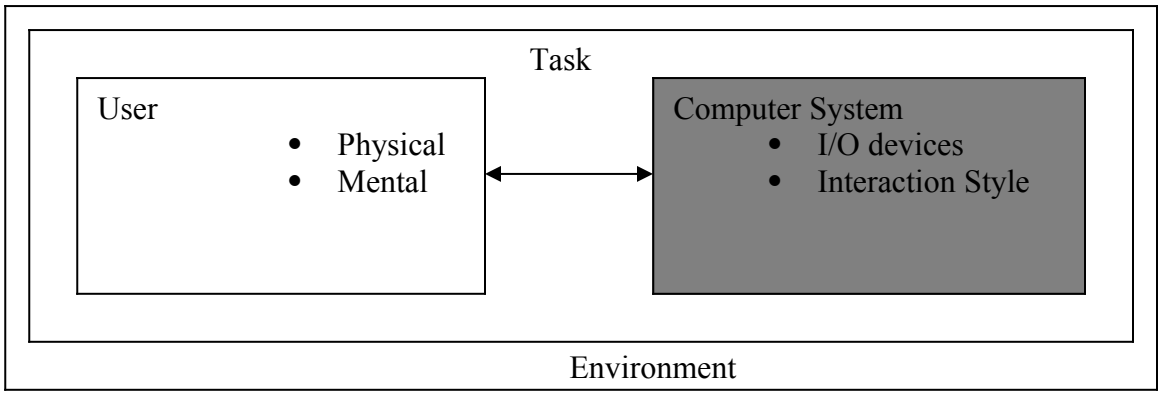
HCI-5- INPUT/OUTPUT DEVICES

Aims and Objectives: the previous three lectures have concentrated on understanding some of human factors (both physical and mental) that affect how people interact with computer systems. In this lecture and the following one we switch focus to look at the computer participant in the interaction. This lecture aims to give an overview of various types of input and output devices and explain some of the factors one may need to consider when choosing devices for a particular system. The next lecture looks at what are termed 'Interaction Styles', which are the **various styles of dialogue** that can support interaction between human and computer.

Lecture Notes

Introduction

The first HCI lecture discussed the goals of HCI. It explained that the fundamental goal upon which the other higher level goals rely is **to build a deep understanding of the factors which affect how well humans interact with computers**. So far we have concentrated on the **human end of the interaction**. In this lecture and the next we are moving to look at the **computer side of the interaction**.



The diagram above shows that **the user** and **computer** are not interacting in a vacuum. They are working together on some **task** (e.g. typing a letter) and exist in some **environment** (e.g. an office with particular lighting conditions). As well as understanding the **human and computer element**, HCI also attempts to understand the **task** and the influence of the **environment.** In this series of lectures we will mainly concentrate on the human and computer elements and look a little at **analysing tasks** when we come to the lectures on design issues. We will not focus directly on the effect of environmental factors in any detail.

When we are interactively using a computer we are constantly switching between input mode (e.g. entering data or telling the computer what we want it to do) and output mode (e.g. receiving the results of some query or getting feedback about the last operation we carried out). In this way a, often fast moving, dialogue is maintained between human and

computer. In the next lecture we will consider the roles of input, types of input devices and how one may select input devices. The last part of the lecture will consider output and output devices.

Roles of Input

We use computer input devices for two distinct but related purposes. Firstly, to **enter data**; for example the text of a letter, numbers to be entered into a spreadsheet, the details of a flight that a customer is booking via a travel agency etc. the second purpose is to **enter some command or select an option**; for example to choose a menu option or to type in a command. Quite often we use different input devices for these two purposes. We will return to this idea when we look at factors that influence the choices of input devices.

A Classification of Interactive Input Devices

Below is a summarised classification of interactive input devices. It is not necessarily complete (new devices are being invented all the time) but it does show a useful classification of the major types of device. Some notes on the classification are given after the classification itself.

