Designing Portable Wireless Eye Movement-Controlled and Microcontroller-based HCI

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Abstract - The development of the computer has made human life more comfortable. But people with severe disabilities such as paralysis of their upper extremities cannot efficiently use computers. Human–Computer Interaction (HCI) involves the study, planning, and design of the interfaces between such users and computers so that they can use computers to make their lives comfortable. In this paper, the design of a portable wireless eye movement-controlled Human-Computer Interface which can be used by the disabled who have paralysis in their upper extremities is suggested.

Keywords – Human Computer Interaction, Wireless eye, VOG, IROG, EOG.

I. INTRODUCTION

The term HCI was popularized by Card, Moran, and Newell in their seminal 1983 book, "The Psychology of Human-Computer Interaction", although the authors first used the term in 1980, and the first known use was in 1975. The term connotes that, unlike other tools with only limited uses, a computer has many affordances for use and this takes place in an open-ended dialog between the user and the computer.

As human–computer interaction studies a human and a machine in conjunction, it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages, and development of environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and user satisfaction are relevant. Engineering and design methods are also considered.

A poorly designed human-machine interfaces may lead to many unexpected problems. A classic example of this is the Three Mile Island accident where investigations concluded that the design of the human–machine interface was partially responsible for the disaster. Therefore, a good design of an HCI must be ensured. Interacting with computers typically engages both hands of the user. This is not a problem for most people, but for people with certain disabilities this scenario is unsustainable. Fortunately, there is considerable research on providing efficient access to computers for disabled users. Several interesting technologies and solutions have emerged such as blink-based text entry and voice-based mouse cursor control. People with severe disabilities who cannot use, or have limited use of, their hands and who cannot speak, might not be able to use a computer. Sometimes the only option is to use the motion of their head to control and use a computer. Many commercial solutions are available. However, these solutions are typically expensive. A solution that costs less would be highly desirable.

II. OBJECTIVE

Depending on users' capabilities, systems such as speech recognition, brain-computer interfaces and infrared head-operated joysticks *etc.* may be employed for Human-Computer Interaction. For users with sufficient control of their eye movements, a gaze-direction detection system can be employed to codify and interpret user messages. Eye-movement detection interfaces may be based on Video Oculography (VOG), Infra Red

Oculography (IROG) and Electro-Oculography (EOG). Furthermore, this type of interface need not be limited to severely disabled persons and could be extended to any individual with sufficient eye-movement control.

EOG is a widely and successfully implemented technique and has proven reliable and easy to use in human–computer interfaces. Gips *et al.* present an electrode-based device designed to enable people with special needs to control a computer with their eyes. Berea described an HCI based on electro-oculography for assisted mobility applications. The problems associated with using EOG are to control graphical interfaces and Berea proposed an electro-oculographic ocular model to resolve these issues. Zheng *et al.* describes an eye movement-controlled HCI designed to enable disabled users with motor paralysis and impaired speech to operate multiple applications. Ohya *et al.* presents development of an input operation for the amyotrophic lateral sclerosis communication tool utilizing EOG. Bulling *et al.* describe eye-movement analysis for activity recognition using electro-oculography. EOG-based systems have also been developed in the robotics field to control mobile robots and guide wheelchairs.

Notable efforts have also been made to reduce and eliminate the problems associated with gaze detection in EOG, such as drift, blink, overshoot, ripple and jitter. Recent new research has focused on using electro-oculograms to create efficient HCIs and developing novel electrode configurations to produce wearable EOG recording systems, such as wearable head phone-type gaze detectors, wearable EOG goggles, or light-weight head caps. The electro-oculography bio potential value varies from 50 to 3,500 μV with a frequency range of about DC-100 Hz. This signal is usually contaminated by other bio potentials, as well as by artefacts produced by other factors such as the positioning of the electrodes, skin-electrode contact, head and facial movements, lighting conditions, blinking, *etc.* To minimize these effects, the system requires high-quality signal acquisition hardware, and suitable analysis algorithms need to be applied to the signal. Signal processing is usually performed on a personal computer. However, a more economical option, and one that also consumes less electricity, is to use a microcontroller-based system. The purpose of this research paper is to develop such a system to capture and analyses EOG signals in order to implement an HCI. Specific hardware has been developed to capture users' bio potentials and a Linux platform has been used to implement the algorithms and graphical user interface.

