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Diabetic Retinopathy Detection and Classification Using Deep Learning Algorithm

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Abstract - *Our project's main objective was to serve as a pivotal step to address the pervasive health concern that is predominant in numerous households: diabetes. Within the context of this prevalent condition, we have stressed on the critical issue of Diabetic Retinopathy, which is a common occurrence that ultimately results from diabetes. Our primary objective lies in the development and implementation of a unique and advanced predictive method that leverages sophisticated feature extraction techniques from an extensive image dataset. By employing an innovative approach rooted in Neural Network processing, we seek to establish a robust framework for accurately detecting and categorizing the severity of Diabetic Retinopathy through efficient classification mechanisms. The core essence of our project lies in its potential to transform the early prediction and classification of diabetic retinopathy severity, thereby facilitating timely and targeted medical intervention. By harnessing the power of deep learning techniques, we aspire to equip medical practitioners and healthcare professionals with an intuitive tool that not only streamlines the diagnostic process but also enhances the overall effectiveness of patient care. Our project's overarching goal is to contribute to the broader mission of improving healthcare outcomes by enabling timely interventions, thereby reducing the potential risks and complications associated with Diabetic Retinopathy. Through the integration of cutting-edge technology and medical expertise, we aim to pave the way for a more practical and responsive approach to diabetic retinopathy management.*

Key Words: Capsule Network (Capsnet), Convolutional Neural Network (CNN), Diabetic Retinopathy (DR), K – Nearest Neighbors (KNN), Machine Learning (ML), Non-Proliferative Diabetic Retinopathy (NPDR), Neural Network (NN), Proliferative Diabetic Retinopathy (PDR), Random Forest (RF), Support Vector Machine (SVM).

1.INTRODUCTION

In this project we have identified a major problem which is retinopathy it a condition present in eyes of the patient that is caused by diabetes. To better understand this medical condition, we can say that in simple terms such as, patients with diabetes could possibly tend to display abnormalities in the eyes that are affected due to the extensive fluid leakage from the eye retina which impacts and highly damages the light sensitive tissue of the eye, to avoid this condition which might even cause loss of vision due to the blood vessel damage inside the eye, so it is create an awareness and ensure that people are cautious about this, and we are aiming to develop a model which makes this task easy for the patients in doubt to easily asses themselves by using this architecture for premature detection of the disease condition. The major concern in identification of this disease is that there no awareness from the patient's side regarding this condition until the vision is completely gone and the retina is completely damage's its tissues. By this time, when the patient would have consulted the doctor, it would have always been too late to treat him/her for the cure as the condition would have worsen to a very critical state where disease treatment will be of no betterment of the condition. If a patient is aware of this condition, then they would consult the doctor immediately after noticing the initial changes in the vision, which are classified as NPDR, otherwise the condition of the eye gets worse and veins get clogged causing blockage of circulation of blood in the veins of the eyes. In this model development process, we will be using the eye's retina images which are required as the dataset to extract necessary features using several processing methods. The dataset of images is given to the model for training, testing purposes and the final model must be capable of determining the level of the severity in the patient.

2. Literature survey

The invaluable insights gained by understanding the work of the authors Mrs. T N Anitha and Brunda, which are followed [1] The progression of technology has suggestively impacted numerous characteristics of our lives, it has also simplified complex tasks for humans and have been extensively improving efficiency. However, certain segments of society still face challenges, particularly in healthcare. Among the visual impairments associated with various diseases, Diabetic Retinopathy stands out, posing a significant threat to vision due to retinal vascular damage caused by prolonged diabetes. This condition, fueled by elevated glucose levels in the blood, often goes unnoticed until vision changes occur, primarily affecting middle-aged and older individuals. Addressing this issue requires early detection and treatment to mitigate vision loss effectively. Utilizing Fundus eye images and employing Image Processing techniques, this study aims to extract features and assess disease severity using the K-

Nearest Neighbor algorithm, offering a potential solution for timely diagnosis and intervention. Vision, being fundamental to daily activities, underscores the importance of such advancements in ensuring a better quality of life for individuals affected by diabetic complications. The development of predictive models not only streamlines healthcare processes but also lays the groundwork for future enhancements in accuracy and classification, ultimately striving towards more precise diagnosis and treatment strategies.