- **Keyboards**
  - Single Key press
    - Qwerty
    - Dvorak
    - ABCD
  - Chord Keyboards
- **Pointing Devices**
  - 2 dimensional
    - Direct
      - Touch sensitive screens
        - Finger contact
        - Stylus
      - Eye-Tracking
        - Electrophysiological
        - Photoelectric
    - Indirect
      - Mice
      - Trackballs
      - Joysticks
      - Cursor Keys
      - Graphics Tablet
      - Touch Pad
  - 3 dimensional
    - 3D mice
    - Data Groves

    - Virtual Reality Helmets
    - Whole body tracking
- **Voice Input**
    - Discrete word recognition
    - Continuous-speech recognition

Notes on Classification of Input Devices

Keyboards are among the most common of input devices. They are particularly useful for entering textual information but can also be used for entering and selecting commands. The most common type of keyboard layout uses the **QWERTY** arrangement of keys. It is interesting to note that this arrangement dates from the days of mechanical typewriters and was deliberately designed to slow down typing speeds and make sure that commonly used combinations of keys are not placed closely together. This was to reduce the incidence of key clash where the mechanical arms that print the letters get jammed if two placed close together are used in quick succession. This benefit of the QWERTY arrangement is no longer valid and alternative layouts (e.g. **DVORAK**) have been developed that allow considerably faster typing speeds to be attained by trained typists. The only reason for the continued dominance of the QWERTY layout is reluctance of manufacturers, employers and trained typist to change.

Another alternative to the QWERTY layout is the **ABCD** layout. The advantage of this layout is that it seems logical for untrained typists. It is used mainly on small portable devices (where touch-typing is impossible even for trained typists) and exists in adapted form on many mobile phones where each key represents three letters.

Chord keyboards differ from those described above in that they have very few keys (perhaps 5) and so each letter is represented by a combination of keys being pressed at the same time. With a short amount of training people can achieve very fast typing speeds using such devices. Chord keyboards are operated using one hand and are considerably smaller than traditional keyboards. This means they can be used in cramped conditions and also makes them suitable for use in portable devices.

There are many different type of **pointing devices** available, the most common being ubiquitous **mouse**. Pointing device are most commonly used for making selections e.g. selecting an option from a menu or clicking an icon, they can also be used for the input of textual information (e.g. using handwriting recognition) or for the input of graphical information. Pointing devices can be divided into those for use in **2 dimensional** and in **3 dimensional** spaces.

Devices such as **touch sensitive screens** can be classified as **direct pointing devices** because you select what you want by pointing at it directly as opposed to moving some separate device that is mapped to a cursor on the screen. Touch sensitive screens may work with the user's finger or use a **stylus**. Some stylus systems (e.g. as some used by Personal Digital Assistants), support handwriting recognition. Handwriting recognition has the advantage over keyboard input of being very natural and being feasible using a

very small device. Some disadvantages are that it is not possible to write as fats as it is possible for trained typists to type and the process is error prone due to individual differences in handwriting.

Touch sensitive screens using **finger contact** have the advantage of being intuitive to use (e.g. for members of the public) and not requiring any equipment other than the screen itself. Such systems can be robust enough to stand up to public use. Disadvantages are that fingers are quite large and so it is not possible to select small objects accurately and that the finger itself tends to obscure some of the screen.

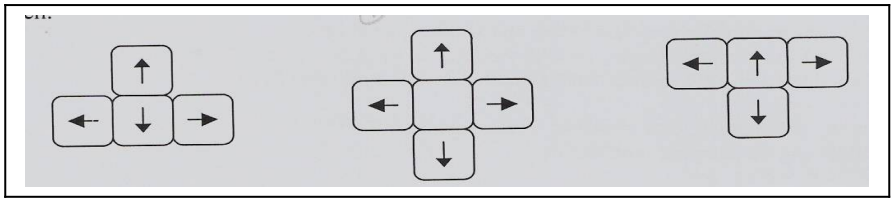
Other direct pointing devices use the direction of the user's gaze to make selections. These **eye-tracking devices** can either work using **electro-physiological** (the movement of eye muscle is detected) or **photoelectric** (a weak laser is shone into the eye and reflected) means. These types of system are of use where the user cannot use their hands. Examples are military applications for pilot of fighter planes and for disabled people.