III. LITERATURE REVIEW

Human–computer Interaction (HCI) involves the study, planning, and design of the interaction between people and computers. It is often regarded as the intersection of Computer Science, Behavioural Science, and several other fields of study. Due to the multidisciplinary nature of HCI, people with different backgrounds contribute to its success.

The historical roots of human-computer interaction can be traced to a human information-processing approach to cognitive psychology. Human information processing (Card, Moran, and Newell 1983; Lindsay and Norman 1977) explicitly took the digital computer as the primary metaphorical resource for thinking about cognition. Research in human-computer interaction (Helenader, Landauer, and Prabhu 1997), as in most of the cognitive sciences, draws on many disciplines in that it involves both people and computer technologies. The goal of creating effective and enjoyable systems for people to use makes HCI a design activity (Winograd 1996). As designed artifacts, interface development involves what Schon (1983) terms *a reflective conversation with materials.* To be effective, though, interfaces must be well suited to and situated in the environments of users.

There are many spheres of research activity in HCI. Three areas are of special interest. The first draws on what we know about human perception and cognition, coupling it with task analysis methods, to develop an engineering discipline for HCI. For examples, see the early work of Card, Moran, and Newell (1983) on the psychology of human-computer interaction, analysis techniques based on models of human performance (John and Kieras 1997), the evolving sub discipline of usability engineering (Nielsen 1993), work on human error (Woods 1988; Reason 1990), and the development of toolkits for interface design (Myers, Hollan, and Cruz 1996).

A second research activity explores interfaces that expand representational possibilities beyond the menus and icons of the desktop metaphor. The new field of information visualization (Hollan, Bederson, and Helfman 1997) provides many examples. The Information Visualizer (Card, Robertson, and Mackinlay 1991), a cognitive coprocessor architecture and collection of 3-D visualization techniques, supports navigation and browsing of large information spaces.

A third active research area is computer-supported cooperative work (CSCW). The roots of CSCW can be traced to Engelbart's NLS system (Engelbart and English 1994). Among other things, it provided the first demonstration of computer-mediated interactions between people at remote sites. CSCW takes seriously what Hutchins (1995) has termed *distributed cognition* to highlight the fact that most thinking tasks involve multiple individuals and shared artifacts.

With HCI, the focus is more on users working specifically with computers, rather than other kinds of machines or designed artefacts. There is also a focus in HCI on how to implement the computer software and hardware mechanisms to support human–computer interaction. Thus, human factors are of greater significance; so HCI could be described in terms of the human factors of computers – although some experts try to differentiate these areas.

Three areas of study have substantial overlap with HCI even as the focus of inquiry shifts. In the study of Personal Information Management (PIM), human interactions with the computer are placed in a larger informational context – people may work with many forms of information, some computer-based, some are not, in order to understand and effect desired changes in their world. In Computer-Supported Cooperative Work (CSCW), emphasis is placed on the use of computing systems in support of the collaborative work of a group of people. The principles of Human Interaction Management (HIM) extend the scope of CSCW to an organizational level and can be implemented without use of computer systems.

There are many literatures and papers related to the study of HCI. Intensive literature survey was conducted and different methods for setting up the interface were observed before developing this interface. During literature survey, it was found that some papers were based on traditional techniques to develop the interface and some others used sensors to design the interface. Gips *et al.* presented an electrode-based device designed to enable people with special needs to control a computer with their eyes. Berea described an HCI based on electro-oculography (EOG) for assisted mobility applications. The paper studies the problems associated with using EOG to control graphical interfaces and proposes an electro-oculographic ocular model to resolve these issues. It also discusses various access options of the graphical interface. Zheng *et al.* describes an eye movement-controlled HCI designed to enable disabled users with motor paralysis and impaired speech to operate multiple applications (such as communication aids and home automation applications). Ohya *et al.* present the development of an amyotrophic lateral sclerosis communication tool utilizing EOG for input operations. Bulling *et al.* describe eye-movement analysis for activity recognition using electro-oculography.

EOG is a widely and successfully implemented technique and has proven reliable and easy to use human–computer interfaces (HCI). Signal processing is usually performed on a personal computer. However, a more economical option, and one that also consumes less electricity, is to use a microcontroller-based system. The purpose of this research paper is to develop a system to capture and analyze EOG signals in order to implement an HCI. The system comprises two electronic modules—the signal Acquisition Module (AM) and the signal Processing Module (PM). Eyewear incorporating a set of appropriately positioned dry electrodes captures the EOG signals, which the AM acquires, digitizes and transmits using the ZigBee protocol.

