3

The interaction

OVERVIEW

- Interaction models help us to understand what is going on in the interaction between user and system. They address the translations between what the user wants and what the system does.
- Ergonomics looks at the physical characteristics of the interaction and how these influence its effectiveness.
- The dialog between user and system is influenced by the style of the interface.
- The interaction takes place within a social and organizational context that affects both user and system.

3.1 INTRODUCTION

In the previous two chapters we have looked at the human and the computer respectively. However, in the context of this book, we are not concerned with them in isolation. We are interested in how the human user uses the computer as a tool to perform, simplify or support a task. In order to do this the user must communicate his requirements to the computer.

There are a number of ways in which the user can communicate with the system. At one extreme is batch input, in which the user provides all the information to the computer at once and leaves the machine to perform the task. This approach does involve an interaction between the user and computer but does not support many tasks well. At the other extreme are highly interactive input devices and paradigms, such as *direct manipulation* (see Chapter 4) and the applications of *virtual reality* (Chapter 20). Here the user is constantly providing instruction and receiving feedback. These are the types of interactive system we are considering.

In this chapter, we consider the communication between user and system: the *interaction*. We will look at some models of interaction that enable us to identify and evaluate components of the interaction, and at the physical, social and organizational issues that provide the context for it. We will also survey some of the different styles of interaction that are used and consider how well they support the user.

3.2 MODELS OF INTERACTION

In previous chapters we have seen the usefulness of models to help us to understand complex behavior and complex systems. Interaction involves at least two participants: the user and the system. Both are complex, as we have seen, and are very different from each other in the way that they communicate and view the domain and the task. The interface must therefore effectively translate between them to allow the interaction to be successful. This translation can fail at a number of points and for a number of reasons. The use of models of interaction can help us to understand exactly what is going on in the interaction and identify the likely root of difficulties. They also provide us with a framework to compare different interaction styles and to consider interaction problems.

We begin by considering the most influential model of interaction, Norman's *execution–evaluation cycle*; then we look at another model which extends the ideas of Norman's cycle. Both of these models describe the interaction in terms of the goals and actions of the user. We will therefore briefly discuss the terminology used and the assumptions inherent in the models, before describing the models themselves.

3.2.1 The terms of interaction

Traditionally, the purpose of an interactive system is to aid a user in accomplishing *goals* from some application *domain*. (Later in this book we will look at alternative interactions but this model holds for many work-oriented applications.) A domain defines an area of expertise and knowledge in some real-world activity. Some examples of domains are graphic design, authoring and process control in a factory. A domain consists of concepts that highlight its important aspects. In a graphic design domain, some of the important concepts are geometric shapes, a drawing surface and a drawing utensil. *Tasks* are operations to manipulate the concepts of a domain. A *goal* is the desired output from a performed task. For example, one task within the graphic design domain is the construction of a specific geometric shape with particular attributes on the drawing surface. A related goal would be to produce a solid red triangle centered on the canvas. An *intention* is a specific action required to meet the goal.

Task analysis involves the identification of the problem space (which we discussed in Chapter 1) for the user of an interactive system in terms of the domain, goals, intentions and tasks. We can use our knowledge of tasks and goals to assess the interactive system that is designed to support them. We discuss task analysis in detail in Chapter 15. The concepts used in the design of the system and the description of the user are separate, and so we can refer to them as distinct components, called the *System* and the *User*, respectively. The *System* and *User* are each described by means of a language that can express concepts relevant in the domain of the application. The *System*'s language we will refer to as the *core language* and the *User*'s language we will refer to as the *task language*. The core language describes computational attributes of the domain relevant to the *System* state, whereas the task language describes psychological attributes of the domain relevant to the *User* state.

The system is assumed to be some computerized application, in the context of this book, but the models apply equally to non-computer applications. It is also a common assumption that by distinguishing between user and system we are restricted to single-user applications. This is not the case. However, the emphasis is on the view of the interaction from a single user's perspective. From this point of view, other users, such as those in a multi-party conferencing system, form part of the system.

3.2.2 The execution–evaluation cycle

Norman's model of interaction is perhaps the most influential in Human–Computer Interaction, possibly because of its closeness to our intuitive understanding of the interaction between human user and computer [265]. The user formulates a plan of action, which is then executed at the computer interface. When the plan, or part of the plan, has been executed, the user observes the computer interface to evaluate the result of the executed plan, and to determine further actions.

The interactive cycle can be divided into two major phases: execution and evaluation. These can then be subdivided into further stages, seven in all. The stages in Norman's model of interaction are as follows:

1. Establishing the goal.
2. Forming the intention.
3. Specifying the action sequence.
4. Executing the action.
5. Perceiving the system state.
6. Interpreting the system state.
7. Evaluating the system state with respect to the goals and intentions.

Each stage is, of course, an activity of the user. First the user forms a goal. This is the user's notion of what needs to be done and is framed in terms of the domain, in the task language. It is liable to be imprecise and therefore needs to be translated into the more specific intention, and the actual actions that will reach the goal, before it can be executed by the user. The user perceives the new state of the system, after execution of the action sequence, and interprets it in terms of his expectations. If the system state reflects the user's goal then the computer has done what he wanted and the interaction has been successful; otherwise the user must formulate a new goal and repeat the cycle.

Norman uses a simple example of switching on a light to illustrate this cycle. Imagine you are sitting reading as evening falls. You decide you need more light; that is you establish the goal to get more light. From there you form an intention to switch on the desk lamp, and you specify the actions required, to reach over and press the lamp switch. If someone else is closer the intention may be different – you may ask them to switch on the light for you. Your goal is the same but the intention and actions are different. When you have executed the action you perceive the result, either the light is on or it isn't and you interpret this, based on your knowledge of the world. For example, if the light does not come on you may interpret this as indicating the bulb has blown or the lamp is not plugged into the mains, and you will formulate new goals to deal with this. If the light does come on, you will evaluate the new state according to the original goals – is there now enough light? If so, the cycle is complete. If not, you may formulate a new intention to switch on the main ceiling light as well.

Norman uses this model of interaction to demonstrate why some interfaces cause problems to their users. He describes these in terms of the *gulfs of execution* and the *gulfs of evaluation*. As we noted earlier, the user and the system do not use the same terms to describe the domain and goals – remember that we called the language of the system the *core language* and the language of the user the *task language*. The gulf of execution is the difference between the user's formulation of the actions to reach the goal and the actions allowed by the system. If the actions allowed by the system correspond to those intended by the user, the interaction will be effective. The interface should therefore aim to reduce this gulf.

The gulf of evaluation is the distance between the physical presentation of the system state and the expectation of the user. If the user can readily evaluate the presentation in terms of his goal, the gulf of evaluation is small. The more effort that is required on the part of the user to interpret the presentation, the less effective the interaction.

Human error – slips and mistakes

Human errors are often classified into *slips* and *mistakes*. We can distinguish these using Norman's gulf of execution.

If you understand a system well you may know exactly what to do to satisfy your goals – you have formulated the correct action. However, perhaps you mistype or you accidentally press the mouse button at the wrong time. These are called *slips*; you have formulated the right action, but fail to execute that action correctly.

However, if you don't know the system well you may not even formulate the right goal. For example, you may think that the magnifying glass icon is the 'find' function, but in fact it is to magnify the text. This is called a *mistake*.

If we discover that an interface is leading to errors it is important to understand whether they are slips or mistakes. Slips may be corrected by, for instance, better screen design, perhaps putting more space between buttons. However, mistakes need users to have a better understanding of the systems, so will require far more radical redesign or improved training, perhaps a totally different metaphor for use.

Norman's model is a useful means of understanding the interaction, in a way that is clear and intuitive. It allows other, more detailed, empirical and analytic work to be placed within a common framework. However, it only considers the system as far as the interface. It concentrates wholly on the user's view of the interaction. It does not attempt to deal with the system's communication through the interface. An extension of Norman's model, proposed by Abowd and Beale, addresses this problem [3]. This is described in the next section.

3.2.3 The interaction framework

The interaction framework attempts a more realistic description of interaction by including the system explicitly, and breaks it into four main components, as shown in Figure 3.1. The nodes represent the four major components in an interactive system – the *System*, the *User*, the *Input* and the *Output*. Each component has its own language. In addition to the *User*'s task language and the *System*'s core language, which we have already introduced, there are languages for both the *Input* and *Output* components. *Input* and *Output* together form the *Interface*.

As the interface sits between the *User* and the *System*, there are four steps in the interactive cycle, each corresponding to a translation from one component to another, as shown by the labeled arcs in Figure 3.2. The *User* begins the interactive cycle with the formulation of a goal and a task to achieve that goal. The only way the user can manipulate the machine is through the *Input*, and so the task must be articulated within the input language. The input language is translated into the core

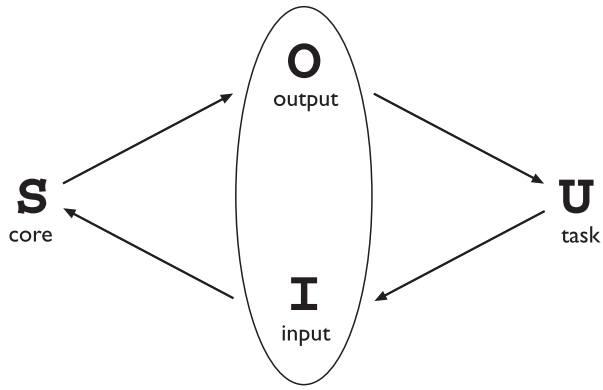


Figure 3.1 The general interaction framework

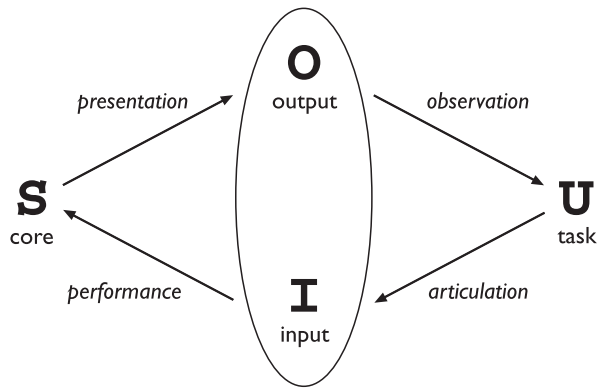


Figure 3.2 Translations between components

language as operations to be performed by the *System*. The *System* then transforms itself as described by the operations; the execution phase of the cycle is complete and the evaluation phase now begins. The *System* is in a new state, which must now be communicated to the *User*. The current values of system attributes are rendered as concepts or features of the *Output*. It is then up to the *User* to observe the *Output* and assess the results of the interaction relative to the original goal, ending the evaluation phase and, hence, the interactive cycle. There are four main translations involved in the interaction: articulation, performance, presentation and observation.

