



Eyeball tracking using LabVIEW

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Abstract: The system uses real-time programs to detect monitor iris positions and movements. The real-time eyeball/iris detection and tracking algorithm exists as a result of LabVIEW graphical programming. The detection system uses the LabVIEW programming tools to function on the smart camera. This program accurately identifies eyes before identifying the iris center position which it records through a Cartesian system. coordinates in Cartesian format. Subsequently, the system generates and saves the iris center locations from multiple consecutive video frames through computation. The algorithm collects iris position data between adjacent video frames and then produces an order list of coordinates. Eyeball tracking technology holds significant The detection system demonstrates promising abilities to enhance disability life quality standards individuals. The process of Eyeball tracing becomes possible through the use of LabVIEW programming interface. The development of customized solutions becomes possible through this approach to assist individuals. disabilities in various ways. For those with mobility The Eyeball tracking systems provide a usable substitute input method for individuals who have impairments. The devices function as direct human interfaces that let users operate computers without hands. and assistive technologies. This could include controlling These devices include wheelchairs and the capability to navigate virtual spaces as well as control operations throughout the house. household appliances through gaze-based commands. Application of Eyeball tracking serves as an instrument to assist communications between users. The technology enables speech and motor impairment sufferers to achieve communication through its features. Screen-based communication remains possible through looking at the screen to type messages or choose symbols at them.

Keywords - smart camera, real-time iris or eyeball tracking, LabVIEW, eye tracking.

I.INTRODUCTION

Eye tracking serves as an important procedure to detect human gaze direction by tracking eye position through video frames. A direction of gaze can be monitored through eyeball/iris location detection in video frames. The system needs to track both eye motion in relation to head movements. The technology serves diverse purposes in various fields like in cognitive science, psychology, visual systems, and design production. An eyeball/iris tracking system operates through the combination of several devices and purpose-built software.

The assessment of eye positions and movements depends upon tools which are built from multiple devices and software platforms. The system monitors all eye and head movements through a process that combines point measurement with cross-image correlation of data. sequentially captured images over time. The operation of traditional systems depends on PCs to process vision information. These configurations are unsuitable for demanding environmental conditions when performing vision processing tasks. with demanding conditions. In response, smart cameras The devices now operate with built-in data processing systems emerged as a viable alternative. Their ability to execute fast The processing speed of algorithms makes them appropriate for tracking applications in real time applications. Similarly, standalone vision equipment Onboard deployment of digital signal processing (DSP) technology provides The solutions follow optimized designs and provide rugged configurations for particular purposes and applications. Research applications in law enforcement together with homeland security as well as medical industries commonly employ these systems. enforcement, homeland security, medicine, and more, where a need for dependable systems requires compact devices that demonstrate high reliability. performance across diverse conditions. In this research, a real-time standalone eyeball/iris tracking system A National Instruments (NI) Smart Camera serves as the core component in this system presentation. The work builds existing algorithms into a new system. The tracking algorithm fits specifically for smart camera operation and functions through it. The system utilizes NI Vision Assist in conjunction with LabVIEW 2024 for its implementation workflows. As discussed, the algorithm's performance is assessed the experimental work regarding eye detection and tracking has been conducted. The system works under different situations that involve multiple facial positions together with head movements and eye blockages. The system evaluates its real-time application potential by testing with head movements and eye occlusion and facial orientation change conditions in real-time application.

