease Diabetes has two categories that are Type 1 and Type 2. Various complications

DOI: 10.4018/IJRQEH.299959

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can develop due to a high blood sugar level, such as cardiovascular diseases, problems related to the nervous system, kidney problems, an increase in blood pressure, vision problems, etc.

INTRODUCTION TO DIABETIC RETINOPATHY

Damage to the retina's blood vessels, which would be the thin membrane that lines the eye's back wall, is to blame for this condition. This layer sends these signals are sent to the brain by this layer, which senses light and interprets what is seen. Some of the symptoms are floaters, blurriness, and dark spots or areas in the visual field. Moderate and mild cases of diabetes do not necessitate immediate treatment, but they should be closely monitored and managed carefully. Advanced circumstances necessitate medical or surgical intervention. The main goal of this study is to look at the findings of multiple studies and the progression of e-participation in India, both rich and poor (Gulati & Telu, 2016). Medical image acquisition is outlined in this article. The authors discuss its most common methods of acquiring images and assessing their significant threats and challenges in image-guided surgery. Medical image reconstruction systems' accuracy, dependability, and efficiency were also discussed (Alam et al., 2018). Diagnosis symptoms include the following:

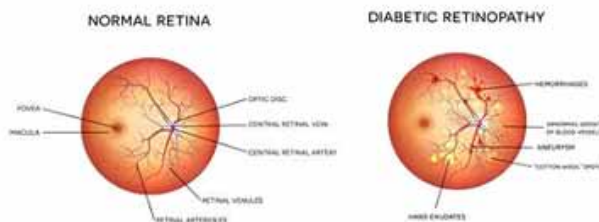
Shadows or flashes of light in your vision

- I. Blurry vision
- II. Fluctuating vision
- III. Colour-blindness impairment

your vision is blurred or distorted

The following figure 1 illustrates the state of diabetic retinopathy types. Figure source [Type 2 Diabetes Complications \(myhealthexplained.com\)](#):

Figure 1. Represented the variances between Normal retina and Diabetic Retinopathy.



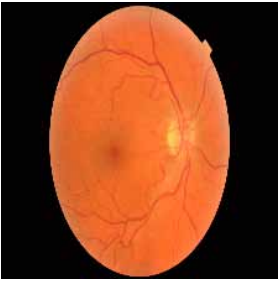

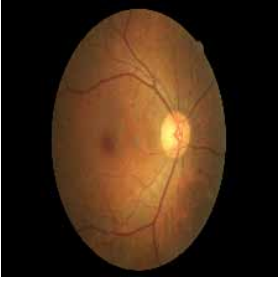


Through a complete eye examination, DR can be diagnosed. Diagnosis may include:

- § Diabetic patients and healthy controls will be compared for retinal thickness and retinal microcirculation (Cankurtaran et al., 2020)
- § Retinal detachment
- § Visual insight measurements to determine the affected area
- § Abnormalities in optic nerve
- § Size of the pressure within the eye
- § Refraction to determine if a new eyeglass prescription is needed

