

A Web Base Application for Keratoconus Detection

M. I. M. Waseem, P. V. D. Sevindi, K. W. Jayinghe, Y. S. Padukka, D. I. De Silva,
W. A. C. Pabasara

*Dept. Of computer science and software engineering, Sri Lanka Institute of Information Technology,
Malabe, Sri Lanka*

Abstract:-Keratoconus, a common eye disorder affecting approximately one in 2,000 individuals worldwide, leads to a significant decline in visual acuity. Early diagnosis is pivotal to halting its progression and preserve vision. The study introduces a machine learning algorithm designed for the early detection of keratoconus, utilizing a comprehensive dataset comprising corneal parameters obtained from diverse clinical sources. The Federal University of Sao Paulo's Institutional Review Board has provided ethical approval in ensuring adherence to ethical principles and the Statement of Helsinki. The dataset was meticulously de-identified to safeguard participant privacy. Employing a range of machine learning models, diagnostic accuracies ranging from 56.57% to an impressive 93.65 % have been identified. This pioneering model supports doctors in evaluating corneal health and keratoconus detection, simultaneously, at the early, preclinical phases of the illness, where subjective evaluations often fall short. Additionally, there is potential for seamless integration of this algorithm into existing methods to capture images of the cornea or software specifically designed for this purpose, significantly enhancing keratoconus detection capabilities.

Keywords: *keratoconus, machine learning, cnn, keras, tensorflow.*

1. Introduction

Keratoconus, a relatively prevalent eye disorder, affects individuals across all racial backgrounds and genders, with an incidence ranging from 50 to 230 cases per 100,000 individuals [1]. This condition stealthily emerges around the onset of puberty, quietly reshaping the transparent front surface of the eye, the cornea, into a conical form, as can be seen in Fig 1. The subtle transformation of the cornea heralds a cascade of visual disturbances, inflicting individuals with blurred and distorted vision. This distortion arises from the cornea's deformation, resulting in irregular astigmatism and myopia, ultimately leading to decreased visual accuracy.

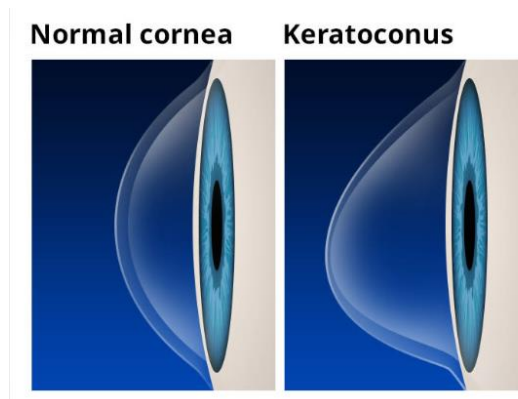


Fig 1 A normal cornea compared to a cornea with keratoconus. [2].

Keratoconus gradually grows throughout adolescence and Reaches a stable state around the age of 40 [3]. While extensive research has explored possible mechanisms, including genetic and enzymatic factors, the exact etiology