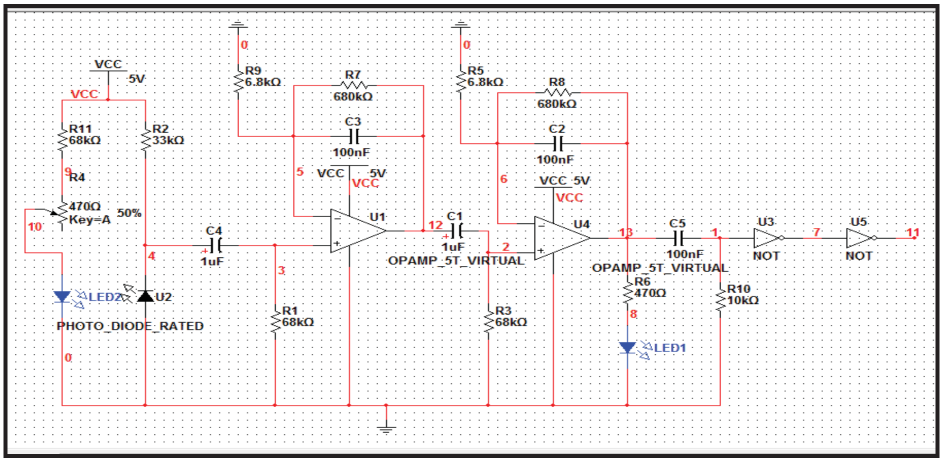
IV. RESEARCH METHODOLOTY AND ANALYSIS

A. The Transmitter-

The system comprises of a Transmitter and a Receiver. The Transmitter includes an Eye Blink Detector, a Sensor Unit, an Accelerometer, The Atmega 328 Microcontroller and the Arduino Tool.

The eye blinking is used for the mouse clicks through the eye blink detector. The eye blink is detected by sensing the movement of the eye lid. It consists of an infrared LED that transmits an IR signal through the eye of the subject, a part of which is reflected. The reflected signal is detected by a photo diode sensor. The magnitude of the output of the photo diode is too small to be detected directly by a microcontroller. Therefore, a two-stage high gain, active low pass filter is designed using two Operational Amplifiers (OpAmps) to filter and amplify the signal to appropriate voltage level so that the pulses can be counted by a microcontroller**.**

The proposed circuit is implemented in Multisim software and the simulation is done to check the results and the physical layout of the circuit can be made on the Vero board. The Circuit Diagram Of Eye Blink Detector is as follows:



The circuit consists of two identical active low pass filters with a cut-off frequency of about 2.34 Hz. The circuit uses ICLM358, a dual OpAmp chip from Microchip. It operates at a single power supply and filters any higher frequency noises present in the signal. The gain of each filter stage is set to 101, giving the total amplification of about 10000. A 1 uF capacitor at the input of each stage is required to block the dc component in the signal. The gain and cut-off frequency of the active low pass filter can be calculated as follows:

$$\text{Gain of each stage} = 1 + \frac{R_f}{R_1} = 1 + \frac{680K}{6.8K} = 101$$

$$\text{Cut-off Frequency} = 1/2\pi R_f C_f = 2.34 \text{ Hz}$$

There is a sensor unit which consists of an infrared light-emitting-diode (IR LED) and a photodiode, placed side by side and any direct crosstalk between the two is avoided. The IR diode transmits an infrared light, and the photodiode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the movement of the eye lid. So, each eye blink slightly alters the amount of reflected infrared light that can be detected by the photodiode. With a proper signal conditioning, this little change in the amplitude of the reflected light can be converted into a pulse. The pulses can be later counted by the microcontroller to detect the eye blink.

An accelerometer is a device that measures the vibration, or acceleration of motion of a structure. Here the ADXL335 3-axis accelerometer is used in this equipment. The ADXL335 accelerometer is used to detect the head movement which is used to move the mouse pointer in the screen. The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. It measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis. This accelerometer is interfaced with the ATMEGA 8 microcontroller to send the movement and direction signals from the transmitter unit. The signals will then be received at the receiver and then decoded which will then be used to move the mouse pointer on the screen.