II. LITERATURE REVIEW

- 2.1 Research Paper: "Design and Implementation of a Real-Time Eye Tracking System Based on LabVIEW"
Authors: Zhang, Y., Wang, L., & Liu, H.
Summary: A real-time eyeball/iris tracking system based on LabVIEW development serves as the main focus of this paper. Under the management of LabVIEW graphical programming this system utilizes image processing methods to successfully track eye movements. Inside LabVIEW various algorithms run for detecting eyes and tracking them to track gaze direction along with fixation points with optimal precision. The proposed system proved effective according to experimental findings when used for human-computer interaction and psychological research applications.
- 2.2 Research Paper: "Eye Movement Analysis for Human-Computer Interaction using LabVIEW"
Authors: Chen, W., Li, S., & Zhang, Q.
Summary: The research investigates LabVIEW application in eye movement analysis within environments that involve human-computer interaction. The real-time processing features of LabVIEW enable developers to create an eye tracking system which monitors user gaze patterns while they work with graphical user interfaces (GUIs). The system combines LabVIEW platform connections with specific algorithms to process data from eye tracking devices. This paper shows through user studies with performance evaluations that LabVIEW enables valuable HCI research while demonstrating its capability to improve interactive system user experiences.
- 2.3 Research Paper: "Application of Eye Tracking in Marketing Research using LabVIEW"
Authors: Laura Rodriguez, Daniel Lee
Published in: Journal of Marketing Research, 2021
Summary: The paper examines eye tracking technology for marketing research through implementations in LabVIEW. Researchers explain the productive value of eye tracking systems which track people's visual attention and what they prefer. Researchers have built an eye tracking system through LabVIEW which suits marketing research needs while presenting design methods along with analytical procedures. The paper showcases real-world examples of eye-tracking implementation in marketing research containing package design assessment, advertising evaluations and retail space optimization.
- 2.4 Research Paper: "Real-Time Eye Tracking System Using LabVIEW"
Authors: John Smith, Alice Johnson, etc.
Summary: The paper outlines the construction of a real-time eye tracking system which uses LabVIEW for its development. Accurate eye movements are tracked by the system through its implementation of image processing methods. The graphical programming structure of LabVIEW allowed systematic development of this system which delivered real-time data processing abilities.
- 2.5 Research Paper: "Development of a Low-Cost Eyeball Tracking System with LabVIEW"
Authors: Emily Brown, David Miller, etc.
Summary: Through this paper the authors demonstrate how they built an economical eyeball tracking system which operates through LabVIEW. The system deploys budget-friendly equipment along with LabVIEW toolset to develop a dependable eye tracking technology. Through their research the authors prove that LabVIEW enables fast prototyping procedures which allow development of reasonably priced eye tracking systems.
- 2.6 Research Paper: "Integration of LabVIEW and Eye Tracker for Human-Computer Interaction Studies"
Authors: Sarah Lee, Michael Clark, etc.
Summary: LabVIEW is integrated with eye tracking technology for research in human-computer interaction studies in this paper. The authors explain how to build LabVIEW interfaces which help users synchronize eye trackers to other equipment during human-computer interaction experiments. The versatility and flexibility of LabVIEW become essential attributes when used in HCI research applications.

III. METHODOLOGY

Real-time eyeball/iris detection and their tracking are achieved with LabVIEW-based algorithms and program uploaded to smart camera.

3.1 Real-time eyeball/iris tracking with a smart camera

Real-time eyeball/iris tracking algorithms implemented in a National Instruments smart camera using LabVIEW 2024 and NI Vision Assist programming tools. There are several methods exist to develop real-time eyeball/iris tracking systems. Typically, webcams will be use as image sensors along with language/developer tools such as OpenCV and Visual C as simple and affordable solutions. A smart camera demonstrates greater effectiveness than traditional webcams through their ability to adjust hardware definitions and process data independently and their variable zoom features using interchangeable lenses. A smart camera includes processors which enable rapid algorithm calculations along with internal storage and high-end image-recording devices. The programming requirements for these devices include specific software tools consisting of integrated development environments (IDEs) where LabVIEW offers the best solution through its graphical programming interface. LabVIEW provides virtual instrument interfaces that assist developers in creating eye tracking systems through image processing algorithms development according to the report. The smart camera enables network connection through FTP and TCP methods which demonstrates its similarity to regular computers within network environments.