of keratoconus remains elusive, and the major triggers of the disease are largely unknown [4]. The disease stage of Keratoconus may affect the symptoms in multiple manners. When the symptoms are clear, an ophthalmologist can quickly determine if an individual has keratoconus [5]. The validation of the detection algorithm is performed using medical data, and its aim is to assist ophthalmologists in observing and analyzing specific corneal patterns that might be challenging for the human eye to recognize on its own [6]. However, the major challenge is identifying Keratoconus in its early stages. Early detection stands as the bedrock of effective intervention, offering a lifeline to halt its inexorable progression and safeguard visual acuity. Without timely identification and intervention, the relentless course of this condition threatens to plunge individuals into a world of worsening vision. In response to this clarion call for early diagnosis, the confluence of research and medical technology has given birth to a new frontier of diagnostic prowess. Machine learning algorithms, standing at the vanguard of innovation, now join the battle against keratoconus, offering a ray of hope to those ensnared by this common eye disorder. Diagnosing keratoconus in its early stages presents a significant challenge, demanding a multifaceted approach involving various investigative procedures and in-depth analyses, particularly focusing on corneal topography and meticulous thickness monitoring. Given that keratoconus often occurs during childhood and adolescence, it becomes important to introduce innovative diagnostic methodologies and tools aimed at enhancing the quality of life and potentially saving futures. Regrettably, the delayed diagnosis frequently results in deteriorating vision, imposing formidable barriers on the affected children's educational pursuits and their integration into society. Developing such models poses a significant challenge due to the notable variations in corneal characteristics among individuals with different stages of keratoconus, including 'Keratoconus', 'Suspect', and 'Normal'. Consequently, the medical field relies on various imaging technologies for corneal assessment in the quest to identify keratoconus. An example of such techniques includes Placido's disc-based corneal topography, which maps the cornea based on its elevation and optical characteristics, as well as coherence tomography (OCT)-based topography, using topography and elevation maps produced with the use of Scheimpflug imaging technology. Despite these advanced tools, achieving a reliable early-stage keratoconus diagnosis remains a formidable undertaking. The algorithm's high accuracy enables timely intervention and appropriate treatment during the disease's early stages, significantly improving patients' quality of life. The results obtained from this study validate the algorithm's performance, making it a viable candidate for integration into ophthalmological instruments. This integration holds the potential to enhance the early detection of keratoconus, ultimately benefiting patients.

2. Literature Review

In a generation where technological advancements are rapidly shaping healthcare, a growing number of solutions have developed to identify eye-specific diseases. However, a prevalent observation is that a significant portion of these applications offer limited features and questionable accuracy in their outcomes, underscoring the need for more reliable options in the field of eye health. This highlights the ongoing challenge of striking a balance between innovation and ensuring the highest standards of accuracy and effectiveness in eye disease detection.

Vision [7] is a notable vision application in the market. It offers four primary features for users which are basic eye testing, quizzes, eye advice, and optician finder. This application's primary benefit lies in its multifaceted functionality, extending well beyond mere eye examinations. However, it does not support a variety of eye tests, offering assessments for only four vision issues and they are also common issues. When considering the optician finder feature, it has some accuracy issues which can lead to misinformation. The number of users who can benefit from this application is limited because the target audience is limited to adults only.

AI-powered Vision Screening [8]. This application has gained prominence due to its potential to automate the screening process, offering both speed and accuracy. AI algorithms analyze images of the eye to detect various eye conditions like cataracts. The advantage of AI-driven applications is their ability to handle large amounts of data efficiently. However, a notable challenge lies in the need for high-quality images and standardized protocols to ensure accurate results, as well as the computational resources required for running complex AI algorithms, which can be a technical disadvantage for resource-constrained environments.

Test Vision [9] is a mobile application made for university students to test their hearing as well as vision. However, it falls short in certain aspects. The user interface is outdated, and it is not suitable for the modern generation. This

application offers a limited number of tests for visions. This restricted functionality and outdated UI may hinder its effectiveness in providing comprehensive hearing and vision assessments for users. One advantage of this application is its relatively small installation size, which means it does not consume much storage space on users' devices. This can be beneficial for students with smartphones or tablets with limited storage capacity.

mHealth Glaucoma Monitoring [10]. This application offers affordable solutions to improve the management of glaucoma, which is especially helpful in places with limited resources like rural areas. They have a clear advantage in making specialized eye care more accessible. The user interface seems user-friendly with a facility to adjust the interface according to users' will. However, a disadvantage of this application is that not all older individuals may have access to smartphones or be comfortable using them, which can limit the reach and effectiveness of these applications.

Healthy Vision [11] is a popular vision app that offers three main features: eye exercises, eye tests, and answers to questions about vision problems. One significant merit of this application, setting it apart from its counterparts, is its offering of practical eye exercises suitable for both adults and children. These exercises cater to a diverse user base, promoting healthier eyes for all. However, there is a notable drawback to Healthy Vision. When it comes to its eye tests, the app falls short of providing clear and helpful information. These tests primarily consist of images illustrating various vision problems. While the intention is to assist users in identifying their vision issues, the execution is lacking. Those already experiencing vision difficulties may struggle to pinpoint their specific problem solely through these images. A more user-friendly and informative approach to vision testing could significantly improve the app's overall usefulness.

