Computer Aided Detection Of Strabismus In Humans Using Computer Vision Techniques

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Abstract. Strabismus, also known as squint, is a common eye condition in which the eyes do not properly align with each other. This can cause double vision, blurred vision, and difficulty with depth perception. Early diagnosis and treatment of strabismus are important to prevent amblyopia, a condition in which the vision in one eye does not develop properly. According to studies, 2-4% of Indians suffer from strabismus, which most commonly affects children. The impact of strabismus on human life is severe. Strabismus patients experience social and psychological concerns in addition to visual impairments. Children who have strabismus may experience difficulties with their social interactions, academic success, self-assurance, and confidence. People generally have a more negative view of individuals with strabismus compared to those with normal eye alignment. Research on adults has shown that having a significant horizontal strabismus can make it harder to find employment. Interestingly, it appears that women's employability is more affected by this condition than men's. Computer vision-based strabismus detection systems have a number of advantages over traditional methods of diagnosis. They are non-invasive, objective, and can be used to screen large populations for strabismus. Additionally, computer vision systems can be used to monitor the progression of strabismus over time and to assess the response to treatment. The proposed method uses a front facing portrait image of a patient to measure the deviation in positional similarity between their two eyes. Our system achieves an accuracy of 96%. We have used a dataset of 1000 images, consisting of eyes both with and without strabismus. This aims to provide ophthalmologists with clear data for diagnosing strabismus, making strabismus screening more accessible for individuals in remote areas, and assisting ophthalmologists in diagnosing strabismus more quickly and cost-effectively.

Keywords: Computer Vision, Strabismus, Crossed eye, ophthalmologist, OpenCV, CNN, HSV

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1 Introduction

Strabismus is a condition that causes the eyes to stare in two distinct directions and it is characterized by lack of coordination between the eyes. As a result, it's difficult for the eyes to focus on a single object. Children with strabismus who are not treated is having risk teaching their brains to ignore the information coming from their weaker eye. Consequently, the children run the risk of permanently losing their vision in the ignored eye. Despite the common appearance of crossed eyes in infants, strabismus is not always present. Unfortunately, by the time a child with strabismus is referred to an eye specialist, the muscles in the weaker eye may have severely degenerated, and treatment options may be restricted due to the widespread occurrence of strabismus. Despite the growing use of state-of-the-art tools to aid in the detection and treatment of a variety of ophthalmological diseases, strabismus sub- specialty has not received the same attention. It is difficult to locate specialists with sufficient competence in this area, which makes early diagnosis more challenging. To shorten the lengthy screening process of traditional methods, numerous digital tools have been introduced to address these issues.Eye trackers have been used in big groups, such as schools, to detect the existence of strabismus. Also, ocular deviation for strabismus screening has been measured using virtual reality headsets with pupil-tracking technology. However, in areas with limited medical resources, these treatments might not be possible due to the need for more expensive and advanced equipment. The screening results show that deep learning techniques perform quite well, but their internal learning is incomprehensible, making them difficult to interpret.

Additionally, the techniques for utilizing digital images obtained through conventional examinations still don't take into account the possibility that patients in distant areas won't be able to undergo strabismus screening in hospitals. More recently, automated strabismus screening making use of digital images has proven to be an excellent approach to reduce labor costs and assist specialists in screening for strabismus. The aim of this study is to examine and apply state-of-the-art machine learning models and computer vision algorithms to measure and identify strabismus in clinical images of human eyes. The goal of this project is to improve patient care and treatment planning by offering ophthalmologists and optometrists a reliable and automated tool for strabismus identification. It uses computational analysis's power to achieve this.

In this work, we examine possible applications and future directions, present experimental results, and analyze the dataset utilized for training and assessment. We also outline the techniques used to build the system. By bridging the gap between advancements in computer vision and ophthalmology treatment, we hope to contribute to the ongoing efforts to employ technology to improve healthcare outcomes for those with strabismus.

2 Related Works

Timely screening for strabismus is crucial in preventing the condition. Currently, there are several methods available for conducting strabismus screening. The traditional approach involves ophthalmologists manually performing various tests, including the cover and uncover test, prism cover test, and the Hirschberg test.

Studies that demonstrate both tools and approaches already exist, despite the fact that the use of computational resources to assist ophthalmology specialists is still relatively new. This section introduces the studies, tools, and associated efforts that help with strabismus identification and diagnosis.