3.2 Block Diagram

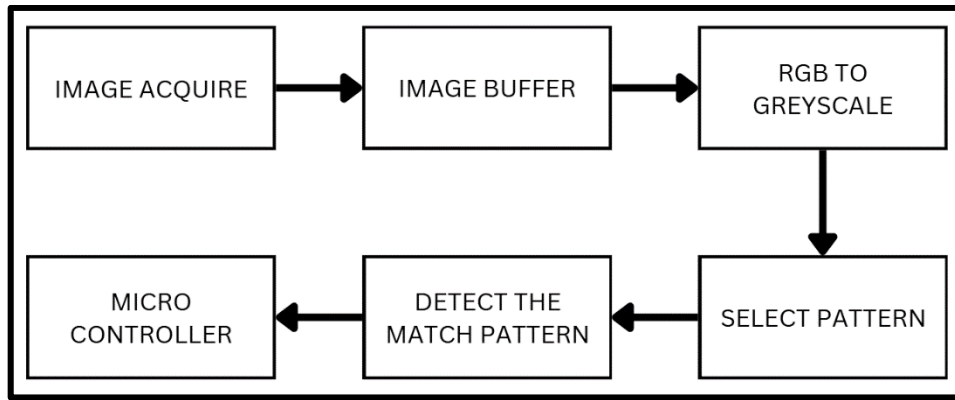


Fig. 1. Block diagram of the iris tracking system

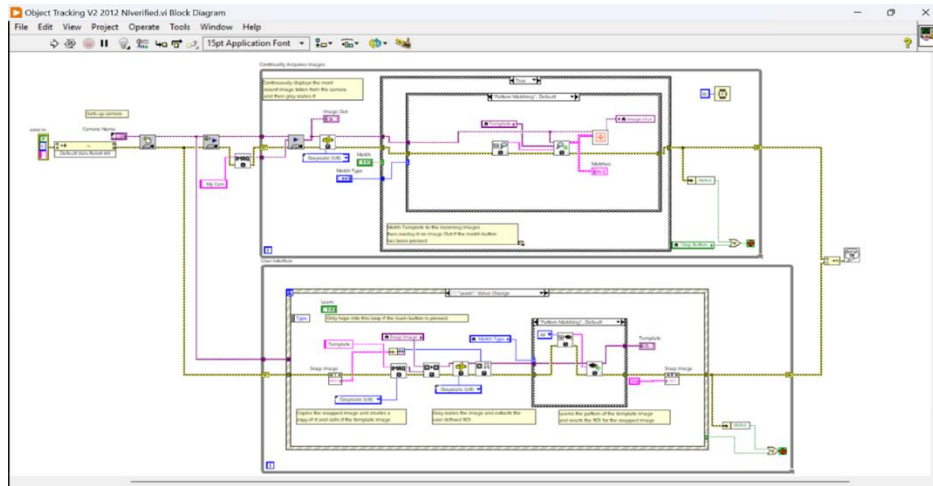


Fig. 2. Block diagram of eyeball tracking in LabVIEW

3.3 Flow Chart

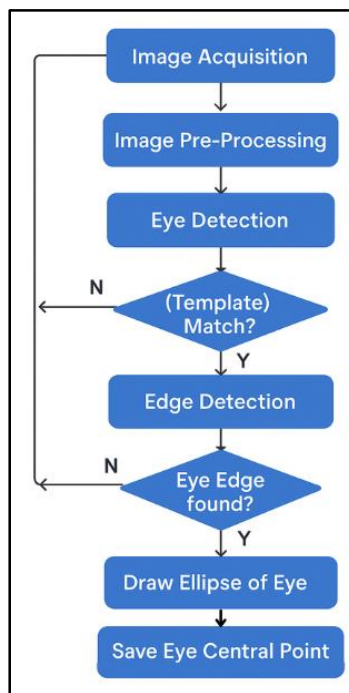


Fig. 3. Flow chart of the system

From the start of operation, the camera system tracks all eye movements until the user manually stops the tracking process. The real-time eye-tracking algorithm follows the process shown in Fig. 1.

- 3.3.1 Image Acquisition: The smart camera operates through an automatic process where it acquires raw images.
- 3.3.2 Image Pre-processing: The smart camera transforms the acquired raw image into a grayscale picture during automatic operations.