The Atmel Atmega 328 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the Atmega328 achieves throughputs approaching 1MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed. The Atmega328 microcontroller is then programmed using a development board from AURDINO to interface the accelerometer and the eye blink detector. After successful testing of the setup, the total setup along with the Atmega328 microcontroller is then fabricated into a mother board. This mother board is the heart of the transmitter module.

Arduino is a tool for making computers that can sense and control more of the physical world than desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

As the output of the Accelerometer is analog in nature, Analog to Digital Converter is used to convert the accelerometer's analog output into digital signal.

We know that ARDUINO is compatible with ATMEGA328, so use ATMEGA328 with the help of ARDUINO to run accelerometer. One more advantage of ARDUINO is that it is already preloaded with some examples including the basics of accelerometer. The eye blink detector circuit is interfaced with the Atmega328 micro controller on the development board and the program is written in the Arduino tool for the eye blink input.

B. Algorithm for Programming the Transmitter Module-

1. Assign all the parameters to their respective pins.
2. Baud rate is assigned to 9600.
3. The 3 co-ordinates of accelerometer (X, Y & Z) are taken into observation.
4. The co-ordinates are assigned by moving the accelerometer in required direction, e.g. for some ranges of X, Y & Z in all the direction, up – 1, down – 2, left – 3, right – 4, up-left – 5, up-right – 6, down-left – 7 and down-right – 8 are sent.
5. The input of The Eye Blink Sensor is kept HIGH**.**
6. When there is 1st blinking pulse i.e. when it goes from HIGH to LOW the timer starts.
7. When there is 2nd blinking pulse i.e. when it goes from HIGH to LOW the timer stops.
8. Between 1st and 2nd pulse, if the time period is 2 seconds then for RIGHT CLICK - 9 is sent; if the time period is 3 seconds then for LEFT CLICK - 0 is sent; if the time period is 4 seconds then for MIDDLE CLICK - A is sent.

The mother board is designed after successful testing of the Atmega328 controller in the Arduino development board. The corresponding pins of the Atmega328 IC are then mapped on to a Vero board to create the mother board connections. The interfacing of the eye blink detector and the accelerometer with the Atmega328 microcontroller becomes permanent now.

C. The Receiver-

The receiver unit consists of a RF modem (FSK Transceiver) and a SIU (Serial Interface Unit). The SIU interfaces the signals from the receiver to the computer through a serial port.

The prime mode of communication is RF (Radio Frequency) modem, which is required for the transmission and reception process. The RF Modem (2.4 Ghz, 100 mts range) features high data rate (adjustable baud rate) and longer transmission distance. The communication protocol is self-controlled and completely transparent to user interface. The module is embedded to the design so that wireless communication can be set up easily. The major features of this module are automatic switching between TX and RX mode, FSK technology, half duplex mode, robust to interference, standard UART interface TTL (3-5V) logic level, no tuning required, PLL based self-tuned and error checking (CRC) of data in built.

This module works in half-duplex mode. After each transmission, module will be switched to receiver mode automatically. The LED for TX and RX indicates whether IC is currently receiving or transmitting data. The data sent is checked for CRC error, if any. If chip is transmitting and any data is input to transmit, it will be kept in buffer for next transmission cycle. It has internal 64 bytes of buffer for incoming data.

The baud rate has to be set when unit is OFF, as the switches are read only during power up. Modifying during power up will have no effect on operation of module. Setting Frequency Channel can be used to have multiple sets operating at same time but without interfering with each other. The pair having same channel setting will be able to communicate with each other. Frequency channel has to be set when unit is OFF, as the switches are read only during power up. Modifying during power up will have no effect on operation of module.

This Transceiver module is designed using the Chipcon IC (CC2500). It is a true single-chip transceiver; it is based on 3 wire digital serial interface and an entire Phase- Locked Loop (PLL) for precise local oscillator generation. It can use in UART / NRZ / Manchester encoding / decoding. It is a high performance and low cost module. It gives 100 meters range with provided external antenna. The major features of this IC are low power consumption, Integrated bit synchronizer, Integrated IF and data filters, High sensitivity (type -104dBm), Programmable output power -20dBm~1dBm, Operation temperature range : -40~+85 deg C, Operation voltage: 1.8~3.6 Volts with available frequency at : 2.4~2.483 GHz

Only a few external components are required along with CC2500 to design the module. The bias resistor R171 is used to set an accurate bias current. C122, C132, L121 and L131 form a balun that converts the differential RF signal on CC2500 to a single-ended RF signal. C121 and C131 are needed for DC blocking. Together with appropriate LC network, the balun components also transform the impedance to match a 50 antenna (or cable). The crystal oscillator uses an external crystal with two loading capacitors (C81 and C101). The power supply is properly decoupled close to the supply pins.

