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A Systematic Review on Diabetic Retinopathy Classification Using AI Techniques and IoMT

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Abstract

Diabetic retinopathy is a complication in the retina of the eye due to the accumulation of high glucose levels among the Type 1 and Type 2 diabetes patients. It has also been noted that early diagnosis of the diabetic retinopathy helps patients overcome vision loss. The Internet of Medical Things (IoMT) is an emerging technology in the medical field that allows patients to send and receive medical data to hospitals and consult with doctors as needed. IoMT applications in diabetic retinopathy assist not only in early detection but also in diagnosis, enabling patients in the early stages to address vision problems. Therefore, this paper presents a survey of various machine learning, deep learning, combined AI techniques, the role of smartphones and handheld devices, and the application of IoMT in the early detection and diagnosis of diabetic retinopathy to mitigate vision loss in patients.

Keywords: Diabetic Retinopathy, Artificial Intelligence, Machine Learning, Deep Learning, IOMT, Smartphone.

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1. Introduction

Diabetic Retinopathy (DR) is one of the side effects of high glucose levels in the blood. It affects the light-sensitive retina part of the eye and can lead to permanent blindness. According to statistics from the National Eye Institute, Diabetic Retinopathy occurs mainly in 77% of cases due to Type 1 diabetes and 22.95% due to Type 2 diabetes. Therefore, individuals with chronic diabetes should undergo regular Diabetic Retinopathy screenings to reduce the risk of vision issues. Since numerous demographic populations are suffering from both Type 1 and Type 2 diabetes, there are many technical aspects required to detect and diagnose Diabetic Retinopathy.

Artificial Intelligence plays a major role in most sectors, with many machine learning (ML) and deep learning (DL) algorithms effectively detecting and diagnosing Diabetic Retinopathy using various imaging techniques and tools. The Internet of Medical Things (IoMT) is an extension of telehealth services merged with the Internet of Things (IoT) that comprises patients' medical devices, which collect necessary information about the disease regularly and transmit it to doctors or hospitals. This helps patients receive medical assistance at their own locations.

This paper surveys the topics of Artificial Intelligence (AI) algorithms, including Machine Learning and Deep Learning methods, as well as the role of IoMT in the detection and diagnosis of Diabetic Retinopathy. The paper is organized as follows: i) Introduction, ii) Machine Learning Techniques, iii) Deep Learning Techniques, iv) Combined AI Techniques and Handheld Devices, v) IoMT, vi) Discussion, and vii) Conclusion.

2. Software and Control System

2.1 Machine Learning Technique for Diabetic Retinopathy

Machine learning techniques in the field of ophthalmology play a vital role in the detection and classification of eye-related issues due to various factors. The importance of early detection and diagnosis of ocular diseases, machine learning algorithms utilized for the analysis of retinal images, the scarcity in the development of advanced ophthalmology equipment and devices, and the integration of handheld devices with machine learning techniques for the early detection of diabetic retinopathy are surveyed in the article [1]. The diagnosis of hypersensitivity and diabetic retinopathy is reviewed in the paper [2], where the authors surveyed papers based on scientometric analysis, country analysis, author analysis, and journal analysis of the usage of various machine learning and AI techniques used for the early detection of diabetic retinopathy. An ensemble-based machine learning algorithm using SVM (Support Vector Machine), decision tree, Naïve Bayes, and random forest is utilized by the researchers in the paper [3], where the processing algorithms use image-based, lesion-based, and diameter of optic-based analysis for the study. The researchers in the paper [4] used 89 ocular images for diabetic retinopathy detection using k-means clustering for segmentation and Random Forest (RF) with SVM for comparing their potential, where the RF showed a 96.62% recognition rate compared with the SVM to detect and automate the process of obtaining unusual blood vessels, cotton wool spots, and exudate dots in the fundus images. The researchers in the paper [5] investigated 17 variables, including images, physical and lab measurements, insulin levels, and demographic information from 32,452 patients in a Chinese central tertiary hospital in Beijing for the detection of retinopathy using the XGBoost algorithm, and compared it with RF, SVM, and Logistic Regression machine learning methods, where the XGBoost using SHAP yielded better results and was clinically interpretable. Fig. 1 shows the ML techniques used for DR diagnosis and detection.