The *User*'s formulation of the desired task to achieve some goal needs to be *articulated* in the input language. The tasks are responses of the *User* and they need to be translated to stimuli for the *Input*. As pointed out above, this articulation is judged in terms of the coverage from tasks to input and the relative ease with which the translation can be accomplished. The task is phrased in terms of certain psychological attributes that highlight the important features of the domain for the *User*. If these psychological attributes map clearly onto the input language, then articulation of the task will be made much simpler. An example of a poor mapping, as pointed

out by Norman, is a large room with overhead lighting controlled by a bank of switches. It is often desirable to control the lighting so that only one section of the room is lit. We are then faced with the puzzle of determining which switch controls which lights. The result is usually repeated trials and frustration. This arises from the difficulty of articulating a goal (for example, 'Turn on the lights in the front of the room') in an input language that consists of a linear row of switches, which may or may not be oriented to reflect the room layout.

Conversely, an example of a good mapping is in virtual reality systems, where input devices such as datagloves are specifically geared towards easing articulation by making the user's psychological notion of gesturing an act that can be directly realized at the interface. Direct manipulation interfaces, such as those found on common desktop operating systems like the Macintosh and Windows, make the articulation of some file handling commands easier. On the other hand, some tasks, such as repetitive file renaming or launching a program whose icon is not visible, are not at all easy to articulate with such an interface.

At the next stage, the responses of the *Input* are translated to stimuli for the *System*. Of interest in assessing this translation is whether the translated input language can reach as many states of the *System* as is possible using the *System* stimuli directly. For example, the remote control units for some compact disc players do not allow the user to turn the power off on the player unit; hence the off state of the player cannot be reached using the remote control's input language. On the panel of the compact disc player, however, there is usually a button that controls the power. The ease with which this translation from *Input* to *System* takes place is of less importance because the effort is not expended by the user. However, there can be a real effort expended by the designer and programmer. In this case, the ease of the translation is viewed in terms of the cost of implementation.

Once a state transition has occurred within the *System*, the execution phase of the interaction is complete and the evaluation phase begins. The new state of the *System* must be communicated to the *User*, and this begins by translating the *System* responses to the transition into stimuli for the *Output* component. This presentation translation must preserve the relevant system attributes from the domain in the limited expressiveness of the output devices. The ability to capture the domain concepts of the *System* within the *Output* is a question of expressiveness for this translation.

For example, while writing a paper with some word-processing package, it is necessary at times to see both the immediate surrounding text where one is currently composing, say, the current paragraph, and a wider context within the whole paper that cannot be easily displayed on one screen (for example, the current chapter).

Ultimately, the user must interpret the output to evaluate what has happened. The response from the *Output* is translated to stimuli for the *User* which trigger assessment. The observation translation will address the ease and coverage of this final translation. For example, it is difficult to tell the time accurately on an unmarked analog clock, especially if it is not oriented properly. It is difficult in a command line interface to determine the result of copying and moving files in a hierarchical file system. Developing a website using a markup language like HTML would be virtually impossible without being able to preview the output through a browser.

Assessing overall interaction

The interaction framework is presented as a means to judge the overall usability of an entire interactive system. In reality, all of the analysis that is suggested by the framework is dependent on the current task (or set of tasks) in which the *User* is engaged. This is not surprising since it is only in attempting to perform a particular task within some domain that we are able to determine if the tools we use are adequate. For example, different text editors are better at different things. For a particular editing task, one can choose the text editor best suited for interaction relative to the task. The best editor, if we are forced to choose only one, is the one that best suits the tasks most frequently performed. Therefore, it is not too disappointing that we cannot extend the interaction analysis beyond the scope of a particular task.

DESIGN FOCUS

Video recorder

A simple example of programming a VCR from a remote control shows that all four translations in the interaction cycle can affect the overall interaction. Ineffective interaction is indicated by the user not being sure the VCR is set to record properly. This could be because the user has pressed the keys on the remote control unit in the wrong order; this can be classified as an articulatory problem. Or maybe the VCR is able to record on any channel but the remote control lacks the ability to select channels, indicating a coverage problem for the performance translation. It may be the case that the VCR display panel does not indicate that the program has been set, a presentation problem. Or maybe the user does not interpret the feedback properly, an observational error. Any one or more of these deficiencies would give rise to ineffective interaction.

3.3 FRAMEWORKS AND HCI

As well as providing a means of discussing the details of a particular interaction, frameworks provide a basis for discussing other issues that relate to the interaction. The ACM SIGCHI Curriculum Development Group presents a framework similar to that presented here, and uses it to place different areas that relate to HCI [9].

In Figure 3.3 these aspects are shown as they relate to the interaction framework. In particular, the field of *ergonomics* addresses issues on the user side of the interface, covering both input and output, as well as the user's immediate context. Dialog design and interface styles can be placed particularly along the input branch of the framework, addressing both articulation and performance. However, dialog is most usually associated with the computer and so is biased to that side of the framework.

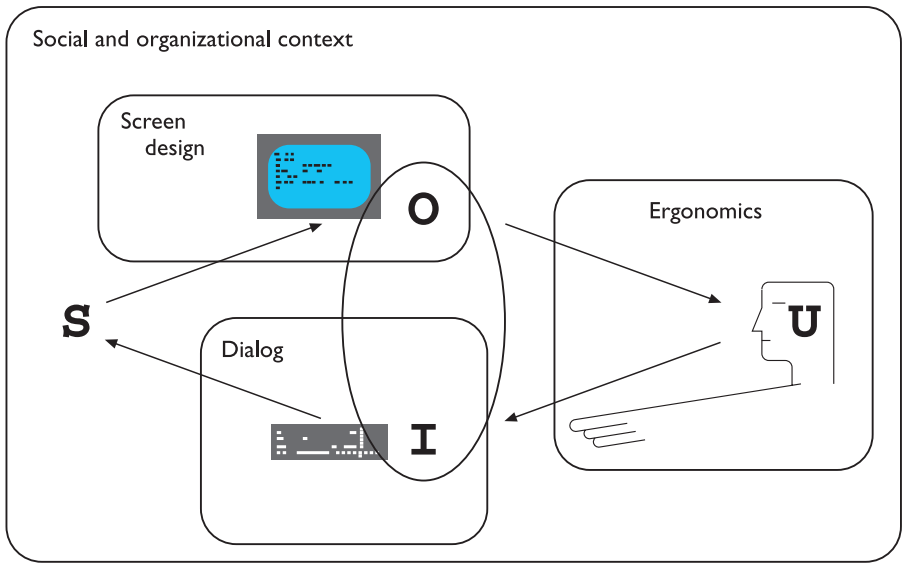


Figure 3.3 A framework for human–computer interaction. Adapted from ACM SIGCHI Curriculum Development Group [9]

Presentation and screen design relates to the output branch of the framework. The entire framework can be placed within a social and organizational context that also affects the interaction. Each of these areas has important implications for the design of interactive systems and the performance of the user. We will discuss these in brief in the following sections, with the exception of screen design which we will save until Chapter 5.

3.4 ERGONOMICS

Ergonomics (or human factors) is traditionally the study of the physical characteristics of the interaction: how the controls are designed, the physical environment in which the interaction takes place, and the layout and physical qualities of the screen. A primary focus is on user performance and how the interface enhances or detracts from this. In seeking to evaluate these aspects of the interaction, ergonomics will certainly also touch upon human psychology and system constraints. It is a large and established field, which is closely related to but distinct from HCI, and full coverage would demand a book in its own right. Here we consider a few of the issues addressed by ergonomics as an introduction to the field. We will briefly look at the arrangement of controls and displays, the physical environment, health issues and the use of color. These are by no means exhaustive and are intended only to give an

indication of the types of issues and problems addressed by ergonomics. For more information on ergonomic issues the reader is referred to the recommended reading list at the end of the chapter.

3.4.1 Arrangement of controls and displays

In Chapter 1 we considered perceptual and cognitive issues that affect the way we present information on a screen and provide control mechanisms to the user. In addition to these cognitive aspects of design, physical aspects are also important. Sets of controls and parts of the display should be grouped logically to allow rapid access by the user (more on this in Chapter 5). This may not seem so important when we are considering a single user of a spreadsheet on a PC, but it becomes vital when we turn to safety-critical applications such as plant control, aviation and air traffic control. In each of these contexts, users are under pressure and are faced with a huge range of displays and controls. Here it is crucial that the physical layout of these be appropriate. Indeed, returning to the less critical PC application, inappropriate placement of controls and displays can lead to inefficiency and frustration. For example, on one particular electronic newsreader, used by one of the authors, the command key to read articles from a newsgroup (y) is directly beside the command key to unsubscribe from a newsgroup (u) on the keyboard. This poor design frequently leads to inadvertent removal of newsgroups. Although this is recoverable it wastes time and is annoying to the user. We saw similar examples in the Introduction to this book including the MacOS X dock. We can therefore see that appropriate layout is important in all applications.

We have already touched on the importance of grouping controls together logically (and keeping opposing controls separate). The exact organization that this will suggest will depend on the domain and the application, but possible organizations include the following:

functional controls and displays are organized so that those that are functionally related are placed together;

sequential controls and displays are organized to reflect the order of their use in a typical interaction (this may be especially appropriate in domains where a particular task sequence is enforced, such as aviation);

frequency controls and displays are organized according to how frequently they are used, with the most commonly used controls being the most easily accessible.

In addition to the organization of the controls and displays in relation to each other, the entire system interface must be arranged appropriately in relation to the user's position. So, for example, the user should be able to reach all controls necessary and view all displays without excessive body movement. Critical displays should be at eye level. Lighting should be arranged to avoid glare and reflection distorting displays. Controls should be spaced to provide adequate room for the user to manoeuvre.

DESIGN FOCUS

Industrial interfaces

The interfaces to office systems have changed dramatically since the 1980s. However, some care is needed in transferring the idioms of office-based systems into the industrial domain. Office information is primarily textual and slow varying, whereas industrial interfaces may require the rapid assimilation of multiple numeric displays, each of which is varying in response to the environment. Furthermore, the environmental conditions may rule out certain interaction styles (for example, the oil-soaked mouse). Consequently, industrial interfaces raise some additional design issues rarely encountered in the office.

Glass interfaces vs. dials and knobs

The traditional machine interface consists of dials and knobs directly wired or piped to the equipment. Increasingly, some or all of the controls are replaced with a glass interface, a computer screen through which the equipment is monitored and controlled. Many of the issues are similar for the two kinds of interface, but glass interfaces do have some special advantages and problems. For a complex system, a glass interface can be both cheaper and more flexible, and it is easy to show the same information in multiple forms (Figure 3.4). For example, a data value might be given both in a precise numeric field and also in a quick to assimilate graphical form. In addition, the same information can be shown on several screens. However, the information is not located in physical space and so vital clues to context are missing – it is easy to get lost navigating complex menu systems. Also, limited display resolution often means that an electronic representation of a dial is harder to read than its physical counterpart; in some circumstances both may be necessary, as is the case on the flight deck of a modern aircraft.

