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EYEQ: An Application to Detect Vision Abnormalities

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Abstract:- The lack of access to eyecare, high costs, low awareness, and common vision conditions pose a major challenge, and can lead to late detection of vision conditions that can compromise eye health. Due to the rise of the technology industry, human lives have become severely hectic, resulting in less situations to prioritize health and well-being. According to the World Health Organization, at least 2.2 billion people have vision impairments, of which at least 1 billion of these could have been prevented if they were detected. This paper introduces an innovative web application, EYEQ, to address these challenges. EYEQ offers a wide range of services to enhance user eye health and wellness, including an eye blink symptom checker, a digitalized tumbling E test, doctor reservation capabilities, and prescription management. EYEQ has been endorsed by respected ophthalmologists and optometrists and has been shown to be accurate in detecting various visual disorders. The application has the potential to improve the early detection of eye conditions and reduce the risk of vision loss and impairment.

Keywords*: web application, hypo-blink, hyperopia, computer vision.*

1. Introduction

The lack of accessible and affordable eye care services is a major barrier to early detection and treatment of vision conditions, which can lead to irreversible damage to eye health. The widespread adoption of technology such as computer screens, smartphones, tablets, and televisions has had a significant impact on human eye health. This impact is not limited to adults: even infants and young children experience eye disorders due to a variety of factors.

Considering the challenges presented by situations such as the COVID-19 pandemic, the traditional approach of in-person visits to healthcare facilities for visual examinations and appointments has been shown to be limited in terms of accessibility, convenience, and scalability. According to the World Health Organization (WHO), at least 2.2 billion people have vision impairments, of which at least 1 billion could have been prevented if detected early [1].

This paper introduces 'EYEQ', an innovative web application with the potential to revolutionize visual healthcare. EYEQ is a testament to the power of technology to bridge the gaps in the medical industry by providing individuals with the means to effectively manage their visual health, including consultations and prescription management. Users can self-evaluate their visual limitations from the comfort of their own homes. The platform's unique features, highlighted by a symptom checker based on eye blinking patterns, show a departure from conventional practices, assuring an enhanced user experience.

The primary objective of this study is to develop a web application that offers users the chance to address the issues in the vision care industry. With the use of medical expertise and advancements in technology, EYEQ facilitates early detection of vision abnormalities leading to better decision making relating to eye health. In addition to the primary objective, this research also focuses on a set of sub-objectives such as improving accessibility, efficient prescription management, accurate vision testing and overall early symptom detection.

As a guide to the research, the following research questions were addressed:

- How effective is the integration of Python and OpenCV libraries into the web application when generating accurate diagnosis in vision tests?

- To what extent can machine learning models accurately detect human eyes via webcam in real time?
- How does the usage of OCR impact the accuracy of managing user prescriptions?

The following section provides a discussion on the previous studies related to vision care applications. Section 3 presents how the study was conducted, including the technological framework used for the development. Section 4 presents the findings of usability testing and the wide range of functionalities available in the solution. Section 5 presents the concluding remarks, including the future work that can be carried out related to vision health.

2. Literature Review

There are several vision testing and care applications available on the market. However, most of them have very limited features and are only capable of identifying a few visual abnormalities. EYEQ addresses these issues by incorporating features such as vision testing and eye tracking, eye blink symptom detection, and prescription management with OCR integration. This literature review aims to demonstrate and support this innovation. To demonstrate the web application's superiority, a comparison of EYEQ with existing eye care applications in terms of accuracy, usability, and user satisfaction is important.

GlassesOff [4] is a comprehensive vision care application, that primarily focuses on improving near-vision reading ability and offers individualized training sessions to increase visual performance. It exercises the visual cortex of the brain, enhancing vision sharpness. Unlike other solutions that rely on magnifiers or temporary relief, GlassesOff boosts the visual cortex, reducing headaches, eyestrain, and fatigue. It does not include prescription management or doctor appointments.

Optomeyes [5] is another vision care app that mainly focuses on booking appointments for doctors and providing eye care products. It has a wealth of information about dry eye treatments, myopia control, computer vision syndrome, specialty contact lenses, and more. However, compared with other existing applications, Optomeyes does not provide self-administered tests, eye blink symptom detection features, or even a prescription management system.