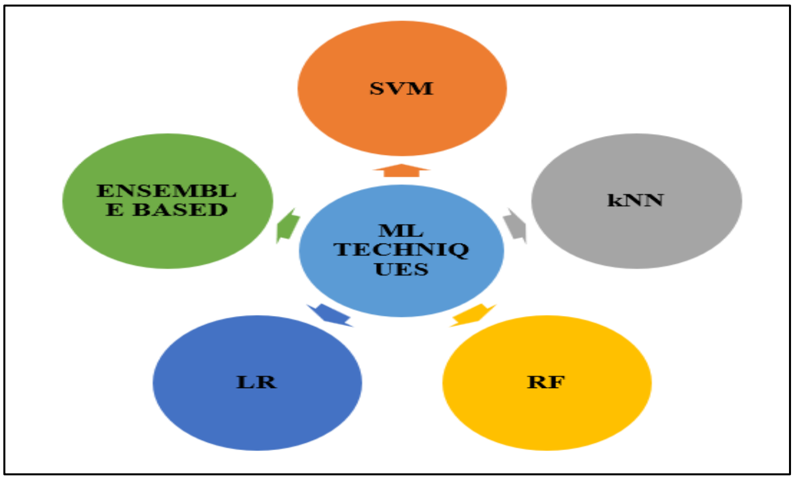

Figure 1. ML Techniques Involved in Diabetic Retinopathy Detection and Diagnosis

The Saudi Diabetic Data is used by the authors in the paper [6] for the detection of Diabetic Retinopathy using the Random Forest machine learning technique along with other clinical information like Body Mass Index (BMI), age of onset, duration of diabetes, HbA1c, systolic blood pressure, age, and medication duration. A home usage-based Diabetic

Retinopathy classifier is proposed in the paper [7], where the authors used SVM and Deep Neural Networks to extract the GLCM (Gray Level Co-occurrence Matrix) feature and calculated the AUC (Area Under the ROC Curve), with the DNN model outperforming the SVM. The early detection of Diabetic Retinopathy is carried out using a segment-based approach utilizing lesions, followed by classifiers and predictors produced in the paper [8]. Parameters such as an AUC of 0.963, specificity of 0.9637, and sensitivity of 0.9637 were estimated. Early diagnosis is emphasized in the detection of Diabetic Retinopathy using the machine learning technique with the ADAM optimizer, which showed 92% efficiency as presented in the paper [9]. The authors in the paper [10] addressed blindness as a major issue in diabetes, which can be mitigated through early detection and diagnosis using machine learning methods employing boosted trees, bagging, logistic regression, KNN (k-nearest neighbors) algorithm, and SVM, with kNN demonstrating better performance.

The HIMLA (Hybrid Inductive Machine Learning Algorithm) is used for feature extraction and classification of the color fundus image dataset CHASE, as implemented in the paper [11], where the efficiency exceeded 96% compared with diagnostic-based, genetic algorithm-based, and neovascularization-based ML techniques. Ensemble-based machine learning techniques employing decision trees, logistic regression, ADABOOST, kNN, and Random Forest classifiers for the detection of Diabetic Retinopathy using fundus images are proposed in the paper [12], where the min-max normalization method is used to efficiently extract healthy and unhealthy DR images. Two modes of deep transfer-based representative learning, such as fine-tune mode and feature extraction mode using Inception V4, are utilized in [13] by the researchers, where the primary mode showed 96.6% accuracy and the secondary mode showed 97.7% accuracy in the disease grading processes. Three machine learning techniques—Simple Tree, Weighted kNN, and Cubic SVM—are applied to the DIARETDB0 and DIARETDB1 datasets, and the researchers, along with the machine learning techniques, emphasized preprocessing methods such as converting binary to grayscale, binarization, edge detection using the Canny method, image dilation, and erosion for cleaning the initial dataset images, which improved the accuracy of all the ML techniques, with Simple Tree outperforming the other two [14]. A survey on the image quality assessment of datasets for Diabetic Retinopathy available in general is carried out in the paper [15].

