



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

RESEARCH ISSUES IN DESIGNING IMPROVED EYE GAZE BASED HCI TECHNIQUES FOR AUGMENTATIVE AND ALTERNATIVE COMMUNICATION

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Abstract: *Augmentative and Alternative communication (AAC) refers to the domain of communicating methods or techniques that provide improved human-human or human-system interaction. AAC techniques enable users with certain communication disabilities to participate in everyday conversations with or without helpers. Eye gaze is a very significant area of human computer interaction (HCI). The gaze estimation and detection is used for understanding, processing and executing different commands from a distinct location. An effective eye gaze detection and estimation can help to develop improved AAC devices for better interactive communication. In this research paper an extensive research study has been carried out to understand the domain of AAC and to explore the significance of eye gaze based methods for designing better AAC systems. The objective of this research study is to identify and utilize eye gaze models for developing better and more effective AAC devices. It has been observed that eye gaze based models are being used in various fields for AAC. Certain limitations and research issues related to the performance and effectiveness of these models have been discussed. This study shall highly be useful for further research in this domain.*

Keywords: *Augmentative and alternative communication (AAC), human-computer-interaction (HCI), eye gaze, interactive communication.*

I. Introduction

Augmentative and Alternative Communication (AAC) is an area of clinical practices that helps to compensate for different impairment and disability pattern. AAC includes devices, systems, or methods that improve the ability of an individual with communication impairment to communicate effectively. AAC devices are primarily electronic devices that are used to augment an individual's natural means of communication [1]. AAC can encourage the subject to be an active participant during communicative interactions [2]. These systems may incorporate all the different devices that are used for enabling effective communication and gestures for day to day life. AAC devices are covered as durable medical equipments (DME) which are routinely purchased for the treatment of severe communication disabilities [3].

These systems are used to express thoughts, needs, wants and ideas of a disabled person. In addition to, using sign language, communication boards, symbols of pictures or objects, such devices use a variety of human computer interaction (HCI) models [4]. HCI refers to different techniques and algorithmic processes of non physical contact with the computing devices. These techniques are used to design, evaluate and implement various interactive computing systems [5]. HCI techniques help in developing and improving the user's interaction with the computer and are effective, efficient, safe, low cost and time saving. HCI based AAC models enable symbol based human to human and human to machine communication in a computer and networking environment [6]. Some of the AAC devices include Eye Link, partner assisted scanning (PAS), and E-Trans [7].

AAC may use different methods of communication for HCI as per the requirement and convenience. In direct selection method the selection is made by pointing to the desired symbol using a finger or an alternative pointer. Eye gaze, head stick and head or eye-controlled mouse are some of the direct selection methods. Indirect selection or scanning method scans the displayed items for selection using switches. Eye gaze involves measuring of individual's eye movements at any given time and the sequence in which the person's eyes are shifting from one location to another. Eye gaze based methods can be used for executing desired instructions by the user to the computing system for investigation and analysis for meaningful interaction. A gaze based dictionary has also been developed for text based processing. Further eye gaze based models are safer to be used by the persons with different degrees of disabilities. Further such models may also be used in case of advanced medical disorders or ailments where the movement of the subject is moderately or severely restricted. Various applications of eye gaze based HCI techniques are gaze based system controls, understanding intention and

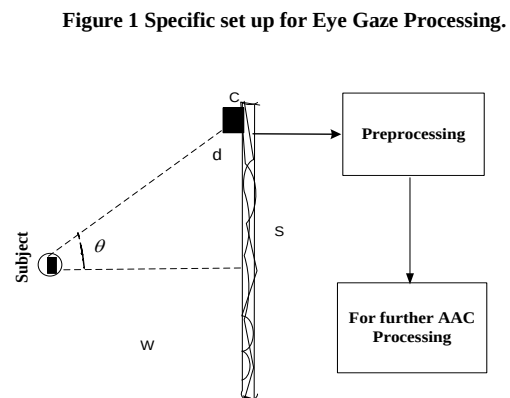
desires of the subject, car driver's behaviour, simulators for surgical and medical, sports, advertising, interactive dictionary, gaze reactive intelligent tutoring system etc .