B2 Eye Test [12] is a popular vision application available in the market. It provides vision tests, a survey, and a quiz. However, one of the notable drawbacks of this application is its outdated user interface, which lacks the modern design elements seen in many other apps. Additionally, it offers a limited set of features.

3. Methodology

Machine learning techniques, particularly Convolutional Neural Networks (CNNs), have greatly improved the identification and classification of keratoconus, a complex eye disorder. This study harnesses the power of CNNs as the central component of its diagnostic algorithm. The major diagnostic method for keratoconus involves corneal topography, which is typically illustrated by specialized ophthalmologists. These corneal topography images are utilized as inputs for the neural network's learning process. This involves fine-tuning the connections between neurons by adjusting their weights, with the ultimate goal of minimizing errors in both classification and learning. The advent of advanced algorithms, including multilayer neural networks, has significantly contributed to the recognition of essential characteristics, patterns, and features in the context of categorization tasks. These innovative advancements have instilled confidence in the application of such algorithms across various medical domains. The focus will be on analyzing corneal topography images, which are crucial for identifying the unique patterns associated with keratoconus.

The proposed methodology involves creating a specialized dataset of these images, optimizing segmentation and feature extraction processes to highlight relevant information, and splitting the dataset into training and testing subsets. A pre-trained CNN model will be chosen to undergo further training using the curated dataset. The trained model will then be rigorously tested using the testing dataset to evaluate its accuracy, specificity, and sensitivity in correctly identifying cases of keratoconus. By implementing this comprehensive approach, the research aims to contribute to more accurate and efficient keratoconus diagnosis, potentially leading to improved patient care and timely intervention. The popular library TensorFlow from Google is used to build deep learning models. [13], and it plays a central role in the context of detecting keratoconus eye disease. Leveraging the Keras library as an interface, TensorFlow offers a user-friendly approach to building complex neural networks. Keras streamlines the process of building models, all while leveraging its powerful performance capabilities of TensorFlow. This amalgamation enables efficient model development, facilitated by high-level APIs for seamless execution and swift debugging. In the specific domain of keratoconus detection, this technology fusion proves instrumental. As can be seen in Fig 2 demonstrates the process and steps used in the suggested system. Hallett et al. developed an

unmonitored and partially supervised deep-learning classification model tailored for the early detection of keratoconus., providing clinicians with ample time to select suitable treatment options [14]. Their study achieved an accuracy level of 80.3%, albeit with a limitation due to a relatively small sample size of 124. keratoconus eyes, which might restrict the generalizability of their findings. In a separate study [15], researchers employed a statistical model using logistic regression to identify cases of keratoconus in its early stages. Nonetheless, this research solely relied on the auto keratometer as the corneal parameter, potentially limiting the comprehensiveness of their approach.

