Universal Design

Chapter Summary

10.1 Introduction

Universal design is the process of designing products so that they can be used by as many people as possible in as many situations as possible. In our case, this means particularly designing interactive systems that are usable by anyone, with any range of abilities, using any technology platform.

Two ways of achieving this -

- Designing systems to have built in redundancy
    - Example - an interface that has both visual and audio access to commands
- Designing systems to be compatible with assistive technologies
    - Example - a website that provides text alternatives for graphics so that it can be read using a screen reader

10.2 Universal Design Principles

Examples of design that attempt to take account of user diversity -

- The curb (the divider between the pavement/sidewalk and the road) may be lowered, to enable people who use wheelchairs to cross more easily. The paving near the curb may be of a different texture – with raised bumps or ridges – to enable people who cannot see to find the crossing point.
    - The parent with a child in a buggy, or the traveller with wheeled luggage, can cross the road more easily.
- Many modern buildings have automatic doors that open on approach.
    - The shopper with heavy bags, or the small child, can enter the building.

- Most lifts offer both visual and auditory notification of the floor being reached.
    - People are less likely to miss their floor because they weren't paying attention.

Universal design is primarily about trying to ensure that you do not exclude anyone through the design choices you make but, by giving thought to these issues, you will invariably make your design better for everyone.

In the late 1990s a group at North Carolina State University in the USA proposed seven general principles of universal design. These principles give us a framework in which to develop universal designs.

1. **Equitable use -** Wherever possible, access should be the same for all; where identical use is not possible, equivalent use should be supported. Where appropriate, security, privacy and safety provision should be available to all.
2. **Flexibility in use -** the design allows for a range of ability and preference, through choice of methods of use and adaptivity to the user's pace, precision and custom.
3. **Simple and Intuitive to use -** The design needs to support the user's expectations and accommodate different language and literacy skills. It should provide prompting and feedback as far as possible.
4. **Perceptible information -** Redundancy of presentation is important: information should be represented in different forms or modes (e.g. graphic, verbal, text, touch). Essential information should be emphasized and differentiated clearly from the peripheral content.
5. **Tolerance for error -** Systems should minimize damage caused by mistakes. Potential hazards should be shielded by warnings. Systems should fail safe from the user's perspective and users should be supported in tasks that require concentration.
6. **Low physical effort -** The physical design of the system should allow the user to maintain a natural posture with reasonable operating effort. Repetitive or sustained actions should be avoided.
7. **Size and space for approach and use -** The placement of the system should be such that it can be reached and used by any user regardless of hand size, body size, posture or mobility. Important elements should be in the line of sight for both seated and standing users.

These principles are closely related to the ones we met in Chapter 7, in the context of general user-centered design rules, indicating again that universal design is fundamentally good design for all.

10.3 Multimodal Interaction

10.3.1 Sound in the interface

Applications

- The addition of audio confirmation of modes, in the form of changes in key clicks, reduces errors.
- Video game experts tend to score less well when the sound is turned off than when it is on.
- The dual presentation of information through sound and vision enables access for users with visual and hearing impairments respectively.
- It also enables information to be accessed in poorly lit or noisy environments.
- Sound can convey transient information and does not take up screen space, making it potentially useful for mobile applications.

Speech in the interface

- Structure of speech
    - The English language is made up of 40 ***phonemes***, which are the atomic elements of speech. Each phoneme represents a distinct sound, there being 24 consonants and 16 vowel sounds.
    - The alteration in tone and quality of the phonemes is termed ***prosody*** and is used, in addition to the actual words, to convey a great deal of meaning and emotion within a sentence.
    - Owing to the manner in which sound is produced in the vocal tract, mouth and nose of the speaker, the limitation in response speed means that phonemes sound differently when preceded by different phonemes. This is termed ***co-articulation***. The resulting differences in sound can be used to construct a set of ***allophones***, which represent all the different sounds within the language.

- There are between 120 and 130 allophones which, in turn, can be formed into ***morphemes***, which represent the smallest unit of language that has meaning.
- We can't understand the meaning of sentences just by decomposing them : the syntax (structure) only serves as a standard foundation upon which the semantics (meaning) is based.