[2] Diabetic Retinopathy (DR) presents a significant challenge for individuals living with diabetes for over two decades, often leading to blindness due to elevated blood glucose levels. Early diagnosis is crucial for effective treatment, yet current methods like Fluorescein Angiography are slow and inaccessible to many. This study offers a pioneering approach by integrating CNN, for detecting DR using RGB retina images, achieving a remarkable accuracy of 90.32%. The dataset utilized, sourced has been obtained from Kaggle website, contained approximately 3.6k RGB retina images, laying a solid foundation for accurate diagnosis and intervention.

The introduction delineates the severity of Diabetic Retinopathy, emphasizing the detrimental effects of prolonged high glucose levels on retinal blood vessels. While Fluorescein Angiography remains a gold standard for diagnosis, its complexity and cost hinder widespread accessibility. In contrast, Convolutional Neural Networks offer a promising alternative, leveraging their capacity in obtaining various features from dataset, thereby enhancing accuracy thus advancing diagnosis. This transition to CNNs marks a significant advancement in image processing, surpassing traditional methodologies and facilitating quicker, more efficient diagnosis of DR.

The conclusion underscores the successful implementation of CNNs for DR classification based on fundus color images, highlighting their efficacy despite slower training times. Moreover, it points to avenues for future research, including the integration of pre-trained models to enhance performance and the potential deployment of the model in web-based architectures to improve accessibility in underserved regions. This research not only advances the field of medical imaging but also holds promise for early disease detection and personalized treatment strategies, ultimately improving patient outcomes and healthcare accessibility worldwide.

[3] Diabetic retinopathy which is a foremost reason for losing of eye sight among individuals with diabetes, underscores the critical need for early detection and intervention. This study addresses this urgency by proposing a transformed capsule network that is mainly known for its ability in generating a model with accurate detection and classification of DR's lesions in fundus images. They have utilized the convolution layer for the network extracts feature from retinal image dataset and then the primary capsule layers to estimate the possibility of the image class using their class capsule in a combination with (the multi class classifier) SoftMax layers. Remarkably, the projected network achieves high accuracy rates of around 97 percent to 98 percent on the retinal/fundus images, respectively, which are obtained using the Messidor dataset.

The introduction highlights the escalating global prevalence of diabetes, with projections estimating a rise to 693 million individuals by 2045. Diabetes poses a myriad of complications, including diabetic retinopathy, which affects individuals irrespective of age, leading to vision-related issues. The severity of diabetic retinopathy underscores the importance of early detection to mitigate vision loss. Traditional diagnostic methods often lack efficiency and accuracy, necessitating the exploration of advanced technologies like deep learning. Capsule networks, a recent development in deep learning, offer promising results for diabetic retinopathy diagnosis by circumventing issues encountered with traditional CNNs.

In conclusion, diabetic retinopathy remains a significant challenge for individuals with diabetes, emphasizing the imperative for early detection to prevent vision loss. The proposed Capsule Network presents a viable solution, demonstrating superior performance compared to existing CNN approaches. By accurately identifying retinal problems across all stages, the Capsule Network offers a promising avenue for early diagnosis and intervention. Future research endeavors aim to extend the model's capabilities to encompass a broader spectrum of diabetic retinopathy classes, ultimately enhancing diagnostic precision and patient outcomes.

[4] The escalating global prevalence of diabetes, currently affecting over 470 million individuals worldwide and projected to reach 700 million by 2050, underscores the urgent need for effective detection and management strategies. While Type 1 diabetes remains chronic and incurable, early identification of Type 2 diabetes holds the potential for successful treatment. However, detecting anomalies in retinal images, indicative of diabetic complications, presents a formidable challenge due to their subtle nature. This necessitates the development of non-invasive techniques for uncovering these abnormalities, facilitating timely intervention.

The introduction delves into the multifaceted challenges posed by diabetes, citing a 5% increase in diabetes-related deaths from 2000 to 2016, with 1.6 million deaths annually. Particularly in India, diabetes emerges as a significant public health concern, exacerbated by indistinct symptoms and lifestyle factors. The disparity between ophthalmology trained professionals and patients further complicate the diagnosis and treatment of diabetic retinopathy, propelled

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by the global surge in diabetes cases. Addressing issues such as screening time and device sensitivity, the introduction advocates for automated detection systems based on standalone algorithms, leveraging advancements in image processing and classification techniques.

In conclusion, the proposed approach successfully identifies exudates and micro-aneurysms, crucial indicators of diabetic retinopathy. Morphological operations, including closure and erosion, facilitate accurate detection and classification of these anomalies, enhancing the efficiency of screening processes. By also comparing with the SVM and KNN classifiers, the system effectively grades disease severity, offering valuable insights for treatment decision-making. While the proposed methodology exhibits promise, ongoing research endeavors aim to refine existing algorithms and improve the overall effectiveness and complexity of automated detection systems for diabetic retinopathy.

