Ocular Disease Detection Using state of the art Machine Learning techniques based Clinical Decision Support System for Ophthalmologist

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Abstract. Machine learning is vital in enabling medical practitioners to detect diseases such as Ocular at an early stage. It is important to detect ocular disorder to overcome the eternal damage to eyes. Ophthalmic disorders are generally not fatal, but if progress over time, they can significantly affect the quality of life. Diabetic Eye Diseases such as Cataract, Glaucoma and Diabetic retinopathy are the main causes of vision loss. Traditional approaches with subjective clinical testing are worth developing and applying automated, fast, and accurate solu- tions. Therefore, this article proposed a system namely Ocular Disease Detection System using state-of-the-art machine learning techniques. This Clinical Deci- sion Support System (CDSS) assists ophthalmologists in detecting cataract, glau- coma, and diabetic retinopathy effortlessly. The system is designed using five state of the art supervised machine learning algorithms that includes Convolu- tional Neural Network (CNN), Support vector machine(SVM), Decision Tree, Random Forest and K-Nearest Neighbour (KNN). These algorithms were imple- mented to evaluate the strengths and weaknesses of each one alone and a com- parison among them showed that CNN is the most robust algorithm among all with accuracy of 80.875%. The system has been trained on the dataset containing 5000 instances of fundus images of 5 different eye diseases. The novelty of the proposed system is in the employment of transfer learning technique using VGG19 model which enabled it to produce an outstanding performance even with limited labelled data. As a result of extensive testing which included cross- validation demonstrated that the developed system exhibited strong robustness and outperforms its competitors. The friendly graphical user interface (GUI) makes it easier for doctors and patients to interact effortlessly. The successful implementation of this system will significantly impact public health by provid- ing them with early detection thus reducing the percentage of blindness being caused.

Keywords: Machine learning, Ocular diseases, Transfer learning Technique, Clinical Decision Support System, Convolutional Neural Network.

1 Introduction and Background

Pakistan being the sixth most populous nation in the world with 67% of its popula- tion living in rural areas, has serious problems with its healthcare system, especially with regard to diabetes and the ocular complications that come with it [1]. According to the World Health Organization approximately 422 million individuals globally are affected by diabetes [2], making up 5% of the adult population worldwide. In 2021, it was estimated by the

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International Diabetes Federation that around 537 million adults between the ages of 20-79 globally had diabetes mellitus. It has been estimated that the number of people affected will rise to 643 million by the year 2030 and 783 million by 2045. Significant progress in AI and machine learning has advanced medical diagnos- tics, particularly for ocular diseases. Michael D. Abramoff et al. in 2010 developed algorithms like Eye Check and Challenge2009 for early diabetic retinopathy (DR) de- tection through pixel feature classification and k-nearest neighbour (kNN) for red lesion identification [3]. However, these were limited to detecting only early DR and red le- sions. Xinting Gao et al. in 2015 utilized Convolutional-Recursive Neural Networks (CRNN) for grading nuclear cataracts using a large dataset (5378 instances) [4]. System outperformed previous methods but faced challenges with obtaining large training data. Lokman Balyen and Tunde Peto in 2019 highlighted deep learning and machine learn- ing for diagnosing diabetic eye diseases [5], using techniques like transfer learning and data augmentation. The study did not fully address false positives and negatives, espe- cially for glaucoma. Tahira Nazir et al. in 2023 expanded on previous work using the CenterNet model for detecting diabetic eye disease, emphasizing data augmentation and transfer learning [6]. Ongoing issues of false positives and negatives and the need for algorithmic improvements in accuracy and specificity were addressed, but detection of non-diabetic conditions like glaucoma was not fully covered. İsmail Topaloğlu in 2023 [7] demonstrated success with a specialized convolutional neural network model for diabetic retinopathy but did not address other significant ocular diseases like glau- coma. Recent advancements in machine learning has assisted ophthalmologists in de- tecting ocular diseases effortlessly, however the challenges such as detection of wider range of ocular abnormalities beyond early DR and red lesions, variations in image quality, disease presentation and need for large and diverse dataset remain. To over- come these limitations, this study is aimed at developing a system that assists ophthal- mologists in diagnosing diabetic eye diseases using state of art machine learning tech- niques effortlessly. Using transfer learning and data augmentation techniques over- comes the challenge of limited training data, enhancing robustness and accuracy.

