Arts and disability interfaces

new technology, disabled artists and audiences
part 2 of 4: technology report

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Abstract

This paper is the second part of a study commissioned by the Arts Council (commencing April 2002) to scope and define a long-term project (to follow this study, possibly commencing late 2002) that will research new and emerging technology of existing and potential use to disabled artists, arts practitioners and audiences. It is a comprehensive survey of existing and new technologies of current or potential use for disabled artists and audiences. A factual list is given, with examples both of the raw technologies and of specific applications, including those made by artists, both disabled and non-disabled. Most references are in the form of links to online sources (live when checked from August to October 2002). Some of the technology is specifically developed as assistive, but much is general. The separate document 'distech-images.jpg' contains the images referenced throughout this report.

Technical definitions and considerations

- A definition of a 'medium' of communication is the disturbance of an environment in such a way that the intended recipient can detect the disturbance. With this in mind, it is easy to see that the variety of potential media (and multimedia) is enormous. For reasons of brevity, the emphasis of this survey has been upon sensors and displays which may be directly influenced and used by humans, rather than sensors for other phenomena (for example, environmental or industrial).

- Most computers spend more processing time interacting with humans than anything else. Of this time, the vast majority is spent on creating output rather than interpreting input. The balance is beginning to change as the need for high-bandwidth input (gesture, speech, eye-movement, etc.) is being recognised.
- Most hardware technologies rely on processing software to produce meaningful interaction. Many of the raw electrical signals are filtered to reduce noise, and processed according to some form of signal analysis to produce an inference of the user's action. Much of the scope for arranging new functionality has and will continue to come from modification or reconstruction of the controlling software.
- In a real-time context, the latency between input and output is important. Users expect a result typically within 0.5 seconds, and prefer instantaneous feedback. Where an input device is directly coupled to an output device, such as on a helmet-mounted display, the latency must be at most 50ms to prevent disorientation.

References and images in this document

For convenience, specific links are added at the end of each featured item or topic, but the following have informed the general content of this document. If specific web page references to material is omitted, the source is given instead. Disabled artists are not always declared as such, depending partly on how they present themselves.

Intersections of Art and Technology
This website contains an attempt to compile an exhaustive list of art-technology links by Stephen Wilson of the conceptual/information arts course at San Francisco State University
http://userwww.sfsu.edu/~infoarts/
the main artists links page is at:
http://userwww.sfsu.edu/~infoarts/links/wilson.artlinks2.html

Nooface: in search of the post-PC interface
(requires free login)
http://nooface.net/

IBM Accessibility Guidelines
http://www-3.ibm.com/able/guidelines.html

Access Denied
(Links for Arts and Disability, compiled June 2000 for the 'Access Denied!' conference, not updated)
http://www.getwired.org.uk/links2.htm

Artists pages, Creativity and Cognition Research Studios (CCRS), Loughborough University Human-Computer Interaction dept., Computer Science
http://creative.lboro.ac.uk/ccrs/gallery/ccrsartists.htm

To keep the size of this document manageable, images referenced throughout the text are included in a separate file 'distech-images.doc', in alphabetical order.

Generic computer technology: current

As the primary input devices in current use, the mouse and keyboard deserve some attention, as do developments and variations based on their technology.

The mouse

The functionality of the mouse can be extended with the addition of more buttons for issuing commands, and scroll-wheels to scroll pages or to zoom in or out. (Such extra functionality may be useful for partially-sighted users, who do not wish to have to visually search for controls.)

Basic mice make use of a rubber ball in contact with rotation sensors to detect the direction of movement. Command actuation is commonly provided with one (Apple Macintosh), two (Windows PC) or three (UNIX Workstations) buttons. So-called 'optical mice' are now available, which use a small CCD (Charge-Coupled Device) to take hundreds of images per second of the surface upon which the mouse rests, comparing them to infer the direction of movement. Such optical sensors can be used on most surfaces (for example, the lap), and require no cleaning. However, they currently lose accuracy when tracking extremely rapid movement.

Howstuffworks 'How do optical mice work?'
http://www.howstuffworks.com/question631.htm

Microsoft pointing devices
http://www.microsoft.com/hardware/mouse/

assistive mouse technology - 'there's a mouse out there for everyone'
http://www.csun.edu/cod/conf2001/proceedings/0014fuhrer.html
http://www.kornreich.org/at_info/mousepres.htm

Some access solutions to mouse problems
http://www.inclusive.co.uk/infosite/mouse.shtml

GyroMouse

[image: gyromouse.jpg]
GyroMouse

This wireless mouse can be used on or off the desktop, using a gyroscopic motion sensor. It broadcasts the motion change via a radio frequency field (RF), avoiding the need to be within sight of the receiver.

GyroMouse
http://www.gyration.com/gyromouse.htm

Trackpads

Track pads generally perform the same function as mice (namely, to provide a means for the user to input direction). They are operated by the user moving a finger about a flat surface, and either tapping or pressing a separate button to issue a command. On most track pads, different areas of the pad can be assigned to different functions (for example, scrolling). On some track pads, an indication of finger pressure can be inferred, allowing further control by using only a single finger.

Interlink Electronics frame on VersaPad, manufacturer of trackpads:
http://www.interlinkelec.com/products/oem/versapadoem.htm

Scroll-dial

As a further example of single-finger control a scroll-dial is a device (notably implemented on a variety of Sony devices) for indicating movement along one dimension (usually scrolling, but also navigating a menu), by rotating it with the thumb or fingers. Pushing the dial inwards actuates the current selection. More recent implementations have added 'upward' and 'backward' switches, actuated by pushing the scroll-dial perpendicular to the direction of rotation.

Software using the [Clie] Jogdial
http://euroclie.free.fr/Uk/soft_jd.html

Graphics tablets and whiteboards

Used most often by designers, graphics tablets are flat surfaces, of size A6 to A2 or larger. This surface is usually linearly mapped to the screen (the top-right corner of the tablet always corresponds to the top-right corner of the screen – compare this with mice or track pads, where the cursor moves relative to the input direction). The user uses a (sometimes wired, but usually wireless) pen or a mouse-like 'puck' to move about the surface, pressing a button or 'tapping' to issue a command.

Graphics tablets are generally accurate and precise, and can usually detect the level of pressure that the user is applying, and in some cases, which way up the pen is and angle of tilt.

An extension to this idea has come with the interactive whiteboard, where drawings on an actual whiteboard can be detected and transferred to a computer. The whiteboard has the capability of detecting which colour pen is used, and whether the eraser is used. New pages can be added, or the image can be layered or overlaid in successive input sessions. The image on the board is reproduced on the computer screen, or on multiple screens, and can be saved to play back later, with variable playback options.

Before You Buy a Graphics Tablet
http://graphicssoft.about.com/library/weekly/aa001213a.htm

SMART Board Interactive Whiteboard
http://www.smarttech.com/products/smartboard/index.asp

Minio Interactive Whiteboards and Flipcharts
http://www.mimio.com/meet/xi/

Touch panels

[image: touchpad-1.jpg]
[image: touchpad-2.jpg]

Above are examples of the capabilities of touch-pad technology today, the FingerWorks touch-stream. This pad has the capability to determine the position of all 10 fingers, and the same surface can be used for typing, cursor movement, and gesture recognition. For example, gradually spreading all 5 fingers out zooms in.

Touch panels are used in a variety of situations. They generally consist of a flat surface with a low-to-high-resolution level of touch-sensitivity, requiring little pressure to actuate. In contrast with track pads, they are not usually used to move a pointer, but more often to select commands. In devices such as PDAs, high-resolution touch panels are used for handwriting and 'drawn gesture' recognition.

From a user's perspective, there are two primary types of touch panel – those that are sensitive to any pressure (produced by finger or stylus, sometimes from behind glass), and those that are sensitive only to fingers or metal objects, because of electrical conductivity.

A straightforward example of a touch panel is where one is positioned underneath a printed sheet (which may usually be replaced according to the application). The sheet contains areas for different commands, and is most useful where a large command area is required.

Perhaps the most widely-known application of touch panels is as a transparent overlay to screens, both CRT and LCD (transparent touch panels that are not attached to a screen are also available). Such displays are commonly found in PDAs and public-access computer displays.

A commercially-available combination of the graphics tablet and touch panel - the Wacom Cintiq - allows direct on-screen drawing (or whatever, depending on software used). Similar but more limited commercial adaptations from Displaymate exist for large front and rear projected images and plasma screens, allowing touch control of computer controls and dry marker overlays directly on screen. These are both commercially available from large computer distributors such as Computer Warehouse (http://www.cwonline.co.uk).