The devices based on the eye gaze techniques can be explored further for high end applications in the field of AAC. Eye gaze based techniques can help for improving efficiency of AAC devices effectively. The AAC research area would obviously benefit from increased attention and awareness of eye gaze based techniques. AAC can make the system more user friendly, convenient, natural and faster helping in penetration of IT and different sections of society and thereby reducing the digital divide. In this research paper the extent of the applications of eye gaze techniques for designing AAC devices is studied. Issues related to the performance and effectiveness of HCI based AAC models have also been studied. These research issues are discussed in section IV after a detailed literature review. The eye gaze based techniques and their applications in AAC are discussed in the following section.

II. Eye Gaze Techniques and AAC

Eye gaze is being used as hands free pointing tool enabling hands-free operation of the display for the user. This technique is faster, more natural and convenient. It is being used to develop more intuitive and natural human interfaces. Eye tracking is for measuring eye positions and eye movements [8]. The process of eye gaze has been shown in Fig. 1. Here, W is the workspace involving the setup for image capturing and placement of the subject. The subject is placed at a distance d from the screen S . The image is captured by a capturing device C . Captured image is then given as input to the next preprocessing phase. Issues like image formats, compression, denoising, identification and removal of distorted objects, online and offline acquisition or retrieval are resolved at preprocessing stage. The size of the image thus obtained is then normalized. The image signal is sent for further processing like denoising, adjustment of colour tone, region detection and estimation. The results from the outcome phase after processing can be used in variety of HCI and AAC applications.

Different types of features of eye like pupil, glint, purkinje image, iris and cornea etc. may be taken into consideration for accurate estimation and detection of eye gaze. Low cost gaze tracking system or dwell free eye typing interface is being used as a low tech communication. Since this process does not require any external power source, such models are safer and power efficient.



III. Literature Review

There are various industrial, scientific, agricultural and other real time and interactive high end applications of eye gaze techniques for human computer interaction.

Medical and educational fields are significant areas of application of eye gaze based AAC models. In the field of education AAC with eye gaze may further facilitates language development interfaces, provide learners especially children with power and control. The inclusion of AAC in general education classrooms promotes participation of the disabled child in the class and also with other students. These devices will certainly help to develop social and academic leadership skills of these children. The use of AAC aids also gives a chance to update the educators with the new skills of teaching aids of AAC and thus promotes regular education teacher creativity [9].

Individuals with Amyotrophic Lateral Sclerosis (ALS) and Parkinson's diseases may benefit from a variety of AAC systems. However, systems that involve eye movements are highly recommended in these diseases due to severe muscular disability. The resultant gaze is transformed into meaningful communication through eye pointing. Many ALS patients have little or no previous IT experience. For them AAC systems with eye gaze should be designed with multimodal input for better interaction. A. S. Johansen investigates mobile text entry and proposes a solution which is a combination of the use of language modeling and careful interaction design and verification. The paper emphasizes on the relevance of the mobile text entry problem in AAC [10].

A medical condition called rett syndrome is a progressive neuro-developmental disorder caused by X-linked genetic mutations that occurs primarily in girls and females in the ratio 1:10,000. This disease results in loss of purposeful hand movements. Eye gaze based diagnostic techniques can be of great help in such cases. In the children's hospital at Montefiore, New York, the eye-gaze technology is being explored for improving the quality and condition of girls with rett syndrome, including the need to communicate [11], [12]. In the field of behavioral sciences, gaze detection can be used to build real time contact free eye gaze tracking system for detecting the gaze of a driver which will also be useful for the handicapped people. The results have shown that the system quickly recovers from the tracking errors due to sudden head movements or slow blinking in case of drowsiness. It is also helpful in detecting the drowsiness in the patients in certain medical problems [13]. Eye

gaze plays an important role in finding out the gaze analyses of experienced surgeons over novice with the help of VR laparoscopic surgical simulator. M. Wilson et al. recorded different parameters of surgeons and novice and compared them to ascertain gaze analyses of experienced over novice. The findings of the study are useful for the utility of examining strategic gaze behaviour and eye-hand coordination [14]. Eye tracking is used to study oculomotor behavior, visual functions and vision deficiencies. An AAC system AutVisComm, is developed for children with autism that can run on smart phones and tablets. The researchers measured their learning rates and correlated them with their behavior traits like joint attention, symbolic processing and imitation [15].