Diabetic Retinopathy Types

Diabetic retinopathy is classified into two types: (NPDR) and (PDR). To establish a baseline for the historical development of diabetic retinopathy (DR) through emerging clinical practice (Moshfeghi et al., 2020). To investigate the presence of diabetic retinopathy (DR), proliferative retinopathy (PDR), and non-proliferative retinopathy (NPDR) in Asian patients with type 2 diabetes mellitus (T2DM) (Yang et al., 2019). NPDR is also known as the early stage where walls of blood vessels of the retina become weaker. At this level, new capillaries are not grown. People with diabetes are affected by both non-proliferative (NPDR) and proliferative (PDR) retinopathy without diabetic macular edema (DME) around the world. There is a growing body of research on how to best treat these patients, as there is little agreement on the best way to put that research into action in clinical settings (Yonekawa et al., 2020). This study Aims to DR progression and worsening in patients with type 1 diabetes (T1DM) can be predicted four years in advance using ophthalmic imaging markers, such as retinal thickness measurements corneal nervous morphology (Srinivasan et al., 2018). According to the current study, microalbuminuria or moderately reduced glomerular filtration rate (GFR) may be better predictors of retinopathy development and progression in type 2 diabetic patients (Chen et al., 2012). The purpose of this study was to identify the most common clinical markers that predict NDRDs in patients with type 2 diabetes (Dong et al., 2016). The blood leaks from the blood vessels as the microaneurysms (MA) bulge out from the walls of the blood vessels in the retina. People with type 2 diabetes and kidney disease, can use this meta-analysis to determine whether diabetic retinopathy can differentiate diabetic nephropathy from non-diabetic renal diseases (He et al., 2013). Diabetic patients and healthy controls will be compared for retinal thickness and retinal microcirculation. Methods: On 86 diabetics (44 normal albuminuric and 42 microalbuminuric) and 51 control participants without diabetic retinopathy (DR), this prospective cross-sectional study was conducted (Cankurtaran et al., 2020). PDR is the higher and advanced stage of diabetic retinopathy. New blood vessels begin to grow in the rear side of the retina. When there is a lack of oxygen supply reaching the eye, retinopathy develops in microvascular complications of diabetes, a disease of small vessels. Table 1 represents the Diabetic Retinopathy Stages.

Table 1. Table 1 represented the Diabetic Retinopathy Stages

SNo	Stage Name	Type	Image	Percentage
1	No DR	Patient not suffering from Diabetic Retinopathy		82.6%
2	Mild NPDR	Patients have at least one Microaneurysm (slight red swelling in the walls of the retina) (18)		51.7%
3	Moderate NPDR	The capillary blockage begins. In one to three retinal quadrants, patients exhibit hemorrhages or MAs and cotton wool patches or hard exudates. (18)		35.6%
4	Severe NPDR	Due to more capillary blockages, retinal areas do not receive adequate blood flow. Owing to this, The retina is unable to produce new blood vessels to replace those that have been destroyed. (18)		4.6%
5	PDR	The retina begins to generate new blood vessels, but these are fragile and aberrant. As a result, they may leak blood, causing vision loss. (18)		8%

DR Stages

ROLE OF DATA MINING

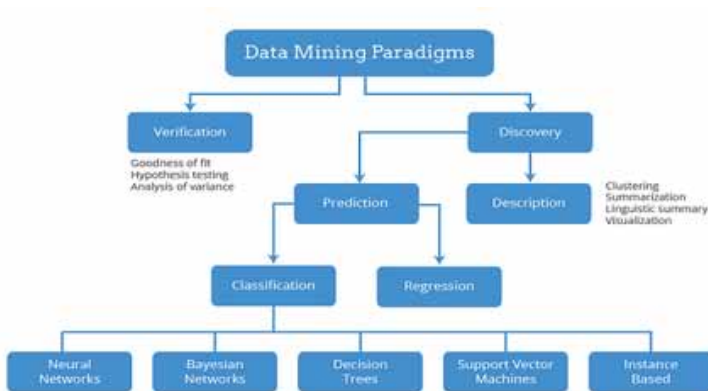
Blindness and visual impairment due to diabetic retinopathy are common occurrences. 4.8 percent of the world’s 37 million blind people were caused by diabetic retinopathy, according to current estimates. Patients who have had diabetes for an extended period are at risk of developing permanent blindness due to this condition. Symptoms began to appear in patients with vision problems at an early age. As a result, regular eye exams and early intervention usually keep this disease under control. Diabetes retinopathy early prevention and intervention studies frequently use different predictive models to arrive at their conclusions. It’s becoming increasingly commonplace for people to store their medical records in databases and digital storage devices. As a result, data mining techniques aid in discovering functional patterns while also taking into account issues with sensitive health records. Diabetic retinopathy can be predicted using data mining, and side effects associated with this disease can be identified in people with type II diabetes. The LR, Decision Tree, and ANN data mining models were chosen for this investigation. The ophthalmology Treatment center, UiTM Medical Specialist Centre, selected 361 Type II diabetic patients between January 2014 and December 2018, and the dataset contains 17 variables(Khairudin et al., 2020).