Touch Screens
http://www.abilityhub.com/mouse/touchscreen.htm

FingerWorks
http://www.fingerworks.com/

Light pens
Light pens are (wired) pens which are used to 'draw' on the screen. They feature greater precision than finger-operated touch screens, and do not physically mark or dirty the screen.

Light Pens from Inkwell Systems
http://www.inkwellsystems.com/products.htm

Joysticks
[image: joystick.jpg]
Adaptive joystick

Examples of joysticks can be found in gaming applications, industrial control devices and for disability-specific controls. Like track balls, joysticks have a static base, and are available in a variety of sizes, from thumb- or finger- operated to large joysticks specifically aimed at disabled users. Commercial joysticks are designed to be held in the hand, and usually have stick-mounted buttons accessible to the fingers and thumb, whilst joysticks for disables users are usually straight and have separate buttons.

Joysticks are generally available in two main types - those that automatically return to the centre (which is likely to be more useful for users with motor disabilities), and those that do not. Additionally, joysticks may either move in four discrete directions (which may often be combined to produce eight), each of which may be either on or off. More precise joysticks are available that can detect the amount by which a joystick has been moved, in a continuous range of angles.

SAM - Joystick (switch-adapted mouse - assistive joystick)
http://www.rjcooper.com/sam-joystick/index.html

Penny and Giles (assistive joystick)
http://www.penny-gilescp.co.uk/products/product.asp?ProductID=29

Game pads
Game pads arose as a replacement for joysticks where a flat surface may not be available - they consist of a device usually held in both hands, with one thumb used mainly for directional control and the other for command buttons. More advanced game pads have arisen recently, with multiple directional controllers, and buttons accessible to other fingers. They can be made to vibrate (like mobile phones) in synchronisation with events on screen, using very elementary physical technology.

Game Pad directory at JoystickReview.com
http://www.joystickreview.com/gamepad/

Smart fabric keyboard
The first product to use a smart fabric is the 5mm thick Logitech KeyCase, a soft keyboard that doubles as a fabric case for handheld PDAs. It is made of a material called ElekTex, a 'sensing fabric' that converts position and pressure anywhere on its surface into electronic data. The fabric has been developed by international design consultancy IDEO[2].

KeyCase product
www.logitech.com

Smart fabric
www.eleksen.com

Remote wireless keyboard/mouse and pointer
Communicates via a single-frequency base station using a USB port over a10 metre range, plugs straight in to existing computers (no drivers required). The keyboard contains two buttons and a rubber nipple type mouse replacement. An extra remote pointer (like a TV remote) has the same mouse device, with programmable function keys. Enables remote control of (say) a projected image.

Remote wireless keyboard/mouse and pointer
www.interlinkelectronics.com

LED element displays
[image: led-display.jpg]
A large LED display

Small LED displays are commonly seen as the scrolling display at hardware shops or inside train carriages, but large versions are used at concerts and sports events. Arrays of LEDs are an effective way to present bright, high contrast (but low-resolution) displays, and are not limited to rectangular arrays.

A tale of managing LED displays
http://www.possibility.com/Cpp/Led.html

Laser displays

[image: laser-display.jpg]
A laser display

Laser displays work by reflecting one or more beams off two or more rapidly-moving mirrors (one each for x/y). If this is done rapidly enough, images and animations can be built up. The current state of the art is a full-colour, high complexity, high-power laser display. Certain laser projectors are able to transmit two oppositely-polarised images, which, when viewed through corresponding polarised glasses can produce a 3D image.

International Laser Display Association
http://www.ilda.wa.org/

Microphones/audio

Microphones are available for an enormous variety of applications, from extremely small and cheap piezoelectric microphones which can be placed on or in most places (a musical cactus was a striking example), to high-quality vocal microphones used in commercial recording studios. Microphones (either the built-in version on some computers or - better - external models) are also used for voice recognition for both text input and vocal control of the computer. Speech recognition is now available on most platforms. It was a built-in option with the Apple Macintosh system for some time, and voice control of basic (and customisable) functions of the Unix-based Macintosh System OSX is now a standard feature. (Also see 'Speech Recognition' below)

Piezoelectric Microphones (product code QY13P)
http://www.maplin.co.uk

Crown microphone information and 'how to'
http://www.crownaudio.com/mic_htm/mic_pubs.htm

Sonic art examples

Perhaps surprisingly, it seems that much interactive art (especially with novel interfaces) outputs sound rather than graphics. This could perhaps relate to most people's experience with musical instruments making such interactions easier to comprehend, and perhaps to some artists' distaste for the digital image.

A popular software tool for use by artists for sonic manipulation is MAX/MSP, which is a simple graphical programming language for use with audio (and many other types of signal).

Max/MSP visual sound programming software - favourite of sound artists
http://www.cycling74.com/products/maxmsp.html

Gregory Shakar: 'sensory whiskers'
[image: copper-urchin.jpg]
Copper Urchin, interactive sonic artwork by Gregory Shakar

Copper Urchin is one of a set of interactive sonic artworks by Gregory Shakar that is played by stroking its robust set of 'sensory whiskers'. Here the participant is able to experience the sensation of creating musical sound while their hands are enveloped in a responsive and malleable medium. The whiskers are metal wires that when deflected cause a musical note to play. An amber light at the base of each sensor illuminates to indicate that it has been deflected to a sufficient degree and remains lit for the duration of the participant's gesture.

Gregory Shakar: 'Copper urchin'
http://www.moodvector.com/

Laetitia Sonami: 'lady's glove'
Laetitia Sonami is a composer, performer and sound installation artist who designs and builds her own instruments. Her *lady's glove* allows her to control sounds, mechanical devices, and lights in real-time.

Laetitia Sonami: 'lady's glove'
http://www.sonami.net/lady_glove2.htm
http://www.sonami.net/LS-reviews/rev_EM6_98.htm

Generic computer technology: emerging

3D Printing
3D Printing, or stereolithography, is a process of creating solid 3D objects from CAD data in a matter of hours. It works by using a laser to harden a liquid in a tank at certain points, building up the model layer by layer (also see Karen Welsh, Art & Technology Partnerships, under 'Haptic (touch) interfaces' below).

How Stereolithography (3-D Layering) Works
http://www.howstuffworks.com/stereolith.htm

Virtual and augmented reality
[image: vr-headset.jpg]
A virtual reality headset

These displays move as the user moves their head, and may be transparent (images are overlaid on the real world – commonly used in so-called Augmented Reality) or opaque (the user is 'immersed' in the display - used in much Virtual Reality, and recently in a commercially available 'mobile home cinema' system, involving a headset that gives the appearance of watching a screen some distance away). In Virtual Reality (VR), if the display needs to change as the user moves, a position/orientation sensor is attached. Most HMDs consist of one screen per eye, and can therefore display stereoscopic images. Problems have been found with disorientation, physical balance and nausea with 'opaque' VR headsets, a factor that has led to the evolution of 'Augmented Reality' (AR), and the following application, developed by Gethin Roberts Institute of Engineering Surveys at Nottingham University, is a good example of how AR is being applied to real-world scenarios.

> 'Engineers at Nottingham University are developing an augmented reality system comprising a [transparent] VR headset and a backpack containing a Global Positioning System (GPS - see 'Active position/orientation sensors') receiver, a 3D imaging computer and a battery. The computer uses GPS to work out where the user is to the nearest 10 metres, and fine-tunes its position by working out its distance from a radio base station. It then superimposes 3D video images of buried pipes and cables onto the scene the viewer is seeing.[3]

Projected displays (including projected VR)

[images vr-1.jpg]
A projected VR display

[images vr-2.jpg]
The 'vision dome' - a self-contained immersive VR environment at Loughborough University (artists cutaway impression)

[images vr-3.jpg]
A projected VR display from Fakespace Systems

Computer-generated images can be rear- or front-projected by a data projector, which converts the screen image into a projectable one. These devices commonly feature either three separate CRT guns which converge on the screen (often used for video), or a single light source shining through an LCD panel. As well as the commonplace flat-screen projection, it is possible to use wide-angle or multiple projectors to project onto curved screens (panoramic and spherical) or multiple flat screens (such as the CAVE system - see 'Accessible virtual reality room'), to give an immersive feel to the image.

Research into the so-called 'Everywhere Display' is being carried out by IBM, and involves the combination of a projector and rotating mirrors, enabling an image to be projected on any surface in a room. This can be combined with a moveable video camera, to detect hand or body movement over the projected area, enabling interaction with the projected display.

