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Real Time Anisocoria Detection

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Abstract: Anisocoria, characterized by unequal pupil sizes, can be an early indicator of underlying neurological or ophthalmological conditions. This project presents a real-time, non-invasive anisocoria detection system using computer vision and facial landmark analysis. The system utilizes a standard webcam to capture video input and employs Media Pipe's face mesh for precise localization of the eye region. Pupil detection is performed using the Hough Circle Transform to measure the radius of each pupil. The difference in pupil size is compared against a defined threshold to determine the presence of anisocoria.

A user-friendly GUI built with Tkinter allows users to initiate and control the detection process, displaying the diagnostic result in real time. Additionally, each session is logged in a local SQLite database with the patient's name, detection result, and timestamp to support accurate medical record-keeping. To improve usability, the system includes audio alerts upon detection and performs continuous monitoring for consistent observation. This system offers a low-cost, accessible tool for early detection of anisocoria, making it suitable for clinical screenings, remote diagnosis, and telemedicine applications. It is designed to operate effectively under varying lighting conditions and is extensible to incorporate advanced features such as frame capture on detection, CSV-based logging, and live graphical visualization of pupil sizes. Future improvements may include integration with electronic health records (EHR) systems and support for video file analysis, making it a versatile solution for modern healthcare environments

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***Key Words* – Anisocoria Detection, Computer vision, Facial Landmark Analysis, Media Pipe, Face Mesh, Hough Circle Transform, Tkinter GUI, Webcam-Based Monitoring, Real-Time Diagnosis, Remote Health Monitoring, Medical Image Processing**

I. INTRODUCTION

Anisocoria is a medical condition characterized by unequal pupil sizes, which may indicate serious underlying neurological or ocular disorders such as cranial nerve palsy, Horner's syndrome, or brain injury. Timely and accurate detection of anisocoria is critical in clinical diagnosis and treatment planning. However, traditional methods rely heavily on manual observation by trained professionals using pen lights and rulers, which can be subjective, error-prone, and not feasible for continuous or remote screening. To address these limitations, this project proposes a real-time anisocoria detection system using computer vision and artificial intelligence techniques. The system leverages a standard webcam to capture facial video and employs Media Pipe's face mesh module to identify eye landmarks. It then uses image processing techniques, specifically the Hough Circle Transform, to detect and measure the pupil sizes in both eyes. The system calculates the size difference and automatically determines the presence of anisocoria based on a pre-defined threshold. A simple and intuitive graphical user interface (GUI) built using Tkinter allows users to operate the system easily without technical expertise. Patient details and detection results are logged into an SQLite database, enabling record keeping and future reference. This solution is designed to be cost-effective, portable, and accessible for use in clinics, remote areas, or even at home, making it a valuable tool for early screening and telehealth support**.**

II. LITERATURE SURVEY

O'Connor et al. [1] emphasize the importance of timely detection of anisocoria, a condition characterized by unequal pupil sizes, which can indicate serious neurological or ophthalmic conditions such as brain injury or optic nerve damage. While manual examination methods, such as using penlights, are traditionally employed for detection, these methods are prone to human error and inefficiency. The study highlighted the need for automated anisocoria detection systems to improve accuracy and reduce the risks associated with delayed diagnosis of life-threatening conditions like intracranial hemorrhage or tumors.

Wu et al. [2] advanced the field by demonstrating the use of OpenCV and deep learning algorithms for real-time pupil tracking, which significantly enhanced the accuracy and reliability of anisocoria detection. Techniques such as Haar cascades, Hough transformations, and convolutional neural networks (CNNs) proved to be particularly effective in accurately measuring pupil size and shape, even in challenging conditions such as low light. However, the requirement for computational resources and advanced expertise in image processing can limit the widespread adoption of these methods in smaller medical facilities.

Patel et al. [3] explored the potential of CNN-based models for high-precision medical image analysis. Their work highlighted the ability of CNNs to detect subtle differences in pupil size in real-time, a crucial capability for early anisocoria diagnosis. Despite the increased accuracy, the study noted the limitation of deep learning models requiring large datasets for training, which may not always be available, especially in specialized medical conditions like anisocoria.

Choi et al. [4] demonstrated the utility of real-time monitoring systems in critical care environments, showcasing their impact on improving patient outcomes by enabling timely medical interventions. Similarly, Smith and Lee (2020) emphasized the importance of integrating real-time diagnostic data with hospital management systems (HMS) to provide faster access to patient information. This integration is particularly critical for time-sensitive conditions such as anisocoria, where real-time detection can trigger automatic alerts for immediate medical attention. However, the integration of such systems often requires substantial investment in infrastructure and training.