TECHNIQUES OF CLASSIFICATION

Machine learning, data mining methods, and tools have been used primarily in the field of diabetes study for a variety of purposes, including a) Prediction as well as Diagnosis, b) Diabetes patients Complications, c) Genetic Origins and Environment, d) Health Care and Management, and e) (Kavakiotis et al., 2017)Classification is one of the crucial tasks in data mining. Classification is a predictive method for predicting a data instance’s group membership—weather forecasting, medical diagnosis, scientific experimentation, and other fields use classification.

In medical data mining, classification algorithms are commonly utilized. Bayesian classifiers, Neural networks, Decision trees, Random trees, Support Vector Machines, Random Forest, and other classification approaches are available in data mining represented in figure 2.

Figure 2. Represented the Paradigms of Data Mining



There are two steps to classification:

- Step1: Model construction: The prediction model is developed using the suitable method in this step.
Step2: Model Application: The prediction model is applied to actual data in this step, and predictions are made as a result.

LITERATURE REVIEW

A Neural Network for DR Diagnosis

Patients with long-term diabetic conditions are most likely to develop diabetic retinopathy (DR), leading to blindness. The disease can be prevented or delayed by early detection of biomarkers and effective treatment. To better understand the prevalence and progression of DR, researchers have looked into several biomarkers. The existence of microaneurysms, exudates, hemorrhages, and the like in the patients' retinas all contributed to the disease. A strategy for preventing blindness has been suggested by looking at iris images from time to time. This study used a DR dataset and various machine learning classification algorithms to predict the occurrences of the DR in this study (Vadloori et al., 2019). The main focus of this paper is on the use of data mining and fuzzy system techniques in the diagnosis of diabetes. (Thakkar et al., 2021). To detect type II diabetes, data mining algorithms such as Naïve Bayes classifier, RBF System, and J48 are described in this article. Diagnoses are made with Weka by the so-called algorithms. (Sa'di et al., 2015)

Naive Bayes And Decision Trees For DR Diagnosis

Diabetes is a long-term condition that occurs when the body does not make enough insulin or is unable to utilize the insulin properly. Naive Bayes and SVMs, two of the most popular Machine Learning techniques, have been used to classify data in most systems. (Parthiban & K. Srivatsa, 2012) Data mining algorithms and their implementations were examined in this paper. Self-organizing maps outperformed Random Forest as well as other data mining algorithms, such as naive Bayes, decision trees, SVMs, and MLPs, in the evaluation of their ability to accurately diagnose diabetes. (Alalwan, 2019). Based on eye fundus images, this article aims at developing a classification algorithm that can identify diabetic retinal disease in patients. (Abreu et al., 2021). The CNN model for detecting plants and flowers, was discussed in this article (Wassan et al., 2021). Li et al. devise a scoring model to help patients with type 2 diabetes distinguish between diabetic nephropathy (DN) and non-diabetic renal disease (NDRD)(Li et al., 2020). In this study, the authors compare and contrast various machine learning-based classifiers. The COVID-19 pandemic tweet datasets were used in experiments by the author. The author used seven machine learning-based classifiers (Wisetsri et al., 2021). Amputations of the diabetic foot in patients are predicted by specific clinical characteristics identified in this study (Sayiner et al., 2019).

Table 2. Represent the Algorithm Performance Result

Algorithm	Accuracy
Neural Network	94.83%
Naive Bayes	87%
SVM	91%
Decision Tree	73.3%
Random Forest	64%

Table 2 demonstrates the accuracy of several categorization systems. The chart below shows a visual depiction of the accuracies as mentioned above. The neural network provides the best accuracy in the prediction of diabetic retinopathy, as can be seen in this figure 3.