2 Methodology

Machine Learning is a division of Artificial Intelligence focused on creating algo- rithms for machines to mimic human behaviour. Arthur Samuel characterizes ma-chine learning as the field of study wherein computers can acquire knowledge with-out ex- plicit programming [8]. Machine Learning depends on Algorithms to interpret data. By using machine learning algorithms, the proposed system is aimed at providing ophthal- mologist with an intelligent model that will assist them at diagnosing ocular diseases early and reducing the amount of blindness that can be caused if ocular diseases are left untreated. The proposed methodology of the system is shown in Fig 1.

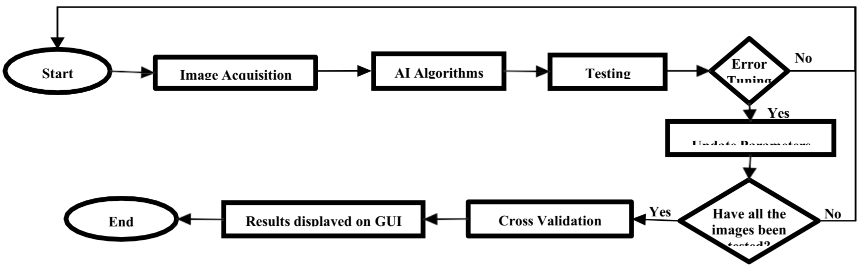

Fig. 1. Methodology of proposed system

The "Ocular Disease Intelligent Recognition (ODIR)" dataset of 5000 fundus im- ages, sourced from Kaggle, was utilized in the development of this system. Among the 5000 images, the collection of data included 594 images showing cataracts 1,818 im- ages of fundus showing proliferative and non-proliferative phases of diabetic retinopa- thy, 610 fundus images of glaucoma and 1278 fundus images with other ocular dis- eases. Each image was pre-processed to normalize brightness and contrast, and aug- mented through rotation, flipping, and cropping to enhance model robustness. The sys- tem incorporates several preprocessing techniques such as label extraction, image resiz- ing and normalization. For data processing, model designing, model training and model testing NumPy, Pandas, Scikit-learn (Sk learn), Tqdm, Matplotlib, Tensor-flow and Keras were used. To detect ocular diseases based on fundus images, the proposed model has been trained on 5 algorithms namely Convolutional Neural Network (CNN), Sup- port Vector Machine (SVM), K-Nearest Neighbour (KNN), Decision Tree, Random Forest. Additionally, a graphical user interface (GUI) has been developed that enables users to upload fundus images, choose the preferred algorithm and see the classification of ocular diseases in a user-friendly way. The GUI for this system is designed using the Tkinter library. To ensures that high-quality fundus images are captured consistently and that the analysis is performed efficiently the hardware setup consisting of a chin rest stand, microscope camera and a laptop has also been incorporated in the system as shown in Fig 2, to ensures accurate capturing of retinal images by adjusting the patient’s head hence minimizing motion artefacts.

Fig. 2. Hardware Setup

3 Results and Discussion

The proposed system for detecting ocular diseases, specifically diabetic eye diseases has shown positive results in identifying ocular complexities. The incorporation of transfer learning methods boosts the model's capacity to generalize across various da- tasets and clinical environments. The comparative analysis of algorithms showed that CNN is the most robust algorithm among all with accuracy of 80.875% as shown in Table 1. Confusion matrix of CNN is shown in Table 2. The visual representation of CNN model results on testing data are shown in Figure 3, and result of GUI when CNN algorithm is selected is shown in Figure 4.

Table 1. CNN Classification report showing Accuracy, Precision, Recall, F1 score, and support Metrics

Labels	Precision	Recall	F1 Score	Support	Accuracy
Normal (0)	71%	37%	49%	134	
Cataract (1)	83%	93%	88%	110	
Diabetic Retinopathy (2)	87%	90%	89%	368	80.875%
Glaucoma(3)	74%	86%	79%	126	
Others (4)	69%	90%	78%	62	

Table 2. CNN confusion matrix with diagonals showing true positives of each class.

