Grenze International Journal of Engineering and Technology, June Issue

A Critical Analysis of Human Computer Interaction using Eye Gaze Technology for Differently Abled People

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***Abstract*— Motor neuron diseases, such as Amyotrophic Lateral Sclerosis (ALS), pose challenges to individuals' motor abilities, limiting computer interactions. This research addresses this by utilizing eye gaze technology in Human-Computer Interaction (HCI). Tracking eye movements empowers users to control computers effectively, restoring engagement with digital resources. Motor neuron diseases create barriers to computer interaction, hindering access to essential digital functionalities. Our proposal advocates for integrating eye gaze technology into HCI to reestablish computer interaction for users with motor neuron diseases, fostering independence and enhancing overall quality of life. Introducing ELITA, an HCI system designed for physically challenged individuals, employing eye movement tracking for effortless computer tasks. ELITA includes a visual keyboard operated through eye gaze technology, enhancing accessibility. This research serves as a beacon of hope, bridging the digital divide for those with motor neuron diseases. Through the proposed eye-based computer interaction system, ELITA, we strive to empower users and contribute to a more inclusive technological landscape.**

***Index Terms*— Eye-Gaze, Visual-keyword, Computer Vision, Human Computer Interaction (HCI), Oculography Technique, HOG.**

I. INTRODUCTION

Throughout the past few decades, eye gaze-based Human-Computer Interaction (HCI) technologies have been created and studied. HCI technology has proven essential in developing interfaces that are accessible and user-friendly for individuals with disabilities. The technology enables hands-free interaction with computers, mobile devices, and other electronic equipment by sensing user eye movements and converting them into input commands. Users can communicate with computers and other digital devices by using their eyes in eye gaze-based Human-Computer Interaction (HCI) systems. These systems monitor the user's eye movements and translate these into instructions for the computer to follow using a mix of hardware and software. In particular, for those with physical limitations who might struggle to utilize conventional input devices like a mouse or keyboard, eye gaze-based interaction offers the potential to provide a more natural and intuitive means of communicating with computers. Screen readers, eye-tracking devices, and speech recognition software, among other things, have enabled persons with impairments to communicate, study, work, and access information. To understand how users interact with

Grenze ID: 01.GIJET.10.2.255

graphical user interfaces (GUIs) and other computer-based systems, these systems concentrate on tracking and analyzing users' eye movements and pupil dilation. It is possible to assess user involvement, attentiveness, and levels of interest by using eye gaze monitoring technologies. Here, we present an overview of HCI technologies for differently abled individuals, highlighting the problems and solutions in building accessible interfaces. This article discusses essential technologies, applications, benefits, and limitations in eye gaze-based HCI research as it evaluates recent developments in the field. The study also discusses possible uses for the technology in the future.

II. Related Work

Various work has been done on the Eye-Gaze system to provide an effective and easy way to communicate with computers for differently abled people. The physically challenged person always faces problems in performing all the tasks for which physical body-parts movement is essential.

Table I- Representing The Disabled Population In India By Age Group According To A Survey.

Age Group	Percentage
0-4 years	5%
5-9 years	7%
10-19 years	17%
20-29 years	16%
30-39 years	13%
40-49 years	12%
50-59 years	9%
60-69 years	10%
70-79 years	7%
80-89 years	3%
90+ years	4%

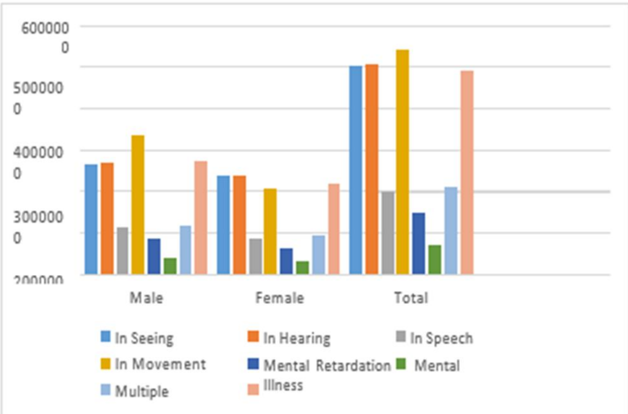

Fig 1. Graph of Rate of differently abled people in India

The University of Virginia developed an electronic eye-monitoring system for Windows, integrating seamlessly and allowing eye-based writing, typing, and mouse operations through an external camera beneath the monitor. A provided keyboard aids typing, but achieving precision remains challenging [1]. Eye-gaze Interaction is faster than mouse-based selection, utilizing algorithms understanding eye behavior. A hardware setup with a gaze tracker and infrared lights efficiently tracks eye movement but is limited to browsers and eye-driven tasks [2]. This paper explores cost-effective, accurate eye-tracking methods, presenting various approaches for implementation. The insights aid in choosing an approach with optimal accuracy and lower costs. They discover various methods of implementation of eye-tracking that are as follows-

Electro-Oculography

A sensor attached around the eyes records the electric field during eye rotation, estimating eye position by measuring potential difference. Strategic electrode placement enables precise tracking of horizontal and vertical eye movement.