M. Deblijak et al. studied two cases of children with severe motor disabilities in which they were tested for eye movements and the results have shown significant improvement in interaction and communication for both users by the eye gaze techniques [16]. Y. Wu et al. presented a systematic review in order to explore the effectiveness of AAC intervention on expressive communication for individuals with developmental disabilities. The results generated from the eight different studies indicated that the AAC interventions could smooth the progress of the expressive communication performance. However, this review also raised some essential issues like conducting a high quality intervention and studies [17].

K. K. Shyu, proposes a low-cost field-programmable gate-array (FPGA) based brain computer interface (BCI) multimedia control system, with the help of eye gaze techniques. Experimental results show that the subjects with eye gaze can successfully control the multimedia device through the proposed BCI system with high identification accuracy. This system can also be useful for handicap persons with muscular disabilities [18]. Similar research work is done in the University of Tubingen, Germany to understand the relationship between MRI data [19].

Another use of graphic symbols in teaching learning process with eye gaze techniques can also be another domain of research especially for mentally challenged children. S. D. Mello et al. have developed an intelligent tutoring system (ITS) for detecting student boredom and disconnection by monitoring student's gaze patterns with the help of an eye gaze tracker. The proposed tracker identifies the student's interest or attention in the subject. The proposed system reorients the attentional patterns and attempts to reengage the student with different dialog moves. The gaze reactive ITS can also be used in the classrooms as better and effective teaching aid and can be extended to the areas of information retrieval and education [20], [21].

DASHER is a database of English words in which individual words can be typed and searched by using eye gaze only is developed by D. Ward et al. It can be of great help for the learners who want to learn a new language or enhance their vocabulary power in their own language with eye gaze. This technique is friendly, accurate and faster. It can work in most language and adapts to the user's language [22]. A further alternative to DASHER has been proposed by M. Urbina et al. The proposed method called pEYEWwrite achieves better text entry speeds. An important limitation of the proposed system is that the use of pEYEWwrite combined with bigram entry repeats entry of double errors [23]. Further high speed text entry applications need to be developed for improved augmentative and alternative communication. Communication in the Arabic language with gaze using dwell time has been designed by A. A. Wabil et al. with the development of eye typing interface iWriter which will be helpful in the optimization of the gaze typing interfaces for Arabic script [24].

Other useful applications in AAC using eye gaze techniques include gaming environment, shopping behaviour, gaze based security, eye based user interfaces on mobile phones etc. Real time face detection combined with eye gaze tracking can provide better gaming environment [25].

Eye gaze based password authorization assistance is one another field of applications in AAC. Weaver et al. proposes gaze based password authentication systems for entering passwords by looking at the proper symbols on the computer monitor in the appropriate order. This method is reportedly immune to the practice of shoulder surfing [26]. It has been found that designing a phone that follows gaze gestures specific application mobile phone user interface may be more accurate than blinks. It can be another way of improving augmentative communication. Eye-based user interfaces on mobile phones could provide users with more options for controlling their phones applications [27].

C. Demmans et al. developed four algorithms to provide context-based or just-in-time vocabulary support to users even with the smart phones. These algorithms make this possible to retrieve relevant vocabulary from Internet-based corpora. The approach identifies appropriate context-specific words that will complement general AAC vocabularies [28].

Eye gaze based devices especially in AAC development require certain specific features like ease of use, more interactivity, effectiveness etc. As evident eye gaze based models have various research issues like real time detection, simulation, blinking problem, accuracy of desired region detection etc. Besides these there are also other significant factors like user's convenience, simpler design, high speed gaze based text entry, better response, cost and complexity issues etc. The accuracy of the eye gaze models may also depends on certain significant factors like shape and size of the object, distance from the subject, texture, light conditions, colour orientation, head movement, calibration, environmental set up etc. It becomes very essential to design the AAC based eye gaze models and optimize their performance by taking these parameters into consideration [29]. A detailed discussion of various research issues in the development of eye gaze based models with respect to AAC in different fields is presented in the next section.