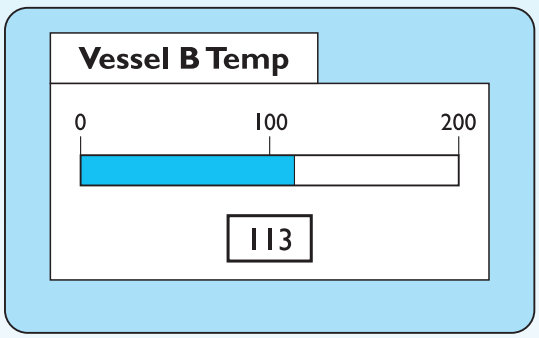


Figure 3.4 Multiple representations of the same information

Indirect manipulation

The phrase 'direct manipulation' dominates office system design (Figure 3.5). There are arguments about its meaning and appropriateness even there, but it is certainly dependent on the user being in primary control of the changes in the interface. The autonomous nature of industrial processes makes this an inappropriate model. In a direct manipulation system, the user interacts with an artificial world inside the computer (for example, the electronic desktop).

In contrast, an industrial interface is merely an intermediary between the operator and the real world. One implication of this indirectness is that the interface must provide feedback at two levels

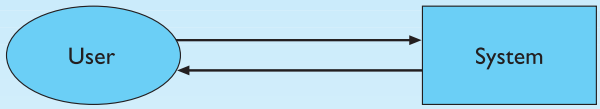


Figure 3.5 Office system – direct manipulation

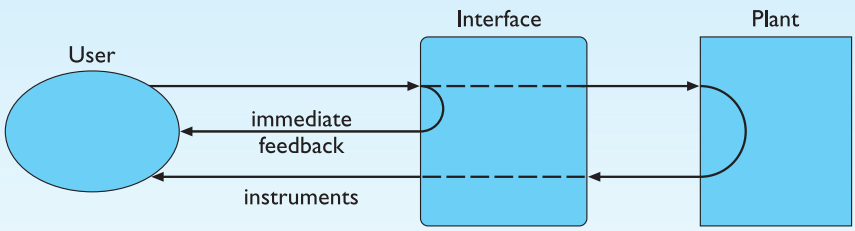


Figure 3.6 Indirect manipulation – two kinds of feedback

(Figure 3.6). At one level, the user must receive immediate feedback, generated by the interface, that keystrokes and other actions have been received. In addition, the user's actions will have some effect on the equipment controlled by the interface and adequate monitoring must be provided for this.

The indirectness also causes problems with simple monitoring tasks. Delays due to periodic sampling, slow communication and digital processing often mean that the data displayed are somewhat out of date. If the operator is not aware of these delays, diagnoses of system state may be wrong. These problems are compounded if the interface produces summary information displays. If the data comprising such a display are of different timeliness the result may be misleading.

3.4.2 The physical environment of the interaction

As well as addressing physical issues in the layout and arrangement of the machine interface, ergonomics is concerned with the design of the work environment itself. Where will the system be used? By whom will it be used? Will users be sitting, standing or moving about? Again, this will depend largely on the domain and will be more critical in specific control and operational settings than in general computer use. However, the physical environment in which the system is used may influence how well it is accepted and even the health and safety of its users. It should therefore be considered in all design.

The first consideration here is the size of the users. Obviously this is going to vary considerably. However, in any system the smallest user should be able to reach all the controls (this may include a user in a wheelchair), and the largest user should not be cramped in the environment.

In particular, all users should be comfortably able to see critical displays. For long periods of use, the user should be seated for comfort and stability. Seating should provide back support. If required to stand, the user should have room to move around in order to reach all the controls.

3.4.3 Health issues

Perhaps we do not immediately think of computer use as a hazardous activity but we should bear in mind possible consequences of our designs on the health and safety of users. Leaving aside the obvious safety risks of poorly designed safety-critical systems (aircraft crashing, nuclear plant leaks and worse), there are a number of factors that may affect the use of more general computers. Again these are factors in the physical environment that directly affect the quality of the interaction and the user's performance:

Physical position As we noted in the previous section, users should be able to reach all controls comfortably and see all displays. Users should not be expected to stand for long periods and, if sitting, should be provided with back support. If a particular position for a part of the body is to be adopted for long periods (for example, in typing) support should be provided to allow rest.

Temperature Although most users can adapt to slight changes in temperature without adverse effect, extremes of hot or cold will affect performance and, in excessive cases, health. Experimental studies show that performance deteriorates at high or low temperatures, with users being unable to concentrate efficiently.

Lighting The lighting level will again depend on the work environment. However, adequate lighting should be provided to allow users to see the computer screen without discomfort or eyestrain. The light source should also be positioned to avoid glare affecting the display.

Noise Excessive noise can be harmful to health, causing the user pain, and in acute cases, loss of hearing. Noise levels should be maintained at a comfortable level in the work environment. This does not necessarily mean no noise at all. Noise can be a stimulus to users and can provide needed confirmation of system activity.

Time The time users spend using the system should also be controlled. As we saw in the previous chapter, it has been suggested that excessive use of CRT displays can be harmful to users, particularly pregnant women.

3.4.4 The use of color

In this section we have concentrated on the ergonomics of physical characteristics of systems, including the physical environment in which they are used. However, ergonomics has a close relationship to human psychology in that it is also concerned with the perceptual limitations of humans. For example, the use of color in displays is an ergonomics issue. As we saw in Chapter 1, the visual system has some limitations with regard to color, including the number of colors that are distinguishable and the relatively low blue acuity. We also saw that a relatively high proportion of the population suffers from a deficiency in color vision. Each of these psychological phenomena leads to ergonomic guidelines; some examples are discussed below.

Colors used in the display should be as distinct as possible and the distinction should not be affected by changes in contrast. Blue should not be used to display critical information. If color is used as an indicator it should not be the only cue: additional coding information should be included.

The colors used should also correspond to common conventions and user expectations. Red, green and yellow are colors frequently associated with stop, go and standby respectively. Therefore, red may be used to indicate emergency and alarms; green, normal activity; and yellow, standby and auxiliary function. These conventions should not be violated without very good cause.

However, we should remember that color conventions are culturally determined. For example, red is associated with danger and warnings in most western cultures, but in China it symbolizes happiness and good fortune. The color of mourning is black in some cultures and white in others. Awareness of the cultural associations of color is particularly important in designing systems and websites for a global market. We will return to these issues in more detail in Chapter 10.

3.4.5 Ergonomics and HCI

Ergonomics is a huge area, which is distinct from HCI but sits alongside it. Its contribution to HCI is in determining constraints on the way we design systems and suggesting detailed and specific guidelines and standards. Ergonomic factors are in general well established and understood and are therefore used as the basis for standardizing hardware designs. This issue is discussed further in Chapter 7.

3.5 INTERACTION STYLES

Interaction can be seen as a dialog between the computer and the user. The choice of interface style can have a profound effect on the nature of this dialog. Dialog design is discussed in detail in Chapter 16. Here we introduce the most common interface styles and note the different effects these have on the interaction. There are a number of common interface styles including

- command line interface
- menus
- natural language
- question/answer and query dialog
- form-fills and spreadsheets
- WIMP
- point and click
- three-dimensional interfaces.

As the WIMP interface is the most common and complex, we will discuss each of its elements in greater detail in Section 3.6.

```
sable.soc.staffs.ac.uk> javac HelloWorldApp
javac: invalid argument: HelloWorldApp
use: javac [-g][-O][-classpath path][-d dir] file.java…
sable.soc.staffs.ac.uk> javac HelloWorldApp.java
sable.soc.staffs.ac.uk> java HelloWorldApp
Hello world!!
sable.soc.staffs.ac.uk>
```

Figure 3.7 Command line interface

3.5.1 Command line interface

The command line interface (Figure 3.7) was the first interactive dialog style to be commonly used and, in spite of the availability of menu-driven interfaces, it is still widely used. It provides a means of expressing instructions to the computer directly, using function keys, single characters, abbreviations or whole-word commands. In some systems the command line is the only way of communicating with the system, especially for remote access using *telnet*. More commonly today it is supplementary to menu-based interfaces, providing accelerated access to the system's functionality for experienced users.

Command line interfaces are powerful in that they offer direct access to system functionality (as opposed to the hierarchical nature of menus), and can be combined to apply a number of tools to the same data. They are also flexible: the command often has a number of options or parameters that will vary its behavior in some way, and it can be applied to many objects at once, making it useful for repetitive tasks. However, this flexibility and power brings with it difficulty in use and learning. Commands must be remembered, as no cue is provided in the command line to indicate which command is needed. They are therefore better for expert users than for novices. This problem can be alleviated a little by using consistent and meaningful commands and abbreviations. The commands used should be terms within the vocabulary of the user rather than the technician. Unfortunately, commands are often obscure and vary across systems, causing confusion to the user and increasing the overhead of learning.

3.5.2 Menus

In a menu-driven interface, the set of options available to the user is displayed on the screen, and selected using the mouse, or numeric or alphabetic keys. Since the options are visible they are less demanding of the user, relying on recognition rather than recall. However, menu options still need to be meaningful and logically grouped to aid recognition. Often menus are hierarchically ordered and the option required is not available at the top layer of the hierarchy. The grouping

```
PAYMENT DETAILS          P3-7

please select payment method:
  1. cash
  2. check
  3. credit card
  4. invoice

  9. abort transaction
```

Figure 3.8 Menu-driven interface

and naming of menu options then provides the only cue for the user to find the required option. Such systems either can be purely text based, with the menu options being presented as numbered choices (see Figure 3.8), or may have a graphical component in which the menu appears within a rectangular box and choices are made, perhaps by typing the initial letter of the desired selection, or by entering the associated number, or by moving around the menu with the arrow keys. This is a restricted form of a full WIMP system, described in more detail shortly.

3.5.3 Natural language

Perhaps the most attractive means of communicating with computers, at least at first glance, is by natural language. Users, unable to remember a command or lost in a hierarchy of menus, may long for the computer that is able to understand instructions expressed in everyday words! Natural language understanding, both of speech and written input, is the subject of much interest and research. Unfortunately, however, the ambiguity of natural language makes it very difficult for a machine to understand. Language is ambiguous at a number of levels. First, the syntax, or structure, of a phrase may not be clear. If we are given the sentence

```
The boy hit the dog with the stick
```

we cannot be sure whether the boy is using the stick to hit the dog or whether the dog is holding the stick when it is hit.

Even if a sentence's structure is clear, we may find ambiguity in the meaning of the words used. For example, the word 'pitch' may refer to a sports field, a throw, a waterproofing substance or even, colloquially, a territory. We often rely on the context and our general knowledge to sort out these ambiguities. This information is difficult to provide to the machine. To complicate matters more, the use of pronouns and relative terms adds further ambiguity.