Advanced VR Research Centre, Loughborough University
http://www.avrrc.lboro.ac.uk/

FakeSpace Systems
http://www.fakespacesystems.com/

The Everywhere Display
http://www.research.ibm.com/people/p/pinhanez/cp_research_ed.htm

Mobile Devices

Artists are beginning to exploit the possibilities offered by mobile devices as a new means for communicating with audiences. Programs can be created to generate, send and receive text messages; custom applications for PDAs can be used to engage the user in a personal context. One example is *Hubbub*, a research prototype that allows 'instant message' type connection to a group of people to be continuous from desktop PC to handheld PDA, so you can carry your 'buddies' around on the move. A person's presence and indications (for instance) of their readiness to communicate are indicated by short sounds that convey information without the need to view the screen.

Hubbub home page
http://www.hubbubme.com
Hubbub academic paper: 'Hubbub: A sound-enhanced mobile instant messenger that supports awareness and opportunistic interactions'
http://www.izix.com/pro/lightweight/hubbub.php

Palmtop art: Sarah Minney, 'Unity, the Handheld Best Friend'
http://www.sarahminney.com/

Text messaging in art
http://www.guardian.co.uk/Print/0,3858,4171904,00.html

Active position/orientation sensors

[image: position-track-1.jpg]
3D controller joystick of the type originally used in flight simulators

Commonly found in Virtual Reality applications, these sensors operate using a combination of accelerometers, gyroscopic sensors, and electromagnetic field disruption to produce an indication of the position and orientation of the sensor. In virtual reality, the two main applications are to detect the locations of head-mounted displays and input devices such as data gloves and virtual reality (VR) joysticks. The biggest limitation of current technologies is drift, where the accuracy of the reported position and orientation changes over the time since calibration.

[image: position-track-2.jpg]
Mapping movement using Global Positioning

Position and orientation sensors are available in both wired and wireless forms. Perhaps the most widely-used type of position sensor is the Global Positioning System (GPS), which is able to tell its position anywhere in the world down to around 1m, or with additional local transmitters, down to sub-centimetre accuracy.

Position Tracking: Where Are We, Where Are We Going, and What Are We Going to Do When We Get There? - presentation explaining evaluation criteria (Microsoft PowerPoint required)
http://www.cc.gatech.edu/grads/w/Chad.Wingrave/papers/vepres_trackers.ppt

Inition - Motion Capture and Tracking (product page from VR-centric company)
http://www.inition.co.uk/inition/products.htm#MoCap

GPS Drawing (large-scale drawing from GPS logs)
http://www.gpsdrawing.com/

Sonic flashlight

[image: sonic-flashlight.jpg]
Ultrasound and actual images merged

The Sonic Flashlight merges images created by ultrasound with the actual view of the subject.
http://www.stetten.com/george/rttr/

New forms of visual output

Related to the standard monitors and LCD flat-panels supplied with computers, variations and adaptations of these two primary technologies form the basis of some emerging ideas on types of visual display. Three examples are given in the links below.

Experiments on the Future of Reading
http://www2.parc.com/red/projects/xfr/xfr_guide.html

Stereoscopic Images from a standard display
http://www.gregturner.co.uk/essays/stereoscopic/stereoscopic.htm

[image: eye-trek.jpg]
The eye-trek system

The commercially-available eye-trek system offers the experience of a large projected image from a choice of multiple input sources, using a portable device driving wearable glasses. It claims to work outdoors as well as inside.
www.eye-trek.com

Generic computer technology: experimental

Nanotechnology

[image: ibm.jpg]
The Letters 'IBM' Written in Atoms: Don Eigler, 'The Beginning', xenon on nickel produced with a scanning tunneling microscope.

[image: quantum-corral.jpg]
'Quantum Corral'**,** iron on copper.
'The discovery of the STM's ability to image variations in the density distribution of surface state electrons created in the artists a compulsion to have complete control of not only the atomic landscape, but the electronic landscape also. Here they have positioned 48 iron atoms into a circular ring in order to "corral" some surface state electrons and force them into "quantum" states of the circular structure. The ripples in the ring of atoms are the density distribution of a particular set of quantum states of the corral. The artists were delighted to discover that they could predict what goes on in the corral by solving the classic eigenvalue problem in quantum mechanics - a particle in a hard-wall box.'

Eric Drexler[4] introduced the term nanotechnology In the mid 1980s to describe atomically precise molecular manufacturing systems and their products. Atomically precise manipulation is now commonplace, and the next goal is to build 'assemblers', tiny machines that can automate this process at a molecular level. The applications of nanotechnology are potentially vast, and have considerable ethical implications. The most famous example of 'art' using nanotechnology is the famous 'IBM' logo made from atoms of iron on copper by Don Eigler, a research fellow at IBM's Almaden Research Center. The caption to the image (above) reads:

> 'Artists have almost always needed the support of patrons (scientists too!). Here, the artist, shortly after discovering how to move atoms with the STM, found a way to give something back to the corporation which gave him a job when he needed one and provided him with the tools he needed in order to be successful.'

The following article (condensed but verbatim) is one technologist's vision of the future of nanotechnology:

> '…speech-recognition pioneer Ray Kurzweil said that by 2030 nanosensors could be injected into the human bloodstream, implanted microchips could amplify or supplant some brain functions, and individuals could share memories and inner experiences by "beaming" them electronically to others.
>
> Even now, manufacturers and research groups are experimenting with wearable computers utilizing magnetic and RF sensors embedded in clothing. Just as MIT's wearable computers

> enable business users to exchange business cards simply by shaking hands, Kurzweil believes it will be possible to "beam" someone your experience, tapping all five senses.
>
> With so much intelligence embodied in sensors and microchips, Kurzweil speculated that between 2030 and 2040 non-biological intelligence would become dominant. But his conjecture rejected the common image of the science-fiction cyborg: Instead of mechanically bonding with micromachines or "nano-bots," might it be possible to swallow them like pills?, he asked. Or to inject them directly into the bloodstream? Why not explore how such human-computer pairings could increase life expectancy?
>
> Cochlea implants are already rebuilding the hearing of previously deaf patients, and implanted chips have been shown to aid the muscle control of patients with Parkinson's disease.'[5]

atomic art, includes the famous 'IBM' motif
http://www.almaden.ibm.com/vis/stm/atomo.html

Data gloves
[image: dataglove.jpg]
A virtual reality data glove

The data glove is a device worn on the hand like a glove; position and orientation is supplied with a sensor as described above, and different commands can be initiated by touching of each finger to the thumb. Despite widespread popular recognition, it is still in the experimental stage and is reckoned to be not yet reliable enough in use for general applications. The website 'nooface' carried an article recently reviewing the hype behind the actual usability of VR, and pointed out that the envisaged vista that it promised in the mid-90s failed to appear, although it has found many practical applications since in industry. Data gloves were cited as part of this 'failure' to deliver the VR promise.

Jack Hsu, 'Active Interaction Devices' (surveys the range of devices for inputting actions, including data gloves)
http://www.hitl.washington.edu/scivw/EVE/I.D.1.a.ActiveInteraction.html

Pocket scanner
The Sainsbury's 'Pocket Shopper' is a pocket scanner designed to be taken home by customers so they can scan barcodes as products run out. A pilot project involving 200 people is being carried out at the company's Hazel Grove store in Manchester. Rival supermarkets say they are monitoring the success of the trial and Tesco are testing a similar device based on a Symbol SPT 1500 Palm III touch-screen personal organiser with integral scanner, backed up by intelligent software that 'learns' buying habits. Sainsbury's customers link the egg-shaped device to an in-store computer so staff can pick out the items on their electronic shopping list.

Technology section, *Ananova* website, 4.8.02
http://www.ananova.com/news/story/sm_643439.html

Custom construction with sensor components
Many companies sell simple sensor components, which may be assembled, with corresponding software construction, into a more complex, purpose-built sensor. Instead of direct input through mouse and keyboard, sensors offer the possibility of controlling a computer without obvious physical input, and are therefore crucial in the development of pervasive computing (see separate report). Sensors are increasingly becoming part of emerging computing applications and exist in many forms:

- Light sensors (both single and in very large arrays, of various frequencies of light)
- Touch sensors (for example, switches)
- Pressure sensors
- Lateral and rotational movement sensors

The creative use of sensors has as wide a range of possibilities as exist in any raw medium. For instance, few sensors translate directly into sound, but could be used as modulators for digital sound elements (to be obvious and simplistic, heartbeat-to-tempo; perspiration-to-pitch); or modifying stage lighting from bodily information during a live performance.

source of raw sensors
http://www.infusionsystems.com/products/index.shtml

Raw sensors for any use are available from Infusion Systems (link: tilt2D inclination sensor)
http://www.infusionsystems.com/products/tilt2d.shtml

Penny & Giles Controls (sensor components)
http://www.pgcontrols.com/
Assistive computer products from the same source
http://www.penny-gilescp.co.uk/

Soundnet by SensorBand (experimental musicians/instrument makers)
http://www.sensorband.com/soundnet/index.html

Optical and radio sensing

[image: motion-sensor.jpg]
Motion tracking sensors

An extension of the technology used in the head mouse in which several reflective spots are worn on the body, each of which may be tracked by the computer system to determine the location of each part. Systems with two sensors spaced apart can work out the 3D location of each spot, whereas systems with one sensor can use rules about the flexibility of the body to infer where each sensor might be.