IV. Research Issues

As discussed above there are various research issues of the eye gaze based models for designing AAC applications and devices. Since the domain of AAC includes primarily subjects with some mental, muscular, physical and other types of disabilities, the AAC devices require certain constraints and specific features. The devices should have better accuracy and a wider range of parametric acceptability. For instance tolerance to certain natural head movements, orientation, visual angle, tolerance to noises, ability to work in limited lighting conditions whether indoor or outdoor are some of the important research issues for consideration. The devices that are required for AAC should be of low cost, more interactive, easy to use, convenient and requires less maintenance. One of the significant issues in gaze based AAC models is to undo the given command or backtrack to the previous step. However it is very difficult to undo or go back to the previous state using eye gaze techniques. Since eye gaze based models primarily works on identifying eye gaze, there are various factors that need to be considered while designing these models. Significant factors include use of low cost systems, optimal use of existing available resources, maximizing the extent of visual angle, reducing the complexity of the algorithms. Minimizing resource utilization is also an important consideration. Other improvement in eye gaze models can be done by minimal use of infra red light source and good gaze estimation accuracy under varying illumination conditions and natural head movements. The eye movements are difficult to detect when the head is moving because of the unwanted features around the head boundaries, the eyebrows, nose, mouth, and other parts of the face. Further there is a need of a gaze tracking system that will have a distant camera and starts gaze detection as and when required to strongly improve the above mentioned research issues. These issues need further improvement in order to accept the eye gaze technique as a natural computer input device. The estimated gaze should have high level of accuracy. The detected regions should only have the required regions of the eye only. Future directions for AAC methods should be focused on improving device interfaces, reducing the prices, reducing the cognitive and linguistic demands of AAC, and the barriers to effective social interaction.

The accurate detection and estimation of the pupil or cornea of the subject is also one of the important factors for the eye gaze models. This factor further depends on the distance of the subject to the camera, age related intrinsic property, orientation, illumination which affects the accuracy of the eye gaze techniques. Further it has been observed that to enhance and improve the working of the eye gaze techniques, most of the existing devices and techniques should use specific devices and light sources for eye gaze estimation. To increase the reliability of the recorded data, eye tracking technology needs to be improved. The captured data should be robust and accurate so that the reliability of the recorded data can be improved and the point of regard measurement remains accurate without the need for frequent recalibration. The gaze tracking framework should be user independent, non intrusive, automatic initialized and robust to eye glasses.

To increase the effectiveness of eye gaze based models designing specific applications for AAC with the following factors like calibration, sensitivity to lighting condition, wider noise margins, accuracy in eye detection, specific region detection is required. The efficiency and effectiveness of the eye gaze detection depends on these factors and therefore have to be analysed. Careful selection of the parameters, controlling and adjustments of parameters may be done to enhance the output. Further the system should be of low cost and convenient to use.

V. Conclusion

In this research work various applications of designing different eye gaze based devices in the domain of AAC have been explored. AAC requires these devices for enhancing interactivity and communication of the patients. AAC techniques help in enabling users with different communication disabilities to participate in their day to day activities in a more efficient and augmentative way.

An extensive literature survey has been presented to understand the extent of developments and research in this area. The significance of eye gaze based methods for designing better AAC system has also been explored. Since AAC devices are primarily designed for the persons with certain neuro or muscular disorders, therefore it is essential that such devices should be safer, interactive, hassle free, affordable and convenient to use. Further there are issues of interactivity, cost, orientation, visual angle, tolerance to noises, ability to work in limited lighting conditions whether indoor or outdoor, maintenance real time detection, simulation etc in designing such devices. The issue of backtracking is very important in eye gaze based text processing as discussed above. These research issues have been studied in detail so that eye gaze models may be used more effectively for designing AAC devices.

In future, this research may further be explored for the possibility of designing better and effective AAC models.

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