Indirect pointing devices are more common than direct pointing devices. Some piece of equipment is manipulated (e.g. a mouse) by the user and its movement is mapped to a cursor on a screen. The **mouse** was originally prototyped in about 1964 must be the most commonly used pointing device. Mice allow you to move the cursor around the screen and to carry out operations (e.g. selecting something) by clicking buttons. Mice typically have from one to three buttons. Once users are familiar with it using a mouse seems very intuitive however the hand-eye
co-ordinations required can be a barrier for some users.

Trackballs are like upside down mice where the user moves the ball directly. An advantage over mice is that they don't take up much space and can be built-in to some larger device (e.g. a keyboard). This makes them very suitable for use with notebook and laptop computers.

Joysticks can be used to perform similar function to mice and trackballs. They take up little space and are particularly popular for use with games applications.

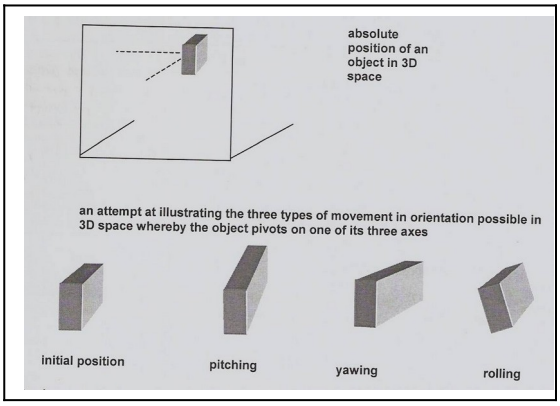
Most keyboards include one of more sets of **cursor keys** that can be used to control the screen cursor. They are found in a variety of layouts, three of which are shown below. Advantage of cursor keys are that they are cheap, robust and easy to use, for instance within a text editing program. Disadvantages are that more many applications they are rather slow, especially for making diagonal movement across the screen.



A **graphic tablet** is a touch-sensitive device that is separate from the screen. They are usually laid flat and so can be comfortably used for drawing. They are often used with a stylus and may be high resolution and so can be used for the input of very accurate graphical information. Graphics tablets are mainly used for graphical applications (e.g. design) but may also be used for the input of textual information when used in conjunction with handwriting recognition software.

Touch pads are like very small graphics tablets. They are used as an alternative to trackballs and mice with some notebook and laptop computers. The user controls the cursor by moving their finger across the device. They take a bit of getting used to and are not popular with all users.

3 dimensional input devices are necessary for dealing with 3D space. This may be 3D space a simulated on a normal flat screen or a more immersive virtual 3D environment. Moving and manipulating things in 3 dimensions in considerably more complex that dealing with 2 dimensions. Not only does the actual location in 3 dimensions matter but orientation is also significant – see the diagram below.



3D mice is a generic term for a number of different types of device that can act (though not necessarily) look like 3 dimensional mice. The mouse (perhaps a small cube) is manipulated in 3 dimensions and its position and orientation is detected (e.g. by ultrasound).

Data gloves are gloves that are wired up with optical fibres so the position and orientation of the glove can be detected. It is possible to detect the gesture (e.g. a clenched fist) which opens up the possibility for communicating with computers via sign language. The cursor that appears in the 3D world is often in the shape of a hand that mimics the gesture of the user. The data glove provides a very natural way of interacting with objects in 3D space e.g. picking up and moving an object. At present sophisticated data glove are too expensive for widespread use.

Virtual reality helmets allow the user's head movement to be detected. This in turn can be used to change the image that is fed back to the user through goggles so that as the user tilts their head their view of the virtual world shifts accordingly.

Whole body tracking devices detect the movement and orientation of the body. The most sophisticated are like whole body data gloves. Such devices are obviously necessary to give a fully immersive virtual reality experience so that the user can move through the virtual world as if it were real.