A similar technology involves the tagging of objects with radio-resonant tags (much as store security systems do), and detecting how they interfere with a field. This can be used to infer their position.

These techniques are used in animation to capture realistic movement, and in experimental interfaces to track the movement of tagged objects.

Computer-Vision-Based Human Motion Capture
http://citeseer.nj.nec.com/moeslund01survey.html

Sensopad (manufacturer of radio tagging system – aimed at domestic appliances)
http://www.sensopad.com/technology.htm

Polhemus StarTrak (motion capture system)
http://www.polhemus.com/stards.htm

The Tangible Media Group Homepage (much technology using tagged objects) http://tangible.media.mit.edu

Natural Point TrackIR (user review of spot-tracking device)
http://www.dansdata.com/trackir.htm

Juliet Robson's project 'Norman' used spot-tracking motion capture to make an animation of her movements when not using a wheelchair. (requires QuickTime)
http://www.innotts.co.uk/~deveritt/matrix/norman.htm
Work done under Creativity and Cognition Studios residency
http://creative.lboro.ac.uk/ccrs/gallery/jrobson/jrobson.htm

Infra-red interfaces

These types of interface involve measuring the interference (or reflection) of a beam of infra-red light. The user can provide such interference by movement – by moving between the emitter and detector (usually a binary output), or by reflecting the emitter into the reflector (a continuous output). Infra-red sensors are actually quite simple - when a beam is broken a signal is sent. Software can convert these simple signals into (for instance) complex moving images, or any other computer output required.

Applications of such interfaces include detecting the position or movement of the user within a grid of such sensors; producing a controller operated by waving arms over the sensor.

Virtual infra-red keyboard

[image: ir-keyboard.jpg]
The VKB virtual keyboard (artist's impression)

The virtual keyboard functions by projecting a keyboard (using a laser) onto any flat surface, with infra-red sensing that detects the movement and position of the fingers.

The VKB Virtual Keyboard: http://www.vkb.co.il/

Artwork using infra-red sensors

[image: autopoiesis.jpg]
Autopoiesis - one of the blue arms is swinging to the right toward the photographer while the other arms dance in the background. Photo, Yehia Eweis

Autopoiesis by Ken Rinaldo is a robotic sculpture installation commissioned by the Kiasma Museum in Helsinki, Finland as part of Outoaly, the Alien Intelligence Exhibition curated by Erkki Huhtamo, 2000.
http://www.accad.ohio-state.edu/~rinaldo/works/autopoiesis/autopoiesis.html

Divided We Stand by Miroslaw Rogala (infra-red sensors in artwork)
http://www.mcachicago.org/exhibit/speak/shanken.html

[image: sensorgrid.jpg]
images of movement density through an infra-red sensor grid

Mike Quantrill and Dave Everitt produced as part of a residency at the CCRS studios, Loughborough University, a digital art piece using various ways of tracking human movement through an infra-red sensor grid. As participants wander about the space, the form and intensity of the dynamic projected image changes to reflect the accumulative density of movement through the grid, while five notes from a whole-tone scale sound as beams are crossed, with two beams triggering an entire tone sequence. Part of the research behind the project involved experiments in

the direct control of various properties of the image by certain activities.
http://www.innotts.co.uk/~deveritt/grid/grid.htm

Infra-red video detection

[image: infra-red-video.jpg]
detecting (warm-blooded) humans using infra-red video

Although the technology to interface a video camera to a computer has long existed, the process of decomposing and understanding the video image in a meaningful way is very much in development. Researchers are working on recognising faces, movement and gestures and other specific targets (see the separate report 'pervasive-technology.doc'). However, infra-red video has specific uses. The use of infra-red video for detecting the presence of (warm-blooded) humans has met with some success. Another project at Stanford University uses infra-red video to detect touches on a projected screen.

Computer Vision Homepage
http://www-cgi.cs.cmu.edu/afs/cs/project/cil/www/vision.html

BareHands
http://interactivity.stanford.edu/projects/barehands.html

Wearable computing

[image: steve-mann.jpg]
The author's wearable computer system (as pictured on the cover of Toronto Computes, 1999) consists of a small computer that fits in a shirt pocket, and apparatus concealed under ordinary clothing. The eyeglasses, which provide an infinite depth of focus image, have a normal (e.g. not an unusual) appearance.

Dr. Steve Mann is regarded by many as the inventor of the wearable computer (computing being distinct from special purpose devices like ordinary wristwatches and eyeglasses, etc.), and of the EyeTap video camera and 'reality mediator', which scans items in the environment and intelligently edits them according to the user's specifications. For instance, billboard advertising can be 'blanked out'. Steve Mann is currently a faculty member at University of Toronto, Department of Electrical and Computer Engineering.

Steve Mann 'wearcam' website, technical paper
http://wearcam.org/itti/itti.htm

Bio-sensors and transhumanism

Used in medicine for many years, artists have recently adopted biosensors for use in interactive and performance artwork. Sensed functions include: pulse, breath, temperature, perspiration, breath-alcohol level, the female fertility cycle and electrical activity (muscular, nervous and neurological). This range could be extended to include more complex (for example, ultrasound, MRI) and more intrusive applications, for example by swallowing sensors.

One example of bio-sensor application is The Meditation Chamber, which demonstrates how biofeedback-driven visual, auditory, and tactile stimuli can create, guide, and maintain meditation and relaxation experiences.

The Meditation Chamber
http://www.gvu.gatech.edu/meditation/

MRI Scans (explanation)
http://www.netdoctor.co.uk/health_advice/examinations/mriscan.htm

Visible Human Dataset (unified cross-sections of a human body)
http://www.uke.uni-hamburg.de/institute/imdm/idv/visible/visiblehuman_head.en.html

Biofeedback products and resources
http://webideas.com/biofeedback/index/index.shtml

Transhumanism is a term used by those who aim to augment the human body through interfacing with technology directly and physically. Its philosophies have proved attractive to some disabled artists working directly with technology to augment the body.

> 'Like humanists, transhumanists favor reason, progress, and values centered on our well being rather than on an external religious authority. Transhumanists take humanism further by challenging human limits by means of science and technology combined with critical and creative thinking. We challenge the inevitability of aging and death, and we seek continuing enhancements to our intellectual abilities, our physical capacities, and our emotional development. We see humanity as a transitory stage in the evolutionary development of intelligence. We advocate using science to accelerate our move from human to a transhuman or Posthuman condition.' - statement from the Extropy Institute website

The Extropy Institute: 'Extropy is defined as a measure of a system's intelligence, information, energy, life, experience, diversity, opportunity, and growth. It is the collection of forces which oppose entropy'
http://www.extropy.org/

Anders Transhuman Page: 'Transhumanism […] encourages research into such areas as life extension, cryonics, nanotechnology, physical and mental enhancements, uploading human consciousness into computers and megascale engineering.'
http://www.aleph.se/Trans/

Alexander (Sasha) Chislenko, Mind Age essay on Transhumanism
http://www.lucifer.com/~sasha/mindage.html

Examples of artwork using bio-sensors
[image: terrain.jpg]
Ulke Gabriel, Terrain '01

Terrain '01 by Ulke Gabriel, uses brain currents to control a light installation, and thus the activity of solar-powered small robots. The more relaxed a person becomes, the brighter the lights become.
http://www.foro-artistico.de/english/program/system.htm

Osmose and *Ephemere*. Char Davies was amongst the first artists to create an audience-navigable abstract world in virtual reality. She had extensive involvement in the development of the technology. In late 1987, she became a founding director of Softimage, building it into one of the world's leading of 3-D animation developers and, in 1997, founded her own art & technology research company, Immersence Inc.