	Normal	Cataract	DR	Glaucoma	Others
Normal	50	17	35	19	13
Cataract	2	102	1	4	1
DR	12	1	331	14	10
Glaucoma	4	3	10	108	1
Others	2	0	3	1	56

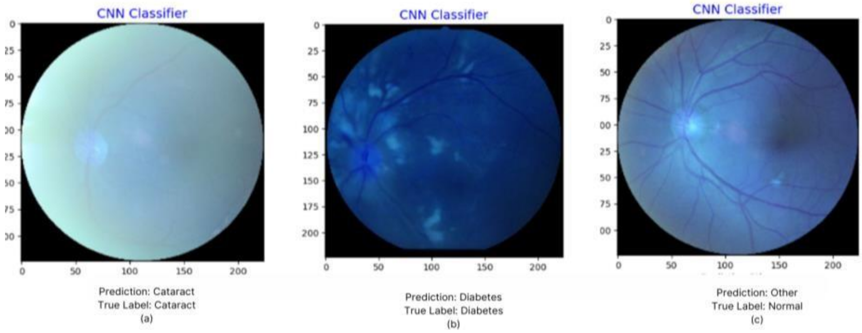

Fig. 3. CNN model results on testing data. (a) Predicted: Cataract, True Label: Cataract; (b) Predicted: Diabetes, True Label: Diabetes; (c) Predicted: Other, True Label: Normal.

The Clinical Decision Support System (CDSS) could potentially change eye care into a more efficient approach; by providing easy to use interface for health professionals and so enabling accurate diagnosis in real-time, resulting in better patient outcomes, greater clinical efficiency and improved care delivery. The fact that the CDSS is capa- ble of offering personalized solutions and aiding in diagnosis on time makes invaluable for patient care. Additionally, the system's scalability ensures that it can be adapted to various healthcare settings, addressing both urban and rural healthcare challenges.

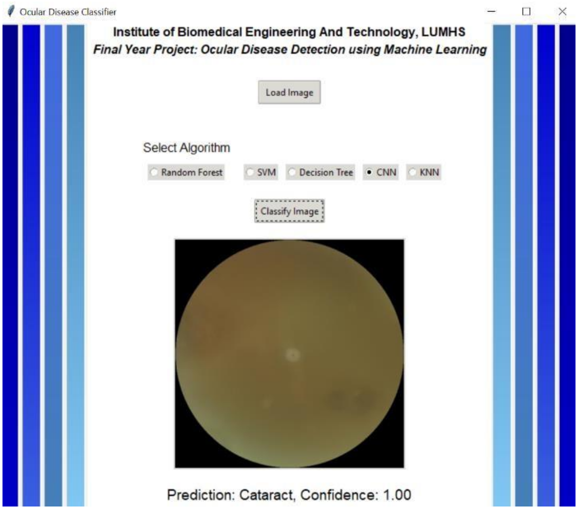

Fig. 4. GUI display showing the implementation of the CNN algorithm, illustrating the model's predictions for ocular diseases and the user-friendly interface designed for healthcare profes- sionals

4 Conclusion

To sum up, the Ocular Disease Detection System using state-of-the-art machine learn- ing techniques represents a significant advancement in the field of ophthalmology. This Clinical Decision Support System (CDSS) for ophthalmologists demonstrates the trans- formative potential of machine learning in eye care by integrating sophisticated algo- rithms to accurately diagnose diabetic retinopathy, cataracts, and glaucoma from fun- dus images. By conducting a comparative analysis of 5 robust machine learning algo- rithms, the system harnesses the unique strengths of each technique to enhance detec- tion confidence and reliability. The CDSS outperformed traditional diagnostic methods, showcasing remarkable accuracy and robustness in identifying ocular diseases. The user-friendly interface and real-time analysis capabilities make it an invaluable tool for healthcare professionals, enabling timely and precise diagnoses that can lead to better patient outcomes. Despite the promising results, the system is not without limitations.

Challenges such as variations in image quality and differences in disease presentation across patients can affect performance. Ongoing research and development efforts fo- cused on addressing these limitations and refining the algorithms will be crucial to max- imizing the system's impact and ensuring its widespread adoption in clinical practice.

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