Given these problems, it seems unlikely that a general natural language interface will be available for some time. However, systems can be built to understand restricted subsets of a language. For a known and constrained domain, the system can be provided with sufficient information to disambiguate terms. It is important in interfaces which use natural language in this restricted form that the user is aware of the limitations of the system and does not expect too much understanding.

The use of natural language in restricted domains is relatively successful, but it is debatable whether this can really be called natural language. The user still has to learn which phrases the computer understands and may become frustrated if too much is expected. However, it is also not clear how useful a general natural language interface would be. Language is by nature vague and imprecise: this gives it its flexibility and allows creativity in expression. Computers, on the other hand, require precise instructions. Given a free rein, would we be able to describe our requirements precisely enough to guarantee a particular response? And, if we could, would the language we used turn out to be a restricted subset of natural language anyway?

3.5.4 Question/answer and query dialog

Question and answer dialog is a simple mechanism for providing input to an application in a specific domain. The user is asked a series of questions (mainly with yes/no responses, multiple choice, or codes) and so is led through the interaction step by step. An example of this would be web questionnaires.

These interfaces are easy to learn and use, but are limited in functionality and power. As such, they are appropriate for restricted domains (particularly information systems) and for novice or casual users.

Query languages, on the other hand, are used to construct queries to retrieve information from a database. They use natural-language-style phrases, but in fact require specific syntax, as well as knowledge of the database structure. Queries usually require the user to specify an attribute or attributes for which to search the database, as well as the attributes of interest to be displayed. This is straightforward where there is a single attribute, but becomes complex when multiple attributes are involved, particularly if the user is interested in attribute A or attribute B, or attribute A and not attribute B, or where values of attributes are to be compared. Most query languages do not provide direct confirmation of what was requested, so that the only validation the user has is the result of the search. The effective use of query languages therefore requires some experience. A specialized example is the web search engine.

3.5.5 Form-fills and spreadsheets

Form-filling interfaces are used primarily for data entry but can also be useful in data retrieval applications. The user is presented with a display resembling a paper

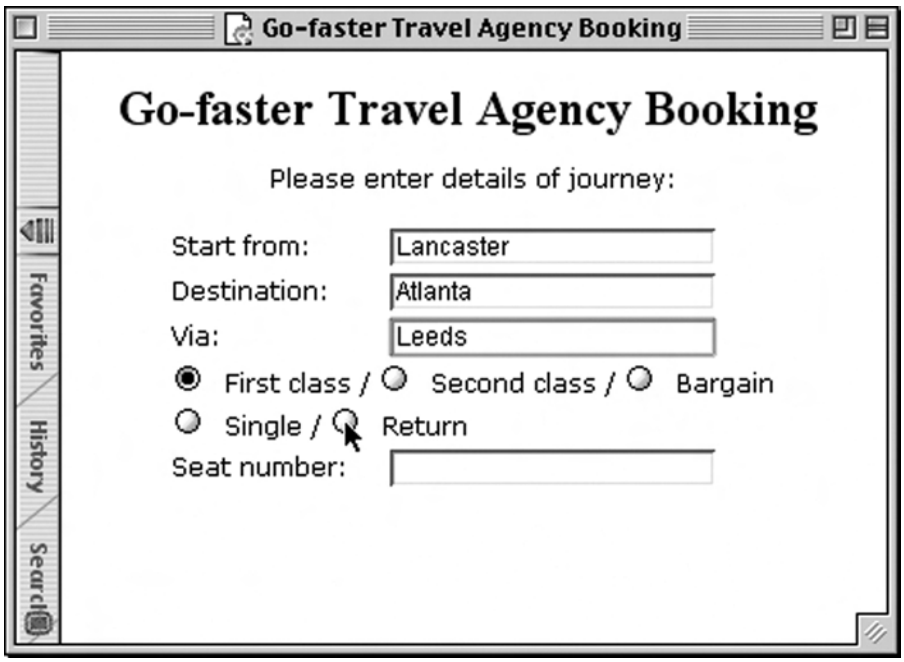


Figure 3.9 A typical form-filling interface. Screen shot frame reprinted by permission from Microsoft Corporation

form, with slots to fill in (see Figure 3.9). Often the form display is based upon an actual form with which the user is familiar, which makes the interface easier to use. The user works through the form, filling in appropriate values. The data are then entered into the application in the correct place. Most form-filling interfaces allow easy movement around the form and allow some fields to be left blank. They also require correction facilities, as users may change their minds or make a mistake about the value that belongs in each field. The dialog style is useful primarily for data entry applications and, as it is easy to learn and use, for novice users. However, assuming a design that allows flexible entry, form filling is also appropriate for expert users.

Spreadsheets are a sophisticated variation of form filling. The spreadsheet comprises a grid of cells, each of which can contain a value or a formula (see Figure 3.10). The formula can involve the values of other cells (for example, the total of all cells in this column). The user can enter and alter values and formulae in any order and the system will maintain consistency amongst the values displayed, ensuring that all formulae are obeyed. The user can therefore manipulate values to see the effects of changing different parameters. Spreadsheets are an attractive medium for interaction: the user is free to manipulate values at will and the distinction between input and output is blurred, making the interface more flexible and natural.

	Pooches Pet Emporium				
Date	*Description*	*Dog*	*Income*	*Outgoings*	*Balance*
9/2/02	Fees – Mr C. Brown	Snoopy	96.37		96.37
10/2/02	Rubber bones			36.26	60.11
10/2/02	Fees – Mrs E. R. Windsor	7 corgis	1006.45		1066.56
12/2/02	Special order: 7 red carpets			47.28	992.28
16/2/02	Fees – Master T. Tin	Snowy	32.98		1025.26
17/2/02	Beefy Bruno's Bonemeal			243.47	781.79
21/2/02	Fees – Mr F. Flintstone	Dino	21.95		803.74
21/2/02	Special order: 1 Brontosaurus bone			6.47	797.27
28/2/02	Wages – Mr S. H. Ovelit			489.46	307.81

Figure 3.10 A typical spreadsheet

3.5.6 The WIMP interface

Currently many common environments for interactive computing are examples of the *WIMP* interface style, often simply called windowing systems. WIMP stands for windows, icons, menus and pointers (sometimes windows, icons, mice and pull-down menus), and is the default interface style for the majority of interactive computer systems in use today, especially in the PC and desktop workstation arena. Examples of WIMP interfaces include Microsoft Windows for IBM PC compatibles, MacOS for Apple Macintosh compatibles and various X Windows-based systems for UNIX.

Mixing styles

The UNIX windowing environments are interesting as the contents of many of the windows are often themselves simply command line or character-based programs (see Figure 3.11). In fact, this mixing of interface styles in the same system is quite common, especially where older *legacy systems* are used at the same time as more modern applications. It can be a problem if users attempt to use commands and methods suitable for one environment in another. On the Apple Macintosh, HyperCard uses a point-and-click style. However, HyperCard stack buttons look very like Macintosh folders. If you double click on them, as you would to open a folder, your two mouse clicks are treated as separate actions. The first click opens the stack (as you wanted), but the second is then interpreted in the context of the newly opened stack, behaving in an apparently arbitrary fashion! This is an example of the importance of *consistency* in the interface, an issue we shall return to in Chapter 7.

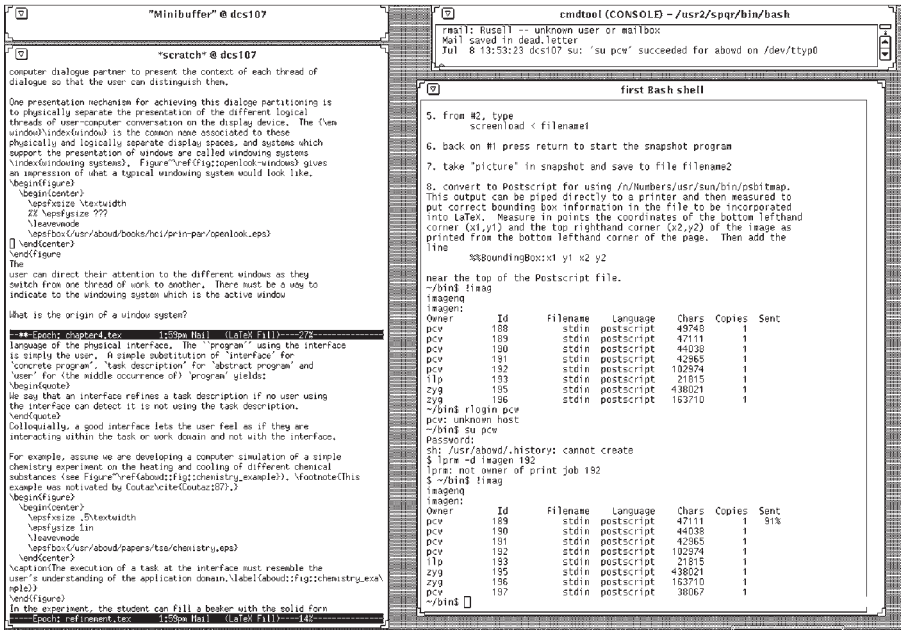


Figure 3.11 A typical UNIX windowing system – the OpenLook system. Source: Sun Microsystems, Inc.

3.5.7 Point-and-click interfaces

In most multimedia systems and in web browsers, virtually all actions take only a single click of the mouse button. You may point at a city on a map and when you click a window opens, showing you tourist information about the city. You may point at a word in some text and when you click you see a definition of the word. You may point at a recognizable iconic button and when you click some action is performed.

This point-and-click interface style is obviously closely related to the WIMP style. It clearly overlaps in the use of buttons, but may also include other WIMP elements. However, the philosophy is simpler and more closely tied to ideas of *hypertext*. In addition, the point-and-click style is not tied to mouse-based interfaces, and is also extensively used in touchscreen information systems. In this case, it is often combined with a menu-driven interface.

The point-and-click style has been popularized by world wide web pages, which incorporate all the above types of point-and-click navigation: highlighted words, maps and iconic buttons.

3.5.8 Three-dimensional interfaces

There is an increasing use of three-dimensional effects in user interfaces. The most obvious example is virtual reality, but VR is only part of a range of 3D techniques available to the interface designer.

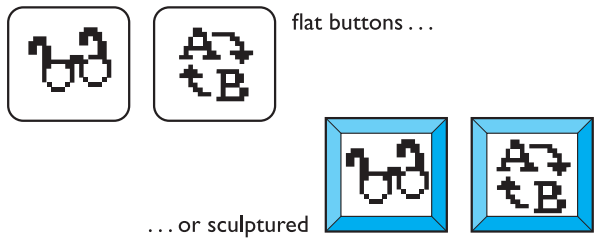


Figure 3.12 Buttons in 3D say 'press me'

The simplest technique is where ordinary WIMP elements, buttons, scroll bars, etc., are given a 3D appearance using shading, giving the appearance of being sculpted out of stone. By unstated convention, such interfaces have a light source at their top right. Where used judiciously, the raised areas are easily identifiable and can be used to highlight active areas (Figure 3.12). Unfortunately, some interfaces make indiscriminate use of sculptural effects, on every text area, border and menu, so all sense of differentiation is lost.