> 'Osmose (1995) is an immersive interactive virtual-realty environment installation with 3D computer graphics and interactive 3D sound, a head-mounted display and real-time motion tracking based on breathing and balance.'

http://www.immersence.com/

[image: stelarc.jpg]
Stelarc

Stelarc is an Australian-based performance artist whose work explores and extends the concept of the body and its relationship with technology through human/machine interfaces incorporating the Internet and Web, sound, music, video and computers.
http://www.stelarc.va.com.au/

Robotics

Robotics is becoming more prevalent as the motor and hydraulic technology required to produce it becomes more advanced. Many researchers are investigating the types of information that can be displayed through motion.

Lego Mindstorms (cheap and flexible robotics kit - firmware can be modified)
http://mindstorms.lego.com/

Actuated Workbench (use of magnetic forces to produce movement)
http://tangible.media.mit.edu/projects/actuatedworkbench/actuatedworkbench.htm

Walking Machines Catalogue (extensive list)
http://www.fzi.de/divisions/ipt/WMC/preface/walking_machines_katalog.html

ArtBots

[image: artbot-sumi.jpg]
Eva Sutton and Sarah Hart, 'Sumi-ebot'
'Sumi-ebots can perform as single artbots or as a group […] each sumi-ebot communicates with the next via infrared transmission. Once the bot has finished its mark, it signals the next bot to begin. Thus a chain of sumi-e bots can sequentially paint marks along a scroll, in the tradition of Japanese brush painting. Sumi-e bots are also equipped with edge-detection capabilities via a light sensor which signals the demarkated edges of the scroll, preventing sumi-ebots from painting outside of the paper surface.'
http://artbots.org/2002/participants/sumi-ebot/

[image: artbot-turntable.jpg]
Douglas Irving Repetto, 'do not break anything' (after christian wolff)
'*do not break anything* consists of a large, slowly spinning turntable covered with a variety of rocky surfaces, and three robotic tone arms […] with various objects (a stone, a piece of metal, a piece of wood) at the ends. As the tone arms move to different parts of the turntable and lower their "needles" to the surface, different kinds of sounds are created. The robotic tone arms are improvisers. They have some naive understanding of what their comrades are doing, and they use that information and some simple rules to generate their improvised behavior. The result is a quietly complex sound world drawn out of simple stones.'
http://artbots.org/2002/participants/do_not_break_anything/

The website ArtBots carries details of creative, autonomous robots. Some ArtBots are musicians, each with its own style and technique for making music. Others are visual artists and will demonstrate their drawing and painting capabilities to an audience. There are also ArtBots whose talents are a bit harder to nail down, and which might be called cybernetic performance artists.
http://artbots.org/

Survival Research Labs

[image: mark_pauline.jpg]
Mark Pauline

> 'In 1982, Pauline lost most of the fingers on his right hand while experimenting with rocket fuel. He had two of his toes grafted onto his hand so he can still use it for holding things.'[6]

Mark Pauline is an artist who builds 'extreme', and often web-controlled, machines from industrial spares and scrap. Under *the Survival Research Labs* (SRL) he has gathered a loose collection of participating artists and enthusiasts. SRL shows are regarded as dangerous, chaotic, but in the forefront of robotics. Here's an eye-witness account:

> 'Pauline then introduced his Swarmers. These were waist-high cylindrical mobile robots that skittered around in a flock. Where the flock would go was anyone's guess; no one Swarmer directed the others; no one steered it. […] The ultimate aim of SRL is to make machines autonomous. […] Yet he is ahead of many heavily funded university labs in attempting to transfer control from humans to machines. His several-hundred-dollar swarming creatures - decked out with recycled infrared sensors and junked stepped motors - beat […] the MIT robot lab in an informal race to construct the first autonomous swarming robots.'[7]

Survival Research Labs
http://www.srl.org

survival research labs and 'extreme Java' - controlling machines over the web
http://www.javaworld.com/javaworld/jw-08-1998/jw-08-srl_p.html

Karen Marcelo - Survival Research Labs participant artist (includes her other projects)
http://www.karenmarcelo.com/projects.html

Emotion

[image: kismet-faces.jpg]
Kismet, developed by Dr. Cynthia Breazeal, displays robotic expressions in response to human cues, from left to right: sadness, happiness, surprise.

[image: kismet.jpg]
Kismet and Dr. Breazeal

Kismet is a robot developed Dr. Cynthia Breazeal (MIT Artificial Intelligence Laboratory) to take in cues from human interaction using various sensors, and to display an appropriate facial response to indicate the kind of emotion that a human might feel under similar circumstances. Kismet:

> 'socially interacts with people using para-linguistic cues such as facial expressions, body posture, vocal prosody, and gaze direction. Building a socially responsive robotic creature that engages humans in natural and intuitive interactions has been a hard core engineering endeavor. The software runs on a network of 15 computers. A number of theories from psychology, ethology, and developmental psychology were adopted to design the robot's models of visual attention, facial displays, emotive responses, motivations, auditory processing, expressive vocalizations, and so forth.'[8]

Emotion is the essential element that creates the difference between robotic behavior and lifelike, engaging behavior. Several researchers have looked at the use of robotics to simulate facial movement in response to programmable signals, and hence to communicate emotion.

Ian Russell, an Emotional Interactive Exhibit consultant for museums, stresses the importance of emotion to draw visitors in, and to awaken curiosity in participants.

The Experimental Interaction Unit (EIU) was established to directly confront the threatening conformity and standards of technology in science and industry. EIU rejects the current interfaces between humans and machines, insisting on exploring new techniques and systems necessary for our inevitable co-habitation with machines. EIU endeavours to employ state-of-the-art techniques and technologies to conceive, design, and construct interaction systems which will simultaneously study, distract, and assault our future interactions with machines.

Kismet (robot displaying 'feelings')
http://www.ai.mit.edu/projects/humanoid-robotics-group/kismet/

Ian Russell, Emotional Interactive Exhibit consultant for museums
http://www.interactives.co.uk

Experimental Interaction Unit
www.eiu.org

Interactive Animatronics Initiative
http://www.etc.cmu.edu/projects/iai/

[image: lucy.jpg]
Lucy, an experiment in artificial life

Steve Grand, 'Lucy': 'I'm a robot. A robot baby orang-utan to be precise. Or at least, a robot with the mind of a baby, who looks vaguely like an orang-utan. I'm an experiment in Artificial Life, apparently'
http://www.cyberlife-research.com/about/index.htm (intro to Lucy)
http://www.cyberlife-research.com/about/anatomy.htm (technical details on Lucy)

Cyberlife Research (uses artificial life techniques to modify behaviour)
http://www.cyberlife-research.com/about/index.htm

Talking Heads
http://www.haskins.yale.edu/haskins/HEADS/contents.html

Artificial Emotion (Gamasutra article – registration required)
http://www.gamasutra.com/features/19990507/artificial_emotion_01.htm

MIT Affective Computing Lab
http://affect.media.mit.edu/

Affective Tigger (A reactive expressive toy)
http://affect.media.mit.edu/AC_research/projects/Atigger.html

Brain activity
Although sensors exist which can detect areas of activity in the brain, anything more than basic interpretation of these readings remains in the realm of science fiction. Systems are available today which allow the user to control a pointer by thinking (although these sometimes make use of eye movements too) and to turn devices on and off.

Such devices work by measuring readings from EEG sensors, which are small sensors attached to the head. Such devices are becoming relatively inexpensive, and many artists are taking advantage of the possibilities this presents.

- David Rosenboom, an influential experimental composer, has conducted extensive research into information processing modes of the brain as they relate to aesthetic experience and has published two books on the subject, *Biofeedback and the Arts* (1976), and *Extended Musical Interface with the Human Nervous System* (1990).

- Influenced by early experiences with hypnosis, Paras Kaul began research using a brain wave interface to the computer as related to neural networks and cognitive thought in 1992. This research evolved from an interest in human dolphin communication, and has resulted in performances and interactive 'game' exhibits.
- Brainball is a two player game where one must be considerably more relaxed than one's opponent to win. The little ball on the game's table is controlled by the player's brainwaves, where both a calm state and a stressed state have a direct influence on the match. The player who is most passive can watch the ball roll away towards the opponent's goal and can be sure of winning.

