An Empirical Exploration of Artificial Intelligence in Medical Domain for Prediction and Analysis of Diabetic Retinopathy: Review

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Abstract. The country like India, the majority of people suffering from diabetic retinopathy, is caused by diabetes. Diabetic retinopathy may affect the eyesight of diabetic patients. This paper aims to explore the basics to advance artificial intelligence technology uses to detect diabetic retinopathy. The paper focuses on how different artificial intelligence methods will help detect diabetic retinopathy early, and it is more crucial to recover the vision for timely treatment. Various diabetic retinopathy detection methods are available for diabetic retinopathy, different datasets used in different ways some researcher uses primary datasets, and some use secondary datasets like eyepacs, messidor, kaggle, drive, and many more. Many of these datasets acquired by retinal fundus camera, which in the type of images or .cvs, it is again raw and manual annotations. Many machine learning and deep learning algorithms verify the specificity, sensitivity, and accuracy or classify different stages of diabetic retinopathy. The analysis included many retinal datasets; many artificial algorithms that use many methods and apply on different datasets that give different results vary between sensitivity 85% to 95%, specificity 85% to 96%, and accuracy 87% to 99%. This paper describes diabetic retinopathy’s detection with three primary facets; retinal datasets, methods to detect diabetic retinopathy, and performance evaluation metrics. To defeat the research challenges of the researchers that overall study and observations provide the clue in the field of diabetic retinopathy.

Keywords: Retinal Fundus Images; Ophthalmology; Diabetic Retinopathy; Artificial Intelligent; Machine Learning; Deep Learning

1. Introduction

India is a diabetic capital now; diabetes affects almost all the body organs with particular reference to the eye. It can damage the retina, and people with high blood sugar blind instantly. Diabetes eye disease refers to eye complications that can occur due to diabetes. Without diagnosis and treatment, diabetic illness can cause severe vision loss or maybe blindness. Now-day diabetic retinopathy is the leading explanation for vision loss due to diabetes caused by changes inside the eye blood vessels’ fundus. The retina is the light-sensitive membrane of tissue at the rear of the eye on the inside. A healthy retina is crucial for a good vision. In people with diabetes, unwanted blood vessels grow on the retina’s surface, and sometimes blood vessels might swell, break and leak fluid or blood. However, over time, diabetic retinopathy will go downhill. It has symptoms like spots floating in vision or a general blurring of vision. It is necessary to detect diabetic retinopathy as early as possible for prevention or delay in diabetic retinopathy. In that case, artificial intelligence plays an important role.
Technological changes have marked their presence in most areas of human life in the last few years. Artificial intelligence, the evolving domain, has provided an excellent enhancement for converting the human work capability into machine work. The explosion of the human population has called the machine automation industry to meet people’s daily living standards as human capability is not enough for it. Artificial Intelligence, the field was explored, and there came the answer to the above problem in the form that why we cannot provide some intelligence to the machine? They can self learn to respond in different situations, giving birth to machine learning and deep learning algorithm. Machine learning provide the capability to the machine to think and respond to the particular situation depending upon the experience derived from the refined dataset. Artificial intelligence has found its significant importance in the field of medical study, as it is very tough to categories the number of diseases based on their symptoms as most of them are significantly related to each other, and a thin line defers them. Human intelligence is a powerful tool for predicting and diagnosing the diseases, but analyzing all possibilities for a disease diagnosis requires time. Significant scale efficiency that becomes an overhead as patients suffering from the disorders does not have enough time for their survival, which leads to the introduction of artificial intelligence in medicine, where the artificial intelligence domain was significantly explored for disease prediction by considering and analyzing the massive scale of learning data and using cases of the previous patient.