3. Deep Learning Techniques for Diabetic Retinopathy

In the paper [16], a three-field deep learning system was adopted for screening 575,431 eyes based on the internal and external validation sets, and the results are compared with a one-field deep learning system. The proposed model outperforms the conventional system by a 5% improvement in glycated hemoglobin, and the number of years with diabetes is discussed. Fig. 2 depicts the DL algorithms for DR detection and diagnosis. The densely connected convolutional neural network is used in the two datasets to check the accuracy of the applied algorithm for the early detection of diabetic retinopathy, rated in terms of no DR, mild, moderate, severe, and proliferative DR, as discussed in the paper [17]. The UCI machine learning repository, using Harris Hawks optimization, extracts features and applies Principal Component Analysis for the Diabetic Retinopathy Debrecen dataset, which shows better performance compared with kNN PCA, Naive Bayes PCA, SVM PCA, conventional DNN, and DNN PCA, as shown in the paper [18]. The CNN-based deep learning is adopted in the paper [19], where the authors diagnosed five categories of DR: absence, mild, moderate, severe, and proliferative. They concluded with the accuracy based on the number of epochs, where the maximum accuracy attained was 83.6%, and compared the results with statistical classification, fuzzy logic, and decision support systems. The severe cases of DR are considered in the paper [20], where the Inception V3 algorithm is used for classification. The evaluation parameters are tested for an input resolution size of 896×896, where cases such as hard exudates, cotton wool spots, preretinal hemorrhage, and vitreous hemorrhage were easily classified. However, the authors' proposed method showed difficulty in the recognition of IRMA lesions.

