A Gaze Detection System for Neuropsychiatric Disorders Remote Diagnosis Support

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Abstract

Accurate and early diagnosis of neuropsychiatric disorders, such as Autism Spectrum Disorders (ASD) is a significant challenge in clinical practice. This study explores the use of real-time gaze tracking as a tool for unbiased and quantitative analysis of eye gaze. The results of this study could support the diagnosis of disorders and potentially be used as a tool in the field of rehabilitation. The proposed setup consists of an RGB-D camera embedded in the latest-generation smartphones and a set of processing components for the analysis of recorded data related to patient interactivity. The proposed system is easy to use and doesn’t require much knowledge or expertise. It also achieves a high level of accuracy. Because of this, it can be used remotely (telemedicine) to simplify diagnosis and rehabilitation processes. We present initial findings that show how real-time gaze tracking can be a valuable tool for doctors. It is a non-invasive device that provides unbiased quantitative data that can aid in early detection, monitoring, and treatment evaluation. This study’s findings have significant implications for the advancement of ASD research. The innovative approach proposed in this study has the potential to enhance diagnostic accuracy and improve patient outcomes.

CCS Concepts

• Applied computing → Health informatics; • Human-centered computing → Pointing devices;

1. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by socialization, communication, and behavioral impairments [LMS09]. Early and accurate detection of ASD is crucial for implementing appropriate treatment and improving patient outcomes. Intervention at an earlier stage has been shown to be more effective, leading to better speaking and behavioral skills, as well as higher IQ scores [HMCM09; DRM*10]. However, timely and accurate diagnosis remains a challenge due to the complexity of clinical markers and the subjective nature of traditional assessments. In this context, the use of real-time gaze tracking and recognition (gaze detection) has emerged as an innovative strategy to support ASD diagnosis across patients of all cognitive levels and ages [PCH*11]. Gaze detection technology enables accurate monitoring and recording of eye movements, providing valuable information on visual-related cognitive activities and differences in attention mechanisms. For example, it can reveal whether a child primarily focuses their gaze on specific facial regions such as the mouth or eyes of a speaker [KJS*02; CIN*18]. Gaze analysis allows for the extraction of quantitative data, in contrast to the subjective nature of conventional diagnostic methods [FKP*18; BAQ23]. However, technical challenges to be faced include accuracy and calibration issues, environmental noise and interference, eye fatigue, and experimental setup. Although eye trackers have become more user-friendly, with the potential for remote usage [HCKH15], inaccuracies and low data quality raise concerns in experts [HCKH15; HNKH17]. To overcome the aforementioned issues, we propose a novel tracking system that is not only reliable and accurate but also easy to set up, and portable in a way that it could be directly incorporated into complex systems. The framework provides gaze recognition, tracking, and recording in a way to accurately measure and interpret eye movements in real-time. The system contains a calibration and a verification module, allowing for an accurate identification and quantification of pupil movements and the detection of abnormalities associated with the ASD condition. The main features of the system are the following:

• a quantitative data analysis tool of recorded signals (E.g. speed of movement): the proposed processing component goes beyond simple qualitative observation and it allows to formulate a diagnosis based on semi-objective analysis;

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• a processing tool for checking the consistency between proposed pattern and followed trajectory: we provide a preliminary evaluation of trajectory accuracy and preliminary guidelines for determining normal and abnormal gaze patterns;

• a proof-of-concept implementation of the system: we exploit the capabilities of state-of-the-art smartphones (in this case iPhone) equipped with RGB-D camera and we implement live, as well as remote analysis routines to support the diagnosis. Our prototype does not require spatial constraints between the visualization screen and the acquisition camera, providing a flexible experimental setup that easily allows for remote use.

Tools and Methods To capture images Record3D app on the iPhone is used:

• Depth camera provides grayscale images with 640x480 resolution, where pixel values were obtained in meters relative to the camera position;

• RGB camera captures color images focused on the eyes and pupils to detect markers

The acquired data is processed using Python: specific libraries, such as OpenCV, are leveraged for image processing and extraction of gaze tracking features. The pin-hole camera model and perspective projection model are applied to calculate the three-dimensional position of the pupils, with the origin centered on the camera itself. The Direct Linear Transformation (DLT) model [AKH15] and calibration parameters are used for correlation between pupil position and objects displayed on the screen. The observed position on the screen is obtained by linearly combining the calibration parameters with the position of the pupils in space. For face point detection and tracking, the MediaPipe MeshFace [LTN*19] model is used, which leverages machine learning techniques to create a three-dimensional representation of the face and identify key points such as the eyes, nose, and mouth. Finally, Matlab is used for visualization, filtering and data analysis.

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References