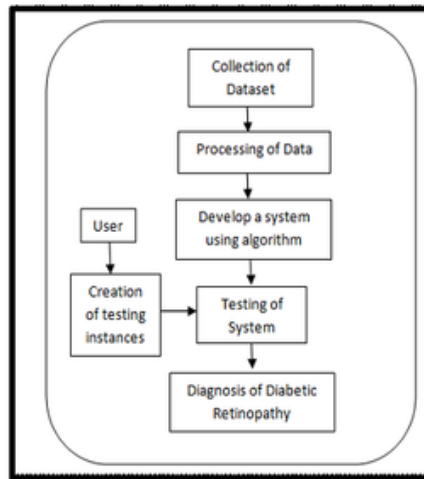
Figure 3. Algorithm accuracies depicted graphically



THE SYSTEM'S BASIC STRUCTURAL DESIGN

1. **Dataset collection:** The first step will be to collect data that may include various features such as blood group, Age, weight, genetic history, blood pressure, smoking habits, etc. This information will help develop a prediction system.
2. **Data Processing:** The dataset you've just gotten might have some noisy or null values in it. It's possible that some of the information isn't complete. As a result, it must be processed before original data can be used as input to the system. In this section, incorrect or null values can be fixed or erased. Figure 4 presents the model design.
3. **System development:** During this phase, a variety of tasks must be completed:
 - a) The dataset is analyzed.
 - b) The activation functions are chosen.
 - c) Using algorithms like SVM, Bayesian algorithms, feed-forward neural networks, naive Bayes, decision trees, random forests, and so on...
 - d) Detection and repair of errors
 - e) Put the system into action.

Figure 4. Display the System Architecture



Testing System

The testing system refers to determining whether or not the designed system is correctly identifying the condition based on symptoms. A testing instance is created when a user submits a query. And the testing module receives those test instances. The testing routine will detect diabetic retinopathy by considering all of the symptoms.

Materials And Methods

In this study, we have considered the data of a bunch of recurring outpatients for DR prediction. The information of various patients was collected and hand-picked from some private hospitals. Our dataset comprises 900 records. For our research work, we have recognized 10 different physical features. These features are Age of the patient, Gender of the patient, Term of diabetes mellitus, BMI (Body Mass Index), (SBPM), and (DBPM), HbA1C measure, Smoking habit, Level of lipoprotein (LDL), Level of Microalbuminuria.

Patients of all age groups and both genders have been taken into consideration. Duration of diabetes is the key feature in this study. HbA1C level is classified into two terms: less than 8 and more than 8. BMI is a binary measure that takes value 1 if it exceeds 30. Otherwise it takes 0. Measure of LDL is divided into three categories; 0, 1 and 2; for values – below 84 mg/dl, 84-111 mg/dl and above 111 mg/dl respectively. Smoking propensity holds 1 for smokers and 0 for non-smokers. Smoking propensity holds 1 for smokers and 0 for non-smokers. The degree of systolic and diastolic pulse estimations assumes an indispensable part. Microalbuminuria is the level of albumin, and its value of less than 30 is considered normal. Value among 30-300 demonstrates kidney issues (nephropathy). Each of the above features was chosen by specialists, and assessment was made dependent on these attributes.

Experimental Setup

In our work, we focus on the prediction of diabetic retinopathy. For this disease prediction, supervised learning models are best suitable, as the dataset contains labeled variables and values. Five distinct classification models have been applied to the dataset. Before applying the algorithm, as depicted in the structural diagram, A training data set and a testing dataset comprise the dataset. The training data set is being used to develop the DR forecasting models, while the test data is used to evaluate the model's accuracy.