Scleral Search Coils

This method employs Faraday's Law, using a wire coil attached to the eyes via contact lenses. As the coil moves in the magnetic field around the eyes, induced voltage generates signals indicating eye position.

Infrared Oculography

Infrared light reflection from the sclera determines gaze position. The eyes are illuminated with infrared light, and the sensor reads eye position based on the difference in reflected light.

Video Oculography

Video Oculography, a popular eye-tracking method using Infrared illumination with single or multiple cameras, includes head and body posture measurements for enhanced gaze position calculation. For precise movement measurement, four L-shaped lights in the monitor's corners illuminate the entire face [3]. Eye-tracking system uses Infrared light, an eye camera, and two head cameras for accurate measurement. Supported by four IR lights, exhibits 0.5 to 1 cm error at a 60 cm user distance [4]. Non-invasive eye-tracking employs a computer-mounted camera and Electro-Oculography for gaze direction. Wearable gaze trackers generate an electric field, recording position through potential difference. Glasses include a keyboard display [5]. EyeLive's infrared sensors transmit eye reflections to a microcontroller for a unique Human-Computer Interaction model for ALS and LOCKED-IN DISEASES. Adapting to cost-effective infrared sensors and eye lenses results in higher error rates and slower typing speeds [6]. Wearable eye-tracking for Google Maps uses long blinks as double-clicks. Mouse control for application initiation, map selection, and Street View. Dedicated keyboard offers extra controls, with zooming through eye fixation. Challenges include cursor positioning and unintended clicks [7]. System uses a central LED for pupil images through corneal reflection, allowing eye position measurement. Real-time video processed into images using computer vision reads pixels for eye tracking. Not suitable for bright sources or uncovered windows [8]. Employs eye gaze for a virtual keyboard, aiding information sharing. Features a pointer controlled by the user's gaze to select letters, but typing is slower and complex. Eye-gaze tech, once complex and costly, is now simpler and more affordable with technological advancements [9].