Artificial intelligence has leveraged its power in the form of Machine learning (ML) and deep learning (DL) analysis, where ML is used for training & learning the system by creating a various neural-based model approach for categorizing the problems based on the different learning artifacts [1] [2]. On the other hand, Deep Learning uses the gathered knowledge by the ML to provide a platform which teaches machine how the human behaves by exploring the different possibilities in the known and unknown scenario for diseases prediction and diagnosis. The predicted results are more accurate as they predicated form the large sets of results database obtained by diagnosing the previous patients.

2. Machine learning and Its Types

Artificial Intelligence, a relevant domain in the field of computer science study, has marked its presence and dominancy in every industry sector, from small to large scale ones. The accurate, timely, and efficient analysis of the user’s data has become a bottleneck problem for many researchers as this insight provided is time-dependent that needs to be meet as early as possible. The use of artificial intelligence with different analytics tools like machine learning [3], deep learning [4] , image processing and many more have facilitated with excellent and good knowledge generation and summarization for the overall growth of the industry ranging from e-commerce sector to advance health care and medical domain where high efficiency of work desired [5].

Machine learning algorithm has three types, like supervised, unsupervised, and reinforcement learning algorithm. [6] [7].

2.1 Supervised learning

A supervised learning algorithm learns from well-labeled, which predicts output for new input data. It compares to learning which takes place in the presence of a trainer. Supervised learning allows us to gather data or produce a knowledge output from the previous experience.
Fig. 1 Supervised Learning

Fig. 1 gives a schematic diagram of supervised learning. In supervised learning, the number of training instances, each training instance comprises of input (X) and output (y), all these training instances are given to the learning algorithm to come up with a model, and this model can be used to classify or to find the corresponding output value (y) for a new observation X.

2.2 Unsupervised Learning

Unsupervised learning is a machine learning plan of action that mainly deals with unlabelled data, which do not have to supervise the model that permits the model to figure on its own to get information. It allows performing more critical processing tasks compared to supervised learning. It uses to find every type of unidentified pattern in information and find features that may be helpful for classification.

Fig. 2 Unsupervised Learning

Fig. 2 In unsupervised learning, we have different unlabeled inputs X (A, B, A, C, D, B, A...). The learning algorithm will produce clusters and group this data based on the similarity of data items to each other, so we can find out certain groups among the data, so that is called unsupervised learning.

2.3 Reinforcement Learning

Reinforcement learning neither supports supervised learning nor did unsupervised learning. The algorithms learn to react to a situation on their own.
Fig. 3 Reinforcement Learning

Fig. 3 In reinforcement learning, have an agent acting in an environment and wishes to search for what actions the agent must take at every step. The response that the agent takes base on rewards or penalties that the agent achieves in several states [7] [8]. For a learning agent, there is a beginning state and finish state, to achieve the highest state, there might be a particular path.

3. Analysis of Some Deep Learning Algorithms

3.1. Deep neural network (DNN)
It is the most straightforward deep learning algorithm use in classification related to applications; it has many hidden layers. Advantages of DNN broadly used with improved performance and superior accuracy, the disadvantage is the training operation required extra time.

3.2. Convolution neural networks (CNN)
The CNN algorithm usually employs for image-related applications; advantages are that the system’s learning process is fast with good accuracy and performance; disadvantage classification related applications required too many well-labeled training data.

3.3. Recurrent neural networks (RNN)
RNN is useful in sequential operation-related applications, and the weight of the network shares all system nodes. The advantages of RNN have superior accuracy in applications related to the identification. A disadvantage is for better performance, RNN required large datasets.

3.4. Deep belief network (DBN)
DBN helps supervised learning and unsupervised learning; there is a hidden layer of each sub-network that is available for the next sub-network to predict the output better greedy norms used in each segment of the network. Disadvantages at the time of the training process it required higher computational complexity.

3.5. Deep Autoencoder (DA)
DA is useful for the dimensional reduction of image features. It is another type of a supervised learning algorithm in which the input and output dataset's size is the same. The advantages of DA a well-labeled dataset did not require, and input data get robustness. The disadvantage, before using it required the pre-training process.

