Passive Eye Monitoring: – the Next Step in the Human Computer Interface?

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ABSTRACT

Much energy goes into speculating about the future role of computers in education, finance, manufacturing and home entertainment. But there is a potential area for development that transcends – or perhaps cuts through - all these important fields, namely the way in which we interface (communicate) with our computers.

Innovation in the area of Human Computer Interface (HCI) promises to open up new ways for these ubiquitous machines to assist humans to manage increasingly complex tasks, as well as enable people with a severe physical disability to take a much greater measure of control over their lives.

Exciting new concepts open up the way for the computer to work in partnership with the user, rather than simply as a dumb slave. One of these methods – Passive Eye Monitoring – has the potential to allow a person who is totally paralysed to read a book, call an assistant, invoke a helper-machine, and even steer a vehicle. Given this ability, such a person could become an economically viable independent unit – thereby increasing the person's self-worth and at the same time reducing the financial burden caused by high levels of care-giving.

In this paper I shall explain the principles of passive eye monitoring, and examine the developments needed to make this advanced concept into a reality.

KEYWORDS

Passive Eye Monitoring, Eyetracking, Eye Tracking, Computer Vision, Mind's Eye, Vision Systems, Vision Technology

1. INTRODUCTION

We have been reminded that the theme for this year's conference is innovation:

- Innovation in computing research
- Innovation in computing practice
- Innovation in computing education.

But what exactly do we mean by Innovation - novelty,

modernism, improvement, advancement, originality are all given as definitions - but they're not quite right. A further rummage through the thesaurus came up with a better set - freshness, creativity, imagination, which finally led to 'Mind's eye'. So I feel quite justified in presenting a paper which is purely a 'mind's eye' view of an area of research that is close to my heart.

2. BACKGROUND

My research lies in the area of 'Human Computer Interface' (sometimes Interaction) or HCI, and stems from two observations: the extreme dependence on others by a person with severe physical disability, and the work of a Russian scientist by the name of Leon Theremin. These observations are supplemented by a life-long passion for robotics, electronics and science fiction - fertile ground for innovation.

My observation subject was born quadriplegic, and although unable to move or speak, was able to express himself through his eyes, and quickly learnt to signal 'yes' and 'no' by eye movement. Now nine years old, he has been mainstreamed all his life and attends a normal school with the aid of his care person, his normal support equipment, and an ©EyeGaze computer system.

3. CURRENT TECHNOLOGY

The ©EyeGaze product is an active eye movement tracking system using a video camera mounted on the monitor stand (or attached to the screen of a laptop). The camera is fitted with an infrared light-source and software processes the angle between the light source and the reflected light from one pupil. Changes to this angle are translated into mouse movements by the software, which also translates a presetable 'no-move' or dwell time into a 'click' event.

The device provides a level of freedom for the user that was previously undreamed of. It allows a person to call for help, call for a drink, turn on a light or fan etc. More importantly, it enables communication via an on-screen keyboard and a voice synthesiser. A recent ©EyeGaze development is the control of a second PC - one machine being the input / output device and the other running standard applications, thus enabling the user to access everyday office and educational software.

4. RATIONAL

But wonderful as it is, this device falls far short of perfect. Firstly, because it is based on measuring angles, it is very 'fixed distance - fixed position' dependent - hardly a natural environment for any person. Sitting with one's head in a rigid position is tiring and stressful. Loss of control caused by a sudden uncontrolled movement of the head can take tens of seconds to restore - again, very stressful. The device also requires calibration for each user. The use of a second PC doubles the cost of hardware and reduces the portability of the system - at current prices it would cost about NZ$40,000 to install a system at both school and home.

At the time of installation in 1999 the technology was crude - little better than a prototype. It has since been upgraded to incorporate new developments, but it became increasingly obvious to me that many problems result from the fundamental design concept - i.e. the measuring of precise reflection angles. I was doubtful that this device would fully meet all the identified needs - but how to do it better? ©EyeGaze is based on USAF fighter pilot's 'look aim and fire' research, and they surely have better funding and resources than anyone.

Yes, they may have better funding and resources but they do not have exclusive claim to 'innovative' thinkers, people like Leon Theremin and Isaac Asimov. Asimov and others science fiction writers opened up horizons by simply refusing to think inside the cube - something that all teachers should aspire to, but especially in computing education - to be innovative, you have to sometimes move outside the comfort zone.

Theremin moved outside the comfort zone when he created a 'music machine' that responded to his hands weaving in the air. Built in the mid-twenties, it was cutting edge thermionic tube technology - mounted in a smart wooden box with an aerial and a coil on top. His device was not only cutting edge

technology - it was innovative (and considered by many to be a complete waste of time and money). Because it had neither commercial value - nor any practical value that anyone could see - it was classed as a modernistic novelty. But aren't those words also definitions of innovative? Then maybe to be innovative in computing research we need to introduce the 'novelty' factor, and how about a few dollops of freshness, creativity, imagination and originality while we are at it. Move outside the comfort zone again!