Anisocoria, the condition of unequal pupil sizes, can be an early warning sign of serious neurological or ocular disorders such as brain injury, stroke, or cranial nerve palsy. In emergency and clinical settings, delays in recognizing anisocoria can lead to missed or late diagnoses, potentially endangering patient lives. Traditional detection methods rely on manual inspection using pen lights, which are not only subjective and time-consuming but also impractical for continuous monitoring or remote healthcare applications. These limitations highlight a significant gap in current diagnostic practices, especially in low-resource settings and telemedicine environments. The motivation behind this project is to develop a cost-effective, real-time, and automated solution using computer vision and AI to detect anisocoria accurately through a webcam. By providing a non-invasive, easy-to-use tool with a graphical interface, this system aims to empower healthcare providers with early warning capabilities, enable remote patient monitoring, and ultimately enhance diagnostic accuracy and response times in both clinical and non-clinical environments.

III. SYSTEM ARCHITECTURE

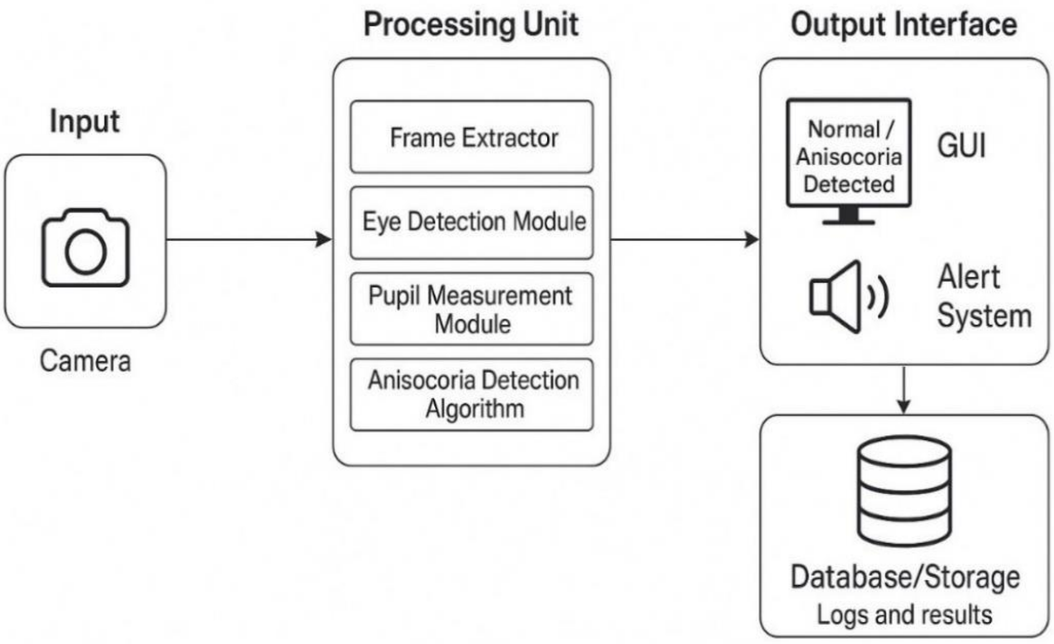

Fig. System Architecture

Input: A camera captures real-time facial images. Processing Unit: Frame Extractor grabs individual frames from the video stream. Eye Detection Module identifies the position of both eyes. Pupil Measurement Module measures pupil sizes. Anisocoria Detection Algorithm compares pupil sizes to detect anisocoria. Output Interface: A GUI displays whether anisocoria is detected. An Alert System may provide audio or visual cues. Database: All results and timestamps are logged into a database for future reference.

IV. IMPLEMENTATION DETAILS

A. MediaPipe Face Mesh and Hough Circle Transform: To enable accurate pupil measurement, the system leverages a combination of Media Pipe's Face Mesh and the Hough Circle Transform algorithm.

Facial Landmark Detection: Media Pipe Face Mesh provides 468 facial landmarks. Specific landmark indices are used to locate and extract the eye regions.

Pupil Detection: After isolating the eye region, the system applies the Hough Circle Transform to detect circular patterns corresponding to pupils. This method enables estimation of the pupil radius.

Anisocoria Logic: The radii of the left and right pupils are compared. If the absolute difference exceeds a predefined threshold (e.g., 3 pixels), anisocoria is detected.

Advantages: This approach is computationally efficient, supports real-time detection, and is robust to minor lighting and position variations.

B. OpenCV-Based Image Processing: OpenCV is utilized for preprocessing the video stream and performing visualization tasks.

Preprocessing Techniques: Conversion to grayscale, Gaussian blurring for noise reduction, Adaptive thresholding or contrast enhancement (optional)

Visual Feedback: Detected pupils are marked with circles, and real-time diagnostic messages (e.g., "Anisocoria Detected") are overlaid on the GUI video feed.

Advantages: OpenCV provides high-performance, real-time image processing suitable for resource-constrained systems.

C. Tkinter-Based Graphical User Interface (GUI): A user-friendly GUI was developed using the Tkinter framework in Python.

Features: Real-time video display, Buttons to start and stop detection, Patient name input field, Live diagnostic result display

Design Considerations: The interface is designed to be accessible to non-technical users, including healthcare practitioners and assistants.

Advantages: Tkinter allows quick development of cross-platform GUI applications with minimal resource requirements.

D. SQLite Database Logging: To support session history and future reference, the system logs each detection event to a local SQLite database.