- Speech recognition
  - *Problems*
    - *Background noise can interfere with the input, masking or distorting the information.*
    - *Speakers can introduce redundant or meaningless noises into the information stream by repeating themselves, pausing or using 'continuation' noises such as 'ummm' and 'errr' to fill in gaps in their usual speech.*
    - *Variations between individuals also cause problems. New speakers present different inflections to the system, which then fails to perform as well.*
    - *Regional accents upset the trained response of the recognition system.*
    - *Everything from phonemes up can be different for different languages.*
  - Applications
    - When a user's hands are already occupied, such as in a factory, speech may prove to be the ideal input medium.
    - Speech input can be used in lightweight mobile situations since it does not require a cumbersome keyboard.
    - An alternative means of input for users with visual, physical and cognitive impairment.
    - Speech-based word processors are easily available and several computers use speech input as a marketing feature.
    - Telephone-based systems also use speech, but they face a more difficult task as they must be speaker independent.

        - Information systems for airline bookings are interactive. The system reflects back to the user its interpretation of the speech input, allowing the user to enter into a dialog to correct any errors.
    - Phonetic Typewriter
        - Uses a neural network that clusters similar sounds together.
        - Designed to produce typed output from speech input in Finnish (a phonetic language, one which is spelt as it sounds).
        - Trained on one particular speaker, and then generalizes to others (poor performance).
        - Relies on a large dictionary of minute variations to supplement its general transcription mechanism.
        - *Problem - most languages do not have a straightforward mapping between sound and text. Think of English words such as 'wait' and 'weight' or 'one' and 'won', for example.*

- Speech synthesis
    - *Problems*
        - *We are so used to hearing natural speech that we find it difficult to adjust to the monotonic, non-prosodic tones that synthesized speech can produce.*
        - *An effective automatic reader would need to be able to understand natural language, which is difficult. However, for 'canned' messages and responses, the prosody can be hand-coded, yielding much more acceptable speech.*
        - *Being transient, spoken output cannot be reviewed or browsed easily.*
        - *It is intrusive, requiring either an increase in noise in the office environment or the use of headphones.*
    - Applications
        - For users who are blind or partially sighted, synthesized speech offers an output medium which they can access.
        - Screen readers are software packages that read the contents of a computer screen, using synthesized speech. Modern screen readers read exactly what they find including icons, menus,

punctuation and controls. They also read events, such as dialog boxes opening.

    - HTML ‘alt’ tags should always be used for necessary graphics.
    - Text alternative menus and navigation controls should be provided.
    - Most read text across the page, so text arranged in columns can become garbled.
    - Links (instead of embedding in text) to the main sections should be provided in a clear location where they will be read horizontally, such as at the top of the page.
  - A communication tool to assist people with physical disabilities that affect their speech. Most communication tools of this type use predefined messages, enabling the user to select a message appropriate to the context quickly and easily.
  - Speech can also enhance applications where the user’s visual attention is focused elsewhere, such as warnings in aircraft cockpits and, more recently, in cars.

- Uninterpreted speech
  - Applications
    - Fixed pre-recorded messages can be used to supplement or replace visual information. Recordings have natural human prosody and pronunciation, although quality is sometimes low.
    - Segments of speech can be used together to construct messages, for example the announcements in many airports and railway stations.
    - Recordings of users’ speech can also be very useful, especially in collaborative applications, for example many readers will have used voicemail systems.
    - Recordings can be attached to other artifacts as audio annotations in order to communicate with others or to remind oneself at a later time. For example, audio annotations can be attached to Microsoft Word documents.

        - Digital signal-processing techniques can accelerate a recording while keeping the same pitch. Speech can be played back at up to twice the normal rate without any loss of comprehensibility. This can be used in a telephone help desk where a pre-recorded message asks the enquirer to state his problem. The problem can then be replayed at an accelerated rate to the operator, reducing the operator time per enquiry. The utility of such methods needs careful analysis, however. The operator may often begin to act on a message while it is still playing, hence reducing any gain from faster playback. Furthermore, reduced interactivity may lead to more misunderstandings, and the enquirer's waiting time may be increased.

Non-speech sound

Worked exercise
Think of a set of naturally occurring sounds to represent the operations in a standard drawing package (for example, draw, move, copy, delete, rotate).
Answer
This can exercise the imagination! Are there natural analogies? For example, does the physical action, say, of drawing have a sound associated with it? The sound of a pencil on paper may be appropriate but is it identifiable? Similarly, a photocopier whirring could represent the copy operation, and tearing paper delete. Rotate and move are more difficult since the physical operation is not associated with a sound. Perhaps direction and movement can be indicated by sounds becoming nearer or more distant?