5. SYSTEM REQUIREMENTS ANALYSIS

So let's move outside the comfort zone - which in this case is the 'too hard basket' and briefly analyse the problem:

- the user has good eye control and little else
- the user should not be required to wear a device or be fitted with anything
- the user may move the head without warning
- cost and portability are important factors
- user training should be minimal or not required at all
- recovery should be automatic and quick
- the user should be able to replicate any actions (events) required by 'off-the-shelf' software
- the user should be able to activate the system without calling for assistance (the "Keyboard Error - press F1 for Help" syndrome)
- both software and hardware should be readily upgradeable without undue premium
- the whole system should reside and operate within a single PC.

What a surprise - this set of criteria could be applied to anyone with a special need - for example a surgeon, pathologist, dangerous goods handler, or anyone wearing a mask and gloves. In fact, there are many occupations that require a person to have both hands full whilst attempting to access something on a computer. But why stop there, why not have your TV, video recorder, microwave or phone operated this way, and how about the lift - wouldn't it be nice to step in and glance at your floor number. And how far is it to make the step to controlling a vehicle, or a plane, or a fighter pilot's 'look, aim and fire' system. Oops, that's how we got here.

6. DEVELOPMENT THEORY

But seriously, if we turn the problem round and examine it from the 'Theremin machine' point-of-view, we can get a different picture. His 'machine' is essentially an oscillator with part of its feedback mechanism being the electro-magnetic coupling of the coil to the aerial - radiating through the air surrounding it, rather like a radio transmitter but at a much lower frequency. In fact, it operates at a frequency close to infrared!

The human body is a large object and has a dampening effect on electro-magnetic radiation (we absorb infrared and low frequency radio waves as heat) so placing the hands in the field of radiation will change the frequency of the oscillator, and thence the sound. This is not hazardous, but at valve system power levels can produce a warming effect on the hands and is similar to diathermy.

Any movement of the hands increases the 'instability', and a skilled user can draw an eerie sound from this strange machine - rather like the sound of a musical saw crossed with a violin. I was playing around with a modern version that I built (tack-it-together, 9volt battery, shove it through the CDplayer stuff) when it struck me that a similar principle could be applied to translating hand movement into computer input.

Of course, this process would be largely passive, in that the field is static until a hand is passed through it. We would not need to touch or pause or calibrate within this field, because the system need only respond to change analogous to movement - rather like measuring the ripples caused by moving a hand through water.

At this point, factors start to combine to lead to a new conclusion - If we can use a disturbed radio frequency field to generate input, can we disturb an infrared field with eye reflection and use it the same way? Instead of active eye monitoring, this more passive analog method would fulfil many of the criteria of our analysis. Just as the Theremin machine creates a field of electro-magnetic energy in the low end of the radio spectrum that is stable until altered by hand

movement, why not a device that creates a field of energy in the infrared spectrum that is stable until altered by eye reflection.

This concept forms the core of ©Mind's-Eye "Transparent Interface Technology", which can be defined as: an interface layer superimposed on the active window space that enables the user to control the current application by interacting with the interface layer. A fundamental principle of the design strategy is adherence to current 'best design practices' to maximise the user's available cognitive skills, however limited they may be. These limitations have now been broadened to include users in a hostile or difficult work environment, rather than being limited to persons with disability.

Development criteria now include the following directives:

- Must not create additional user stress
- Must not cause additional cognitive load
- Must not impose physical presence
- Fast initiation
- Quick recovery
- Low sensitivity to environmental conditions
- Portability
- Ease of use
- Fast initial learning phase
- Full integration with existing applications
- Universality rather than Specificity
- Availability at a reasonable cost.

7. HARDWARE AND SOFTWARE REQUIREMENTS

The hardware requirements of this interface layer are currently being investigated - so far a crude prototype has shown promise but needs considerable further development. The actual method of creating the required infrared field and detecting change I have not published - for obvious reasons, but the technology is available. Such a development has a distinct commercial potential and will undoubtedly be the subject of patent.

A preliminary software analysis has been initiated to support the concept - early findings are positive, with no perceived problems above the ordinary software development issues. However time and finance constraints prevent significant progress.

8. CONCLUSION

This is an exciting field (no pun intended) with great potential. Significant benefits will accrue to the developers of a successful, easy to use, cost effective passive eye monitoring system. Much use can be made of such a system commercially – for educational, medical and marketing research. Valuable data on almost any product can be obtained by monitoring and analysing the way in which a potential customer 'sees' the product.