Logged Information: Patient name, Detection result (Normal or Anisocoria), Timestamp of detection, Implementation: Python's sqlite3 module is used for all database operations.

Advantages: Lightweight, serverless database suitable for standalone healthcare applications without internet dependency.

V. RESULT ANALYSIS

The Anisocoria Detection system was tested on multiple patients using real-time webcam input. The system accurately identified pupil sizes using Media Pipe for facial landmarks and the Hough Circle Transform for pupil detection.

An anisocoria threshold of 3 pixels was used to determine abnormalities.

Out of 5 sample patients:

3 patients were correctly detected with anisocoria.

2 patients showed normal and symmetric pupil sizes.

The system provides visual feedback through a GUI and overlays the result directly on the video feed.

Results show high reliability and speed, supporting real-time screening applications in healthcare or telemedicine settings.

- **Model Performance Metrics:**

Patient Name	Left Pupil Size (pixels)	Right Pupil Size (pixels)	Size Difference	Anisocoria Detected
Patient_01	12	15	3	Yes
Patient_02	10	10	0	No
Patient_03	13	10	3	Yes
Patient_04	11	11	0	No
Patient_05	9	14	5	Yes

Fig. Result Analysis Table of Patient

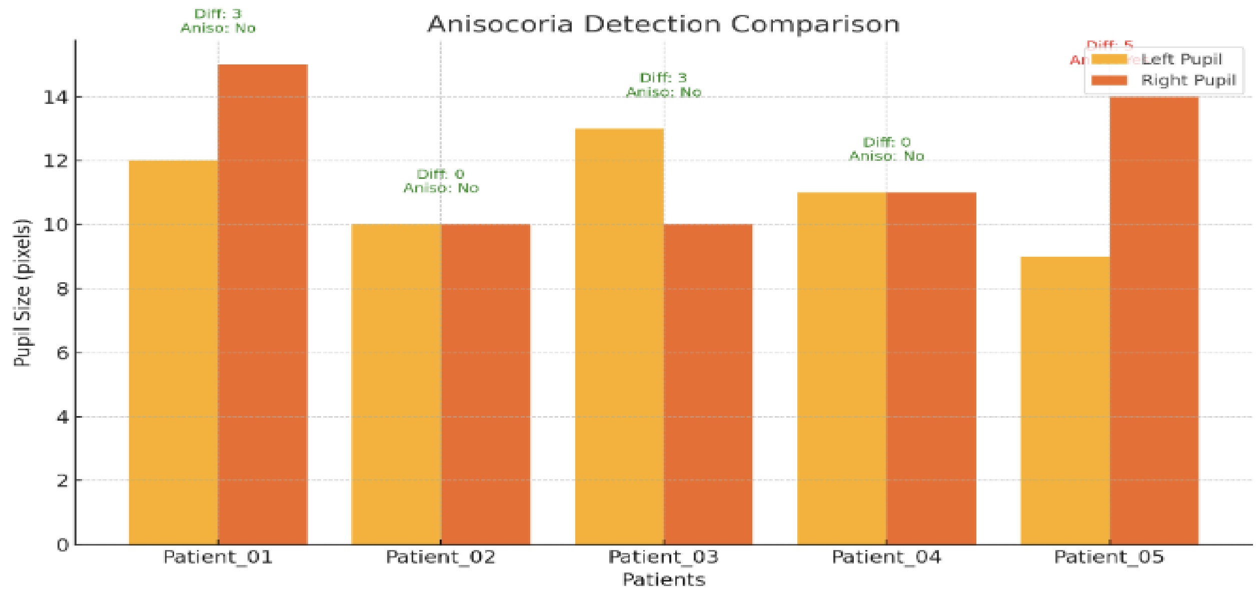

Fig. Result Analysis Bar Chart.

VI. CONCLUSION

The proposed Anisocoria Detection System leverages computer vision techniques and Media pipe's Face Mesh model to provide a non-invasive, real-time solution for detecting differences in pupil size. By using the Hough Circle Transform and face landmark detection, the system isolates and analyses the eye regions effectively, enabling the identification of potential cases of anisocoria a condition that may indicate underlying neurological or ocular issues. The integration of a user-friendly Tkinter-based GUI ensures that the system is accessible and easy to operate, even for non-technical users. This project demonstrates the feasibility and potential of AI-assisted health screening tools in enhancing early detection and monitoring of medical conditions. The lightweight design and minimal hardware requirements make it suitable for deployment on low-end systems, allowing broader accessibility, especially in remote or resource-limited settings. Overall, the system lays a strong foundation for future advancements in automated eye health monitoring technologies.

In the future, the system can be enhanced by incorporating deep learning models for more accurate iris segmentation and robust pupil detection under various lighting conditions. Features like cloud integration for medical data storage, voice-assisted interaction for hands-free operation, and mobile compatibility can greatly expand its usability. Additionally, the system could evolve into a multipurpose diagnostic tool by including functionalities for detecting other ocular or facial abnormalities, ultimately contributing to more comprehensive and accessible telemedicine solutions.

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