Voice input has the obvious advantage of being a very natural form of communication for the user. The most successful systems are where discrete words are organised for a restricted vocabulary. This can be used as a way of selecting a command. Such systems are successfully used with telephone systems for the general public (e.g. booking cinema tickets). Continuous-speech recognition is an alternative to the use of keyboards for textual input. It is a difficult task to design software that can recognise continuous speech accurately enough to be useful. As with handwriting recognition one of the major difficulties is dealing with individual differences between people. However commercial applications are becoming available and are likely to become more widely used in the future. One drawback of such systems is that it is not possible to speak as fast as a trained typist can type.

Quick Quiz Question 1

(a) What are the two major roles of input?
(b) Give one advantage of each of the following:
- Chord keyboards
- Touch sensitive screens
- Trackballs

Choosing Appropriate Input Devices

The factors to be taken into account when choosing input devices for use in a given situation can be considered under the heading of: human, task, environmental and other constraints.

Human

The expected user's level of experience, skills and training can be a factor. For example where users are likely to include those with little computer experience then the most natural devices (e.g. touch screens) are appropriate. ***QS: Why do most banking systems use touch screens as a form of input devices?***

Any physical disabilities need to be taken into account and where appropriate particular devices chosen that make best use of the user's abilities. For example an eye-tracking device may be appropriate for a user who has limited mobility in the rest of their body.

The user's physical comfort should be taken into account. For example, because it usually requires the arm to be held up using a touch screen can be tiring for prolonged periods.

The Task

The type of input required by the task has implications for the choice of appropriate input device. For example a mouse is very appropriate for selecting options and clicking icons but is not at all suitable for the input of textual material and very limited for the input of freehand graphical material.

The repetitiveness of a task is also significant. For example using a 3D mouse can be quite tiring. If the same set of 3D movements is to be repeated frequently then it may be best to make them available by selecting an option on screen using a more traditional 2D mouse.

The complexity of the task can also have an influence. For example it is possible to use a drawing package to do simple drawing using a mouse but if complex drawings are required a graphics tablet is probably more suitable.

For some tasks the effect of errors may be less significant than for others. Where the accuracy of input is essential then it is important not to use an error prone input device. For example keyboard input may be more appropriate than hand-written input using a stylus when figures are to be entered that are highly critical (e.g. dosages of drugs to be given to patients in a hospital).

Environmental Factors

The availability of space is obviously significant. For example where space is very limited a chord input device may be more appropriate than a normal keyboard.

A very noisy environment may make the use of voice recognition inappropriate. Where there is a lot of dust or other dirt it is important to choose devices that will not be affected. For example using a mouse in a very dusty environment is likely to mean it will get clogged up and stop working. Equally using a mouse where there is a lot of movement (e.g. on board a plane) may not be sensible, as it is likely to roll around. In some cases security needs to be taken into account. Some devices are more vulnerable to being stolen or interfered with than others.

Other Constraints

In reality lots of other constraints may influence the choice of devices. These include existing equipment, costs and availability of the desired devices.

Roles Of Output

Output produced by a computer has a number of roles. The most obvious is to convey information to the user, for example: the text of an email, the results of a search on the internet, the availability of some item of stock that a customer has enquired about.

Other uses are to prompt the user to do something (e.g. enter a username) and to provide feedback. Feedback is very important, for example when you move the mouse you expect to get the feedback of seeing the cursor move on the screen, without this the device becomes unusable.

A classification Of Output Devices

As with the classification of input devices the following list is probably not complete but does attempt to show a useful classification of the major types of device. Some notes on the classification are given after the classification itself:

- **Visual (eyes)**
  - Screens
    - 2D
      - Cathode RAY Tube (CRT)
      - Liquid Crystal Display(LCD)
      - Plasma panels
      - Head-up displays
    - 3D
      - Goggle mounted
      - Polarised or blanked out spectacles
      - Holographic
  - Printers
    - Dot matrix
    - Inkjet
    - Laser
- **Auditory (ears)**
  - Speech synthesis
  - Musical
  - Other sounds
- **Touch (fingers)**
  - Pressure feedback devices
  - Virtual reality
  - Braille output

Notes on the Classification of Output Devices

The major categories of the classification above are made according to the human sense that the computer output is intended for. Unsurprisingly smell and taste don't appear!