- Auditory icons
    - Use natural sounds to represent different types of objects and actions in the interface.
    - The SonicFinder for the Macintosh was developed from these ideas, to enhance the interface through redundancy.
        - auditory icons are used to represent desktop objects and actions.
        - a folder is represented by a papery noise.

        - throwing something in the wastebasket is represented by the sound of smashing.
        - *Problem - Some objects and actions do not have obvious, naturally occurring sounds that identify them. For example, copying has no immediate analog sound and in the SonicFinder it is indicated by the sound of pouring a liquid into a receptacle, with the pitch rising to indicate the progress of the copying.*
        - A file arrives in a mailbox and, being a large file, it makes a weighty sound.
        - If it is a text file it makes a rustling noise, whereas a compiled program may make a metallic clang.
        - The sound can be muffled or clear, indicating whether the mailbox is hidden by other windows or not, while the direction of the sound would indicate the position of the mailbox icon on the screen.
        - If the sound then echoes, as it would in a large, empty room, the system load is low.
- Earcons
    - Devise synthetic sounds.
    - Earcons use structured combinations of notes, called motives, to represent actions and objects.
    - *Compound earcons* combine different motives to build up a specific action, for example combining the motives for 'create' and 'file'.
    - *Family earcons* represent compound earcons of similar types. As an example, operating system errors and syntax errors would be in the 'error' family.
    - Earcons can be hierarchically structured to represent menus.
    - *Problem - they require learning to associate with a specific task in the interface since there is an arbitrary mapping.*
    - People can learn to recognize earcons, and the most important element in distinguishing different sounds is timbre, the characteristic quality of the sound produced by different instruments and voices.
    - Little effect of musical ability : users were able to identify around 80% of earcons from hierarchically ordered sets of 30 or more, regardless of their musical background.

    - It is also possible to create compound earcons by playing sounds in parallel as well as serially.
- Natural sounds have been used to model environments such as a physics laboratory, called SharedARK (Shared Alternate Reality Kit) and a virtual soft drinks manufacturing plant, ARKola.

10.3.2 Touch in the interface (haptic interaction)

Advantages

- Touch is the only sense that can be used to both send and receive information.
- A primary source of information for users with visual impairments.
- A richer multi-modal experience for sighted users.

Cutaneous Perception (tactile sensations through the skin)

- Haptic devices based on vibration against the skin
- Braille displays are made up of a number of cells (typically between 20 and 80), each containing six or eight electronically controlled pins that move up and down to produce braille representations of characters displayed on the screen.
- Printed braille - six dots per cell
- Electronic braille
    - eight pins, with the extra two representing additional information about that cell, such as cursor position and character case.
    - benefit from two factors: a well-established tactile notation (braille) and a user group with expertise in using this notation.
- A graphical display will need more pins because of the required resolution, which raises the problem of fitting the necessary number of fast actuators (to move the pins) into a few cubic centimeters.

Kinesthetics (perception of movement and position)

- Haptic devices based on resistance or force feedback
- The force feedback device provides kinesthetic information back to the user, allowing him to feel resistance, textures, friction and so on.

- The PHANTOM range, from SensAble Technologies, provides three-dimensional force feedback, allowing users to touch virtual objects.
    - offers the functionality of the mouse
    - The user’s movement is monitored by optical sensors on the device.
    - These, together with models of the virtual objects, are used to calculate the forces applied back to the user.
    - The user can feel the outline and resistance of objects, their texture and position.
    - has potential application for simulations and training situations where touch is important, such as medicine
    - It can also be used to provide a haptic ‘image’ of an interface.

Problem

- At present, the hardware needed to support haptic interaction is prohibitively expensive for most users.

10.3.3 Handwriting recognition

Technology for handwriting recognition

Digitizing Tablet

- Free-flowing strokes made with a pen are transformed into a series of coordinates, approximately one every 1/50th of a second.
- Rapid movements produce widely spaced dots.
- Refined by incorporating a thin screen on top to display the information, producing electronic paper.
- Devices are small and portable enough.

Recognizing handwriting

Problems

- The variation between the handwriting of individuals is large.
- The handwriting of a single person varies from day to day, and evolves over the years.