RS-232 Serial Port Connector is a serial communications standard that provides asynchronous and synchronous communication capabilities, such as hardware flow control, software flow control, and parity check. It has been widely used for decades. Almost all gears, instruments with digital control interface, and communications devices are equipped with the RS-232 interface. The typical transmission speed of an RS-232 connection is 9600 bps over a maximum distance of 15 meters. RS-232 uses only two voltage states, called MARK and SPACE. MARK is a negative voltage, and SPACE is positive. In a two-state coding scheme, the baud rate is identical to the maximum number of bits of information, including control bits that are transmitted per second. RS-232 serial ports come in two sizes, the D-Type 25-pin connector and the D-Type 9-pin connector. As both of these connectors are male, you require a female connector is required on the device. Data bits are sent with a predefined frequency, the *baud rate*. Both the transmitter and receiver must be programmed to use the same bit frequency. After the first bit is received, the receiver calculates at which moments the other data bits will be received. It will check the line voltage levels at those moments. RS-232 Level Converters are required to transform the RS-232 levels into 0 and 5 Volts.

The output of the serial port is fed to the Microcontroller through a SIU circuit, because the transition output signal of the PC serial port is not compatible with the Microcontroller serial port. The SIU unit will converts the CMOS output signal into serial transition output TTL signal which is compatible with the serial port of the controller.

The receiver module is setup with the RF module is connected to the SIU which consists of a voltage doubler circuit. The serial port is connected from the output of the SIU which can then be connected to the computer. The circuit is powered using a 9V battery which is connected using a voltage regulator. The receiver unit is then connected to the computer through the serial port/ USB port. The receiver was then interfaced with the system file of the mouse in the operating system of the computer using C# programming language. The algorithm for the interfacing of the mouse pointer is as follows:

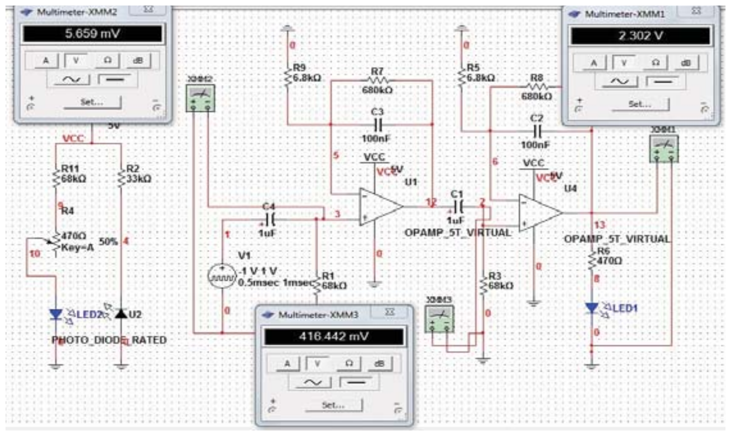
D. Algorithm for Interfacing of the Mouse-

1. Create an object of serial port class.
2. Connect to the provided com port with this object by passing the parameter values.
3. Received data through serial port.
4. Get the current (x, y) coordinator of mouse curser.
5. The mouse cursor moves to the direction by received data from serial port by increase or decrease the value of x or y, e.g. when it receives **1** then it will move up-word having the coordinate x, y-1, when it receives **2** then it will move down-word having the coordinate x, y+1, when it receives **3** then it will move left having the coordinate x-1, y, when it receives **4** then it will move right having the coordinate x+1, y, when it receives **5** then it will move up left having the coordinate x-1, y-1, when it receives **6** then it will move up right having the coordinate x+1, y-1, when it receives **7** then it will move down left having the coordinate x-1, y+1, when it receives **8** then it will move down right having the coordinate x+1, y+1.
6. Now For Clicking purpose import SYSTEM32.DLL into the program.
7. When it gets particular value for click, then click and open the selected file or folder- e.g. when it receives **0** the left mouse button comes into action; when it receives **9** the Right mouse button comes into action; when it receives **'A'** the middle mouse button comes into action.

Finally the movement of the mouse pointer was obtained through the human computer interface which can be observed on the computer screen. The head movements control the directional movement of the mouse while the eye blink control the left and right clicks and the scrolling functions.