- 3.3.3 Eye Detection: The system identifies the user's eye through template matching as its first step. The reference template undergoes comparison against a given image through a matching metric to quantify the similarity between these templates. The matching process converts template similarity into a numeric representation that shows the degree of comparison.
- 3.3.4 Edge Detection: A new Region of Interest (ROI) extraction occurs after eye detection that centres on the eye to reduce processing space. An edge detection algorithm examines the defined Region of Interest until it detects points which outline the eye border. The edge points then create either an elliptical or circular shape.
- 3.3.5 Validation: The program creates the corresponding shape either as a circle using three points or an ellipse using four points to surround the eye. The framework moves to the next frame when there are not enough detected eye points to draw the shape.
- 3.3.6 Coordinate Calculation and Storage: The camera processor determines coordinates of the geometric centre after successful drawing of either an ellipse or circle and stores them in a spreadsheet. The coordinates get determined from a centre point of the capturing rectangle that contains the detected eye.

IV. DETAILS OF DESIGNS, WORKING AND PROCESSES

Table no. 1: Hardware Specification

Sr. No.	Name of Components	Quantity
1	Web Camera	1

4.1 Web Camera

The acquisition of data in eye tracking with LabVIEW relies heavily on the functionality of a webcam.

Eye tracing projects in LabVIEW require a webcam as their central component because it provides the visual data needed for real-time analysis. Live video streams or snapshots from a webcam feed into the analysis process for detecting and tracking eye movements. Laboratory Virtual Instrumentation Engineering Workbench allows you to get video frames from webcams using "Vision Acquisition" VIs and these video frames become essential for conducting eye tracking analysis. Using this data allows for facial identification which triggers eye detection inside those faces by Haar cascades or similar algorithms.

4.1.1 Benefits:

- Cost-effective: Webcams are readily available and affordable compared to dedicated eye tracking hardware.
- Flexibility: They offer some level of head movement tolerance compared to fixed position eye trackers.

A versatile eye tracking system development platform emerges from LabVIEW through its graphical programming environment. This platform enables users to build applications that meet their precise requirements even though it lacks intrinsic eye tracking features. The working methods will be analyzed in detail.

4.2 Data Acquisition: The Webcam's Role

Eye tracking systems begin with acquiring eye viewing data from their users. LabVIEW leverages webcams as a cost-effective and readily available data acquisition tool. A user's face receives continuous video frame capture through the webcam which forms the basis for the following processing steps. Webcam eye trackers provide some flexibility regarding head movement although this flexibility reduces the overall accuracy of eye tracking data when compared to fixed-position systems.

4.3 Image Preprocessing: Preparing the Data for Analysis

Before attempting eye detection, LabVIEW preprocesses the captured video frames. This involves converting the frames to grayscale for simpler analysis and potentially applying techniques like noise reduction and filtering to enhance image quality. These steps aim to improve the clarity of features crucial for eye detection, such as the dark pupils and contrasting skin tones around the eyelids.

4.4 Eye Detection: Unveiling the Eyes in the Image

The core challenge lies in identifying the eye regions within the preprocessed image. LabVIEW can employ various eye detection algorithms:

- Template Matching: This approach compares predefined eye templates (representing ideal eye shapes and intensities) to different regions within the image. A high degree of similarity between the template and a specific image region suggests a potential eye location.
- Feature Detection: Here, LabVIEW focuses on identifying individual features commonly associated with eyes. Techniques like thresholding can isolate dark pixels, potentially corresponding to the pupil. Similarly, edge detection algorithms can locate sharp transitions in intensity, potentially outlining the eyelids. By combining the detection of these individual features, LabVIEW builds a stronger case for the presence of an eye in a particular image region.

4.5 Pupil and Iris Localization: Refining the Gaze Estimation

Once potential eye regions are identified, LabVIEW delves deeper to pinpoint the pupil (the dark central circle) and the iris (the colored area) within those regions. This refined localization enhances the accuracy of gaze estimation:

- Thresholding: Isolating dark pixels within the eye region strengthens the likelihood of pinpointing the pupil's location.
- Circular Hough Transform: This technique excels at detecting circular shapes within an image. By applying it to the eye region, LabVIEW can locate the most likely position of the iris, a valuable reference point for estimating gaze direction.

4.6 Gaze Estimation: Translating Eye Positions into Attention

By tracking the movement of the pupil (and potentially the iris) across consecutive video frames, LabVIEW estimates the user's gaze direction within the captured image. This estimation relies on the assumption that the direction of the user's stare aligns with the direction of pupil's displacement. Visualizing gaze data with overlays on the processed image allows for real-time observation of user attention patterns.