- The equivalent of coarticulation (speech recognition) is also prevalent in handwriting, since different letters are written differently according to the preceding and successive ones.
- There are no systems in use today that are good at general cursive script recognition.
- If systems are tested on an untrained person, success is limited.

10.3.4 Gesture Recognition

Advantages

- Being able to control the computer with certain movements of the hand would be advantageous in many situations where there is no possibility of typing, or when other senses are fully occupied.
- It could also support communication for people who have hearing loss, if signing could be 'translated' into speech or vice versa.

Problems

- Like speech, gestures are user dependent, subject to variation and co-articulation.
- The technology for capturing gestures is expensive, using either computer vision or a special dataglove.
- The interpretation of the sampled data is very difficult, since segmenting the gestures causes problems.

Practical Applications

- A team from Toronto has produced a gesture recognition system that translates hand movements into synthesized speech, using five neural networks working in parallel to learn and then interpret different parts of the inputs.
- The Media Room at MIT has one wall that acts as a large screen, with smaller touchscreens on either side of the user, who sits in a central chair. The user can navigate through information using the touchscreens, or by joystick, or by voice. Gestures are incorporated by using a position-sensing cube attached to a wristband worn by the user. The "*put that there*" system uses this gestural

information coupled with speech recognition to allow the user to indicate what should be moved where by pointing at it.

10.4 Designing For Diversity

10.4.1 Designing for users with disabilities

- At least 10% of the population of every country has a disability that will affect interaction with computers.
- In many countries, legislation now demands that the workplace must be designed to be accessible or at least adaptable to all.
- The design of software and hardware should not unnecessarily restrict the job prospects of people with disabilities.

Visual impairment

- Today the standard interface is graphical (not text-based). Screen readers and braille output are far more restricted in interpreting the graphical interface, meaning that access to computers, and therefore work involving computers, has been reduced rather than expanded for visually impaired people.
- The use of sound
    - Speech, earcons and auditory icons have been used in interfaces for blind users.
    - Soundtrack is an early example of a word processor with an auditory interface, designed for users who are blind or partially sighted. The visual items in the display have been given auditory analogs, made up of tones, with synthesized speech also being used.
        - *Problem - it was a specialized system; it could not be used to augment commercially available software.*
    - Mathtalk is a system developed as part of a European project to create a mathematics workstation for blind people. It uses speech synthesis to speak formulae, and keyboard input to navigate and manipulate them.

    - Outspoken is a Macintosh application that uses synthetic speech to make other Macintosh applications available to visually impaired users.
    - *Problem - A common problem with this and other screen readers and talking browsers is the sheer amount of information represented. Browsing is difficult and all of the information must be held in the head of the user, putting a heavy load on memory.*
- The use of touch
    - Tactile interaction is already widely used in electronic braille displays, which represent what is on the screen through a dynamic braille output.
    - Force feedback devices also have the potential to improve accessibility to users with visual impairment, since elements in the interface can be touched, and edges, textures and behavior used to indicate objects and actions.
        - *Problem - objects must be rendered using specialist software in order for the devices to calculate the appropriate force to apply back to the user.*

Hearing impairment

- Email and instant messaging are great levellers and can be used equally by hearing and deaf users alike.
- Gesture recognition has also been proposed to enable translation of signing to speech or text, again to improve communication particularly with non-signers.
- Many multimedia presentations contain auditory narratives. If this is not supplemented by textual captions, this information is lost to deaf users.
- Captioning audio content, where there is not already a graphical or textual version, also has the advantage of making audio files easier and more efficient to index and search.

Physical impairment

- Many find the precision required in mouse control difficult.
- Speech input and output is an option for those without speech difficulties.
- An alternative is the eyegaze system, which tracks eye movements to control the cursor, or a keyboard driver that can be attached to the user’s head.

    - If the user is unable to control head movement, gesture and movement tracking can be used to allow the user control.
    - If the user has limited use of a keyboard, a predictive system, such as the Reactive keyboard, can help, by anticipating the commands that are being typed and offering them for execution.

Speech impairment

- Multimedia systems provide a number of tools for communication, including synthetic speech, text-based communication (slower and less effective) and conferencing systems.
- Predictive algorithms have been used to anticipate the words used and fill them in, to reduce the amount of typing required.
- Conventions can help to provide context, which is lost from face-to-face communication, for example the 'smilie' :-), to indicate a joke.
- Facilities to allow turn-taking protocols to be established also help natural communication.
- Speech synthesis also needs to be rapid to reflect natural conversational pace, so responses can be pre-programmed and selected using a single switch.