3. Project Goal

To be successful in creating a system which makes use of the most suitable Deep Learning Algorithm that ultimately aids in the early detection and can classify multiple stages of diabetic retinopathy accurately and efficiently, which common people without any prior knowledge of this specific system or any working architecture can use and obtain accurate result easily.

4. Problem Identification

Traditionally, the diagnosis of diabetic retinopathy has relied on manual assessment of retinal images by trained Eye Specialists. This procedure is highly time taking, labor-intensive, and is subjective to simple error which might lead to a very wrong diagnosis. With the advancement of artificial intelligence and deep learning techniques, there's a remarkable opportunity to automate and enhance the detection and classification objective which we have taken in the case of diabetic retinopathy. Thus, introducing a modern NN architecture, which has the potential to address some of the limitations faced by traditional methods while handling complex spatial relationships and variations in pose. It aims to capture hierarchical features and part-whole relationships in images, which is particularly relevant for detecting subtle changes in retinal structures indicative of diabetic retinopathy.

5. Dataset Description

The dataset selected for this specific task was extracted from online source named as Kaggle, in which the entire folder was approximately 16mb with roughly 2500 images that are split into two, they are training and testing in approximately 9:1 proportion for better training of the model, where they are sub categorized into DR and No-DR fundus images of RGB format, with each image ranging from 2.5kb to 6kb of size.

The images are of Fundus type retina images, due to their RGB format it increased the complexity, due to the presence of 3 dimensions that is variables, so we have also stressed more on the preprocessing part of the execution to reduce the complexity without compromising image quality or the feature extraction property for our model.

The images have to be classified into 5 different classes which are follows: **Mild NPDR** which is the earliest stage of this disease advancement, **Moderate NPDR** at this stage a specialist is advised to generally take certain steps to ensure that the condition stays under control, **Severe NPDR** at this stage the retina specialist is recommended, **PDR** is a very advanced stage of the disease which can result in vision loss or blindness and **No DR** in patient.

Fig -1: Retina Image of a No DR patient

Fig -2: Retina Image of a DR patient

6. Proposed Method

6.i. Input Dataset:

The input dataset for this study comprises retinal images obtained from diabetic patients, with each image labeled according to the severity of DR. These images serve as the primary data source for training and evaluating the deep learning algorithms employed in this specific detection of this disease with multi classification ability of DR. The dataset includes retinal images captured through various imaging modalities, such as fundus photography, ensuring diversity and representativeness in the data. Additionally, the dataset may be augmented with metadata providing patient demographics and clinical information, enhancing the contextual understanding of the images.

6.ii. Preprocessing:

Prior to model training, input is the dataset fundus images which undergoes the preprocessing stage which tries to boost the quality and makes it easy to extract appropriate features from the dataset. This preprocessing pipeline typically includes resizing the images to a standard resolution, normalization to scale pixel values within a uniform range, and application of morphological operations to remove artifacts and noise. Additionally, techniques such as histogram equalization and median filtering are employed to enhance contrast and reduce image noise, respectively. These preprocessing steps are crucial for standardizing the input data and facilitating effective feature extraction by the deep learning models.

6.iii. Convolutional Neural Network (CNN):

The core of the proposed methodology lies in the utilization of CNNs to be used for this task, that is disease detection and multi-class classification of DR. CNNs are well-suited for image-based tasks due to its innate ability in learning the hierarchical way of representing features directly from the data. The architecture of the CNN typically comprises convolutional layers followed by pooling layers, enabling the network to extract spatial hierarchies of features from the input images.

Subsequent fully connected layers and activation functions facilitate the integration of extracted features for classification. The CNN is trained using labeled retinal images, optimizing model parameters through backpropagation and gradient descent to minimize classification errors.

6.iv. Model Evaluation:

The trained CNN model has to be evaluated through various performance metrics, which mainly include the most prominently used ones that are listed in the below figure. Through the usage of these specific metric's, we obtain insights of the model's capability to correctly classify the dataset's images.

Additionally, the model may undergo validation using an independent test dataset to assess its generalization capabilities and mitigate overfitting. Cross-validation techniques may also be employed to further validate the robustness of the model across different subsets of the data.