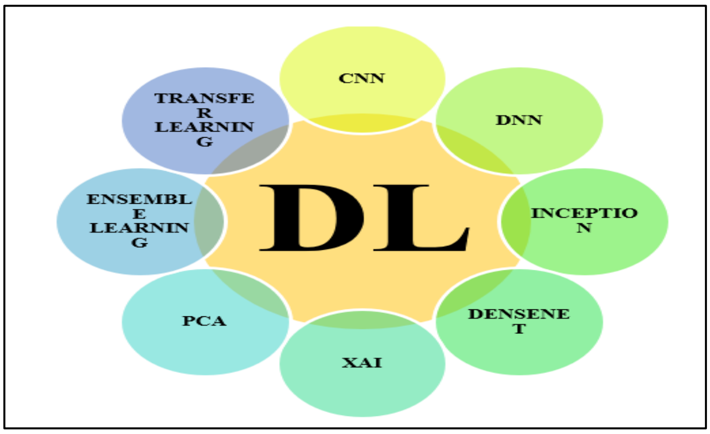

Figure 2. DL Algorithms for DR Detection and Diagnosis

4. Combined AI Techniques and Handheld Mobile Devices

The survey on DR screening technologies like IDx-DR biomarkers, RetmarkerDR software, Eye ART, Google, Singapore SERI-NUS, BOSCH DR algorithm, Retinalyze, etc., is discussed in detail, focusing on automated lesion classification, challenges, and improvements in DR detection and diagnosis, as addressed in the paper [21]. Figure 3 shows the techniques covered in AI. Smartphone-based low-sleek fundus camera images are classified based on ML and DL algorithms to achieve the highest accuracy, making treatment accessible for people in remote areas, as proposed in [22]. The telehealth-based DR detection and diagnosis are reviewed in the paper [23], where the authors emphasize the importance of regular screening, coverage of risk factors in DR for diabetic patients in rural areas, discussing knowledge of vision-threatening issues and diabetic macular edema, the need for early prediction, and treatment. The importance of CNN in deep learning, the cost-effectiveness of tomography devices, the development of handheld devices, the roles of ML and DL in classifying DR using fundus images recorded by smartphones, and the significance of telehealth are discussed in the paper [24]. The sight loss due to diabetes, screening methods, AI development in DR detection and diagnosis, ML and DL algorithms for fundus image and lesion-based image classification of DR severity, the importance of handheld devices for self-assessment, and telehealth-based DR analysis and scanning using confocal ophthalmology are surveyed broadly in the paper [25]. The authors in paper [26] surveyed 74 journal papers concerning various image processing techniques covering topics like ML detection algorithms, DL detection algorithms, and various optimization techniques involved in diabetic retinopathy detection and diagnosis. In the perspective of developing DR detection and diagnosis based on demographics, graders, and technological perspectives like ML and DL algorithms used, head-to-head validation datasets, comparison of available algorithms in practical situations, cost, equity, biases, and legal measures are presented in the paper [27]. In [28], researchers attempted bibliometric analysis for DR detection algorithms using AI techniques and provided insights into the impact of journals, books, and authors on the study. Recent developments in DR and the involvement of OCT in DR detection, important ML and DL algorithms like RF, CNN, ANN, SVM, and DNN, survey various papers and datasets used in different journals, with 84 entries simulated for all the ML, DL, and hybrid algorithms accumulated and presented in [29]. The concepts of mydriasis and non-mydriasis, mobile photography of the retina, advanced tools for photography, and the challenges faced by smartphones in capturing retinal images with clarity for detection and diagnosis, application of ML and DL algorithms, the need for DL that moves from the application of ML algorithms, and the deployment of DR screening centers based on countries are surveyed in [30]. Explainable AI (XAI) is the current trend in DR detection and diagnosis, where the authors in paper [31] surveyed various XAI techniques applied and addressed the importance of solving the black-box problem in this domain.