A more complex technique uses interfaces with 3D workspaces. The objects displayed in such systems are usually flat, but are displayed in perspective when at an angle to the viewer and shrink when they are 'further away'. Figure 3.13 shows one such system, WebBook [57]. Notice how size, light and occlusion provide a sense of

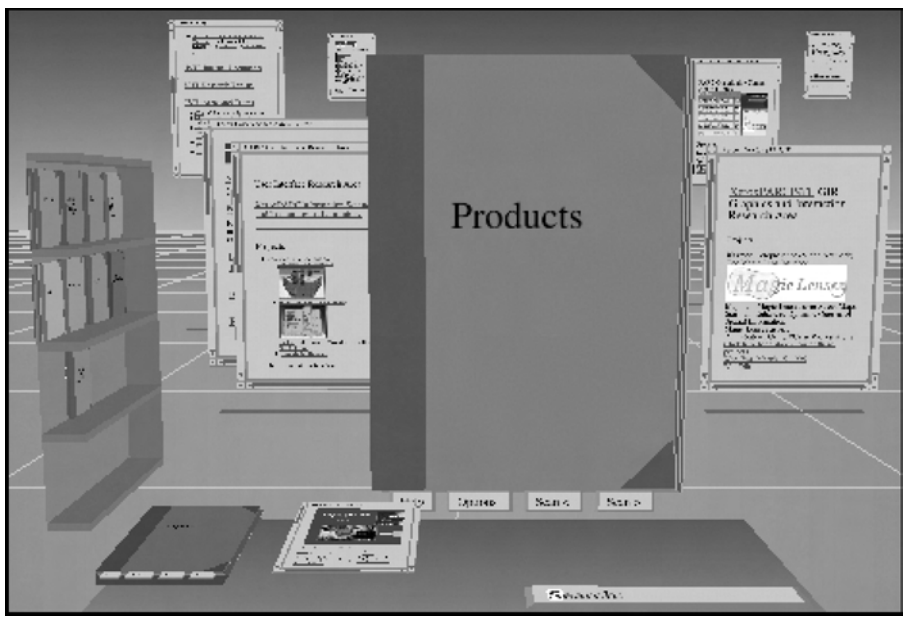


Figure 3.13 WebBook – using 3D to make more space (Card S.K., Robertson G.G. and York W. (1996). The WebBook and the Web Forager: An Information workspace for the World-Wide Web. *CHI96 Conference Proceedings*, 111–17. Copyright © 1996 ACM, Inc. Reprinted by permission)

distance. Notice also that as objects get further away they take up less screen space. Three-dimensional workspaces give you extra space, but in a more natural way than iconizing windows.

Finally, there are virtual reality and information visualization systems where the user can move about within a simulated 3D world. These are discussed in detail in Chapter 20.

These mechanisms overlap with other interaction styles, especially the use of sculptured elements in WIMP interfaces. However, there is a distinct interaction style for 3D interfaces in that they invite us to use our tacit abilities for the real world, and translate them into the electronic world. Novice users must learn that an oval area with a word or picture in it is a button to be pressed, but a 3D button says 'push me'. Further, more complete 3D environments invite one to move within the virtual environment, rather than watch as a spectator.

DESIGN FOCUS

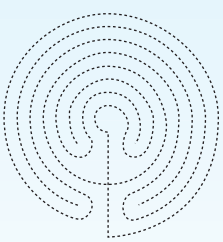
Navigation in 3D and 2D

We live in a three-dimensional world. So clearly 3D interfaces are good . . . or are they? Actually, our 3D stereo vision only works well close to us and after that we rely on cruder measures such as 'this is in front of that'. We are good at moving obects around with our hands in three dimensions, rotating, turning them on their side. However, we walk around in two dimensions and do not fly. Not surprisingly, people find it hard to visualize and control movement in three dimensions.

Normally, we use gravity to give us a fixed direction in space. This is partly through the channels in the inner ear, but also largely through kinesthetic senses – feeling the weight of limbs. When we lose these senses it is easy to become disoriented and we can lose track of which direction is up: divers are trained to watch the direction their bubbles move and if buried in an avalanche you should spit and feel which direction the spittle flows.

Where humans have to navigate in three dimensions they need extra aids such as the artificial horizon in an airplane. Helicopters, where there are many degrees of freedom, are particularly difficult.

Even in the two-dimensional world of walking about we do not rely on neat Cartesian maps in our head. Instead we mostly use models of location such as 'down the road near the church' that rely on approximate topological understanding and landmarks. We also rely on properties of normal space, such as the ability to go backwards and the fact that things that are close can be reached quickly. When two-dimensional worlds are not like this, for example in a one-way traffic system or in a labyrinth, we have great difficulty [98].



When we design systems we should take into account how people navigate in the real world and use this to guide our navigation aids. For example, if we have a 3D interface or a virtual reality world we should normally show a ground plane and by default lock movement to be parallel to the ground. In information systems we can recruit our more network-based models of 2D space by giving landmarks and making it as easy to 'step back' as to go forwards (as with the web browser 'back' button).

See the book website for more about 3D vision: /e3/online/seeing-3D/

3.6 ELEMENTS OF THE WIMP INTERFACE

We have already noted the four key features of the WIMP interface that give it its name – windows, icons, pointers and menus – and we will now describe these in turn. There are also many additional interaction objects and techniques commonly used in WIMP interfaces, some designed for specific purposes and others more general. We will look at buttons, toolbars, palettes and dialog boxes. Most of these elements can be seen in Figure 3.14.

Together, these elements of the WIMP interfaces are called *widgets*, and they comprise the toolkit for interaction between user and system. In Chapter 8 we will describe windowing systems and interaction widgets more from the programmer's perspective. There we will discover that though most modern windowing systems provide the same set of basic widgets, the 'look and feel' – how widgets are physically displayed and how users can interact with them to access their functionality – of different windowing systems and toolkits can differ drastically.

3.6.1 Windows

Windows are areas of the screen that behave as if they were independent terminals in their own right. A window can usually contain text or graphics, and can be moved

Figure 3.14 Elements of the WIMP interface – Microsoft Word 5.1 on an Apple Macintosh. Screen shot reprinted by permission from Apple Computer, Inc.

or resized. More than one window can be on a screen at once, allowing separate tasks to be visible at the same time. Users can direct their attention to the different windows as they switch from one thread of work to another.

If one window overlaps the other, the back window is partially obscured, and then refreshed when exposed again. Overlapping windows can cause problems by obscuring vital information, so windows may also be *tiled*, when they adjoin but do not overlap each other. Alternatively, windows may be placed in a *cascading* fashion, where each new window is placed slightly to the left and below the previous window. In some systems this *layout policy* is fixed, in others it can be selected by the user.

Usually, windows have various things associated with them that increase their usefulness. *Scrollbars* are one such attachment, allowing the user to move the contents of the window up and down, or from side to side. This makes the window behave as if it were a real window onto a much larger world, where new information is brought into view by manipulating the scrollbars.

There is usually a title bar attached to the top of a window, identifying it to the user, and there may be special boxes in the corners of the window to aid resizing, closing, or making as large as possible. Each of these can be seen in Figure 3.15.

In addition, some systems allow windows within windows. For example, in Microsoft Office applications, such as Excel and Word, each application has its own window and then within this each document has a window. It is often possible to have different layout policies within the different application windows.

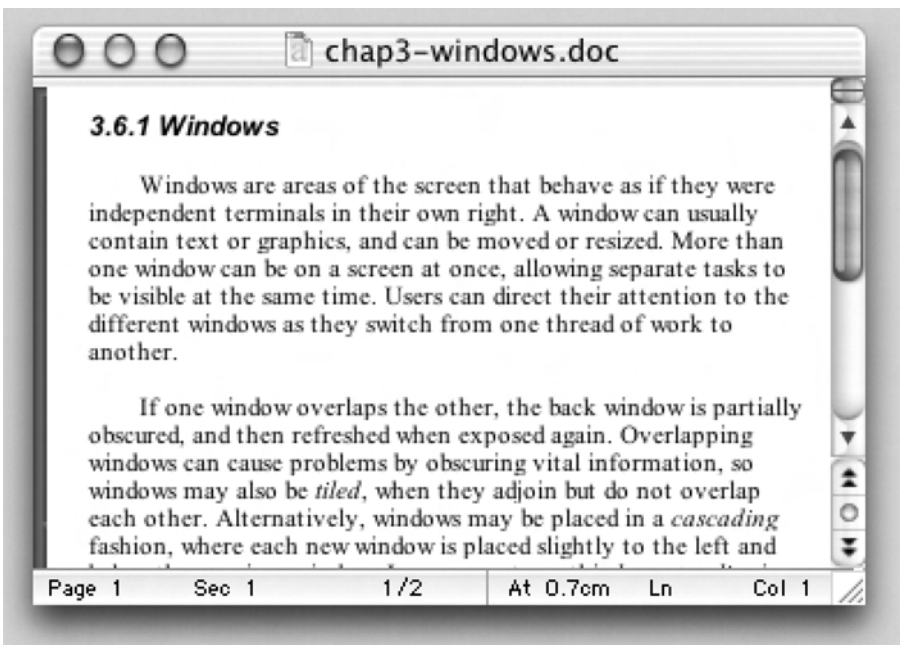


Figure 3.15 A typical window. Screen shot reprinted by permission from Apple Computer, Inc.

Figure 3.16 A variety of icons. Screen shot reprinted by permission from Apple Computer, Inc.

3.6.2 Icons

Windows can be closed and lost for ever, or they can be shrunk to some very reduced representation. A small picture is used to represent a closed window, and this representation is known as an *icon*. By allowing icons, many windows can be available on the screen at the same time, ready to be expanded to their full size by clicking on the icon. Shrinking a window to its icon is known as *iconifying* the window. When a user temporarily does not want to follow a particular thread of dialog, he can suspend that dialog by iconifying the window containing the dialog. The icon saves space on the screen and serves as a reminder to the user that he can subsequently resume the dialog by opening up the window. Figure 3.16 shows a few examples of some icons used in a typical windowing system (MacOS X).

Icons can also be used to represent other aspects of the system, such as a waste-basket for throwing unwanted files into, or various disks, programs or functions that are accessible to the user. Icons can take many forms: they can be realistic representations of the objects that they stand for, or they can be highly stylized. They can even be arbitrary symbols, but these can be difficult for users to interpret.