The evaluation process serves to validate the efficacy of the proposed methodology in accurately detecting and classifying diabetic retinopathy.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN}$$

$$Precision = \frac{TP}{TP+FP}$$

$$Recall = \frac{TP}{TP+FN}$$

$$F1\text{-}score = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}$$

Fig -3: Evaluation metrics

6.v. Comparison with Traditional Classifiers:

In addition to CNNs, the proposed methodology may includethe exploration and comparison of several other traditional ML classifiers which are as follows Support Vector Machines that is widely known for its ability to provide a solution to the classification limitations by determining appropriate boundaries, K-Nearest Neighbors this algorithm follows the idea that similar units in a dataset will tend to possess the same label, and Random Forests for its decision-making ability from multiple possibilities. These classifiers are trained and evaluated using the same input data and performance metrics as the CNN model, enabling a comparative analysis of their effectiveness in diabetic retinopathy detection and classification. Such comparisons provide remarkable insights of the strengths and weaknesses of deep learning algorithms versus traditional machine learning approaches in the context of medical image analysis.

Overall, the proposed methodology integrates the popular state-of-the-art technique of deep learning with rigorous preprocessing and assessment approaches to develop an effective architecture for our DR task of disease detection and multi class classification.

By leveraging the inherent capabilities of CNNs and exploring alternative classifier paradigms, the methodology aims to advance the medical field of retina image analysis and contribute to a better disease diagnosis in diabetic retinopathy management.

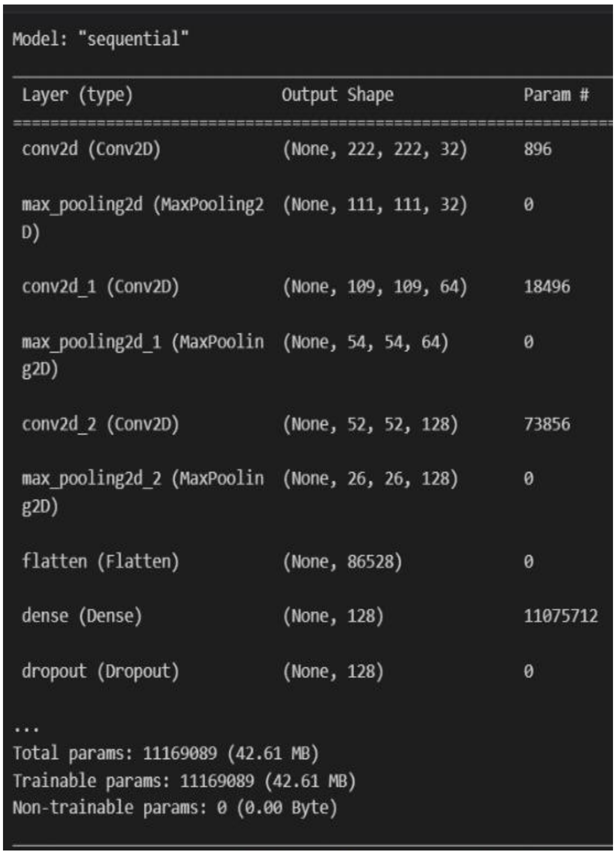
7. Methodology

The provided code encompasses various stages, each contributing to the overall efficacy of the model. Initially, the code imports necessary libraries and defines lists to store processed data. The `preprocess_test_image` function plays a pivotal role in image preprocessing, where images undergo resizing, normalization, morphological operations for blood vessel removal, median filtering for noise reduction, and histogram equalization for contrast enhancement.

These preprocessing steps are crucial for enhancing image quality and extracting relevant features, thereby improving the model's accuracy. Furthermore, the code utilizes label mapping to assign numerical labels to different classes of diabetic retinopathy, streamlining the classification process. The preprocessing of test images involves applying the `preprocess_test_image` function iteratively, ensuring consistency and standardization in image preparation.

Moreover, the code employs the `ImageDataGenerator` class for data augmentation and normalization during model training, facilitating robustness and generalization. The convolutional neural network (CNN) architecture is defined using the `Sequential` model, comprising convolutional with pooling layers to extract features and minimizing the complexity, which is followed by dense layers that are equipped with dropout regularization to prevent overfitting. The model is compiled with appropriate loss and optimization functions, setting the stage for training.