3.6. Deep Boltzmann machine (DBM)
DBM is one of the extensions of RNN and worked in unidirectional. Advantages it is more robust against interference, and it is also working efficiently for discrete predicted value. The disadvantages: some parameters are not possible for big datasets such as optimization, utilization, and analysis.
4. Literature Review

The prediction of diabetic retinopathy based on their symptoms, physical parameters reports like blood sugar monitoring, retina scan, and other diagnostic tools that illustrate the patient’s condition. The artificial intelligence-based system uses the above essential body parameters and medical science knowledge as an input study for the prediction and making decisions. The existing artificial intelligence system reviewed in the literature review consists of some basic fundamental prototype, and many researchers are extensively innovating this essential for making the system more human-like.

| Sr.No. | Author Name                  | Method used                                                                 | Classifiers                           | DataSets used                                                                 | Sensitivity (%) | Specificity (%) | Accuracy(%) |
|--------|------------------------------|----------------------------------------------------------------------------|---------------------------------------|-------------------------------------------------------------------------------|----------------|-----------------|-------------|
| 1      | Bhavana Sosale et al. [9]    | Smartphone-based diagnosis of diabetic retinopathy run offline              | Medios artificial intelligence algorithm | Primary dataset included non mydriaticretinal images. from 900 individuals    | 93             | 92              | NA          |
| 2      | Arun Pradeep et al. [10]     | The grade of exudates                                                     | Fuzzy rule set                        | DIARETDB0 and DIARETDB1                                                         | 98.1           | 96.96           | 98.2        |
| 3      | Enrico Borrelli et al. [11]  | Dilated fundus ophthalmoscopy                                              | Cohen’s kappa coefficient (κ) 0.96     | Primary dataset of Thirty-seven eyes (20 patients, 8 females)                  | NA             | NA              | Kappa coefficient (κ) 0.96 |
| 4      | K. Shankar et al. [12]       | Severity level                                                            | Synergetic Deep Learning              | Messidor DR dataset.                                                           | 98.54          | 99.38           | 99.28       |
| 5      | Payal Shah et al. [13]       | Images graded                                                             | Convolution neural networks           | Internal validation set/MESSIDOR1                                              | 99.7/90.4      | 98.5/91         | NA          |
| 6      | J. Anitha Gnanaselvi et al. [14] | Retinal blood vessels                                              | Multi-resolution curvelet             | STARE datasets                                                                | 97             | 96              | 97          |
| 7      | Quang H. Nguyen et al. [15]  | diabetic retinopathy progression.                                         | CNN, VGG-16, and VGG-19               | EyePACS dataset from Kaggle 2015                                               | 80             | 82              | 82          |
| 8      | Thippa Reddy Gadekallu et al. [16] | Component analysis based deep neural network model                          | DNN-PCA-GWO model                     | Diabetic retinopathy debrecen dataset                                           | 91             | 97              | 97.3        |
| 9      | Noratikah Mazlan et al. [17]  | The morphological operation carried out to enhance the images before feature extraction [17]. | MLP                                    | E-optha database                                                              | 86.8           | 92.1            | 92.28       |
| 10     | Anbaji S. Jadhav et al. [18]  | Image preprocessing, blood vessel removal, feature extraction, optimal feature selection, and classification [18]. | MGS-ROA-DBN                           | Kaggle dataset                                                                | 86.36          | 95.75           | 93.18       |
5. Metrics for Performance Measure

Confusion matrix obtained tree performance measures sensitivity, specificity, and accuracy as shown in Table 2.

| Actual Positive (AP) | Predicted Disease (D) | Predicted No Disease (C) | Total (n) |
|----------------------|------------------------|--------------------------|-----------|
| True Positive (TP)   | nD=TP+FN               | nC=FP+TN                 | n=nD+nC=nP+nN |
| False Positive (FP)  | nP=TP+FP               |                          |           |
| Actual Negative (AN) | False Negatives (FN)   | True Negatives (TN)      | nF=FN+TN  |