3.6.3 Pointers

The pointer is an important component of the WIMP interface, since the interaction style required by WIMP relies very much on pointing and selecting things such as icons. The mouse provides an input device capable of such tasks, although joysticks and trackballs are other alternatives, as we have previously seen in Chapter 2. The user is presented with a cursor on the screen that is controlled by the input device. A variety of pointer cursors are shown in Figure 3.17.

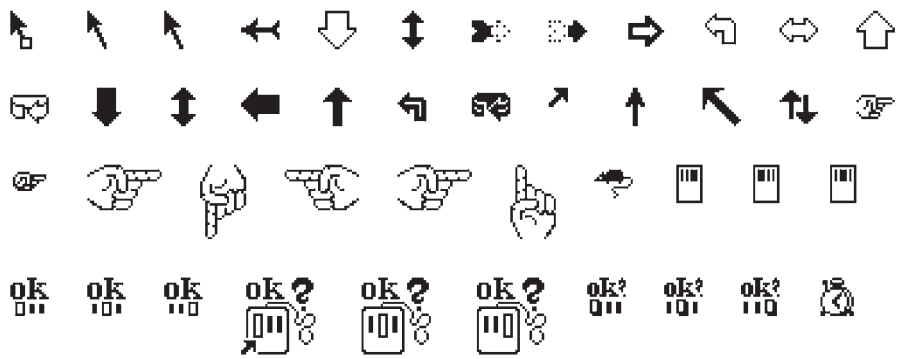


Figure 3.17 A variety of pointer cursors. Source: Sun Microsystems, Inc.

The different shapes of cursor are often used to distinguish *modes*, for example the normal pointer cursor may be an arrow, but change to cross-hairs when drawing a line. Cursors are also used to tell the user about system activity, for example a watch or hour-glass cursor may be displayed when the system is busy reading a file.

Pointer cursors are like icons, being small bitmap images, but in addition all cursors have a *hot-spot*, the location to which they point. For example, the three arrows at the start of Figure 3.17 each have a hot-spot at the top left, whereas the right-pointing hand on the second line has a hot-spot on its right. Sometimes the hot-spot is not clear from the appearance of the cursor, in which case users will find it hard to click on small targets. When designing your own cursors, make sure the image has an obvious hot-spot.

3.6.4 Menus

The last main feature of windowing systems is the *menu*, an interaction technique that is common across many non-windowing systems as well. A menu presents a choice of operations or services that can be performed by the system at a given time. In Chapter 1, we pointed out that our ability to recall information is inferior to our ability to recognize it from some visual cue. Menus provide information cues in the form of an ordered list of operations that can be scanned. This implies that the names used for the commands in the menu should be meaningful and informative.

The pointing device is used to indicate the desired option. As the pointer moves to the position of a menu item, the item is usually highlighted (by inverse video, or some similar strategy) to indicate that it is the potential candidate for selection. Selection usually requires some additional user action, such as pressing a button on the mouse that controls the pointer cursor on the screen or pressing some special key on the keyboard. Menus are inefficient when they have too many items, and so cascading menus are utilized, in which item selection opens up another menu adjacent to the item, allowing refinement of the selection. Several layers of cascading menus can be used.

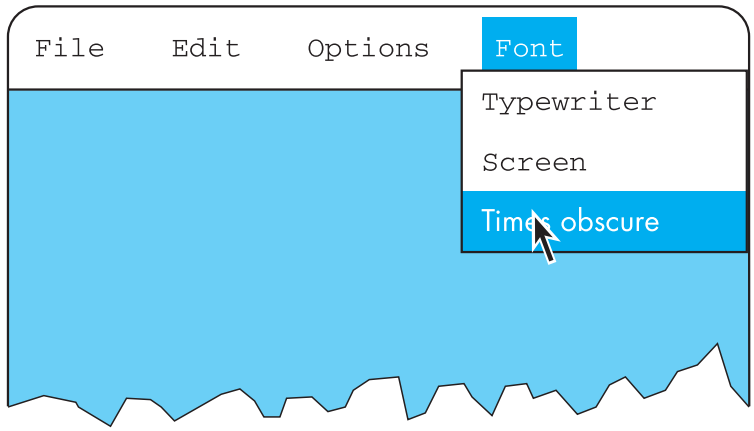


Figure 3.18 Pull-down menu

The main menu can be visible to the user all the time, as a *menu bar* and submenus can be pulled down or across from it upon request (Figure 3.18). Menu bars are often placed at the top of the screen (for example, MacOS) or at the top of each window (for example, Microsoft Windows). Alternatives include menu bars along one side of the screen, or even placed amongst the windows in the main 'desktop' area. Websites use a variety of menu bar locations, including top, bottom and either side of the screen. Alternatively, the main menu can be hidden and upon request it will pop up onto the screen. These *pop-up menus* are often used to present context-sensitive options, for example allowing one to examine properties of particular on-screen objects. In some systems they are also used to access more global actions when the mouse is depressed over the screen background.

Pull-down menus are dragged down from the title at the top of the screen, by moving the mouse pointer into the title bar area and pressing the button. Fall-down menus are similar, except that the menu automatically appears when the mouse pointer enters the title bar, without the user having to press the button. Some menus are pin-up menus, in that they can be 'pinned' to the screen, staying in place until explicitly asked to go away. Pop-up menus appear when a particular region of the screen, maybe designated by an icon, is selected, but they only stay as long as the mouse button is depressed.

Another approach to menu selection is to arrange the options in a circular fashion. The pointer appears in the center of the circle, and so there is the same distance to travel to any of the selections. This has the advantages that it is easier to select items, since they can each have a larger target area, and that the selection time for each item is the same, since the pointer is equidistant from them all. Compare this with a standard menu: remembering Fitts' law from Chapter 1, we can see that it will take longer to select items near the bottom of the menu than at the top. However, these *pie menus*, as they are known [54], take up more screen space and are therefore less common in interfaces.

Keyboard accelerators

Menus often offer *keyboard accelerators*, key combinations that have the same effect as selecting the menu item. This allows more expert users, familiar with the system, to manipulate things without moving off the keyboard, which is often faster. The accelerators are often displayed alongside the menu items so that frequent use makes them familiar. Unfortunately most systems do not allow you to use the accelerators while the menu is displayed. So, for example, the menu might say

Find	F3

However, when the user presses function key F3 nothing happens. F3 only works when the menu is *not* displayed – when the menu is there you must press 'F' instead! This is an example of an interface that is *dishonest* (see also Chapter 7).

The major problems with menus in general are deciding what items to include and how to group those items. Including too many items makes menus too long or creates too many of them, whereas grouping causes problems in that items that relate to the same topic need to come under the same heading, yet many items could be grouped under more than one heading. In pull-down menus the menu label should be chosen to reflect the function of the menu items, and items grouped within menus by function. These groupings should be consistent across applications so that the user can transfer learning to new applications. Menu items should be ordered in the menu according to importance and frequency of use, and opposite functionalities (such as 'save' and 'delete') should be kept apart to prevent accidental selection of the wrong function, with potentially disastrous consequences.

3.6.5 Buttons

Buttons are individual and isolated regions within a display that can be selected by the user to invoke specific operations. These regions are referred to as buttons because they are purposely made to resemble the push buttons you would find on a control panel. 'Pushing' the button invokes a command, the meaning of which is usually indicated by a textual label or a small icon. Buttons can also be used to toggle between two states, displaying status information such as whether the current font is italicized or not in a word processor, or selecting options on a web form. Such toggle buttons can be grouped together to allow a user to select one feature from a set of mutually exclusive options, such as the size in points of the current font. These are called *radio buttons*, since the collection functions much like the old-fashioned mechanical control buttons on car radios. If a set of options is not mutually exclusive, such as font characteristics like bold, italics and underlining, then a set of toggle buttons can be used to indicate the on/off status of the options. This type of collection of buttons is sometimes referred to as *check boxes*.

3.6.6 Toolbars

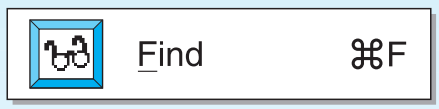
Many systems have a collection of small buttons, each with icons, placed at the top or side of the window and offering commonly used functions. The function of this *toolbar* is similar to a menu bar, but as the icons are smaller than the equivalent text more functions can be simultaneously displayed. Sometimes the content of the toolbar is fixed, but often users can *customize* it, either changing which functions are made available, or choosing which of several predefined toolbars is displayed.

DESIGN FOCUS

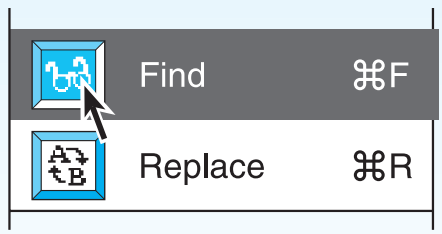
Learning toolbars

Although many applications now have toolbars, they are often underused because users simply do not know what the icons represent. Once learned the meaning is often relatively easy to remember, but most users do not want to spend time reading a manual, or even using online help to find out what each button does – they simply reach for the menu.

There is an obvious solution – put the icons on the menus in the same way that accelerator keys are written there. So in the 'Edit' menu one might find the option



Imagine now selecting this. As the mouse drags down through the menu selections, each highlights in turn. If the mouse is dragged down the extreme left, the effect will be very similar to selecting the icon from the toolbar, except that it will be incidental to selecting the menu item. In this way, the toolbar icon will be naturally learned from normal menu interaction.



Selecting the menu option = selecting the icon

This trivial fix is based on accepted and tested knowledge of learning and has been described in more detail by one of the authors elsewhere [95]. Given its simplicity, this technique should clearly be used everywhere, but until recently was rare. However, it has now been taken up in the Office 97 suite and later Microsoft Office products, so perhaps will soon become standard.

3.6.7 Palettes

In many application programs, interaction can enter one of several *modes*. The defining characteristic of modes is that the interpretation of actions, such as keystrokes or gestures with the mouse, changes as the mode changes. For example, using the standard UNIX text editor vi, keystrokes can be interpreted either as operations to insert characters in the document (insert mode) or as operations to perform file manipulation (command mode). Problems occur if the user is not aware of the current mode. Palettes are a mechanism for making the set of possible modes and the active mode visible to the user. A palette is usually a collection of icons that are reminiscent of the purpose of the various modes. An example in a drawing package would be a collection of icons to indicate the pixel color or pattern that is used to fill in objects, much like an artist's palette for paint.

Some systems allow the user to create palettes from menus or toolbars. In the case of pull-down menus, the user may be able 'tear off' the menu, turning it into a palette showing the menu items. In the case of toolbars, he may be able to drag the toolbar away from its normal position and place it anywhere on the screen. Tear-off menus are usually those that are heavily graphical anyway, for example line-style or color selection in a drawing package.