We have additionally implemented validation on the DR dataset as this progression has assisted with discovering high-quality parameters for our DR prediction version and is likewise beneficial to forestall overfitting. Two distinct procedures we used to perform the validation step on our dataset are:

- § K-fold Cross-Validation
- § Hold-out Validation

Hold-out is the specific category of cross-validation. In this type, data is partitioned into two groups: training and testing data, and then the model is then developed using these sets. We have selected hold-out validation to facilitate dividing the data into train and test sets. A training set will be utilized to train the model. Subsequently, The model’s performance on the obscure data will be evaluated using a test dataset. In our experiment, one data split was used as a test set and the other as a training set. The additional data split was utilized as a test set, and the remaining data were used as the training set.

In k-fold cross-validation, data has been subjectively isolated into k sets, where k is any positive whole number. In these k groups, there are k-1 training sets, and 1 group is a test set. The dataset that we have collected in our study contains records of patients, which is restricted to 900 records. To generate a more precise and defined outcome, we have employed k-fold cross-validation. In this validation, the developed model will be trained for k times. Each time while training the model, it will result in a unique fold from training data, and afterward, it will be utilized for the testing set. Finally, the average value of the outcome of all these sets is calculated to get the execution accuracy. In this manner, we can avoid overfitting and get more accurate disease prediction results.

ALGORITHM ACCURACIES AND RESULT ANALYSIS

We used various classification techniques to predict DR. Logistic regression, K closest neighbor, support vector machine, bagged trees, and boosted trees are examples of these techniques. We used two forms of validations to test machine learning models on a small data sample: k-fold cross-validation and hold-out validation. The accuracy table for 10 fold and 20 fold cross-validation using the above-listed classification algorithms is given below:

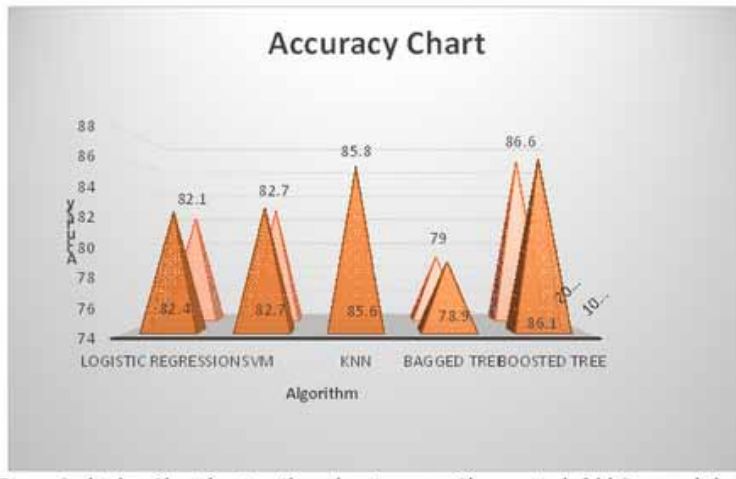
Table 3. The Algorithms Accuracy using k-fold cross-validation

Algorithm	Accuracy (in %)	
	10 fold CV	20 fold CV
Logistic Regression	82.4	82.1
SVM	82.7	82.7
KNN	85.6	85.8
Bagged Tree	78.9	79
Boosted Tree	86.1	86.6

From the above table, it can be observed that the boosted tree has performed superior to all other classifiers. It has resulted in 86.1% accuracy with 10 fold cross-validation and has given 86.6% accuracy with 20 fold cross-validation. The reason behind getting the best accuracy in boosted trees is that boosting is based on the principle of high bias and low variance concept and is built on weak learners. In turn, boosting reduces error by blending a learning algorithm in a chain. Similarly, in the

case of our DR detection boosting has achieved a strong learner from many weak learners. In our case, K nearest neighbors algorithm has also turned to good accuracy with 85.8% in the case of 20 fold cross-validation. Bagged trees resulted in the lowest accuracy, which is 79%. A more clear picture of the above accuracies can be seen through given graphical representation in the form of 3-D pyramids.

