ATTENTION RESPONSIVE TECHNOLOGY AND ERGONOMICS

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The ART (Attention-Responsive Technology) research project is developing a system to enable mobility-impaired individuals to access technology efficiently. The system monitors both the individual and any ICT devices in his/her environment. It then uses the individual's gaze direction to determine to which ICT device they are potentially attending. This information is relayed to a user-configurable control panel, which then displays only those controls that are appropriate, both to the user and to the particular device in question. The user can then choose to operate the device if s/he wishes. The initial ergonomic challenges in the development of the ART system are described.

Introduction

Increasingly Information and Communication Technologies (ICT) devices are commonplace, both in the workplace and at home. Whilst these devices offer users many advantages they can pose a problem for some disabled people, who wish either some degree of, or total, autonomy in operating and interacting with them. How best then can individuals who have limited mobility operate such devices?

For some disadvantaged individuals head or breath operated switches can be used. However, various disabilities seriously restrict an individual's mobility but can leave saccadic eye movement control intact. Consequently, this raises the possibility of using such eye movements, which can be voluntarily controlled, to operate both communication or control systems. There are numerous techniques to record saccadic eye movements and various commercial eye movement monitoring systems already exist which have been specifically designed to afford physically impaired individuals the ability to interact with a computer or other devices by using their direction of gaze (e.g. the Eyegaze system). Using such a system the user's gaze direction can be used to operate some selection process, such as 'typing' simply by looking at the required keys displayed on an on-screen keyboard, or alternatively the user can select an item which is displayed on-screen in a suitable menu arrangement. More sophisticatedly, Ward and MacKay (2002) describe the Dasher system, based on a language model, which can similarly be operated by an individual's eye movements and where a very reasonable 'typing speed' can be attained.

The various issues concerning the development of technologies and standards for such eye controlled communication systems has led recently to the formulation of the COGAIN Network of Excellence (2004) which will run for the next five years.

The major potential drawback to such eye controlled systems is the 'always-on' direct linking of the user's gaze direction to some presumed visual attentive selection process (c.f. 'what you look at is what you get') and whilst one's direction of gaze is usually associated with the direction of visual attention unfortunately this is not always the case. This is the 'Midas touch' problem (Jacob, 1990) where a system which uses the user's point of gaze to activate controls directly can be prone to false alarms as the point of gaze is drawn to objects which attract the visual system. In other domains this gives rise to the 'look but not see' type of error, for instance in driving or visual inspection scenarios.

Consequently, users generally find that such direct eye movement control systems can be both unreliable and over time somewhat fatiguing to use. A good ergonomic solution to this problem is therefore required.

Attention Responsive Technology

The above issues have therefore led to the development of the ART project.

Saccadic eye movements can be both consciously and subconsciously controlled. Therefore the concept behind the current project is to build upon the natural function of the eyes in selecting environmental objects (either accidentally or deliberately), rather than using the eyes actually as a control mechanism to operate such objects.

Land and Hayhoe (2001) well demonstrate that our point of gaze typically precedes action, namely we look at an object before we implement some action concerning it. Consequently, saccadic eye movements can be used as an indicator of the intention of the individual when interacting with his/her environment (Vertegaal, 2002). Limiting the operational function of the eyes in this way offers a distinct advantage. By not using the eyes primarily to control some device should therefore help to overcome the problem of potential false alarms, although this remains to be proved in subsequent experimental trials.

The ART concept is that a user, with very limited physical mobility is located within an environment that contains numerous ICT devices ('objects'). The user may well be able to move about the environment, for instance in a motorized wheelchair. The ICT objects include both domestic and work-related items such as: TV, room lighting, curtains, telephone, air conditioning, door entry system, computer, etc. Whilst some of these objects will be in a fixed spatial location (e.g. window curtains), some will be capable of being moved and repositioned around the room. Such repositioning may be deliberate and occur rarely (e.g. moving the television to a new position) or accidental (e.g. an able-bodied person picking up the telephone and subsequently putting it down in a different location after use) and occur quite often.

Most, if not all, of these objects will need to be controlled by the user and the objective of the project is to accurately determine the user's selection of particular objects for subsequent control. It will do this by monitoring the user's eye gaze vector and if s/he is detected as gazing directly at some object then s/he will be afforded the opportunity to control that object. Therefore control of an object does not necessarily follow immediately and directly by simply looking at it but looking does afford the opportunity for control.