V. FINDINGS

The simulation of the eye blink detector in Multisim yielded appropriate results. The observations are shown below.



The physical layout is designed on the Vero board and results are obtained nearly same as the simulated results. The noise factor was a major reason due to the errors obtained. The accelerometer is tested using Atmega328 controller and interfaced with a developer board and the results are studied. The coordinates are assigned and the directions are also setup accordingly. Finally the head-eye controlled mouse is designed and tested successfully. The head movements controlled the directional movement of the mouse on the screen. The eye blink controls the left, right and scroll functions.

VI. CONCLUSION

The HCI is an evolving area of research interest nowadays. This paper aims at helping out the disabled to operate computers. These systems can also be used in various other applications like home automation and robotics. A head mouse is proposed whose operation is based on the user's head movements; motion sensors are used for measuring head movements and IR sensors are used for detecting mouse events. The eye and head controlled devices can become more useful for human–machine interfaces. This paper provides a greater scope for improvement in the near future.

REFRENCES

[1] Abenstein J. and Tompking W., "A New Data-Reduction Algorithm for Real Time ECG Analysis," IEEE Transactions Biomedical Engineering, vol. 29, no. 1, pp. 43-47

[2] Ayang-ang C. and Sison L., "Electrocardiograph Pre-Filtering, QRS Detection, and Palm Display Programming for Biomedical Applications," in Proceedings of the ECE Conference, University of St.Tomas, Manila, 2001

[3] Yu-Luen Chen, "Application of tilt sensors in human-computer mouse interface for people with disabilities", IEEE Trans. on Neural Systems and Rehabilitation Engineering, Vol. 9, pp. 289-294, 2001.

[4] R. Barea, L. Boquete, M. Mazo, and E. Lopez, "System for assisted mobility using eyemovements based on electrooculography", IEEE Trans. On Neural Systems and Rehabilitation Engineering, Vol.10, pp. 209-218, 2002.

[5] Ohno T., Mukawa N., and Kawato S., "Just blink your eyes: A head-free gaze tracking system ", Extended abstract of the ACM Conference on Human Factors in Computing Systems, CHI2003, Apr 2003, pp.950-951.

[6] LoPresti E.F., Brienza D.M., Angelo J., and Gilbertson, "Neck Range of Motion and Use of Computer Head Control", Journal of Rehabilitation Research and Development, Vol 40, N0. 3, May/June 2003, pp. 199-212.

[7] BOLT, R. A. Gaze-orchestrated dynamic windows. Computer Graph, 15, 3 (Aug. 1981),109-119.

[8] CARD, S., ENGLISH, W,, AND BURR, B. Evaluation of mouce, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT. Ergonomics 21, 8 (1978),601-613.

[9] JACOB, R. J. K. A specification language for direct manipulation user interfaces. ACM Trans. Graph. 5, 4 (1986), 283-317. Special Issue on User Interface Software.

[10] JUST, M. A., AND CARPENTER, P. A. A theory of reading From eye fixations to comprehension Psychological Rev. 87, 4 (Jul. 1980), 329-354

[11] LEVINE, J. L. An eye-controlled computer. IBM Thomas J, Watson Research Center, Res.Rep. RC- 8857, Yorktown Heights, N. Y., 1981.

[12] MERCHANT, J., MORRISSETTE, R,, AND PORTERFIELD, J. L. Remote measurement of eye direction allowing subject motion over one cubic foot of space. IEEE Trans. Biomed. Eng.BME-21, 4(Jul. 1974), 309-317.

[13] MYERS, B. A. User-interface tools: Introduction and survey. IEEE Softw. 6, 1 (Jan. 1989),15-23.

[14] SCHMANDT, C, ACKERMAN, M. S., AND HINDUS, D. Augmenting a window system with speech input. IEEE Comput. 23, 8 (Aug. 1990), 50-56.

[15] WARE, C., AND MIKAELIAN, H. T, An evaluation of an eye tracker as a device for computer input. In Proceedings of the ACM CHI + GI'87 Human Factors in Computing Systems Conference (Toronto, Canada, Apr. 5-9, 1987), pp. 183-188.

[16] YOUNG, L. R., AND SHEENA, D. Survey of eye movement recording methods. Behau. Res.Meth. Instrument. 7, 5 (1975), 397-429. ACM.