Computer mind-reading
http://www.cs.man.ac.uk/aig/staff/toby/writing/PCW/bci2.htm

David Rosenboom
http://music.calarts.edu/~david/
http://music.calarts.edu/~david/dcr_recent/dcr_OBIII.html

Paras Kaul
http://condor.gmu.edu/~paras/WEB/
http://condor.gmu.edu/~paras/WEB/pages/MindGardenGame.html

Smartstudio, Interactive Institute, Sweden (Brainball)
http://smart.interactiveinstitute.se/smart/smart_eng/index_eng.html
http://smart.interactiveinstitute.se/smart/smart_eng/brainball_eng/new_brainball.htm

Knocking

Researchers at MIT have demonstrated a touch panel technology that uses acoustic pickups attached to a (glass) pane that can detect a knock to the pane. By attaching pickups to all four corners, it is possible to detect the position of the knock.
The Interactive Window
http://helios.siggraph.org/s2002/conference/etech/interwin.html

Tangible media

The use of tangible media is at the cutting-edge of interface development, and is a vital component of the pervasive or ubiquitous computing vision (see the separate report 'pervasive-technology.doc'). The primary concept involves the user's manipulation of real-world objects, often without wires or cables. The computer can sense this manipulation (see 'Optical and radio sensing' above, often used in tangible media applications) and carry out appropriate calculations.

Origami paper
[image: origami-paper.jpg]
Origami paper

The MIT media lab has created special origami paper which has resonant radio frequency tags affixed to one side. Folding the paper changes its resonant frequency, allowing the computer to infer how it has been folded.
http://web.media.mit.edu/~wendyju/origami/paper.html

Physical manipulation scanner
[image: 3D-scanner.jpg]
3D scanner and clay surface

Again from MIT, an experimental scanner has been developed by the Tangible Media Group. This is able to make a real-time scan of a clay surface (representing a landscape), which allows the user to physically manipulate the surface. Visual results can be projected back onto the clay surface.
http://tangible.media.mit.edu/projects/IlluminatingClay/IlluminatingClay.htm

The Tangible Media Group Homepage
http://tangible.media.mit.edu

Stanford Interactivity Lab
http://interactivity.stanford.edu/projects/index.html

Art using tangible media
[image: undertoe.jpg]
Impression of an audience in Undertoe, by Nathaniel Stern and Greg Shakar

Undertoe, by Nathaniel Stern and Greg Shakar, consists of a space below a water tank equipped with wave generators, and a touch-sensitive floor. The movements of users result in ripples in the water directly above them.
http://nathanielstern.com/gallery/undertoe.html

Multi-sensory user interfaces

Some thinking in software design is moving towards screen displays that engage more than one human sense:

> 'With the advent of Virtual Environment technology it is now possible to construct new styles of user interfaces that provide multi-sensory interactions. For example, interfaces can be designed which utilise 3D visual spaces and also provide auditory and haptic [touch] feedback. Many information spaces are multivariate, large and abstract in nature. It has been a goal of Virtual Environments to "widen the human to computer bandwidth" and so assist in the interpretation of these spaces by providing models that map different attributes of data to different senses.'

- Keith Nesbitt, 'Multi-sensory metaphors for interacting with abstract data within a Virtual Environment', research project, Information Visualisation Research Group, School of Information Technologies, University of Sydney.
http://www.cs.usyd.edu.au/~visual/projects.html

Haptic (touch) interfaces

This type of display is currently an area in which a great deal new research is being conducted. Haptic interfaces concentrate on stimulating the human sense of touch, lending physicality to otherwise virtual objects. People are thus able to use touch, possibly augmented by hearing, to navigate a virtual space in detail.

Haptics Community Web Page
http://haptic.mech.nwu.edu/

Texture
Texture displays are in development, and appear to operate rather like a high-resolution Braille display, creating a textured surface for the fingers to feel.

Vibration
The most low-cost and commonplace haptic display, vibration displays are commonly embedded in joysticks, game pads, consumer devices such as mobile phones, and electronic devices for people with partial or no hearing. Vibration is used to attract the user's attention, and can be made, with different speeds or patterns, to indicate different meanings.

Force Feedback
[image: haptic-glove.jpg]
A haptic (virtual touch) 'glove'

Currently the most advanced haptic display, force feedback devices can produce a force that is contrary to that of the user (but hardly ever overrides it). Simple applications can be seen in mice and trackballs that display a 'bump' when the pointer rolls over the edges of elements of interest. More complex force feedback devices can convey complex surfaces and textures, and even move automatically (commonly seen in aeroplane autopilot systems). These are available as wands, knobs and sticks, or as gloves which limit the movement of the fingers when they close round a virtual object.

Immersion Products
http://www.immersion.com/products/overview.shtml

Sensable Technologies
http://www.sensable.com/haptics/products/phantom.html

An artist using a haptic interface
[image: karen-welsh1.jpg]
Karen Welsh using a haptic interface

[image: karen-welsh2.jpg]
Karen Welsh, untitled, virtual model (left) and resin cast (right).

Karen Welsh is a ceramic sculptor from Sheffield who used a Haptic Interface and Rapid Prototyping Unit (a 3D 'printer' that outputs objects) to produce a range of virtual sculptures at Art & Technology Partnerships, Loughborough University, during April 2002. The aim of the project is:

> 'To explore ways in which new technologies can enable artists and designers who have illnesses such as Muscular Dystrophy and Cerebral Palsy to create prints, animations, product designs and sculptures. […] The technologies employed are usually utilised in commercial product design, this project piloted their potential for enabling artists with disabilities. ETC ultimately aims to create a resource of interactive, on-line learning materials for disabled artists.'

Arts & Technology Partnerships website:
http://www.arts-technology.org

Audio interfaces
The audio interface is the most underused in conventional computing applications, yet has proved invaluable, not only for blind or partially-sighted users, but as an augmentation to other sensory stimulation. Humans find it very difficult to ignore audio, yet are also able to discern between two or more sources simultaneously.

Investigation into auditory display
http://multimedia.pnl.gov:2080/projects/ad/auditory_display.html

Sound effects

Sound effects can be either ambient or demanding in nature, depending on whether they are meant to indicate an event or a state. They can be looped or momentary, to indicate a persistent indication or a short status update. The relative importance can be conveyed by altering the pitch or volume of the sound (or, more generally, its prominence).

[image: damien-robinson.jpg]
Damien Robinson, 'whistle for', 2000

> 'Damien Robinson's work draws together sound and image to convey how sounds might look if they could be experienced visually. She has also explored the relationship between sound and vibration so that aspects of her work, which are conventionally inaccessible to profoundly deaf people such as herself, can be experienced through touch.
>
> For x-space, she will link air pressure levels to sound frequency and trigger visuals developed as a correlative to the sound. High frequency hearing loss leads to distorted sound and speech perception, particularly with 's', 'f' and 'th'. The compression and distortion of speech - an 'airborne' communication method - becomes reflected by changes in the air itself.'

taken from Damien Robinson, x-space commission
http://www.iniva.org/jubilee/project_09.html

Inivia x-space virtual gallery
http://www.iniva.org/xspace/x_space.html

Music

Music is useful as a provider of information, not only as an emotional backdrop. Certain tasks can be encoded into music, using variations in pitch, instrumentation, tempo and pattern to convey meanings and messages (also see 'Musical interfaces' Below).

Can We Use Music in Computer-Human Communication? (MS Word document)
http://www.fased.org/1995%20HCI95%20Music%20paper.doc

Speech

Speech is an effective way of transmitting verbal data, or complex data that could not be conveyed with sound or music alone. Computer-created speech might be useful for where the data is unpredictable, and more natural-sounding pre-recorded speech can be used where a discrete set of outputs will be used. Much work in the arts involving speech seems to be based around story-telling.

Issues in speech user interfaces (discusses conversational interfaces)
http://www.acm.org/sigchi/chi95/Electronic/documnts/papers/ny_bdy.htm

Speech output systems
http://www.rnib.org.uk/technology/factsheets/speech.htm

3D Audio

3D Audio is useful to add an extra element of spatial awareness, whether or not the visual display is 3D and/or stereoscopic. 3D Audio is best felt using either multiple speakers, or by equipping each listener with some headphones, through which simulations of the sound which might be perceived by each ear can be played.

Audio and three dimensional sound links

http://www.users.dircon.co.uk/~wareing/3daudio.htm

Anti-sound

A specific application of vibration sensor technology that has initially been applied to vehicle manufacture to reduce in-car noise or customise engine sound:

> 'Researchers at the Korea Advanced Institute of Science and Technology in Taejon have developed a prototype system that shaves up to 6 decibels off the typical motoring noise of around 60 decibels. […] The system uses anti-sound. Sound travels as pressure waves in air. Two sets of identical waves that are perfectly out of phase cancel one another out, just as two people jumping out of sync on a trampoline eliminate each other's bounce.
>
> Vibration sensors - transducers, rather like microphones - are hooked up to loudspeakers. When the sensors detect noise, a signal tailored to counteract it is almost instantaneously constructed. This technique, called active control, reduces background noise in aircraft, machinery and ships.'[9]

Disability-specific technology: current

Much assistive technology focuses on controlling the normal operations of everyday computer technology, but other technologies designed to be assistive could be adapted for other uses, and have obvious potential for the participation of disabled audiences in computer-based interactive work.