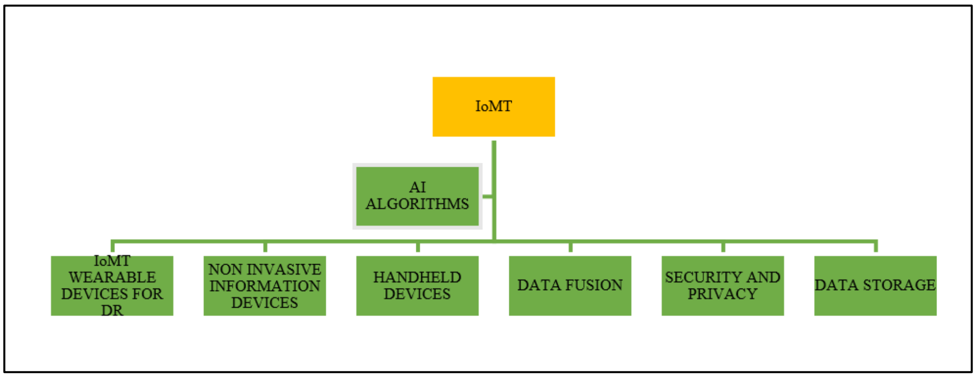

Figure 3. Topics Covered in the AI techniques and Reviews

5. Internet Of Medical Things

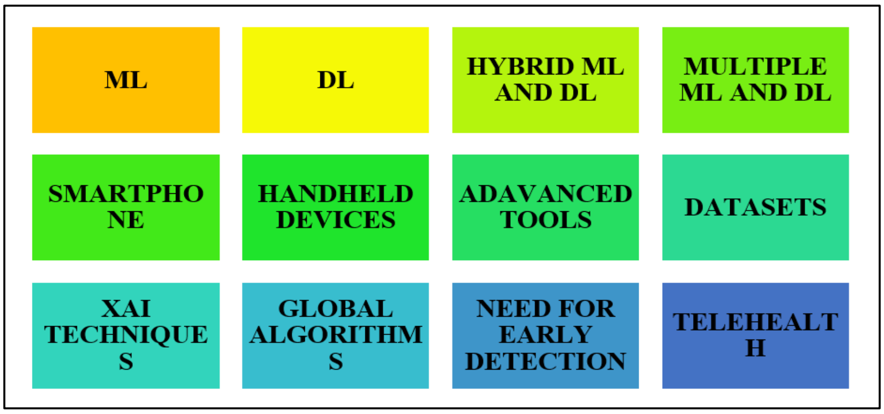

Figure 4. IoMT Challenges in DR Perspectives

IOMT is the Internet of Medical Things, as shown in Figure 4, where patients can access and obtain support from hospitals from their own comfort zones. The detection and diagnosis of diabetic retinopathy (DR) require OMT applications because early detection aids in the complete cure of the disease. In [32], the authors used a Computer-Aided Diagnostic (CAD) based IoMT application for DR detection, utilizing k-means clustering segmentation and CNN-based classification, where a hybrid genetic and colony optimization (HGACO) method is employed to fix the ROI curves in extracting features. This approach performs better compared to conventional CNN techniques in terms of evaluation parameters. Using the Retinopathy Image Dataset [33], the cleansing of fungus images is conducted with the Sequential Bilateral Rolling Guidance Filter (Seq-BR), Dilation U-Net based image preprocessing, and Convolutional Swin Transformer (CST) based Opposition-based Mud Ring Optimization (OMR) for image feature extraction and dimensionality reduction. The Gazeele algorithm-based Ensemble Learning Net for the classification of fundus images resulted in an accuracy of 97.52%. Severity cases such as mild, moderate, severe, and proliferative are classified using a CNN based on the ResNet algorithm, utilizing the HGACO algorithm, which is preprocessed using the k-means clustering algorithm, resulting in 92.78% accuracy, 89.50% sensitivity, and 93.99% specificity as evaluated in [34]. Chapter [35] comprises IoMT technology using various AI techniques, photography tools, and frameworks for Age-related Macular Disease (AMD), which is largely attributed to chronic diseases such as diabetes type 1 and type 2, as surveyed by researchers. The VGG16, ResNet50, and MobileNet V2 models are combined to produce an ensemble hybrid model (HEDN – Hybrid Ensemble DNN) that results in an AUC of 96.2%, with 97% accuracy and precision, and 96% sensitivity and specificity. The Messidor dataset and Eye PACS are used for testing security and privacy using the Secure DR Grading Network, where the authors conducted image processing steps such as DR class-specific Correlation Network (GSN) and Extreme Gradient Boosting (EGB) for feature extraction.

6. Results And Discussions

In Figure 5, the percentage of journals surveyed based on the topic of DR detection and diagnosis from the year 2020 to 2025 is presented. Most of the papers are taken from Scopus, SCI, and conference articles. Review papers are also considered for the AI techniques of DR detection and diagnosis. The survey is based on the highest citations, valid algorithms, and reputable journals.