Detects eye blinks, lacking real-time functionality, has low accuracy, and operates solely on recorded video, posing challenges in recognizing the actual blink rate [10]. Assists dyslexic users in word identification and pronunciation through visually controlled auditory cues. Exclusive to dyslexic users, lacking details on interactions and inputs from disabled individuals [11].Balancing assistive manipulation and direct human control in building control architecture is crucial for effective human-robot collaboration. It enhances wheelchair mobility based on eye gaze, prioritizing user support over system interaction for those with disabilities [12].Balancing human-robot collaboration requires a thoughtful control architecture. The gaze-driven system supports wheelchair and robot arm use for daily tasks, with 14 of 15 participants favoring eye-gaze tracking for their primary AAC device [13]. Empowers physically challenged users using eye-tracking and GUI for Google Maps control, converting eye-gaze into joystick-like navigation. Limited to single-task usage, it utilizes contact lenses and a coil in a magnetic field for eye-tracking [14]. Outlines wheelchair movements using an EGT with a 3D orientation sensor, controlled through a simple GUI device. Confined to wheelchair navigation, it lacks computer interaction capabilities, featuring an interface for movement control [15]. Emphasizes noncontact human-computer interaction in wireless sensor networks, introducing a real-time system using eye state recognition, gaze estimation, SVM [17], HOG [18] features, and a basic CNN model. Achieving high-precision interaction, it replaces traditional input devices with a cost-effective webcam and head pose assessment [16]. This paper presents an assistive system based on eye tracking for individuals with disabilities. It employs the Gazepoint GP3 eye tracker for gaze control, integrating Haar cascade facial landmarks for secure access, ensuring privacy and user verification, enhancing the quality of life for disabled patients [19]. This paper introduces Gaze Capture, a vast eye-tracking dataset recorded on mobile devices with data from over 1450 people and nearly 2.5 million frames. It presents iTracker, a real-time CNN [21] for mobile eye tracking, achieving high accuracy and overcoming previous limitations, making gaze estimation more accessible to a broader audience [20]. Covers two decades of eye gaze tracking progress on various platforms, addressing accuracy, system configurations, and user platforms. Emphasizes standardized evaluation methods [22].Compares eye gaze-based object selection with mouse-based methods, revealing faster interaction. Utilizes a real-time architecture for intuitive input [23].Examines cost-effective gaze tracking using convolutional neural networks (CNNs) with webcams. Predicts gaze coordinates without extra hardware, showcasing accuracy in real-world conditions [24]. Introduces Identification by Random Forest [26] (IRF), a machine-learning[27] method surpassing existing algorithms for automated gaze event classification. Exhibits superior accuracy with potential applications in biometrics [25]. EyeBoard, a gaze-controlled text entry system, optimizes virtual keyboard layouts for improved comfort. Demonstrates a 14% average increase in text entry rates, suitable for compact devices and beneficial for individuals with severe motor disabilities [28].Code Gazer enhances source code navigation via eye gaze, favoring gaze-based "Go to Definition" in user studies. Integrates eye gaze with mouse and keyboard for efficient "look up" tasks [29].Explores eye gaze and typing links in touch and non-touch typists, identifying unique eye movement patterns. Achieves 92% accuracy in recognizing touch-typed strokes. Enhances Web Gazer for improved performance [30].EyeSayCorrect, a hands-free solution, combines speech recognition [32] and eye gaze. Corrects words by looking and speaking, achieving up to 23.79% faster task completion and 40.35% faster text selection on mobile devices [31]. Eye Swipe streamlines text entry, requiring users to glance near virtual keyboard keys. While swiping, potential words pop up, and "reverse crossing" identifies a word's first and last letter [33].The system, using the Haar classifier, recognizes facial movements, especially the mouth and eyes. Controls a virtual keyboard and mouse, enabling hands-free computer interaction with pointer movement and scrolling in all directions [34].The paper categorizes face detection methods, emphasizing the prevalence of Haar-like features. It discusses common challenges, such as lighting conditions and facial expressions. The study highlights the interconnectedness of face and eye detection and anticipates future advancements in gaze estimation techniques [35]. The paper categorizes face detection methods, emphasizing Haar-like features' prevalence. It discusses challenges like lighting and facial expressions, highlighting face and eye detection's interconnectedness. The study anticipates advancements in gaze estimation techniques [36].

TABLE II – REPRESENTING THE COMPARATIVE OF REFERENCES

S. No.	Author	Title	Year	Technology Used	Research Gap	Application Area
1	Chris Langford et	ERICA(Eye-Gaze Response Computer Aid)	2000	Eye-gaze, camera Video- Oculography	Limited to performing typing and low accuracy eye	Operate Mouse and Typing on Windows
2	Carlos H. Morimoto, et al.	Remote Eye-Gaze Tracker	2005	Eye-gaze, Gaze Tracker, 4-L IR Light	Challenges for general interactive use.	AAC System for computers
3	H.R. Chennamma Xiaohui Yyan	Computer Vision and Pattern Recognition	2013	E-O, Scleral-S-C, IR-O, Video-Oculography	Limited future development insight.	Accessing all features in Browser
4	Linda E. Sibert, et al.	Evaluation of Eye Gaze Interaction	2000	Computer Vision, Video- Oculography	Context-specific speed improvement.	Accurately Operate mouse and typing on windows
5	A.Perez, M.L. Corodoba, et al.	A Precise Eye-Gaze Detection and Tracking System	2003	Remote Eye- Gaze tracker, Computer Vision	Implementation without Hardware is not possible	Eye & head pose tracking techniques
6	Shuo Samuel Liu,et al.	An Eye-Gaze Tracking and Human Computer Interface System for people with ALS and other Locker-In Diseases (egelive)	2010	Eye-gaze, IR Sensor, 4-L IR Light	Dependence on camera accuracy.	Operating all computer features
7	Akshay Govind Wanjari, et al.	The Eye-Gaze Communication System	2014	Eye-gaze, Gaze-Goggle and External Camera	Use in well-lit space away from windows for accuracy. Ensure eye control.	Perform Computer Operations
8	Vidya Itsna Saraswati, et al.	Eye Gaze System to Operate Virtual Keyboard	2016	Eye Gaze, Mean Absolute Error (MAE)	The duration of typing using system is longer, More complex to integrate and use	Writing on any computer Interface
9	Sidra Naveed, et al.	Eye Tracking System with Blink Detection	2012	Video- Oculography Integral Projection	The system works on recorded videos, Does not perform actions using eye gaze	Unique Human-Computer Interface
10	Hanif Fermanda Putra,et al.	Navigating through google maps using an eye-gaze interface system	2022	MATLAB R2009a version 7.8.0	locating cursor position due to smaller display, involuntary blinks can cause unintended clicks	Used for navigation purposes without using hand operations
11	John L. Sibert, et al.	The Reading Assistant	2000	G W Gazer	Software aids dyslexics but lacks insights from disabled user interactions.	Reading in any application of computer
12	Md Samiul Haque Sunny, et al.	Eye-gaze control of a wheelchair mounted 6DOF assistive robot for activities of daily living	2021	Eye Tracking, PyGt5	In this the system completely supported the mobility of the user rather than the interaction with the system.	Wheelchair using eye gaze
13	Laura J. Ball, et al.	Eye-Gaze Access to AAC Technology for people with Amyotrophic Lateral Sclerosis	2010	Referred from ERICA	Enhance eye-gaze tech: less optimization, robust in varied conditions.	Computer AAC System
14	Hanif Fermanda Putra ,et al.	Navigating Through Google Maps Using An Eye-Gaze	2022	Eye-gaze	The usage is limited to the navigation system and and less interactive as it cannot multi task.	Used eye-gaze for interaction in Google Maps
15	Q.X. Nguyen, et al.	Electric wheelchair control using head pose free eye-gaze tracker	2012	Eye Gaze Tracker (EGT)	There is no scope of any kind of interaction process with computers as it is confined to only movement of wheelchair.	It can be used for many devices, used by head position and eye gaze