Personal Eyes [6] is another vision care app that focuses on booking appointments for doctors. The application encompasses comprehensive explanations of available services, encompassing LASIK surgery, cataract surgery, and eye examinations. However, the major drawback is that ‘Personal Eyes’ does not offer self-administered tests. If a patient needs to get their eyes tested, the patient should book an appointment and visit the doctor. Furthermore, the application lacks an effective prescription management mechanism.

Visibly, previously known as Opternative [7], is another application accessible in the market. This platform provides both ocular assessments and doctor-sanctioned prescription revisions. In comparison to other existing applications, ‘Visibly’ manages to handle vision prescriptions. Nevertheless, the notable drawback in this application lies in its focus solely on prescription updates, as it does not encompass comprehensive eye health evaluations.

The mobile based application for detecting cataract and conjunctivitis discusses the importance of image preprocessing and classifying these images for data processing [13]. It also utilizes a Convolutional Neural Network (CNN) which can prove helpful in image recognition and classification.

Vision Problem Tester [14] is a fun and educational application that helps children identify their vision problems. It includes a variety of games that test different aspects of vision, as well as a symptom checker that can help parents identify potential eye-related problems of their children. This application is a great way to keep your child's vision healthy. Because it is easy to use and fun to play, children will learn about their vision problems without even realizing it.

Vision Guard [16] is a mobile application that helps people identify their vision problems quickly and easily. It provides information about vision problems, causes, and cures, as well as eye exercises to improve one’s vision.

TABLE I. COMPARISON BETWEEN EYEQ AND OTHER COMPETITORS

Features \ Apps	*EYEQ*	GlassesOff	Optomeyes	Personal Eyes	Visibly
Eye blink symptom checker	✓				
Tests for hyperopia	✓				✓
Tests for myopia	✓				✓
Tests for hyper/hypo-blink	✓				
Visual training sessions	✓	✓			
OCR integrated prescription management	✓				✓
Schedule appointments	✓		✓	✓	
Educational articles about eye conditions and treatments	✓		✓	✓	

While these existing systems may be suitable for some vision applications, they fail to meet the specific requirements of the users. Users seek a unified online application that enables them to perform eye care exercises, track, analyze their eye movements, seek, and reserve appointments with ophthalmologists, properly manage their prescriptions, and receive eye care reminders – all within a single platform. As a result, a new system must be developed that incorporates all the features while meeting the unique requirements of users which the existing systems do not provide.

To bridge the research gaps, several critical areas of investigation were identified. Firstly, conducting longitudinal studies is essential to assess the long-term impact of the EYEQ application on users' eye health, providing insights into whether early detection and prevention efforts translate into sustained visual health improvements. Secondly, research should actively strive for greater diversity in user demographics, encompassing cultural backgrounds, socioeconomic status, and digital literacy levels, to ensure the application's effectiveness is spread across a broad spectrum of users. Thirdly, clinical validation which can be achieved through collaboration with eye care professionals such as ophthalmologists and clinical trials are necessary to establish EYEQ's diagnostic precision and gain the trust among both users and the healthcare providers in the medical community.

In conclusion, this literature review highlights the potential of the EYEQ web application to revolutionize vision care with innovative features like the eye blink symptom checker, digitalized tumbling E test, OCR integrated prescription management, and appointment scheduling. The study shows high user satisfaction and effectiveness in early eye problem detection, visual acuity assessment, and prescription management. Collaborations with healthcare institutions and technological firms will further propel the EYEQ application towards achieving these goals and making a lasting positive impact on vision care within the general public.

3. Methodology

The EYEQ web application was developed using the MERN (MongoDB, Express.js, React, Node.js) stack. The system is integrated with OpenCV and Python to conduct various vision tests and eye tracking functionalities. The architecture incorporates a user-friendly interface that ensures smooth navigation and better interactions for users. During the design phase, special attention is given to the accessibility of the user interface such as color contrasting, text and image sizing.

As part of a comprehensive approach to addressing problems with vision care, an empirical study was conducted to assess the potential impact of the EYEQ web application regarding the early detection of eye conditions, reduced risk of vision loss and impairment, and improved visual acuity. The study conducted was of a mixed-methods approach, which is a combination of both qualitative and quantitative research methods. A sample of 500 participants was taken into the study, including children and adults with varied eye health ranges. Participants were surveyed regarding their experiences with eye care, visual issues, and early detection methods. The study evaluated their willingness to accept the EYEQ application's features, satisfaction with usability, and perceived advantages.