3.6.8 Dialog boxes

Dialog boxes are information windows used by the system to bring the user's attention to some important information, possibly an error or a warning used to prevent a possible error. Alternatively, they are used to invoke a subdialog between user and system for a very specific task that will normally be embedded within some larger task. For example, most interactive applications result in the user creating some file that will have to be named and stored within the filing system. When the user or system wants to save the file, a dialog box can be used to allow the user to name the file and indicate where it is to be located within the filing system. When the save subdialog is complete, the dialog box will disappear. Just as windows are used to separate the different threads of user–system dialog, so too are dialog boxes used to factor out auxiliary task threads from the main task dialog.

3.7 INTERACTIVITY

When looking at an interface, it is easy to focus on the visually distinct parts (the buttons, menus, text areas) but the dynamics, the way they react to a user's actions, are less obvious. Dialog design, discussed in Chapter 16, is focussed almost entirely on the choice and specification of appropriate sequences of actions and corresponding changes in the interface state. However, it is typically not used at a fine level of detail and deliberately ignores the 'semantic' level of an interface: for example, the validation of numeric information in a forms-based system.

It is worth remembering that *interactivity* is the defining feature of an *interactive* system. This can be seen in many areas of HCI. For example, the recognition rate for *speech recognition* is too low to allow transcription from tape, but in an airline reservation system, so long as the system can reliably recognize *yes* and *no* it can reflect back its understanding of what you said and seek confirmation. Speech-based *input* is difficult, speech-based *interaction* easier. Also, in the area of information visualization the most exciting developments are all where users can interact with a visualization in real time, changing parameters and seeing the effect.

Interactivity is also crucial in determining the 'feel' of a WIMP environment. All WIMP systems appear to have virtually the same elements: windows, icons, menus, pointers, dialog boxes, buttons, etc. However, the precise behavior of these elements differs both within a single environment and between environments. For example, we have already discussed the different behavior of pull-down and fall-down menus. These look the same, but fall-down menus are more easily invoked by accident (and not surprisingly the windowing environments that use them have largely fallen into disuse!). In fact, menus are a major difference between the MacOS and Microsoft Windows environments: in MacOS you have to keep the mouse depressed throughout menu selection; in Windows you can click on the menu bar and a pull-down menu appears and remains there until an item is selected or it is cancelled. Similarly the detailed behavior of buttons is quite complex, as we shall see in Chapter 17.

In older computer systems, the order of interaction was largely determined by the machine. You did things when the computer was ready. In WIMP environments, the user takes the initiative, with many options and often many applications simultaneously available. The exceptions to this are *pre-emptive* parts of the interface, where the system for various reasons wrests the initiative away from the user, perhaps because of a problem or because it needs information in order to continue.

The major example of this is *modal dialog boxes*. It is often the case that when a dialog box appears the application will not allow you to do anything else until the dialog box has been completed or cancelled. In some cases this may simply block the application, but you can perform tasks in other applications. In other cases you can do nothing at all until the dialog box has been completed. An especially annoying example is when the dialog box asks a question, perhaps simply for confirmation of an action, but the information you need to answer is hidden by the dialog box!

There are occasions when modal dialog boxes are necessary, for example when a major fault has been detected, or for certain kinds of instructional software. However, the general philosophy of modern systems suggests that one should minimize the use of pre-emptive elements, allowing the user maximum flexibility.

Interactivity is also critical in dealing with errors. We discussed slips and mistakes earlier in the chapter, and some ways to try to prevent these types of errors. The other way to deal with errors is to make sure that the user or the system is able to tell when errors have occurred. If users can *detect* errors then they can correct them. So, even if errors occur, the interaction as a whole succeeds. Several of the principles in Chapter 7 deal with issues that relate to this. This ability to detect and correct is important both at the small scale of button presses and keystrokes and also at the large scale. For example, if you have sent a client a letter and expect a reply, you can

put in your diary a note on the day you expect a reply. If the other person forgets to reply or the letter gets lost in the post you know to send a reminder or ring when the due day passes.

3.8 THE CONTEXT OF THE INTERACTION

We have been considering the interaction between a user and a system, and how this is affected by interface design. This interaction does not occur within a vacuum. We have already noted some of the physical factors in the environment that can directly affect the quality of the interaction. This is part of the context in which the interaction takes place. But this still assumes a single user operating a single, albeit complex, machine. In reality, users work within a wider social and organizational context. This provides the wider context for the interaction, and may influence the activity and motivation of the user. In Chapter 13, we discuss some methods that can be used to gain a fuller understanding of this context, and, in Chapter 14, we consider in more detail the issues involved when more than one user attempts to work together on a system. Here we will confine our discussion to the influence social and organizational factors may have on the user's interaction with the system. These may not be factors over which the designer has control. However, it is important to be aware of such influences to understand the user and the work domain fully.

Bank managers don't type . . .

The safe in most banks is operated by at least two keys, held by different employees of the bank. This makes it difficult for a bank robber to obtain both keys, and also protects the bank against light-fingered managers! ATMs contain a lot of cash and so need to be protected by similar measures. In one bank, which shall remain nameless, the ATM had an electronic locking device. The machine could not be opened to replenish or remove cash until a long key sequence had been entered. In order to preserve security, the bank gave half the sequence to one manager and half to another, so both managers had to be present in order to open the ATM. However, these were traditional bank managers who were not used to typing – that was a job for a secretary! So they each gave their part of the key sequence to a secretary to type in when they wanted to gain entry to the ATM. In fact, they both gave their respective parts of the key sequence to the *same* secretary. Happily the secretary was honest, but the moral is you cannot ignore social expectations and relationships when designing any sort of computer system, however simple it may be.

The presence of other people in a work environment affects the performance of the worker in any task. In the case of peers, competition increases performance, at least for known tasks. Similarly the desire to impress management and superiors improves performance on these tasks. However, when it comes to acquisition of

new skills, the presence of these groups can inhibit performance, owing to the fear of failure. Consequently, privacy is important to allow users the opportunity to experiment.

In order to perform well, users must be motivated. There are a number of possible sources of motivation, as well as those we have already mentioned, including fear, allegiance, ambition and self-satisfaction. The last of these is influenced by the user's perception of the quality of the work done, which leads to job satisfaction. If a system makes it difficult for the user to perform necessary tasks, or is frustrating to use, the user's job satisfaction, and consequently performance, will be reduced.

The user may also lose motivation if a system is introduced that does not match the actual requirements of the job to be done. Often systems are chosen and introduced by managers rather than the users themselves. In some cases the manager's perception of the job may be based upon observation of results and not on actual activity. The system introduced may therefore impose a way of working that is unsatisfactory to the users. If this happens there may be three results: the system will be rejected, the users will be resentful and unmotivated, or the user will adapt the intended interaction to his own requirements. This indicates the importance of involving actual users in the design process.

DESIGN FOCUS

Half the picture?

When systems are not designed to match the way people actually work, then users end up having to do 'work arounds'. Integrated student records systems are becoming popular in universities in the UK. They bring the benefits of integrating examination systems with enrolment and finance systems so all data can be maintained together and cross-checked. All very useful and time saving – in theory. However, one commonly used system only holds a single overall mark per module for each student, whereas many modules on UK courses have multiple elements of assessment. Knowing a student's mark on each part of the assessment is often useful to academics making decisions in examination boards as it provides a more detailed picture of performance. In many cases staff are therefore supplementing the official records system with their own unofficial spreadsheets to provide this information – making additional work for staff and increased opportunity for error.

On the other hand, the introduction of new technology may prove to be a motivation to users, particularly if it is well designed, integrated with the user's current work, and challenging. Providing adequate feedback is an important source of motivation for users. If no feedback is given during a session, the user may become bored, unmotivated or, worse, unsure of whether the actions performed have been successful. In general, an action should have an obvious effect to prevent this confusion and to allow early recovery in the case of error. Similarly, if system delays occur, feedback can be used to prevent frustration on the part of the user – the user is then aware of what is happening and is not left wondering if the system is still working.

3.9 EXPERIENCE, ENGAGEMENT AND FUN

Ask many in HCI about usability and they may use the words 'effective' and 'efficient'. Some may add 'satisfaction' as well. This view of usability seems to stem mainly from the Taylorist tradition of time and motion studies: if you can get the worker to pull the levers and turn the knobs in the right order then you can shave 10% off production costs.

However, users no longer see themselves as cogs in a machine. Increasingly, applications are focussed outside the closed work environment: on the home, leisure, entertainment, shopping. It is not sufficient that people can use a system, they must *want* to use it.

Even from a pure economic standpoint, your employees are likely to work better and more effectively if they enjoy what they are doing!

In this section we'll look at these more experiential aspects of interaction.

3.9.1 Understanding experience

Shopping is an interesting example to consider. Most internet stores allow you to buy things, but do you go shopping? Shopping is as much about going to the shops, feeling the clothes, being with friends. You can go shopping and never intend to spend money. Shopping is not about an efficient financial transaction, it is an experience.

But experience is a difficult thing to pin down; we understand the idea of a good experience, but how do we define it and even more difficult how do we design it?

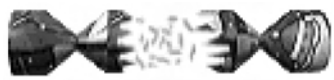
Csikszentimihalyi [82] looked at extreme experiences such as climbing a rock face in order to understand that feeling of total engagement that can sometimes happen. He calls this *flow* and it is perhaps related to what some sportspeople refer to as being 'in the zone'. This sense of flow occurs when there is a balance between anxiety and boredom. If you do something that you know you can do it is not engaging; you may do it automatically while thinking of something else, or you may simply become bored. Alternatively, if you do something completely outside your abilities you may become anxious and, if you are half way up a rock face, afraid. Flow comes when you are teetering at the edge of your abilities, stretching yourself to or a little beyond your limits.

In education there is a similar phenomenon. The *zone of proximal development* is those things that you cannot quite do yourself, but you can do with some support, whether from teachers, fellow pupils, or electronic or physical materials. Learning is at its best in this zone. Notice again this touching of limits.

Of course, this does not fully capture the sense of experience, and there is an active subfield of HCI researchers striving to make sense of this, building on the work of psychologists and philosophers on the one hand and literary analysis, film making and drama on the other.

3.9.2 Designing experience

Some of the authors were involved in the design of virtual Christmas crackers. These are rather like electronic greetings cards, but are based on crackers. For those who have not come across them, Christmas crackers are small tubes of paper between 8 and 12 inches long (20–30 cm). Inside there are a small toy, a joke or motto and a paper hat. A small strip of card is threaded through, partly coated with gunpowder. When two people at a party pull the cracker, it bursts apart with a small bang from the gunpowder and the contents spill out.



The virtual cracker does not attempt to fully replicate each aspect of the physical characteristics and process of pulling the cracker, but instead seeks to reproduce the experience. To do this the original crackers experience was deconstructed and each aspect of the experience produced in a similar, but sometimes different, way in the new media. Table 3.1 shows the aspects of the experience deconstructed and reconstructed in the virtual cracker.