At present by far the most common type of computer output is **visual**. Of the visual output devices the CRT screen is the most widely used. Beams of electrons are fired at a phosphor-coated screen making the phosphor glow for a short time. The electron beam scans the screen repeatedly from left to right and top to bottom. If this scan rate (the 'refresh rate') is too slow there is likely to be a noticeable flicker. High-resolution screens are becoming quite common with 18-inch screens with a resolution of 1600 x 1200 pixels not uncommon. One of the advantages of CRT screens is that they are relatively cheap, display colour well and can be used to show smooth animation (e.g. as a window is moved). Disadvantages are that they are quite power hungry, tend to be bulky and are not

very good at displaying smooth diagonal or curved lines. Another problem is that they have been associated with various health problems especially eyestrain.

The main alternatives to CRT screens are **LCDs**. Here a voltage passed through a thin layer of liquid crystal trapped between two glass plates from the image. The bottom plate is reflective and the top one is polarised. The voltage causes the crystal to twist and later the polarization of the light. LCDs have the advantages of being flat and thin, light and require less power than CRTs. This has made them the common type of display for mobile devices. They also tend not to suffer from flicker and are less tiring to view. At present LCDs are more costly than CRTs and have lower resolution.

Another screen technology is **plasma panels**. Here voltages are passed through capsules of neon-based gasses causing them to glow. Plasma panels like LCDs are flat, thin and light. It is possible to make large plasma panels (e.g. 40 inches) and so it is likely that they will be increasingly used, especially in place of projection facilities where a large image is required.

Head-up displays are devices where the output is projected onto a partially silvered screen (e.g. car or plane windscreen) in the user's line of vision. This allows the user to see important information without having to move their head. An alternative is where the user wears a special helmet of hat with a small partially silvered screen that usually covers just one eye. Again the advantage is that the user can carry on looking at their environment while being able to view output from the computer.

For many purposes (e.g. games) **3D** output can be simulated adequately on a 2D screen using optical 'tricks' such as perspective and occlusion. True 3D vision however requires that each eye be presented with a slightly different image to mimic normal stereoscopic vision. This can be achieved by **goggle mounted** screens where each eye has separate screen in front of it showing a slightly different image. An alternative is to have the user wear glasses which alternate very quickly between **blanking** out the left and right lens. This is synchronised with a single screen that alternately displays images intended for the left and right eyes. An alternative is to use glasses with **polarised** lenses and have polarised filters in front of the screen. In some ways the ideal way of providing 3D visual output would be to have computer generated holographic images. The technology for this does not currently exist.

Printed output continues to be very important. We obviously have not reached the paperless society yet! We will not discuss print technology in any detail here; being more concerned with more interactive devices.

Increasing computer systems are using **auditory** output. The most sophisticated form of auditory output is **speech synthesis**. Examples of where this is useful are: to convey information to a user already has their visual system fully occupied e.g. driving (although a head-up display may be an alternative), for people who have limited vision or for use by members of the public over the telephone. A problem is that synthesised speech tends to lack intonation and emphasis and thus can be tiresome to listen to and sometimes

difficult to understand. Another problem is that it's transient and so not appropriate for complex information that may need to be received.

Musicals sounds obviously have value as entertainment but may have additional uses for example in data 'visualisation'. **Other types of sound** (beeps and swishes etc) are of course commonly used to provide auditory feedback.

Recently a number of relatively inexpensive devices have been marketed that provide output for our sense of **touch.** These include **pressure feedback** joysticks and steering wheels for use with games and also general-purpose mice that tremble and vibrate as you surf the web. It remains to be seen whether such devices are mainly novelties or really do have a useful purpose.

To make virtual **reality worlds** seem real it is essential to have pressure output so that for instance when you pick up a virtual object you can feel its shape and weight.