16	Junhao Huang, et al.	Real-Time Precise Human-Computer Interaction System Based on Gaze Estimation and Tracking	2021	SVM classification algorithm,HOG features,Simple CNN model	Camera-based limitations for precise interaction.	Wireless sensor network, human-computer interaction
19	May Phu Paing, et al.	Design and Development of an Assistive System Based on Eye Tracking	2022	Graphic user interface (GUI), Facial landmarks	Facial landmark authentication challenges	Assistive technology for disabled patients
20	Kyle Krafka, et al.	Eye Tracking for Everyone	2016	GazeCapture	Hardware limitations on some devices.	Mobile eye tracking technology
22	Anuradha Kar, et al.	A Review and Analysis of Eye-Gaze Estimation Systems, Algorithms and Performance Evaluation Methods in Consumer Platforms	2017	Eye Gaze	Lack of standardized evaluation methods.	Eye gaze tracking system evaluation
23	Linda E. Sibert, et al.	Evaluation of Eye Gaze Interaction	2000	Eye Gaze	Reliance on eye tracker maturity.	Enhanced computer interaction through eye gaze
24	Mohd Faizan Ansari, et al.	Gaze Tracking Using an Unmodified Web Camera and Convolutional Neural Network	2021	CNN	Dependent on image quality.	Cost-effective gaze estimation using neural network
25	Raimondas Zemblys, et al.	Using machine learning to detect events in eye-tracking data	2017	Machine Learning	Still needs training data.	Automated eye event classification with machine learning
28	Prateek Panwar, et al.	EyeBoard: A Fast and Accurate Eye Gaze-Based Text Entry System	2012	WebCam, IR filter removed lens, IR lamp, 10 IR LED, C#, VSCode 2010	Use of expensive external devices, Not much user-friendly	Mobile text entry for motor disabilities
29	Asma Shakil, et al.	CodeGazer: Making Code Navigation Easy and Natural with Gaze Input	2019	WebCam, Actigaze, java, Kotlin, IntelliJ IDEA IDE	Limited number of operation, Eye-typing isn't available, limited to source code(Software Development)	Source code navigation with eye gaze
30	Alexandra Papoutsaki, et al.	The Eye of the Typer: A Benchmark and Analysis of Gaze Behavior during Typing	2018	WebCam, WebGazer, Created own dataset	Dataset limitations: time lag between capture and playback.	Improved tracking with eye gaze
31	Maozheng Zhao, et al.	EyeSayCorrect: Eye Gaze and Voice Based Hands-free Text Correction for Mobile Devices	2022	Webcam , Optical Tracker without Direct Contact Infrared Light	Unable to write sentence from scratch, Decrease in font size increase error rate	Hands-free mobile text correction
33	Andrew Kurauchi, et al.	EyeSwipe: Dwell-free Text Entry Using Gaze Paths	2016	reverse crossing, Dynamic Time Warping	External eye-tracker: lower accuracy, learnability, familiarity for performance.	Fast, gaze-based typing method
34	R. Raj Bharath, et al.	Controlling Mouse and Virtual Keyboard using Eye-Tracking by Computer Vision	2022	OpenCV, Haar classifier, Support Vector Machine	Too many operations makes it complex to use	Facial expression control for disabled users
35	Zeynep Orman , et al.	A Study on Face , Eye Detection and Gaze Estimation	2011	Image Processing, Face Detection, Eye Detection, Gaze Estimation	Lacks exploration of emerging methods addressing lighting and occlusion.	Facial recognition, gaze tracking, robotics.
36	T. D'Orazio, et al.	An Algorithm for real time eye detection in face images	2004	Visual C++, Firewire Sony Camera	Prior eye detection lacks versatility; proposed algorithm overcomes constraints effectively.	Face recognition, gaze tracking, human-computer interface, and driver behavior analysis.