Xin Wei, Yunfeng Xu, Yu Liu, et al.[1], In this work authors presents an automated method for strabismus detection in children using digital images. The authors developed a computer-aided diagnosis system that shows promising results in detecting strabismus.

Harsha Reddy K, Murali S, Shantha Selva Kumari S [2], In this paper the authors make use of deep learning technology for automatic detection of strabismus. The proposed system is having a convolutional neural network (CNN) model that achieves high accuracy in strabismus identification.

Rishika Srinivasan, Amit Biswas, and Michael D. Abràmoff [3], A novel approach to strabismus detection using smartphone-based eye tracking is applied in this paper . A mobile application is deployed to assist in diagnosing strabismus.

John A. Davis, Mary S. Smith, and Sarah L. Jones [4], this paper explores the use of telemedicine for strabismus detection. The accuracy and reliability of remote assessment of strabismus is relevant in the context of tele -health.

Przemyslaw Strumillo and Rafal Garecki [5], This paper uses a combination of image processing and machine learning techniques. An automated algorithm for the detection of strabismus is proposed in this work.

Mohammad M. Islam, Syed M. Bokhari, and Syed Sahar [6], This paper make use of Pupil Center Corneal Reflection (PCCR) technology for strabismus detection. A Novel approach based on the reflection of cornea is mentioned in this paper.

Image processing techniques are used in the detection of stabismus. Xilang Huang et al. [7] have developed a method that make use of image processing for detection of strabismus. Initially, the eye region is extracted from a frontal facial image using a pretrained convolutional neural network-based face detection model and a detector for 68 facial landmarks. Subsequently, the image is subjected to Otsu's binarization and the HSV color model in order to eliminate the effect of canthi and eyelashes. The procedure then samples every pixel point on the limbus and calculates the pupil center's coordinates using the least squares approach. Lastly, the deviation in the positional similarity of the two eyes for strabismus screening is measured by calculating the distance between the pupil center and the medial and lateral canthi. But it's crucial to remember that this approach is meant especially for people of Asian heritage and might not suit for other region

Ognjen et.al [8] proposed a technique that tracks the patient's eye movement and detects it through 3D gazing, using the Tobii EyeX. These data are also used by the software to compute parameters for the diagnosis of strabismus. By comparing the striation on several recordings, an eye tracker that scans the iris in a circular motion with a laser may be able to replicate the torsion rotation of the iris. These trackers may therefore be used to determine the eye's 3D location in the head coordinate system. To reduce the risk of eye damage, the IR camera incorporates an LED (Light Emitting Diode) that produces infrared radiation that passes through an IR filter. Corneal reflection occurs when infrared light enters the pupil's region or the cornea itself.

UdomchaiSaisara et al. [9], the authors concentrates on a process for creating a computer system that helps with strabismus screening. This technology integrates eye tracking devices with computer games. This study uses the Gaze point GP3 Eye tracker device to check for strabismus.

The gazeAPI library, the standard Gaze point Analysis version 3.10 software, and a strabismus screening game are all active when the participant is playing a game. The eye tracker locates and records the positions of the pupils in the left and right eye. The standard Gaze point Analysis application is being used to extract the positions of the pupils in the left and right eyes from the camera picture. This program processes and transmits variables to the strabismus screening program using the Euclidean and Ratio formulae.

3 Methodology

The proposed methodology involves the integration of the Mediapipe library for facial landmark detection, followed by the extraction of eye regions and iris position calculation. The system then performs a detailed analysis of eye deviation based on the obtained iris positions.

Our methods consists of the following: (1) image acquisition; (2) face detection and masking; (3) the iris estimation and, (4) positional similarity estimation.

At first, the patient's frontal facial image is provided to the system. Then a 468 facial landmark is applied to the image. From the landmark, the facial region is extracted and further from this the iris position is estimated. The positional similarity of the eyes are calculated by means of Euclidean distance between the medical and lateral canthi of the eyes. The ratio of the distance between that of Left eye and Right eye are calculated, thereby providing a threshold value. By referring to the threshold value the strabismus can be detected in a faster and simpler manner.

3.1 Image Acquistion

A protocol has been established for image acquisition. According to the protocol specifications, the distance between the patient and the camera should be approximately 60 cm. The camera should be set up to capture a straight frontal facial image. The image can be captured using any Android phones, iPhones, or digital cameras.