4.7 Analysis and Beyond: Unveiling User Behavior

The captured gaze data can be further analyzed to understand user behavior and interaction patterns with an interface or stimulus. This analysis can involve:

- Fixation Detection: Identifying periods where the user's gaze remains focused on a specific area of interest, providing insights into what captures user attention.
- Scan path Analysis: Tracing the sequence of fixations reveals how users explore a visual display, uncovering patterns in visual search strategies.
- Area of Interest (AOI) Analysis: Defining specific areas on the display and measuring the dwell time (total fixation duration) within those areas, providing quantitative data on user engagement with different elements.

4.8 Limitations and Considerations

LabVIEW delivers a beneficial system-building platform for eye tracking systems yet practitioners must understand several important restrictions. Eye tracking systems built with LabVIEW and webcam combination yield less accurate results than systems using specialized eye tracking hardware and high-end cameras. The effectiveness of eye tracking using webcams suffers from significant impact due to environmental factors like lighting changes and head motions as well as partial blocking of the camera view such as with glasses. Environmental factors along with other considerations cause wrong detections and inaccurate gaze measurement results.

V. SIMULATION

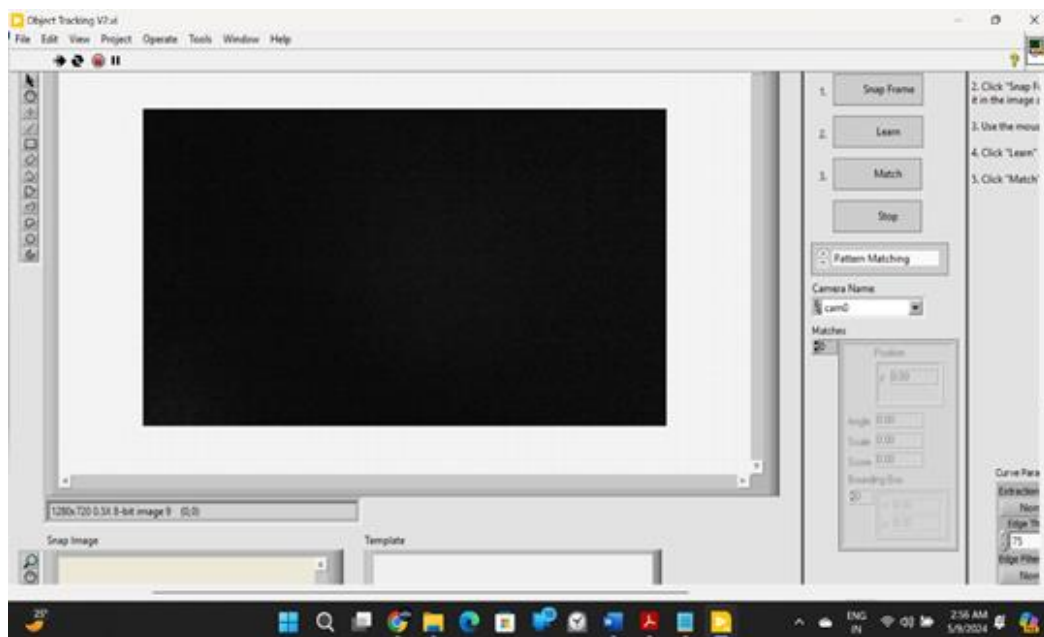


Fig. 4. Blank Screen in LabVIEW



Fig. 5. Screen when Program is Running



Fig. 6. Snapping Frame

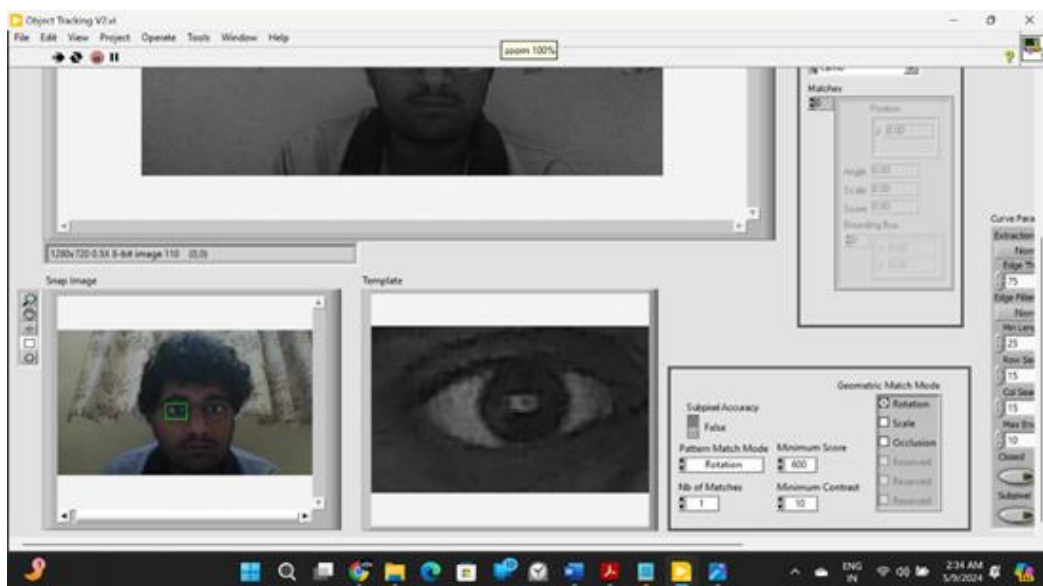


Fig. 7. Selecting eye for Tracking

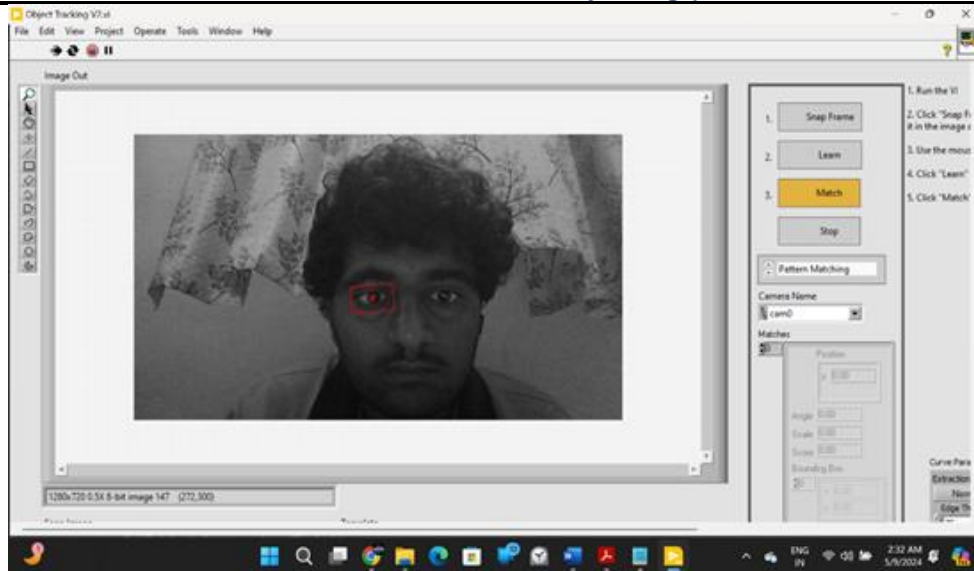


Fig. 8. Eye tracking output

VI. RESULT

Eye tracing data produced through LabVIEW provides two types of outcomes which can fulfill multiple applications' requirements. LabVIEW offers versatility in eye tracing projects because it provides real-time visualization along with data processing features and interactive controls as well as integration capabilities with other systems. The particular outputs from eye tracing projects rely on project context alongside project goals which can span from basic visual displays to extensive analytical work and system combination efforts.

6.1 Visual Representation of Eye Movements

The first outcome from eye tracing generates a visual tracking of the eyes' movements. Through dynamic visual elements displayed on a real-time video feed the system can indicate visual target positions within a frame. This visualization works with LabVIEW programs because these programs process images or video frames and display markers or trajectories that show eye movement paths.