Disability-specific technology: general links

A Directory of Sources for Input Technologies
http://www.billbuxton.com/InputSources.html

DO-IT Publications: Electronic and Information Technology
http://www.washington.edu/doit/Brochures/Technology/

The Alliance for Technology Access – Alternative Input
http://www.ataccess.org/resources/atabook/s02/s02-03a.html

Penny and Giles - Special Needs Control Devices
http://www.penny-gilescp.co.uk/products/product.asp?ProductSection=Special+Needs

Working Together: Computers and People with Mobility Impairments (generalised report/review of current technology)
http://www.washington.edu/doit/Brochures/Technology/wtmob.html

Braille

In addition to Braille printers or embossers, which stamp Braille text onto sheets of paper (which may have conventional print on as well), dynamic Braille displays have been around for some time, and operate by raising the appropriate sets of pins, for the user's fingers to trace across. Different devices feature different numbers of lines and characters. Braille, of course, is only accessible if the individual can read it.

Enabling Technologies - catalogue (Braille printer)
http://www.brailler.com/webcat.htm

ALVA Access Group Product Catalogue
http://www.aagi.com/catalogue/ProductCat.asp

The assistive mouse

See 'The mouse: assistive technology links'

Trackballs

[image: trackball.jpg]
A trackball

Effectively an inverted mouse - the user revolves a large ball in a static base to indicate direction. Trackballs are available in various sizes, from thumb-operated through fingertip-operated to whole-hand-operated. As well as being used for positioning navigation, trackballs are a more direct method of indicating rotation commands.

Trackballs are useful for some users who find mice or track pads difficult to use, as they require no arm movement and do not lose orientation on screen. They are also often preferred in installations and public kiosks as they do not move, cables can be hidden, and they are often more aesthetically-pleasing and less immediately associated with computers.

Safe Computing - trackballs
http://www.safecomputing.com/trackballs.html

Assistive keyboard layouts

As well as the standard QWERTY-layout keyboard provided with almost all computers (which, with practice, is generally faster to type on than an ABCDE layout, but which also helped slow down fast typists to prevent typewriters from jamming), numerous variations exist for use by disabled users.
Ergonomic Keyboards
http://www.worklink.net/keyboards.htm

Dvorak keyboard layout

The Dvorak keyboard layout is a two-handed keyboard with the letters arranged such that the most common letters and letter-pairs are the easiest to type. This configuration generally results in faster typing and improved comfort compared with a QWERTY (conventional key layout starting with the keys for those letters) keyboard, and is a potential solution for users with repetitive-stress injury symptoms.

One-handed keyboard layout

Dvorak also created other configurations of keyboards suited to different styles of use, most notably the one-handed keyboard layouts. These layouts are arrangements of letters for the easiest one-handed typing (the left hand layout is a mirror image of the right hand layout).
Introducing the Dvorak Keyboard
http://www.mwbrooks.com/dvorak/

Bob Harrell Home Page
(One-handed typist)
http://home1.gte.net/bharrell/index.htm

Large keyboards

[image: large-keyboard.jpg]
The Big Key Plus large keyboard

These alphabet layouts are available in larger sizes, for users with reduced motor control, and smaller sizes for users with smaller hands. Users who do not have the

use of their hands may press keys using a pointing stick positioned on the head or in the mouth.
BigKeys Large Keyboards
http://www.rjcooper.com/bigkeys/

Switches
[image: ablenet-switch.jpg]
A large push-button switch from Ablenet Inc. (see 'Switches: links' below)

Aimed specifically at disabled users and children, several manufacturers supply large pushbutton switches. These buttons vary in size, colour and required actuation force. Users can not only issue simple commands, but can also enter more complex information using Morse code and scanning (a process of selecting commands from menus with only the button).

Smaller switches are available for operation by users with limited movement or strength, which can be operated by the mouth, chin, the feet or toes, etc.

Breath-operated switches are available, which are either held in the mouth, or positioned within reach of the mouth. They are operated by the user 'sipping' or 'puffing' (the user breathes normally otherwise) to issue commands.

Sensors which detect the electrical signals produced by muscle movement can be worn wherever the user has controls of the muscles, but might not be able to produce a movement to trigger a physical switch. Example locations are the eyes, knees, etc.

Ablenet Inc. Switches
(variety of large push-buttons)
https://https.kinetic.com/cgi-bin/web_store/web_store.cgi?product=Switches-and-Accessories

Mobility impairments - switching devices
http://polio.dyndns.org/chip/modswich.html

Scottish Sensory Centre - Vision for doing, Appendix 1
(aimed at compound disabilities)
http://www.ssc.mhie.ac.uk/vfdh/vfdpt3.html

Prentke Romich Company switches
(large variety of switching techniques)
http://store.prentrom.com/catalog/prentrom/scan/MM=4935446751:0:2:3:

Head Mouse
[image: headmouse.jpg]
A head mouse and breath switch

[image: breathswitch.jpg]
Origin Instruments sip/puff breath switch

A head mouse consists of an active sensor, usually mounted on top of the screen, and a small reflective sticker worn on the forehead or glasses. From this, the sensor can detect the location of the head (in two dimensions) and use this information to control the mouse. Breath switches can control (for instance) mouse clicks, or any other input according to how the computer is programmed.

> The Sip/Puff Switch is ideal for accessing electronic devices such as The HeadMouse or other mouse emulators, augmentative communication devices, and devices accessed or controlled by scanning. - *Origin Instruments Corporation*

Head Mouse: links

Boost Technology - Tracer
http://www.boosttechnology.com/tracer_description.html

Origin Instruments Corporation - HeadMouse
http://orin.com/index.htm

Accessible virtual reality room

The CAVE is a technology developed in the mid-90s that provides a room in which all surfaces are projected images of a virtual world. Other similar environments use a huge ball in which the user (inside the ball) moves through the space by propelling the ball's 'floor' beneath them. Some VR environments are inaccessible to disabled users, but the following link 'Input Interfacing to the CAVE by Persons with Disabilities' shows that work is being done in VR to address this issue.
http://www.evl.uic.edu/EVL/RESEARCH/PAPERS/DREW/sun9f.html

Disability-specific technology: emerging

Speech recognition

(also see 'lip reading handsets' below)
Software which recognises speech has been marketed for many years now, but is still far inferior to humans' ability to understand speech, in its various languages, accents and non-verbal utterances.

Most current speech recognition software has one of three limitations: either it is not very accurate, or the user must 'train' the software to understand his or her particular voice, or the user must speak a command which conforms to a particular grammar. Developments in Artificial Intelligence and the processing power of computers are resulting in continuous improvement to the computer's ability to recognise speech.

The recognition and transcription of speech is an easier problem to solve than the comprehension of natural language and interpretation of commands, which is a problem that often taxes humans, let alone computers. The comprehension of speech instructions may be aided by the comprehension of gestures associated with the speech.

Speaking to Write: Realizing the potential of speech recognition for secondary students with disabilities
http://www.edc.org/spk2wrt/

MacSpeech (Apple Macintosh-based speech recognition)
http://www.macspeech.co.uk/

Dragon Naturally Speaking
http://www.scansoft.co.uk/naturallyspeaking/

AlphaWolf (commands via howling, growling and barking)
http://badger.www.media.mit.edu/people/badger/alphaWolf/installation.html

The 'Truster' software ('lie detection' via software speech processing, for Windows PC users via microphone or telephone receiver)
http://www.liebusters.com/Truster/trusterinfo.htm

Video-audio conversion
[image: voice-headset.jpg]
The vOICe headset

The vOICe device uses a small CCD camera mounted on the (blind) user's head, and uses this to create a real-time audio representation of the video image. With practice, blind users are supposedly able to tell the position of objects without having to feel for them.
The vOICe
http://www.seeingwithsound.com

Musical interfaces
The following paper ' Communicating Graphical Information to Blind Users Using Music: The Role of Context' explores the possibility of using music as in the same way as a visual interface:

(MS Word document)
http://www.fased.org/1998%20ALty%20Rigas%20CHI98%20Final.doc

Disability-specific technology: experimental

Lip reading handsets
Cellphone maker NTT DoCoMo of Japan are developing the first lip-reading mobile. If you mouth your words silently into the phone a speech synthesiser converts to speech or text. An early prototype works out which words are being said by using a contact sensor near the phone's mouthpiece to detect tiny electrical signals sent by muscles around the user's mouth. Vowels are already recognised with an 'acceptable error rate' but they are still working on consonants, which are harder. Lip-reading accuracy may be boosted by using the tiny cameras that will be common on 3G phones.