Initial research work is targeting potential end user groups and determining which objects, and object controls are most relevant to them. Additionally this work will ascertain potential user demands from such a system and the outputs from this research phase will then help shape the subsequent technical solutions formulated.

It is necessary then for the ART system to constantly monitor the user's environment to account for potential object, and user, movements. Consequently the environment will be comprehensively digitally imaged and a 3D computer model generated in which each object, its relative size and spatial location, as well as the user location, is accurately located. Each object will be uniquely identified by the imaging system and various techniques to achieve this are being developed and tested.

In order to monitor the user's eye gaze vector two related systems will initially jointly be used. The user's eye movements will be monitored by a head mounted system (ASL 501) which will yield data concerning the rotation of the eye with respect to the user's head-facing direction. Head-in-space position and also head-facing vector information will be separately monitored by using a suitable 3D tracking system. Combining data from both detection systems will therefore give the user's direction of gaze with respect to their physical position within the environment. The computer model will then determine whether the user's gaze falls upon an ICT object in the environment. Eye gaze information will be updated several times a second.

A key usability issue which ART will have to address is the accuracy of using such an eye gaze selection approach. Using ART a user must gaze directly at an object in order to select it – simplistically this would assume that the user is foveally fixating upon the object. However, every eye movement recording technique has associated with it a known theoretical lower limit on its spatial (i.e. how correctly it precisely can indicate the direction of regard of the centre of one's fovea) as well as temporal accuracy. Additionally, the fovea of the eye is of a known discrete size and so it could be assumed that in looking directly at an ICT object then its image could potentially fall anywhere on the fovea. Furthermore the psychological concept of useful field of vision (UFOV – the region of the visual field from which the user can extract information at any one time) is relevant. The size of the UFOV for any user will vary depending upon how crowded the visual field is, as well as various user parameters, such as age.

Consequently the real world accuracy of such an eye gaze based approach has to be determined for each user and this will impact upon the physical positioning of objects and their relationship to each other in the environment. For instance, the system must account for partial or full object occlusion behind other possible ICT objects, which renders a key technical challenge.

User control

Given an environment crowded with ICT objects then typically a complex menu system of some kind would be needed which would encompass all of the potential objects together with their various levels of control. This could produce either a relatively small display, incorporating a deep menu structure, or else a broad menu which could require a physically large display. Previous work has favoured the use of broad (a menu with fewer levels) rather than a deep menu as being more efficient (Tullis, 1985; Kiger, 1984). With ART an alternative solution to this is possible.

Having selected a potential object then the user requires a suitable means of control. The initial developmental concept is to utilize a GUI on a touch-operated tablet PC with the object selection process triggering the display of only the appropriate controls related to that particular selected object rather than the need for a GUI to present the user with every conceivable ICT device and their associated controls. The user can then decide whether or not to operate the object.

The actual control of an ICT object is not the key research issue in the project and the GUI approach adopted can be replaced with numerous other potential interfaces/controls to suit a particular user. For instance we have previously demonstrated (Wooding *et al.*, 2002) that users with no training can easily employ their eye movements alone to make selections from on-screen alternatives - 'eye buttons' (c.f. Sibert and Jacob, 2000). The control interface will be configurable to the individual user, depending upon their physical and cognitive abilities. Where necessary the panel could be replaced by one of several commercially available interaction devices designed for disadvantaged users.

Current project status

The opinions of potential users have been canvassed and these are being used to direct the project appropriately. A suitable laboratory has been constructed as an environment, which includes a growing range of both domestic and office ICT objects. The digital imaging system and associated computer model are in initial stages of investigation and development as are the GUI control systems. Two eye movement systems, a head mounted and a head free, are under modification for use.

Conclusions

The ART system arises as a solution to the problem of using gaze based control systems and is designed to overcome the false operation of devices which can come about simply by the user unintentionally looking at the object. The system only provides the user with those controls for the potentially attended-to ICT device whilst overcoming any need for a possibly complex menu control system.

The difference between this system and previous eye movement control systems is that the user's point of gaze does not actually control the object, instead it pre-selects objects for subsequent operation.

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