During model training, the code leverages the `fit` method to train the CNN on the training data while validating its performance on the validation data. This iterative process iteratively optimizes the model parameters, enhancing its ability to generalize to unseen data.



```
Model: "sequential"

Layer (type)                 Output Shape              Param #
================================================================
conv2d (Conv2D)              (None, 222, 222, 32)      896

max_pooling2d (MaxPooling2   (None, 111, 111, 32)      0
D)

conv2d_1 (Conv2D)            (None, 109, 109, 64)      18496

max_pooling2d_1 (MaxPoolin   (None, 54, 54, 64)        0
g2D)

conv2d_2 (Conv2D)            (None, 52, 52, 128)       73856

max_pooling2d_2 (MaxPoolin   (None, 26, 26, 128)       0
g2D)

flatten (Flatten)            (None, 86528)             0

dense (Dense)                (None, 128)               11075712

dropout (Dropout)            (None, 128)               0

...
Total params: 11169089 (42.61 MB)
Trainable params: 11169089 (42.61 MB)
Non-trainable params: 0 (0.00 Byte)
```

Fig -4: Architecture of our CNN Model

Additionally, the code explores the use of the previously mentioned traditional ML classifiers for comparison with the CNN model. These classifiers undergo training and evaluation using the same training and validation data generators, enabling a comparative analysis of their performance metrics, including accuracy.

Overall, the code meticulously orchestrates various preprocessing techniques, model architectures, and classifier implementations to construct a robust diabetic retinopathy detection system. Each component synergistically contributes to the model's accuracy and reliability, ultimately facilitating early diagnosis and intervention in diabetic patients.

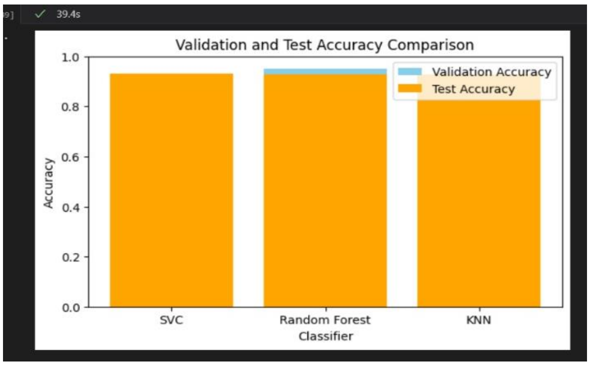
Table-1: Comparision of metrics in a tabular format.

Metrics	**CNN**	**SVM**	**KNN**	**RF**
Accuracy	0.8933	0.9307	0.9110	0.9495
Precision	0.5804	0.9308	0.91108	0.9266
Recall	0.5804	0.9307	0.91105	0.9264
F1-Score	0.5804	0.9307	0.91106	0.9263

8. CONCLUSIONS

In conclusion, the provided methodology implements a comprehensive approach in detecting and classifying diabetic retinopathy condition in patients by leveraging both deep learning and the traditional techniques of machine learning. By including several meticulous preprocessing steps, including image resizing, grayscale conversion, noise reduction, and contrast enhancement, the quality of input data is significantly improved, ensuring better model performance, this also gives us a unique approach in solving the problem. The use of TensorFlow and Keras libraries have given us the ability to develop and training a model, ultimately reflecting a deep learning model, comprising convolutional and pooling layers, finishing it with dense layers which are specifically used for the classification purpose. Dropout layers are incorporated to mitigate overfitting which is a major limitation of multiple models, thus enhancing our model's generalization capability.

Moreover, we have stressed in utilising conventional ML classifiers like SVM, KNN, and Random Forest to compare and evaluate their effectiveness. We have employed several evaluation metrics to verify the ability and performance of each model variation. Overall, the code demonstrates a robust methodology for diabetic retinopathy detection, showcasing the synergy between advanced deep learning techniques and classical machine learning approaches to report a critical healthcare challenge.



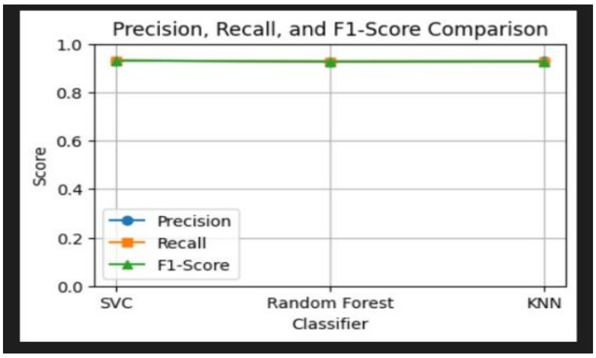


Fig -5,6: Performance comparision of Classifiers.

9. Future scope

In the next phase, we primarily aim to augment the model's accuracy of DR disease detection through fine-tuning the Capsule Network algorithm and also aim to implement our project through various and updated deep learning techniques to compare and contrast, to finally select the suitable algorithm. Ultimately, our goal is to make this model more reliable and efficient in detecting and preventing vision loss in diabetic patients.

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