Braille can be output by printers or other specialised devices. It must however be remembered that in fact other a minority of blind people or people with limited vision can actually read Braille. For this reason, speech output is perhaps more generally useful.

Quick Quiz Question 2

(a) Explain two ways in which stereoscopic vision can be produced using currently available devices. – goggles, polarised glasses

(b) Describe the advantages of LCD screens over CRTs.-light, thin, less power required, no flickers

Choosing Appropriate Output Devices

The factors influencing the choice of output devices can be classified under the same headings as those used for input devices; i.e. human, task, environmental and other.

Human

The user's level of experience, skills and training are perhaps less of a factor with output devices than with input devices except where some particular skill is required e.g. the ability to read Braille. Physical disabilities are obviously again a factor. For example, for someone with limited sight a standard LCD screen may not be bright enough. The user's physical comfort is again an issue. For example using a CRT screen for long periods can cause eyestrain.

The Task

The type of output required for a task has a major influence on the choice of output device. For example, if only text output is required then it would be pointless to use a 3D display. Equally if the output is a set of complex numerical information which the user needs to compare then audio output would normally be inappropriate.

As with input, the significance of errors may be influential. For example, where graphical information is being presented to the user via a screen and the consequences of the user misreading it are highly significant (e.g. in a medical application) then the screen resolution must be sufficient to allow the user to read it accurately.

Other aspects of the task may be important too. If the task requires that the user have their visual system fully occupied (e.g. a surgeon performing an operation) then this may be appropriate to provide auditory output.

Environmental Factors

Again the availability of space is important. If the device is to be used on the move then a CRT screen is unlikely to be suitable. Audio output is unlikely to be appropriate where there is a lot of background noise (e.g. on a factory floor). Obviously, devices that are to be used in dirty (e.g. on a farm) surroundings need to be sufficiently rugged.

Other Constraints

A similar range of other constraints may influence the choice of output devices as those identified for input devices.

Summary

This lecture has described a classification of both input and output devices. It has explained the roles of input and output and examined some of the factors involved in choosing interactive input and output devices.

Having completed it you should:

- Be aware of the range of input and output devices available and understand some of the differences and similarities between devices that enable them to be classified.
- Be able to discus how you would choose devices for a given application.

Tutorial Exercises

1. Make a list of all the types of interactive input and output devices that you can remember having used. Identify where you have used different sub-types of a device (e.g. two and three button mice). Classify the devices according to some scheme similar to those presented in the lecture.

2. One category of input device not covered in the lecture was scanners. Do some research on the Internet or using books and magazine to find out the main types of scanner. Where would you place them in the classification of input devices? What types of input are they particularly useful for?

3. A new device is to be designed for use by hospital doctors. The device will be small enough for the doctor to carry it with him or her at all times when they are on duty and give them remote access to patients details. It will allow the doctor to be contacted for advice about a patient and will allow the doctor to query details of a patient and their condition (e.g. blood pressure, heart rate) and current treatment. The doctor will be able to recommend changes in the patient's treatment e.g. dosage of drugs.

   Discuss the main problems in terms of HCI that would need to be taken into account in the design of such a device. Explain how you might attempt to solve the problems you identified and describe an outline design for the device explaining the main characteristics of its interface,

ANSWERS TO THE QUICK QUIZ QUESTIONS

1 (a) To enter data and to input or select a command
(b) Chord keyboards are small and so are suitable for portable devices. They can be operated with one hand and so are useful if only one hand is free for input.

Touch sensitive screens are a very intuitive input device, are robust and require no external device. All these factors make them suitable for use in public areas.

Tracker balls take up less room than mouse and can be integrated into a larger device. Both these factors make them suitable for use with notebook or laptop computers.

2 (a) the ways described in the lecture are:

- Goggles where a separate screen for each eye displays a slightly different mage;
- Glasses that alternately block images from entering the left and right eyes either by blanking the lens or switching the polarisation. A single-screen is used that displays alternating images.

(b) advantages of LCDs are that they are light, thin, require less power, are less susceptible to flicker.