Table 2. Confusion Matrix

Whereas TP is true positives (Actual Positive, Predicted Disease), TN is true negatives (Actual Negative, Predicted No Disease), FP is false positives (Actual Positive, Predicted No Disease), and FN is false negatives (Actual Negative, Predicted Disease) [20]. If the class label of a record in a dataset is positive, and the classifier predicts the class label for that record as positive, then it is called a true positive. If the class label of a file in a dataset is negative and the classifier predicts the class label for that record as unfavorable, it is called a true negative. If the class label of a file in a dataset is positive, but the classifier predicts the class label for that record as unfavorable, it is called a false negative. If the class label of a file in a dataset is negative, but the classifier predicts the class label for that record as positive, it is called false positive [16], [19].

The following metrics used to evaluate the suggested model.

**Sensitivity:** It is the proportion of true positives that are correctly identified by the classifier during testing. It calculated using the following Sensitivity Equation.

\[
\text{Sensitivity} = \frac{TP}{TP + FN} \times 100 = \frac{TP}{nD} \times 100
\]

**Specificity:** It is the proportion of true negatives that are correctly identified by the classifier during testing. It calculated using the following Specificity Equation.

\[
\text{Specificity} = \frac{TN}{TN + FP} \times 100 = \frac{TN}{nC} \times 100
\]

**Accuracy:** It is the proportion of correct predictions that a classifier has made compared to the actual value of the label in the testing phase. Also, it said as the ratio of several correct assessments to the number of all evaluations. It calculated using the following Accuracy Equation [16], [19].

\[
\text{Accuracy} = \frac{TN + TP}{TN + TP + FN + FP} \times 100
\]
6. Existing Work of Artificial Intelligence System for Diabetic Retinopathy

The diagnosis of the ophthalmology retina diseases extensively highlighted explored with intensive expertly. The deep learning machine learning and Data mining have played a massive role in harnessing the capability of artificial intelligence for the efficient prediction and diagnosis of the diseases.

Fig 4 Artificial intelligence automated System

Fig 4 depicts the different steps that carried out in the field of artificial intelligence diagnosis systems, and many researchers are actively contributing to the artificial intelligence Module and Deep Learning Module to make it highly accurate and more precise. The segmentation and pre-processing steps are taken into consideration to get accurate data for prediction specific methods that also explored while segmenting the input data.

7. Limitation and Research Gap Identification in the existing system

Literature study based on the various model for detecting diabetic retinopathy, the following points indicated its limitations:

1. Very few methods are obtainable base on a machine and deep learning technique for detecting diabetic retinopathy but efficiency less.
2. In most of the plans, refinement of data, segmentation, and feature extraction not adequately implemented.
3. Most of the methods applied using their privet datasets; that is why less consistency in current technologies.
4. Many techniques utilized small datasets here efficiency is too high, but when implemented for the massive size of the datasets, the performance of current methods is doubtful.
8. Some viewpoint needs to improve for the detection of diabetic retinopathy is as below

1. To build an efficient segmentation technique for retinal images.
2. To develop an efficient feature extraction model for retinal images.
3. Design and development of efficient machine learning for classifying diabetic retinopathy.
4. Develop successful models which will for any dimension of retinal images datasets.

9. Discussion & Inference

Artificial intelligence automated system in diabetic retinopathy will be the leading-edge technology in the nearer future based on its applications developed research carried out. In the process, the literature review helps us understand that an AI-based system can help diagnose ophthalmology diseases for retina scans up to a large extent. The automated system also has some challenges and scope that need to be taken care of, and more research needs to do for making the system precision value to 100% as it deals with human life intervention. The review section also highlighted that the development in machine learning, deep learning, and data mining played an inventive role in improving the system's accuracy, precision, and security. Further work concentrated on developing an artificial intelligence automated module to achieve more precision and accuracy towards predicting and shaping the concentrate future towards development.

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