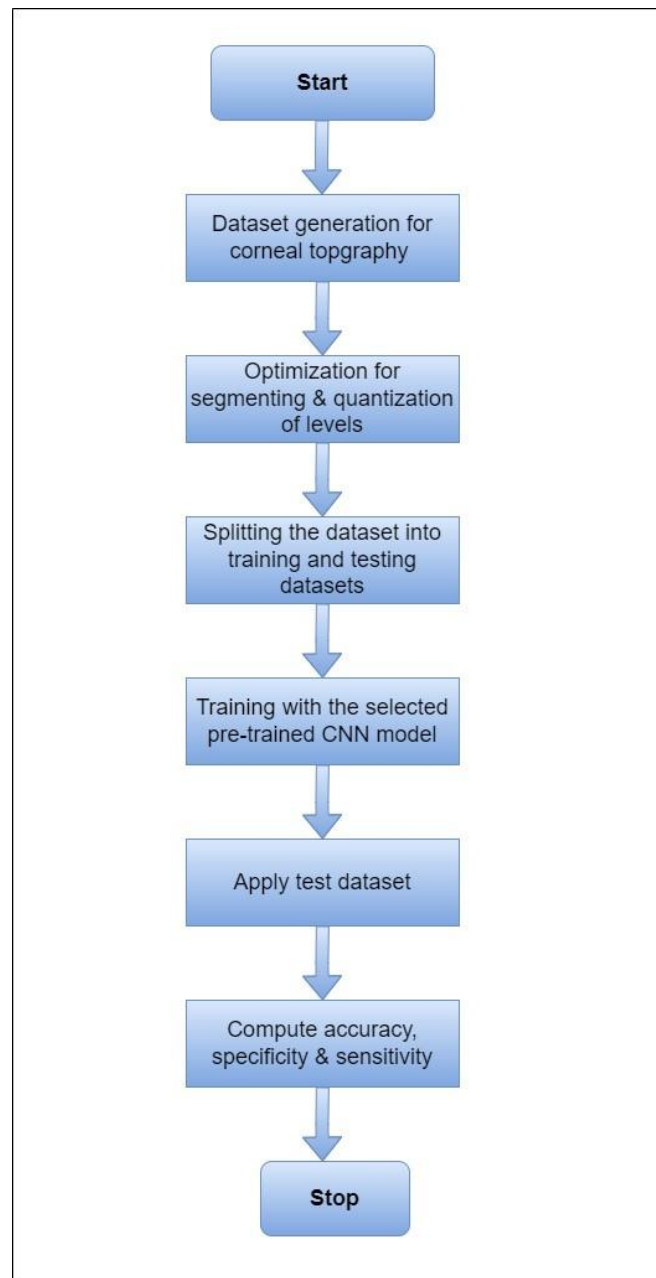


Fig 2 Methodology flowchart

Furthermore, another investigation [16] introduced a categorization strategy utilizing corneal shape data collected from OCT-based tools, which achieved an accuracy rate of 92% when applied to a dataset comprising 244 eyes. Nonetheless, this study lacked information regarding the severity levels of keratoconus eyes and whether early-stage cases were included. Additionally, it featured a relatively small sample size. The application of machine

learning in guiding intra-corneal ring segment implantation has demonstrated significant promise as a keratoconus management method [17]. This suggests that AI models can contribute to various facets of keratoconus management, enhancing the overall quality of care delivery. A recent review [18] offers a brief summary of various machine learning methods used in the detection of keratoconus. It highlights the growing role and significance of developing The utilization of artificial intelligence (AI) algorithms in the prevention and continuous monitoring of keratoconus. [19]. While AI models have shown promising results, there is a collective call for increased efforts to foster the development of more accurate algorithms, particularly for the early detection of the disease. Similar to Accardo and Pensiero [20], the system under consideration utilizes a neural network comprising three layers, trained using backpropagation to classify users' eyes as 'Keratoconus', 'Normal', or 'Suspect'. Once the classification is performed, the application delivers the outcome, indicating the detected condition.

4. Results and Discussion

This study involved the development and assessment of a deep learning model for detecting keratoconus, leveraging the EfficientNetB4 architecture as its foundation. Trained over 25 epochs with a diverse dataset containing both normal and keratoconus-affected eye images, the model showed promising performance. During training, crucial callbacks such as ModelCheckpoint, ReduceLROnPlateau, and EarlyStopping were employed to enhance learning and avoid overfitting. This resulted in a training accuracy of approximately 95.80%, as can be seen in Fig 3, and a validation accuracy of around 80.97%, indicating the model's ability to learn and generalize. However, real-world performance, assessed on an independent test dataset, yielded a test accuracy of approximately 76.19%. While the model excelled at detecting keratoconus cases, its performance in distinguishing normal and suspect cases showed room for improvement. To gain deeper insights, confusion matrices and classification reports were employed. These revealed that the model's precision in identifying keratoconus cases was high. Still, it struggled with recall in normal and suspect cases, suggesting challenges in capturing subtle differences. Visual verification of predictions further aided in pinpointing areas for model refinement. The research highlights the potential of deep learning models for early keratoconus diagnosis. Although promising, the model requires further optimization. Future work should focus on dataset expansion, alternative architectures, and hyperparameter tuning to enhance performance, particularly in identifying normal and suspect cases. The ultimate objective is to equip clinicians with a robust instrument to enhance patient care and outcomes.

