Gaze Controlled Interface For Limited Mobility Environment

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Abstract
This paper investigates design constraints for developing GUI (Graphical User Interfaces) in limited mobility environments. In particular, we have presented a gaze controlled interface for users with severe physical impairment and for pilots in military aviation who are constrained by situational impairment. We have developed and implemented algorithms to investigate visual search pattern and improve pointing and selection tasks in eye gaze controlled GUI. User studies in both environments show that for situational impaired users, there is improved flying performance and significant reduction in pointing and selection times for secondary mission control tasks compared to existing interaction systems.

Author Keywords
Eye Gaze Tracker; Gaze Controlled Interface; Nearest Neighbor; MFD; Cerebral Palsy; Limited Mobility.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

1. Introduction
This study investigates design issues in limited mobility environment due to both situational and physical impairment. In particular, we aim to develop

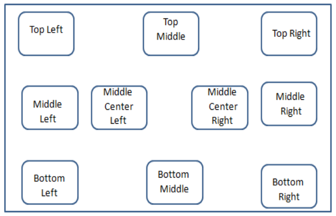

Figure 1: Arrangement of buttons on the screen

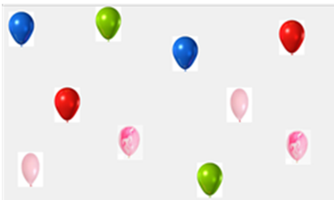

Figure 2: GUI of Balloon application

Figure 3: Adaptive condition GUI of Edutainment Game

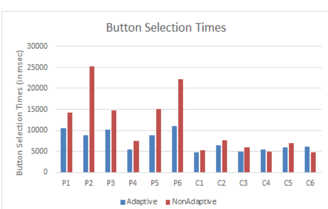

Figure 4: Average selection times for both participants

an algorithm which helps children with spasticity and pilots in a flight system use computers and MFD (Multi-Functional Displays) for their educational purpose and perform secondary tasks respectively with their eye movement. Limited mobility impairment refers to the inability of a person to use one or more of his/her extremities, or lack of strength to walk or lift objects. And physical impairment is a disability that limits a person's physical capacity to move, coordinate actions, or perform physical activities. Children with severe physical impairment are commonly diagnosed as having CP (Cerebral Palsy) showing symptoms of spasticity. Thus, these children do not have control over their body movements and are subject to assistance in almost all everyday activities.

As opposed to limited mobility impairment, situational impairment [1], is the inability to access computers as a result of the situation one is in. Examples include limited space, noise, insufficient lighting, diversions, tasks that need the use of eyes or hands. For instance, in a flight system, use of gaze controlled interface for MFD can be blended as direct controller of pointer movement. This has not yet been tested in military aviation environment. MFDs in flight systems are used for displaying various information ranging from primary flight information to details of airborne objects in a constructive way. Existing military aircrafts have multiple MFDs and physically touch a MFD with gloves, may often turn difficult for small targets present on the display.

Although physical impairment and situational impairment are two seemingly unrelated domains, there exists a common similarity between these users. The degree of disability with pilots is the same as with spastic children due to their physiological changes for a particular situation they are put in. They are unable to use their hands as the pilot is strapped up to his seat in a difficult environment, thus being impaired for that situation. In both users, eye movements may be the only movements that are in their voluntary control. By knowing where the child's eyes are looking, the eye tracking device can control the computer similar to the way a mouse lets you control it with your hand. Similarly, by observing the pilot's eye movement, eye tracker can be programmed in a way that secondary tasks on the MFD can be controlled using pilot's eye. This technique of tracking gaze movement is called eye tracking. Therefore, in our study, we take a novel approach in designing and evaluating inclusive accessible design systems by sculpting the performance of users with wide range of abilities like physical and situational impairment. This has been done in order to improve the performance in activities of above users with ease and at reduced time. We have developed and implemented edutainment software and communication interfaces which are operable with eye movement using gaze controlled user interface algorithm. The purpose of the software or study was not to design a game alone but also to investigate the visual search pattern to improve pointing tasks. Results confirmed that gaze controlled assistive user interfaces can significantly reduce response times and improve user interaction by reducing pointing and selection times.

2. Physical Impairment

Design Constraints: Due to spasticity in children with CP, they could not use any assistive technologies like track ball, push button switch and so on. Therefore, the child's gaze is the one which he/she can voluntarily control. Thus, use of eye gaze tracking to improve literacy of differently abled children is of great interest. The purpose of this study is to explore children having severe disabilities, experience the use of gaze-controlled interface with their eye movements. We conducted user study to investigate response to visual stimuli and visual search patterns of users with cerebral palsy. We used this information to facilitate the development of gaze controlled interactive system for

Figure 5:GUI of Communication Board

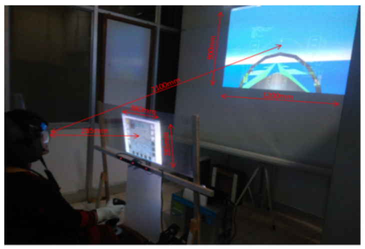
Figure 6: Flight Simulator Set Up

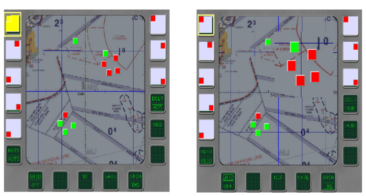
Figure 7: Gaze Controlled MFD

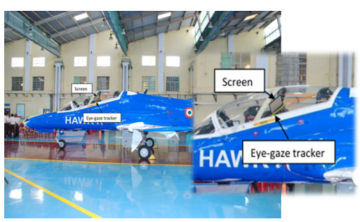

Figure 8: Testing with a Hawk Trainer Aircraft

reduced pointing and selection times. Our end users were teenage students with CP [2] having various level of spasticity. All children were quadriplegic, wheelchair users, cannot speak and with different levels of capabilities of following instruction.