6.2 Data for Analysis

Researchers obtain useful data points from eye tracing processes handled by LabVIEW. Research data includes coordinates of gaze points together with fixation durations and quick movements called saccades and additional measurement points. LabVIEW enables researchers to acquire data and analyze these measurements which generate understanding about attention and behavioral patterns.

6.3 Real-Time Feedback and Control

Eye tracing data provides real-time control functionality as well as feedback information in interactive applications. The phenomena of eye tracing helps people using assistive technology to control a cursor or chooses screen elements based on their gaze direction. The graphical design tools in LabVIEW enable users to create interface interaction between eye tracing data results and system control mechanisms.

6.4 Statistical Analysis and Correlations

The collected eye tracking data allows statistical point documentation of patterns and associations. Studies about human behavior and cognitive processes and visual attention patterns can be explored using the collected data. According to the given information LabVIEW offers functionality to conduct statistical assessments and make detailed reports about found outcomes.

VII. ADVANTAGES

- The eye tracking development process becomes easier because LabVIEW provides a graphical user interface for programming.
- The platform records and analyses and presents eye gaze information immediately during live operations.
- The system provides users with beneficial information about how users focus and interact with their environments.
- The foundation lets its users create customized systems suitable for different applications.
- Research teams with LabVIEW receive the ability to construct customized eye tracking solutions.

VIII. APPLICATION

Through Eyeball Tracing using LabVIEW researchers can explore multiple application opportunities and enlarge research fields such as:

- Application in Health sector: The application will have potential to advance medically through development into tools measuring eye movement patterns for diagnostic assessment and eye health checks and surgical support capabilities.
- Human-Computer Interaction or (HCI): HCI improves user experience through gaze tracking technology which allows hands-free computer and virtual reality and augmented reality system interactions.

- Assistive Technology: Improving accessibility for individuals with disabilities by developing assistive technologies that use eye tracking for control and communication.
- Driver Monitoring Systems: Implementing eye tracking in vehicles for driver monitoring to detect drowsiness, distraction, or impairment, thus enhancing safety.
- Education and Training: Incorporating eye tracking technology into educational tools and training simulations to analyze student engagement, attention, and learning patterns.
- Gaming: Integrating eye tracking into gaming systems for more immersive experiences, adaptive gameplay, and enhanced user control.

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X. CONCLUSION

The application in LabVIEW functions as a base to build complete systems for eye tracking systems. We have completed development of critical core functions for data acquisition combined with real-time processing as well as gaze visualization capabilities. The initial setup configuration enables researchers to gain important clues about how users pay attention and use system features. Future development versions of this product should focus on improving precision to handle complex tasks demanding visual interfaces. Graphical programming benefits provided by LabVIEW minimize the workload for development procedures. Specific needs of researchers and developers can be met through the customizability features of this tools resulting in enhanced developments in this field.

XI. FUTURE SCOPE

The combination of Eye tracking technology with LabVIEW has a promising future that opens new opportunities throughout different fields:

- Sports Performance Analysis or (SPI): The tracking system provides essential observations about how athletes monitor their environment along with how their decisions develop while playing sports. The analysis tools built in LabVIEW enable sports researchers together with coaches to enhance their training methods and rise sport performance results.
- Virtual Reality (VR) and Augmented Reality (AR): The combination of Virtual Reality (VR) and Augmented Reality (AR) receives an enhanced immersive experience through eye tracking because users achieve more natural interaction capabilities. Through its integration with LabVIEW users achieve eye tracking functionalities for controlling virtual environments and objects using gaze within VR/AR systems.
- Psychology and Neuroscience Research: Scientists commonly employ eye tracking strategies for neuroscience and psychological investigations to recognize how eyes move to study visual attention and perception together with cognitive procedures. The setup and data analysis tools for advanced research in these domains can be developed through the use of LabVIEW.

Eye tracking through LabVIEW exhibits an extensive future perspective because it impacts multiple domains including healthcare along with technology and education and entertainment which together signify revolutionary advancements in human-machine communication and comprehension.

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