Figure 5. display Classification Algorithm Accuracy Chart using k-fold Cross-validation



The accuracy table for 10 fold and 20 fold cross-validation using the above-listed classification algorithms is given below:

After analyzing the accuracy after k-fold cross-validation, we have employed hold-out validation on the same DR dataset. As previously stated, the original data is partitioned into training and test sets for hold-out validation to discover the optimal prediction model. We chose the two most common partitions of the data where in the first move, 90% data was used as a training set and the remaining 10% as a test set. In the second case, 80% data was utilized for training the model and 20% to test. The table below depicts the accuracies of different classifiers:

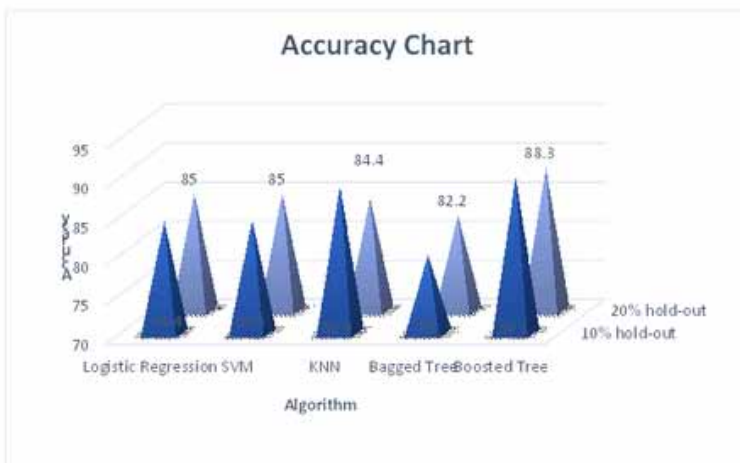
Table 4. Display the Accuracy table using Hold-out validation

Algorithm	Accuracy (in %)	
	10% hold-out	20% hold-out
Logistic Regression	84.4	85
SVM	84.5	85
KNN	88.9	84.4
Bagged Tree	80	82.2
Boosted Tree	90.1	88.3

From the table above, we can monitor that boosted trees, once again, have resulted as the best performer. This time algorithms have been applied with hold-out validation where we have used 10%,

and 20% held out. When applied with 10% hold out, boosted trees resulted in 90.1% accuracy, and when combined with 20% hold out, it has given 88.3% accuracy. As mentioned above, boosting is an ensemble used to create a robust classifier model from several weak learners. Cross-validation allows us to rotate within training and testing with a comparatively small dataset. Boosting combined with hold-out validation offers the best result as it lowers the variance. The k nearest neighbor classifier has also been furnished with 88.9% accuracy, which is quite good, along with the boosted trees. Bagged trees have resulted in the lowest accuracy of 80% when used 105 hold out validation. A comprehensible picture of the above accuracies can be seen through below given graphical representation in the form of 3-D pyramids.

Figure 6. Display the Classification Algorithm Accuracy Chart using Hold-out Validation



CONCLUSION

Diabetic retinopathy is a severe condition that affects a diabetic's eyes. Its high level may cause harm to both eyes. Diabetic retinopathy diagnosis and prediction is thus a real-world issue. This study aims to use physical health records of diabetes patients to predict diabetic retinopathy early. Our dataset consisted of 900 patient records. The classifiers used on the dataset for model creation include logistic regression, K closest Neighbor, Support Vector Machine, Bagged tree, and Boosted trees. K-fold cross-validation and Hold-out validation approaches have been used in conjunction with the classification algorithms to select the optimal features and avoid overfitting. As the experimental outcome of our study, boosted trees have outperformed with the highest accuracy amongst all, which comes to be 90.1% when applied with 10% hold-out validation. It produced 88.3% accuracy with 20% hold-out data. K-nearest neighbor classifier also resulted in a remarkable outcome with 88.9% accuracy. From this study, we can infer that the Bagged tree and KNN are the optimum classifiers for predicting diabetic retinopathy using significant physical health records.

CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

FUNDING AGENCY

Publisher has waived the Open Access publishing fee.

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