Proposed Approach: As a preliminary case study we developed a balloon activity where the participants were asked to gaze at each of the balloon until it explodes (figure2). Details of this study is available in the paper mentioned in reference [3]. We compared performances of children having CP with their able bodied counterpart and it was found that they take more time to fixate attention. It was also found that their eye-gaze movement doesn't follow left-to-right, top-to-down strategy. Rather, they followed nearest neighborhood strategy. Therefore, we conclude that these children had a visual search pattern of looking at the balloons on screen and it was found that the middle or middle-right positions (figure1) were the buttons with high probability of first pointing and selection [3].

Based on these results, we developed an edutainment game which would help build a child's vocabulary. The basic idea behind the game is to identify the picture displayed in the middle of the screen and select correct buttons with letters corresponding to the word associated with the picture (figure3). We implemented a nearest neighborhood predictor which helped users select a target by gazing near the target. Also, users only need to look at near the target item and upon dwelling for 1 sec, the target is automatically selected. Users can also select a target by clicking on the target button. We conducted the study in a reputed spastic society along with the able bodied users. It was found that that all users with CP required less time (6secs) on average to select buttons in adaptive condition (figure4) when compared to able bodied users.

Along with this edutainment game, we also developed an assistive communication board software (figure5) which can be operated using their eye gaze. This software presents an AAC (Augmentative and Alternative Communication) platform which reduces the need of a third person. Therefore, it aids children to operate the pictorial communication board having text to speech capability, with the use of eye gaze. In particular, the child may gaze at a picture to articulate respective phrase. Buttons are arranged in a random fashion such that, most frequently used buttons appear on the first page for quick access. The rearrangement of buttons is done based on recent timestamp and frequency. We also adopted a nearest neighborhood predictor algorithm.

In light of the design constraints of limited body movement, our study found that they have distinctive visual search pattern than their able bodied counterpart. Appropriately designing a screen layout based on their visual search pattern can improve the efficiency of Human Computer Interaction.

3. Situational Impairment

Design Constraints: In commonly used fighter aircraft cockpit, the pilot is strapped to his seat and has to maneuver in high G environment and also undertake a plethora of secondary mission control tasks with TDS (Target Designation System) along with flying. Like the physical impaired users, there exists similar design constraints like limited body movement. Unlike the previous case, the pilots are required to undertake secondary tasks on the MFD as fast as possible in order to keep the situational awareness about the primary flying task.

Proposed Approach: We developed an eye-gaze tracking software with adaptive MFD [6] having intelligent features (figure 7). We implemented hotspot technique i.e. we put dots on certain screen positions to improve the accuracy of the eye tracker. Details will be found in the paper mentioned in reference [5]. We also used automatic zooming feature [4] for a part of the

Figure 9: Testing with a high end simulator

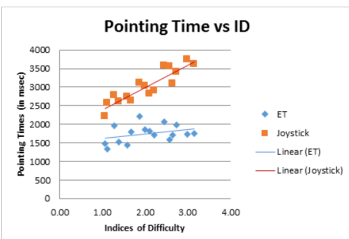

Figure 10: Comparing Pointing and Selection Times w.r.t. ID for gaze controlled system and existing joystick based target designator

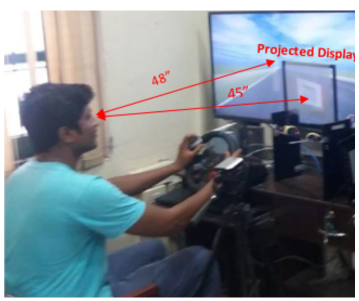

Figure 11. Driving simulator with gaze controlled see through display

display to increase inter-button spacing of densely packed on-screen elements. In order to measure the efficiency and accuracy of our algorithm, we set up a whole flight simulator (figure6) with gaze controlled interface. We also studied gaze controlled interface in a Hawk Trainer Aircraft (figure8) and a high end flight simulator from an institute of flight training.

We have integrated our software with an existing high end simulator at National Aerospace Laboratory, India (figure9) and also collected data from at least one pilot. From our study, we found that, bigger MFD buttons were faster to select using eye gaze when compared to touch screen and smaller buttons were slower to select in eye gaze when compared to touch screen. We also found that, all buttons are easier to select when compared to TDS.

We set up a flight simulator with a GCI (Gaze Controlled Interface) and compared it with the current state-of-the-art. We found that gaze tracking system is promising as it reduces the pointing and selection time for secondary task without affecting the primary flight performance. The average time for selection task is 2.43 secs for Head Down Display and 1.9 secs for Head Up Display. We also plotted selection time with respect to indices of difficulty of target (figure10). The selection times were significantly less for eye gaze controlled interface when compared to joystick. The co relation between indices of difficulty and selection times was 0.34 for gaze controlled interface and 0.91 for TDS (Joystick). The time for context switching from primary task to secondary task is significantly better than existing TDS (2.67 secs) and touch screen (2.8 secs).

In addition to flight simulator, we have also set up a driving simulator with gaze controlled see through display (figure11). The gaze controlled see through display does not require drivers to look down the dashboard or taking their hands off from control, but allow them to operate the dashboard just by looking at it. Initial studies found improvement in driving for ISO 26022 lane changing task with respect to existing touch screen [7].

4. Conclusion

This paper focuses on limited mobility environment from two perspectives. It investigates both physical impairment as well as situational impairment using a single solution of Gaze Controlled Interface. We found that GCI gives promising results in designing and developing intelligent user interface by investigating visual search strategies of users.

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