A pie chart depicts the technological distribution across various references. Additionally, a line graph is made, illustrating the publication frequency of related works over distinct time intervals.

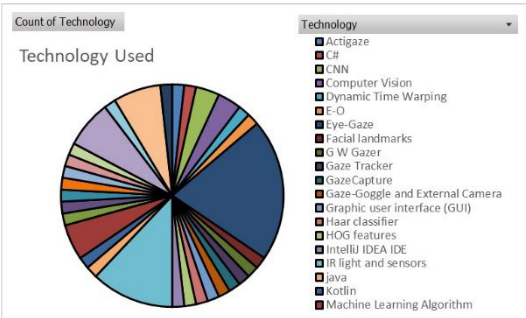

Fig.2 Pie Chart of different technologies used

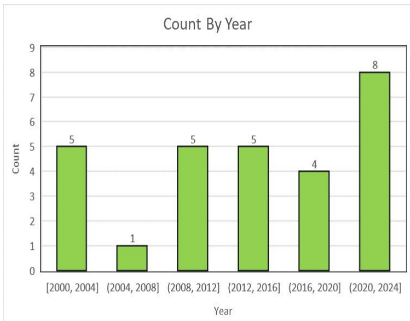

Fig.3 Graph illustrating work accomplished over different years, organized chronologically.

III. CONCLUSIONS

Eye-tracking HCI revolutionizes computer interaction for individuals with physical disabilities, utilizing eye movement and telekinesis. This technology enhances tasks such as typing and mouse operations through a visual keyboard, with verbal commands activating applications for seamless navigation. Despite its promise, common gaps in gaze-based interaction and eye-tracking technology persist, necessitating further attention:

1. *Hardware Dependency*: Specialized eye trackers limit widespread adoption; affordable solutions needed.

2. *Calibration Challenge*: Time-consuming eye-tracking calibration hinders efficient use; simplifying calibration is crucial.
3. *Performance Variability*: Gaze accuracy varies; research should enhance accuracy across diverse users and conditions.
4. *Standardization*: Lack of standardization impedes comparison; developing evaluation methodologies is essential.
5. *Privacy and Ethical Concerns*: Advances in eye-tracking raise privacy and ethical issues; researchers should address data security.
6. *Integration with Everyday Devices*: Gaze-based interaction needs seamless integration; studies should explore practical implementations.

In conclusion, to foster broader adoption and acceptance of gaze-based interaction, addressing critical gaps, including hardware accessibility, calibration simplification, performance consistency, standardization, privacy concerns, and real-world integration, is paramount. The proposed methodology of ELITA, an inclusive eye-based computer interaction system, stands as a promising solution to bridge these gaps and redefine the landscape of accessible human-computer interaction.

FUTURE SCOPE

We've presented data on physically disabled individuals in India by age group, highlighting the percentage of people in each category. Notably, 7% fall within 5-9 years, and 17% are aged 10-19, facing challenges in acquiring knowledge. HCI offers a solution, allowing them to access knowledge easily through the internet. HCI techniques can also enable physically challenged individuals to operate machines effortlessly with eye and head movements, serving as training tools for various tasks. The figure below illustrates a proposed solution employing Human-Computer Interaction (HCI).

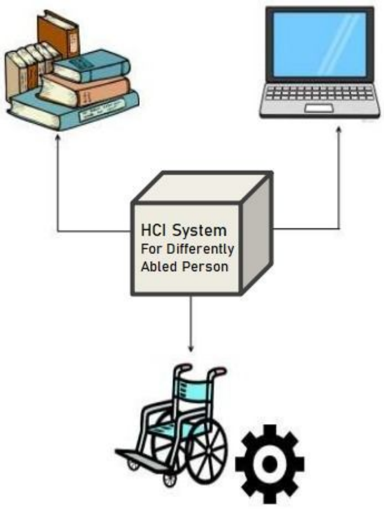

Fig.4 Graph of Rate of differently abled people in India

HCI can allow these physically challenged people to Operate computers & perform every action in such a way that will be different and easy, reading & invoking machines with the help of eye and head pose.

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