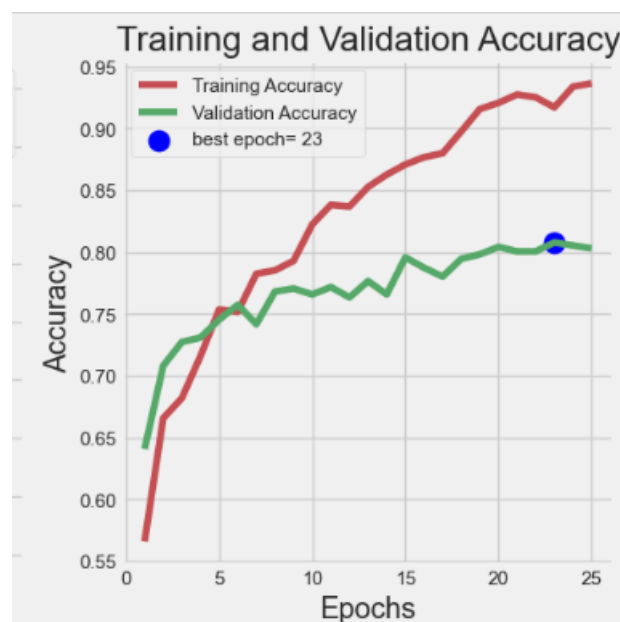


Fig 3 Training and Validation Accuracy

5. Conclusion

This paper's principal focus lies in creating and extensively verifying an algorithm aimed at simplifying the diagnosis of keratoconus, encompassing both its advanced and early stages. This innovative tool is poised to serve as a valuable aid to ophthalmologists, enabling them to identify distinctive corneal patterns that elude the untrained eye. By doing so, it facilitates the timely application of appropriate treatments, thereby playing a pivotal role in the long-term management of keratoconus. Through the potential to decelerate or even halt its progression, this algorithm shows the potential to significantly improve the quality of life for patients. Keratoconus often appears during the pre-pubertal years, making it most common among children. Therefore, it is imperative to create and execute innovative approaches that simplify the identification and diagnosis procedures, ultimately providing affected individuals with the opportunity for a typical life. Another significant aspect of this research involves examining keratoconus and appraising the various techniques and algorithms utilized for diagnosis. The exploration of diverse parameters suitable for incorporation into an automated diagnostic system remains an ongoing endeavor. The focus here is on the continuous enhancement of pertinent data to facilitate early-stage detection of keratoconus. Furthermore, this study conducted an assessment of the existing techniques employed in keratoconus diagnosis, pinpointing the essential parameters required for initial integration into the diagnostic algorithm. The outcomes reveal that the implemented algorithm consistently delivers outstanding performance when distinguishing between these three classes: normal, suspect, and keratoconus-afflicted eyes. Notably, it attains an accuracy rate of around 94% when classifying these three eye conditions. In comparison to other machine learning algorithms documented in specialized literature, the distinctive aspect of the tested algorithm is its ability to differentiate early-stage keratoconus from a healthy eye. This innovation addresses the primary challenge of detecting the illness during its initial phases. The machine learning system suggested for use, which is automated and supervised effectively, distinguishes between preclinical and clinical keratoconus by analyzing corneal shape, thickness, and elevation profiles. The advanced keratoconus model developed has the potential to greatly aid corneal specialists in identifying individuals at an elevated risk of developing keratoconus or those in the disease's initial stages. These findings can also advance comprehension of how keratoconus manifests in the cornea. The algorithm holds immense promise, as it has the potential to streamline the keratoconus diagnosis process and enable early detection, ultimately contributing to saving lives.

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