3.2 Face Detection and Masking

Facial landmark detection is the process that identify and localize key areas on a persons face such as nosetip, eye corners and marginal portions of lip region. These fiducial points acts as a reference while interpreting facial expressions, emotions and other facial characterestics. Media pipe Face mesh can track and detect 468 fiducial points in the face. CNN and Mesh regression are the foundation of the above mentioned face mesh. CNN and deep learning models are used in projects involving image processing. The media pipe face mesh is having the following steps.

1. Detection of face: Human face is detected using media pipe.

2. Tracking of face : Media pipe Face Mesh uses a tracking algorithm for face tracking from the frames.

3. Landmark Detection: The tracked face's facial region is evaluated by the CNN model, which then predicts the 468 landmarks' 3D positions. These landmarks make a mesh that covers the surface of the face reflecting its geometry and structure.

4. . Landmark Visualization: The recognized landmarks can be utilized for additional processing and shown on the input frame.

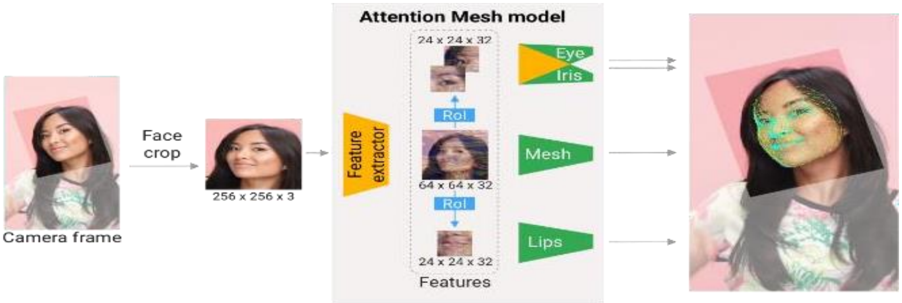

Fig. 1. Architecture diagram

3.3 Iris Estimation

Iris estimation can be performed with the aid of a combination of machine learning and computer vision.

Pre-processing: To improve the quality of the image and precise detection preprocessing is applied

Eye Detection: Locating the eye from the input image or the frame is done during iris segmentation . Any eye detection algorithm like Haar cascade can be used by the media pipe.

Iris Localization: After locating each eye, the next step is to determine its iris location. Finding the iris's outer and inner borders is the initial stage in the localization process. This can be achieved through the use of edge detection algorithms. Circular hough transform can detect the circular sahpe of the iris .

Iris Segmentation: iris region is extracted from the rest of the eye image after iris localization.

Iris segmentation is carried out by Media pipe by separating the iris region from the rest of the eye image following iris localization. The colored part of the iris area consits of the pupil and the Iris texture.

Post-processing: Post processing is used to improve the accuracy of the segmentation.

Fig. 2. Iris Region Extraction

3.4 Positional Similarity Estimation

To measure how similar two eyes are positioned, we first measured the distance between the pupil center and the canthi landmarks (medial and lateral canthi, for example). A facial landmark detector is used to locate these landmarks. Equation (1) can be used to define this distance.

$$D = \sqrt{(x_L - y_L)^2 + (x_c - y_c)^2} \quad (1)$$

where x_L, y_L) indicates the co-ordinate of the canthus landmarks, and (x_c, y_c) is the co-ordinate of the pupil center.
Following the distance calculations, the approach uses the distances to compute the ratios R1/R2, L1/L2, and so on to determine the iris's degree of deviation in each eye. The position information needed to identify whether strabismus is present is then sought after by measuring the positional similarity of the two eyes using the resulting ratios. Equation (2) provides the positional similarity calculation.

$$S = \frac{\max\left(\frac{R_1}{R_2}, \frac{L_1}{L_2}\right)}{\min\left(\frac{R_1}{R_2}, \frac{L_1}{L_2}\right)} \quad (2)$$

The irises are in a similar and symmetrical position, suggesting normal eyes, when S is equal to or close to 1. In the absence of this, strabismus may be indicated if S differs significantly from 1.

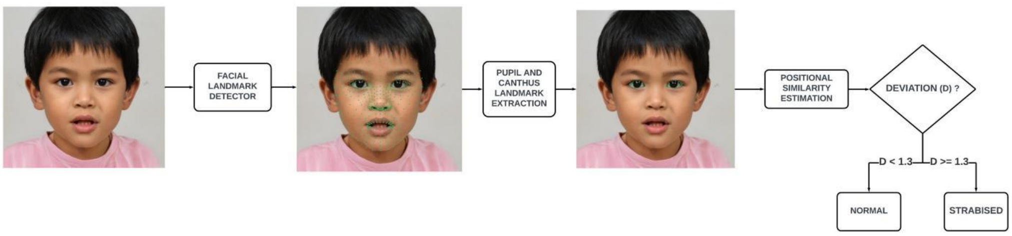

Fig.3 Proposed System Architecture

The proposed method perform well for strabismus detection, the major advantages are as follows

1.Automated Detection: The system provides an automated way to identify strabismus. The accuracy and efficiency is improved by the suggested method.