> 'The technology is also expected to help people who have permanently lost their voice'. - Michael Fitzpatrick, 'It's bad to talk', New Scientist 06.04.02

Eye movement
[image: eyegaze.jpg]
Infra-red eye movement tracking

[image: eyegaze-wheelchair.jpg]
The Eyegaze Communication System

The direction of gaze can be determined by shining an infra-red beam into the eye and analysing the reflection. The first of such devices required attachment to the user's head, but more recently this requirement has been removed. Accuracy is typically around 1cm level at a 2ft distance. Applications of this technology are available for both disabled and non-disabled users.

The Eyegaze Communication System
http://www.eyegaze.com/
detailed medical and technical information

http://www.lctinc.com/doc/ecs_med.htm

[image: dasher.gif]
Dasher - typing by eye movement (© D. MacKay/Dasher Project)

The following is condensed from the Nature News Service website.

> 'New software could allow computer users with disabilities or busy hands to write nearly twice as fast, more accurately and more comfortably than before. The package, called Dasher, "exploits our eyes' natural ability to navigate and spot familiar patterns", says one of its inventors, computer scientist David MacKay of the Cavendish Laboratory in Cambridge, UK.
>
> An eye-tracking device lets users select letters from a screen. Dasher calculates the probability of one letter coming after another. It then presents the letters required as if contained on infinitely expanding bookshelves. "Users have the feeling that whole syllables, whole words, even whole phrases, are simply leaping towards them," says MacKay. He and his colleague David Ward taught Dasher English using passages from Jane Austen's Emma, Lewis Carroll's Alice in Wonderland and other classic texts. "It has huge potential to speed up people who at the moment have to write quite laboriously," says John Willis, a lawyer in Papworth, UK, who has used Dasher.
>
> Devices that use cameras to follow eye movement have already been combined with on-screen keyboards. But typing this way is slow and exhausting. The top speed is about 15 words per minute, and users have to be careful where they look to avoid inadvertently selecting and typing things. Dasher's predictive abilities are "hugely advantageous", says Willis, who was born without hands. Not only does Dasher learn the language - providing a 'u' if a 'q' is selected, for example - it learns each user's favourite words. Users can soon reach a typing speed of 25 words per minute. "They've certainly broken the world record for gaze-operated typing," says John Paulin Hansen, who works on technology for the disabled at the IT University of Copenhagen, Denmark.'

Palmtop computers are also a likely target for Dasher, which may also suit Japanese and Chinese languages, which are poorly suited to keyboards.
http://www.nature.com/nsu/020819/020819-5.html

Bionic eye

The following news story, dated Tuesday 20 August 2002, is condensed (but verbatim) from the website Ananova's technology news section:

> 'Australian inventors say they will soon be looking for volunteers to start human trials of a "bionic eye". The device consists of a silicon chip inserted into the eyeball and a pair of "camera glasses" worn by users. Images from the glasses are broken down into pixels and passed to the tiny chip, which acts like a retina. The chip simulates the images and transmits a message to the retinal cells along a series of small wires. Designer Gregg Suaning, of Australia's University of Newcastle, has been working on the project for five years. He said: "The principle of a bionic eye is very similar to that of the bionic ear. It is a silicon chip which decodes the radio signals and delivers simulations. The chip sends message to the retinal cells through small wires. We broadcast basically into the body. It's like a radio station that only has a range of 25 millimetres."
>
> A separate processing unit makes "sense" of the camera images by looking for certain features, such as doorways of light. Current technology means the unit is only able to send 10x10 pixel images, but Mr Suaning hopes this will improve with time.
>
> ABC reports tests on animals have been successful and [the technology is ready for] trials on a group of about five human volunteers [who] must be profoundly blind as people with partial sight will be excluded because of the potential risk of visual damage.'
>
> http://www.ananova.com/news/story/sm_653784.html?menu=news.technology

Thought-driven robotics

The following news story, dated 16 November 2000, is condensed (but verbatim) from the Nature News Service website:
http://www.nature.com/nsu/001116/001116-9.html

> researchers report that electrical signals from a monkey's brain, instructing its arm to move, can be used to stir identical movement in a robotic arm. The technology could one day help paralysed people control artificial limbs just by willing them to move.
>
> Miguel Nicolelis of Duke University, Durham, North Carolina, and his colleagues wired a monkey to a very simple robot arm that copies two of the animals' actions -- moving its arm left or right and retrieving food. Using the Internet, they also made a second robot arm, hundreds of miles away, mimic the monkey's movement. There is no delay between the monkey moving and the robot copying it, which is crucial for artificial limbs.
>
> "The idea of driving robotic limbs with what effectively amounts to the mere power of thought was once in the realm of science fiction," says prosthetics researcher Sandro Mussa-Ivaldi of Northwestern University Medical School and the Rehabilitation Institute of Chicago, Illinois. "But this goal is edging closer to reality. Gradually researchers are developing the hardware and software needed to connect brains with robotic limbs. It will be important to explore further the ability of this approach to generate movements of the robot arm over a wide region of space, but this work represents a first step in the right direction."
>
> The new research builds on decades of careful study into how brain cells activate when hands and arms move. Researchers can now predict the hand and wrist movements that will follow neuronal activity. But using these electrical signals to drive movement is tricky. It is partly a computing problem. Electrical signals issued by the brain to flex the elbow muscle, for example, can be swamped by a morass of mental instructions: everything from 'scratch that annoying leg itch,' to the date of Aunt Minnie's birthday. So picking out - and artificially acting on - the movement instruction is difficult.
>
> Nicolelis' team have a fairly simple solution to this. Working only on the brain's movement-control centre, the 'motor cortex', they first measured the activities of individual monkey neurons each time the animal completed a very simple action, such as moving its hand to the left. The greater the measured activity, the greater the neuron's importance in this task, they reason. They assigned each nerve cell a number to reflect this -- double the activity, double the number. So these values can now be used to predict and generate movement. Measuring a neuron's activity at a particular moment and multiplying this by its corresponding numerical 'coefficient' gives a clue to the movement about to occur. Adding up the results for different neurons brings the clues together to reveal the answer -- the hand is about to move left, down or whatever. A computer can thus transform each moment's 'answer' into robotic movement, while already calculating what the next move should be.'

- David Adam, 'The power of thought can drive robotic movement and may help paralysed people.'

Gesture recognition

The data glove, video and optical sensing technologies mentioned elsewhere may be used to gather information about gestures that the user is making. Research in this area tends to be divided between hand-based and body-based gestures.

The Gesture Recognition Home Page
http://www.cybernet.com/~ccohen/

Notes

[1] This is included in the format recommended by the Dublin Core Metadata Initiative, which aims to make all documents and online resources extensively searchable via any digital network or a future world wide 'semantic' web that encourages precise information to aid the location and searching of online resources. It may be used in any future online publishing. See http://dublincore.org/documents/dces/. For examples of this in use see http://www.ndltd.org/standards/metadata/current.html and http://standards.edna.edu.au/metadata/elements.html. It is of note that, at the completion date of this document, there is no metadata standard emerging for the arts (as there is, for instance, in the fields of law and education), nor is there any working party that is likely to compile such a crucial standard.

[2] 'Smart fabric makes a soft keyboard', *Mac User* 18.04.02

[3] 'Road gangs don X-ray specs to avoid a shock', *New Scientist* 06.04.02

[4] Eric Drexler's biography is online at: http://www.foresight.org/FI/Drexler.html

[5] Ohr, Stephan, 'Inventor foresees implanted sensors aiding brain functions' in *EE Times* (the 'industry source for engineers and technical managers worldwide'), September 26, 2002 http://www.eet.com/at/news/OEG20020926S0013

[6] 'The Art of War' Lucas, Adam in *World Art* 1/95, available online at: http://www.srl.org/interviews/world_art.html

[7] Kelly, Kevin, 'Out of Control' Chapter 3: 'Machines with an attitude' available online at: http://www.kk.org/outofcontrol/ch3-a.html

[8] from Dr Cynthia Breazeal's home page at MIT: http://www.ai.mit.edu/people/cynthia/cynthia.html

[9] Ball, Philip, 'Noise quietens driving - sensors and loudspeakers reduce in-car racket', *Nature magazine* website, 25 January 2002, http://www.nature.com/nsu/020121/020121-12.html