Dyslexia

- Users with cognitive disabilities such as dyslexia can find textual information difficult.
- In severe cases, speech input and output can alleviate the need to read and write and allow more accurate input and output.
- In cases where the problem is less severe, spelling correction facilities can help users.
    - *Problem - often conventional spelling correction programs are useless for dyslexic users since the programs do not recognize their idiosyncratic word construction methods.*
- Consistent navigation structure and clear signposting cues are also important to people with dyslexia.
- Color coding information can help in some cases and provision of graphical information to support textual can make the meaning of text easier to grasp.

Autism

- Autism affects a person's ability to communicate and interact with people around them and to make sense of their environment.
- Characterized by the triad of impairments :
    - Social interaction
    - Communication
    - Imagination
- Two main areas of interest :
    - communication
    - education.
- Computer-mediated communication and virtual environments have been suggested as possible ways of enabling people with autism to communicate more easily with others, by giving the user control over the situation.
- Some people with autism have difficulties with language and may be helped by graphical representations of information and graphical input to produce text and speech.
- Computers may also have a role to play in education of children with autism, particularly by enabling them to experience (through virtual environments and games) social situations and learn appropriate responses.

10.4.2 Designing for different age groups

Older people

- Factors that have led to an increase in older users :
    - people are living longer
    - more leisure time
    - more disposable income
    - older people have increased independence
- The proportion of disabilities increases with age : more than half of people over 65 have some kind of disability. Technology can provide support for failing vision, hearing, speech and mobility.

- New communication tools, such as email and instant messaging, can provide social interaction in cases where lack of mobility or speech difficulties reduce face-to-face possibilities.
- Mobile technologies can be used to provide memory aids where there is age-related memory loss.
- Some older users, while not averse to using technology, may lack familiarity with it and fear learning. They may find the terminology used in manuals and training books difficult to follow and alien.
- Interests and concerns may also be different from younger users.
- Thought needs to be given to sympathetic and relevant training aimed at the user's current knowledge and skills.

Children

- It is important to involve children in the design of interactive systems that are for their use, though this in itself can be challenging as they may not share the designer's vocabulary or be able to verbalize what they think.
    - Alison Druin's Cooperative Inquiry approach is based on contextual inquiry and participatory design.
        - Children are included in an intergenerational design team that focuses on understanding and analyzing context.
        - Team members, including children, use a range of sketching and note-taking techniques to record their observations.
        - Paper prototyping, using art tools familiar to children, enables both adults and children to participate in building and refining prototype designs on an equal footing.
- Younger children may have difficulty using a keyboard for instance, and may not have well-developed hand–eye coordination. Pen-based interfaces can be a useful alternative input device.
- Redundant displays, where information is presented through text, graphics and sound will also enhance their experience.

10.4.3 Designing for cultural differences

- Other than national cultural differences, factors such as age, gender, race, sexuality, class, religion and political persuasion, may all influence an individual's response to a system.
- Language
    - Localization of software - toolkits, with different language resource databases, facilitate the translation of menu items, error messages and other text into the local language.
    - Layouts and designs may reflect a language read from left to right and top to bottom, which will be unworkable with languages that do not follow this pattern.
- Cultural symbols
    - Symbols have different meanings in different cultures.
        - Ticks and crosses represent positive and negative respectively in some cultures, and are interchangeable in others.
        - The rainbow is a symbol of covenant with God in Judeo–Christian religions, of diversity in the gay community and of hope and peace in the cooperative movement.
        - We need to ensure that alternative meanings of symbols will not create problems or confusion for the user.
        - The study of the meaning of symbols is known as **semiotics** and is a worthwhile diversion for the student of universal design.
- Gestures
    - Use of gesture is quite common in video and animation and care must be taken to ensure that the gestures are not misinterpreted due to cultural differences.
    - As interactions begin to incorporate gestures in virtual reality and avatars, issues such as this will become even more significant.
- Use of color
    - Colors are often used in interfaces to reflect 'universal' conventions, such as red for danger and green for go.
        - As well as danger, red represents life (India), happiness (China) and royalty (France).

        - Green is a symbol of fertility (Egypt) and youth (China) as well as safety (Anglo-American).
    - The intended significance of particular colors can be supported and clarified through redundancy – providing the same information in another form as well.