Many important findings surfaced due to a proper empirical investigation conducted regarding the web application. Thus, the eye blink symptom checker and digitalized tumbling E test were highly praised for their effectiveness in self-assessment and identifying hypo-blink and hyper-blink conditions. EYEQ's OCR integrated prescription management system was highly praised by 82% of participants, ensuring system accuracy and efficiency. Appointment scheduling was also well-received, as it streamlined the process of arranging eye care appointments. Qualitative evaluations revealed that 84% of respondents needed simple tools for eye health checks.

In the empirical study, the EYEQ online application has shown positive results. However, several research gaps need to be addressed. Long-term impact studies are needed to evaluate the long-term effects of the application on users' eye health, particularly in early detection and avoiding eye conditions. Collaboration with eye care professionals is essential for accurate eye problem detection. Privacy and security are also crucial, as the EYEQ application deals with sensitive medical data.

Users are prompted to take vision tests via their device's web camera. The OpenCV library is utilized to analyze generated test results, such as acuity, hyperopia (long-sightedness), and myopia (short-sightedness), providing immediate feedback to users. Additionally, the system incorporates algorithms to detect conditions like hyper-blink (excessive blinking) and hypo-blink (reduced blinking), which can be indicative of underlying eye health issues.

A. Hyper-blink and Hypo-blink

Hypo-blink and hyper-blink conditions show the distinct blinking patterns that offer valuable insights into a patient’s ocular condition.

Hypo-blink, meaning a decreased blinking frequency, can signal various factors, including digital eye strain, dry eye syndrome, or external irritants. Inversely, Hyper-blink, which means that there is an increase in the blinking rate, might indicate underlying discomfort, surface-related issues, or heightened light sensitivity. The mean blinking rate is up to 22 blinks/min which has been reported under relaxed conditions of the human eye [2].

To diagnose these two conditions, EYEQ is powered with the ‘Eye blink symptom detector’. During this test, the vertical perpendicular height of the eye of the patient will be taken via webcam as shown in Fig. 1. When the height is approximately equal to zero, the test will count it as an eye blink. The reason as to why it is taken ‘approximately’ is that it is not practically possible to count a blink when the perpendicular height is exactly equal to zero. The test is expected to run for a period of 1 minute continuously monitoring the user’s eye via a webcam.

During testing, the model analyzes user’s eye movements in real-time, determines the blink count, and identifies if the condition is hypo-blink (less than normal) or hyper-blink (more than normal). The result will be immediately displayed to users, and a detailed report can be generated and stored for future reference.

By integrating these insights into the innovative web application's diagnostic capabilities, users are able to gain a deeper understanding of their eye condition and are empowered to take proactive measures for maintaining optimal eye health.

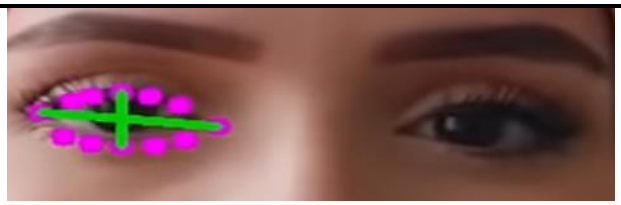

Fig. 1. Perpendicular height taken via webcam.

B. Myopia and Hyperopia

Myopia and Hyperopia are two very common refractive errors that affect the clarity of human vision. Myopia, which is better known as 'nearsightedness', occurs when distant objects appear blurred while close objects remain clear as depicted in Fig. 2. This condition occurs when the eyeball is longer than average or when the cornea has excessive curvature, causing light to focus in front of the retina rather than directly on it.

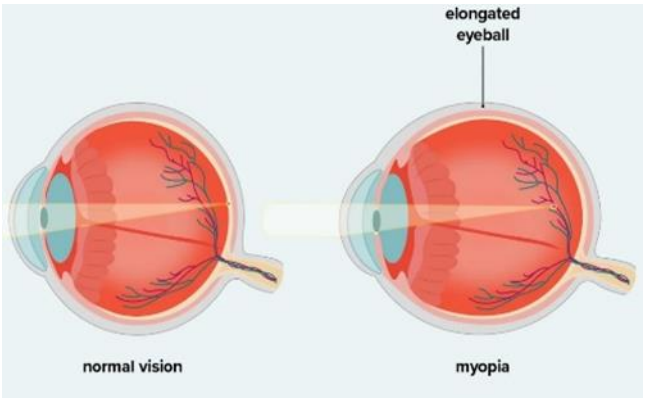

Fig. 2. Myopia (nearsightedness)

Hyperopia, or 'farsightedness', is the scenario where close objects become blurry but faraway objects stay clearer. This condition typically occurs when the eyeball is shorter than average or the cornea has insufficient curvature, leading to light focusing behind the retina as shown clearly in Fig. 3.