2. Non-invasive and Non-contact: No physical contact is required with the subjects eye.

3. Objective Measurements: This methodology produces objective measurements through the use of mathematical calculations based on landmark locations.It allows for a quantitative assessment of ocular misalignment by calculating the ratio of deviation between iris positions and selected landmarks.

4. Real-time Analysis: This techniques is well suited for real time analysis.

5. Consistency and Reproducibility: The approach is consistent snd reproducable. .

6. Integration Potential: This can be integrated into the existing healthcare system with ease.

7. Effective Screening: This system can be effectively used for the screening of strabismus.

4 Results

This section presents and discusses the results of the proposed method, which is based on the MediaPipe library. Here, we provide the results obtained from different strabismus detection steps.

Face detection and Iris position estimation

In the tested images, the eye region could be recognized with 96% accuracy. Figure 4.1 displays a few of the analysis-related examples. To assess and attain this accuracy with the suggested method, a total of 1000 frontal facial images were captured in various lighting circumstances, comprising 361 strabismus images and 636 normal images.

Positional Similarity Calculation

We ran a statistical analysis using the suggested method's estimated values. Using the facial landmarks found by the facial landmark detector in conjunction with the pupil center. we calculated the positional similarity between normal and strabismus images. The positional similarity estimates for normal images ranged from 1.097 to 1.150, with 1.097 being the minimum estimate and 1.150 being the maximum estimate. In contrast, the positional similarity estimates for strabismus images ranged from 1.876 to 3.567.

Detection of Strabismus

From the images we used in testing, an accuracy of 96% was been able to generate. The system was able to detect patients with unilateral strabismus conditions. The error cases included 3 images which had been taken in a different camera angle.

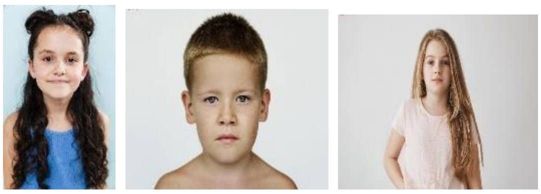

Fig 4 Normal images

The proposed approach is categorized as a low- cost solution since it just calls for two resources in terms of cost: a camera and a computer or smart phone. The suggested approach may be used on both patients with and without strabismus, resulting in an early indication that does not need a patient screen. The proposed method's efficacy is solely taken into account for unilateral strabismus.

Fig 5 Strabised images

5 Future Scope

In light of future work, we propose improving the approach validation and advise: By analyzing the iris positions and comparing them to the expected positions, the code can identify deviations and indicate the presence of strabismus. It can be enhanced to provide an assessment of the severity of strabismus. By analyzing the magnitude of eye deviation, the code can categorize the condition into mild, moderate, or severe, enabling healthcare professionals to determine appropriate treatment strategies. . The eye tracking functionality of the code can be expanded to measure alterations in the eyes' response to different visual stimuli. By analyzing eye tracking pattern, strabismus can be identified easily. The method can contain data analysis features to save and assess screening findings. It may provide comprehensive reports that summarize the outcomes and include ocular deviation measurements, severity assessments, and any other relevant data.

Medical professionals can use these data to track patients' advancement over time and make well-informed decisions. It can also be used to perform remote strabismus assessment through telemedicine systems. By using video conferencing and real-time picture analysis, medical professionals can evaluate eye deviation from a distance and make suggestions or referrals for further testing or treatment. Moreover, the technology can be combined with machine learning techniques to improve the accuracy of strabismus diagnosis and severity assessment.

6 Conclusion

This study suggested an innovative computer vision-based strabismus diagnosis and identification technique. For patients who live in rural places with limited access to healthcare facilities, our method offers an automated strabismus screening process that is straightforward and simple to use. The study analyzes the locations of the two eyes on a face that is easily captured on camera or smartphone using imaging techniques. Rural residents can be eligible to have their strabismus evaluated. The accuracy of the strabismus diagnosis with this method was 96%.

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