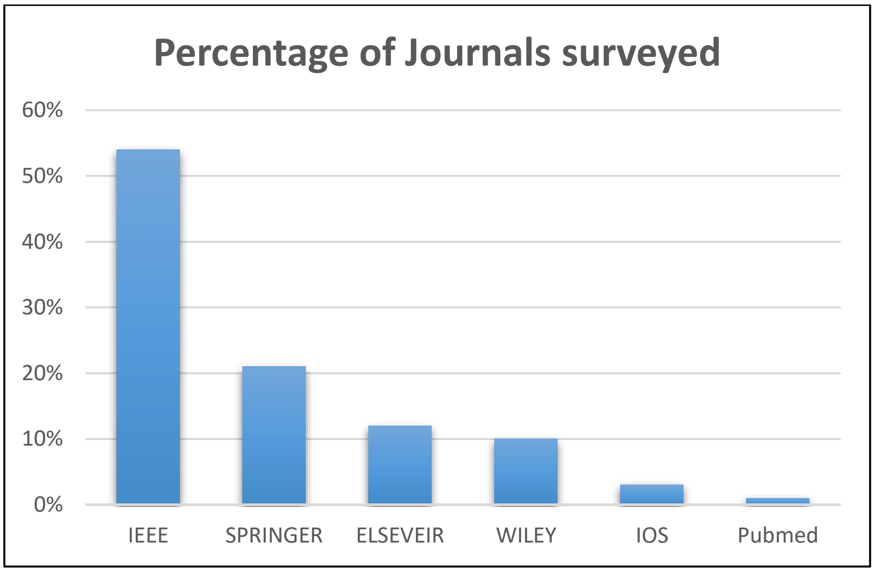

Figure 5. Percentage of Journals Surveyed

This paper review contains a major part on the ML, DL, and AI techniques evolved in Diabetic Retinopathy detection. The diagnosis is given in Figure 6. The new trends and applications of IoMT in DR domain papers are also surveyed. However, as IoMT is newly emerging in the DR domain, more research needs to be conducted.

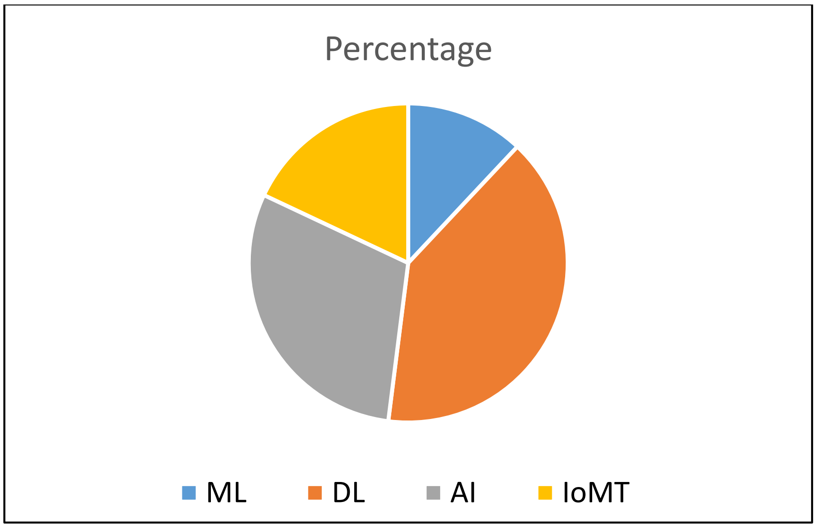

Figure 6. Survey Percentage of ML, DL, AI and IoMT Articles

7. Conclusion and Future Challenges

The survey on Diabetic Retinopathy detection and diagnosis done using machine learning techniques, deep learning techniques, combined AI techniques, smartphones, and handheld devices for data collection regarding DR and IoMT applications has been completed. The articles were reviewed from IEEE, Springer, Elsevier, Wiley, IOS Press, PubMed, etc. From the survey, it is clear that extensive research has taken place in DR detection using machine learning and deep learning with the available datasets. The emergence of smartphones, handheld devices, and IoMT applications helps in the early detection of DR, allowing patients to avoid permanent sight loss. Emerging smartphone applications require high-resolution software and lenses in order to obtain clear fundus and retinal images that lead to more accurate results. Handheld devices or advanced tools are required to record the information necessary for DR detection and need to be cost-effective. The IoMT application for DR detection and diagnosis requires user-end high-resolution devices, data fusion techniques, and high-level communication protocols.

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