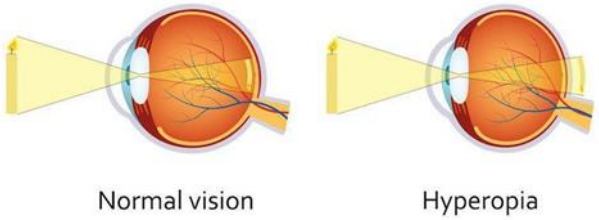

Fig. 3. Hyperopia (Farsightedness)

Both myopia and hyperopia can lead to visual discomfort and strain, affecting many day-to-day tasks such as reading, driving, or computer usage. Both conditions are very common among people and can be cured if detected at an early state.

There is a very specific test known as the 'Tumbling E test' to detect Myopia and Hyperopia conditions. EYEQ will incorporate the digitalized version of the renowned Tumbling E test [3]. This test is the same test a patient receives at an optician. The letter E at the top is large and keeps reducing when moving down. The reason it is known as 'tumbling' is that the letter E has been rotated and is faced in different directions as shown in Fig. 4.

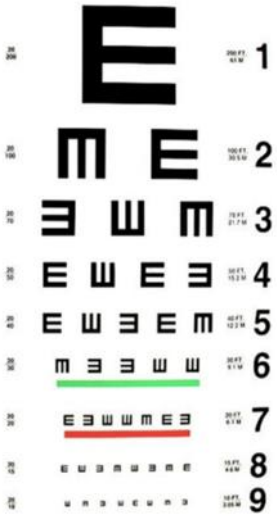

Fig. 4. Tumbling E test

The addition of the digitalized Tumbling E test for assessing these conditions provides users with valuable insights into their refractive status, aiding in early detection and personalized eye care management.

In addition to these vision testing tools, the web application also includes the following features;

C. Prescription management and OCR integration

The prescription management feature is designed to enhance user convenience and streamline the process of managing doctor written prescriptions for users. Users can manually input their prescription details or upload an image of their prescription to the web application.

Optical Character Recognition (OCR) technology is used to extract the required prescription information in a text format from the uploaded images. EYEQ utilizes the 'Tesseract OCR' engine to properly analyze and extract the required text from the image. Recognizing the text in a prescription for a user not in a medical background may prove to be ineffective and inaccurate. This is mainly due because physicians usually write the medicines in an incomprehensible manner [12].

Once the prescription images are uploaded, the application begins several operations including file format conversion, noise reduction techniques such as fine tuning the image by blurring and enhancing it. Users can view, edit, or delete existing prescriptions from the application when necessary. This feature proves valuable as the user will have a history of medical records for future reference. Proving helpful for ophthalmologists when diagnosing future conditions of the patient as well since there is a clear medical history available in the application.

D. Additional vision tests

In addition to the previously mentioned two vision tests, the application will include several simple tests for diagnosing other eye conditions such color blindness, finding your perfect vision, visual acuity as depicted from the user interface in Fig 5.

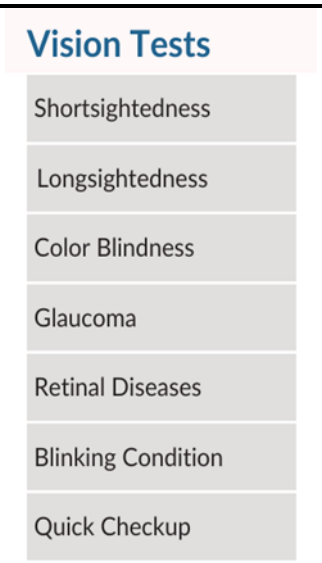

Fig. 5. Application interface for available vision tests

Another special test among the available vision tests in the application is the 'Ishihara test for color-deficiency'. This is a popular exam for red-green color deficiencies and one of the most widely used and well-known color vision deficiency tests used by most ophthalmologists and optometrists globally [15].

The test consists of several plates, each depicting a solid circle of colored dots in random size and color as shown below in Fig 6. Inside the patterns are colored dots which form a number or shape only visible to those with normal color vision, and invisible, or difficult to see, to those with a red-green color vision defect. The remaining plates are intentionally designed to reveal numbers only to those with a red-green color vision deficiency and be invisible to those with normal red-green color vision.

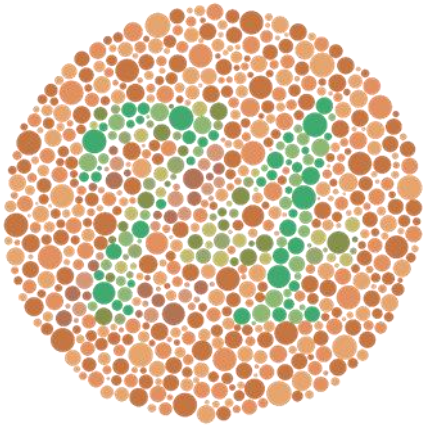

Fig. 6. Ishihara test for color-deficiency

E. Appointment scheduling

Appointment scheduling was favorably accepted by the responded participants since it streamlined the process of arranging eye care appointments without the requirement of a middle-man. The appointment reminder system ensures that users never miss an essential appointment. This feature will particularly help improve the user experience of the application as users will be able to bypass the middleman and do a reservation by themselves. The application can be further improved by introducing a feature to remind the users the specific times to take eye drops in a day.

F. Application accessibility

Since the target group of the application is users with vision deficiencies, it is important to consider how accessibility aspect of the web application. This will help improve the overall user interface and the user experience of the application [11]. Web accessibility is about making sure that applications can be used with people having disabilities. Accessibility is a vital aspect of diversity and inclusion where it may bring a quantitative value to the application but a very qualitative value by improving the user experience of the application to a wider range of users.

To achieve this, EYEQ has a text size slider to change the font sizes according to the ease of the user's vision as shown in Fig. 7.

Fig. 7. Web application accessibility for font sizes

During the design phase, the color contrast of the pages is considered to not cause eye strain for the user. Further improvements in the accessibility aspect may include user functionality to change the color contrast within the web application as support for users suffering from severe eye strain, bright colors, and color blindness.

4. Results

EYEQ offers a wide range of services that enhance the user's eye health and wellness. These services include the Eye Blink Symptom Detection, the Digitalized Tumbling E test, Doctor Reservation capabilities, Prescription Management feature and more. By combining these services, EYEQ facilitates the identification of potential vision disorders and prompt action when necessary. The ultimate goal of EYEQ is early detection of these common vision disorders.

The Eye Blink Symptom Detection feature is a vital part of the platform allowing users to identify a wide range of illnesses including Hypoblink, Hyperblink, dryness in the eye and even neurological disorders. This tool helps users to recognize these symptoms early, paving the path for timely and effective treatments.

The Digitalized Tumbling E test is a powerful tool for determining the level of vision, especially regarding nearsightedness and farsightedness. It eliminates the need for users to travel to different physical sites for tests, reducing the diagnostic procedure and providing effectiveness in a shorter time.

After identifying symptoms or concerns, users can easily schedule appointments with healthcare specialists by using the Doctor Reservation functionality. Furthermore, the platform's Prescription Management tool helps users to keep track of their medications and makes it easier to follow your treatment plans while maintaining a medical history.

It is important to note that EYEQ has been endorsed and recommended by respected ophthalmologists and optometrists in the medical community. A sample group of 40 patients with diverse eye-related diseases were subjected to rigorous testing. The platform displayed impressive accuracy in detecting various visual disorders, confirming its potential as an advanced solution for managing vision health.

5. Conclusion

By combining technology, accessibility, and a user-centric design, the web application offers a comprehensive solution for early detection, effective management, and improved outcomes in vision health. EYEQ holds the possibility of overcoming certain gaps in existing systems and within the industry and it's process by revolutionizing the area of eye assessment and care. EYEQ aims to provide an accurate, efficient, and holistic approach to early detection and vision care for all individuals by promoting self-administered tests, personalized

health data, doctor appointments, prescription management into a single, user-friendly platform. Future work could involve expanded user trials, new user features and integration with different telemedicine platforms. Overall EYEQ can be stated as a solution being able to bridge the gaps between the patients and the medical community while achieving the purpose of detecting vision abnormalities in patients at an early stage.

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