For example, the cracker contents are hidden inside; no one knows what toy or joke will be inside. Similarly, when you create a virtual cracker you normally cannot see the contents until the recipient has opened it. Even the recipient initially sees a page with just an image of the cracker; it is only after the recipient has clicked on the 'open' icon that the cracker slowly opens and you get to see the joke, web toy and mask.

The mask is also worth looking at. The first potential design was to have a picture of a face with a hat on it – well, it wouldn't rank highly on excitement! The essential feature of the paper hat is that you can dress up. An iconic hat hardly does that.

Table 3.1 The crackers experience [101]

	Real cracker	Virtual cracker
Surface elements		
Design	Cheap and cheerful	Simple page/graphics
Play	Plastic toy and joke	Web toy and joke
Dressing up	Paper hat	Mask to cut out
Experienced effects		
Shared	Offered to another	Sent by email, message
Co-experience	Pulled together	Sender can't see content until opened by recipient
Excitement	Cultural connotations	Recruited expectation
Hiddenness	Contents inside	First page – no contents
Suspense	Pulling cracker	Slow . . . page change
Surprise	Bang (when it works)	WAV file (when it works)

Instead the cracker has a link to a web page with a picture of a mask that you can print, cut out and wear. Even if you don't actually print it out, the fact that you could changes the experience – it is some dressing up you just happen not to have done yet.

A full description of the virtual crackers case study is on the book website at: /e3/casestudy/crackers/

3.9.3 Physical design and engagement

In Chapter 2 we talked about physical controls. Figure 2.13 showed controllers for a microwave, washing machine and personal MiniDisc player. We saw then how certain physical interfaces were suited for different contexts: smooth plastic controls for an easy clean microwave, multi-function knob for the MiniDisc.

Designers are faced with many constraints:

Ergonomic You cannot physically push buttons if they are too small or too close.

Physical The size or nature of the device may force certain positions or styles of control, for example, a dial like the one on the washing machine would not fit on the MiniDisc controller; high-voltage switches cannot be as small as low-voltage ones.

Legal and safety Cooker controls must be far enough from the pans that you do not burn yourself, but also high enough to prevent small children turning them on.

Context and environment The microwave's controls are smooth to make them easy to clean in the kitchen.

Aesthetic The controls must look good.

Economic It must not cost too much!

These constraints are themselves often contradictory and require trade-offs to be made. For example, even within the safety category front-mounted controls are better in that they can be turned on or off without putting your hands over the pans and hot steam, but back-mounted controls are further from children's grasp. The MiniDisc player is another example; it physically needs to be small, but this means there is not room for all the controls you want given the minimum size that can be manipulated. In the case of the cooker there is no obvious best solution and so different designs favor one or the other. In the case of the MiniDisc player the end knob is multi-function. This means the knob is ergonomically big enough to turn and physically small enough to fit, but at the cost of a more complex interaction style.

To add to this list of constraints there is another that makes a major impact on the ease of use and also the ability of the user to become engaged with the device, for it to become natural to use:

Fluidity The extent to which the physical structure and manipulation of the device naturally relate to the logical functions it supports.

This is related closely to the idea of *affordances*, which we discuss in Section 5.7.2. The knob at the end of the MiniDisc controller affords turning – it is an obvious thing to do. However, this may not have mapped naturally onto the logical functions. Two of the press buttons are for cycling round the display options and for changing sound options. Imagine a design where turning the knob to clockwise cycled through the display options and turning it anti-clockwise cycled through the sound options. This would be a compact design satisfying all the ergonomic, physical and aesthetic constraints, but would not have led to as fluid an interaction. The physically opposite motions lead to logically distinct effects. However, the designers did a better job than this! The twist knob is used to move backwards and forwards through the tracks of the MiniDisc – that is, opposite physical movements produce opposite logical effects. Holding the knob out and twisting turns the volume up and down. Again, although the pull action is not a natural mapping, the twist maps very naturally onto controlling the sound level.

As well as being fluid in action, some controls portray by their physical appearance the underlying state they control. For example, the dial on the washing machine both sets the program and reflects the current stage in the washing cycle as it turns. A simple on/off switch also does this. However, it is also common to see the power on computers and hifi devices controlled by a push button – press for on, then press again for off. The button does not reflect the state at all. When the screen is on this is not a problem as the fact that there is something on the screen acts as a very immediate indicator of the state. But if the screen has a power save then you might accidentally turn the machine off thinking that you are turning it on! For this reason, this type of power button often has a light beside it to show you the power is on. A simple switch tells you that itself!

3.9.4 Managing value

If we want people to *want* to use a device or application we need to understand their personal values. Why should they want to use it? What value do they get from using it? Now when we say value here we don't mean monetary value, although that may be part of the story, but all the things that drive a person. For some people this may include being nice to colleagues, being ecologically friendly, being successful in their career. Whatever their personal values are, if we ask someone to do something or use something they are only likely to do it if the value to them exceeds the cost.

This is complicated by the fact that for many systems the costs such as purchase cost, download time of a free application, learning effort are incurred up front, whereas often the returns – faster work, enjoyment of use – are seen later. In economics, businesses use a measure called 'net present value' to calculate what a future gain is worth today; because money can be invested, £100 today is worth the same as perhaps £200 in five years' time. Future gain is discounted. For human decision making, future gains are typically discounted very highly; many of us are bad at saving for tomorrow or even keeping the best bits of our dinner until last. This means that not only must we understand people's value systems, but we must be able to offer

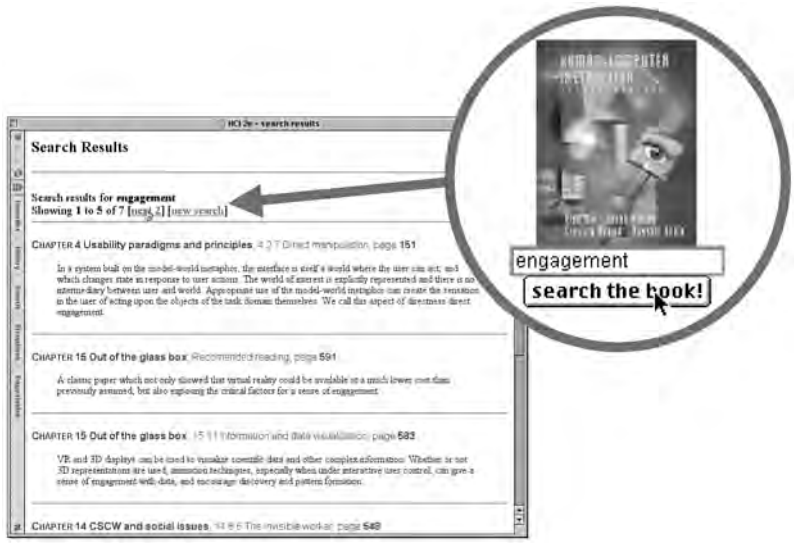


Figure 3.19 The web-based book search facility. Screen shot frame reprinted by permission from Microsoft Corporation

gains sooner as well as later, or at least produce a very good demonstration of potential future gains so that they have a *perceived* current value.

When we were preparing the website for the second edition of this book we thought very hard about how to give things that were of value to those who had the book, and also to those who hadn't. The latter is partly because we are all academics and researchers in the field and so want to contribute to the HCI community, but also of course we would like lots of people to buy the book. One option we thought of was to put the text online, which would be good for people without the book, but this would have less value to people who have the book (they might even be annoyed that those who hadn't paid should have access). The search mechanism was the result of this process (Figure 3.19). It gives value to those who have the book because it is a way of finding things. It is of value to those who don't because it acts as a sort of online encyclopedia of HCI. However, because it always gives the chapter and page number in the book it also says to those who haven't got the book: 'buy me'. See an extended case study about the design of the book search on the website at /e3/casestudy/search/

3.10 SUMMARY

In this chapter, we have looked at the interaction between human and computer, and, in particular, how we can ensure that the interaction is effective to allow the user to get the required job done. We have seen how we can use Norman's execution–evaluation model, and the interaction framework that extends it, to analyze the

interaction in terms of how easy or difficult it is for the user to express what he wants and determine whether it has been done.

We have also looked at the role of ergonomics in interface design, in analyzing the physical characteristics of the interaction, and we have discussed a number of interface styles. We have considered how each of these factors can influence the effectiveness of the interaction.

Interactivity is at the heart of all modern interfaces and is important at many levels. Interaction between user and computer does not take place in a vacuum, but is affected by numerous social and organizational factors. These may be beyond the designer's control, but awareness of them can help to limit any negative effects on the interaction.

EXERCISES

3.1 Choose two of the interface styles (described in Section 3.5) that you have experience of using. Use the interaction framework to analyze the interaction involved in using these interface styles for a database selection task. Which of the distances is greatest in each case?

3.2 Find out all you can about natural language interfaces. Are there any successful systems? For what applications are these most appropriate?

3.3 What influence does the social environment in which you work have on your interaction with the computer? What effect does the organization (commercial or academic) to which you belong have on the interaction?

3.4 (a) Group the following functions under appropriate headings, assuming that they are to form the basis for a menu-driven word-processing system – the headings you choose will become the menu titles, with the functions appearing under the appropriate one. You can choose as many or as few menu headings as you wish. You may also alter the wordings of the functions slightly if you wish.

save, save as, new, delete, open mail, send mail, quit, undo, table, glossary, preferences, character style, format paragraph, lay out document, position on page, plain text, bold text, italic text, underline, open file, close file, open copy of file, increase point size, decrease point size, change font, add footnote, cut, copy, paste, clear, repaginate, add page break, insert graphic, insert index entry, print, print preview, page setup, view page, find word, change word, go to, go back, check spelling, view index, see table of contents, count words, renumber pages, repeat edit, show alternative document, help

(b) If possible, show someone else your headings, and ask them to group the functions under your headings. Compare their groupings with yours. You should find that there are areas of great similarity, and some differences. Discuss the similarities and discrepancies.

Why do some functions always seem to be grouped together?
Why do some groups of functions always get categorized correctly?
Why are some less easy to place under the 'correct' heading?
Why is this important?

3.5 Using your function groupings from Exercise 3.4, count the number of items in your menus.

(a) What is the average?
What is the disadvantage of putting all the functions on the screen at once?
What is the problem with using lots of menu headings?
What is the problem of using very few menu headings?

Consider the following: I can group my functions either into three menus, with lots of functions in each one, or into eight menus with fewer in each. Which will be easier to use? Why?

(b) *Optional experiment*
Design an experiment to test your answers. Perform the experiment and report on your results.

3.6 Describe (in words as well as graphically) the interaction framework introduced in *Human–Computer Interaction*. Show how it can be used to explain problems in the dialog between a user and a computer.

3.7 Describe briefly four different interaction styles used to accommodate the dialog between user and computer.

3.8 The typical computer screen has a WIMP setup (what does WIMP stand for?). Most common WIMP arrangements work on the basis of a desktop metaphor, in which common actions are likened to similar actions in the real world. For example, moving a file is achieved by selecting it and dragging it into a relevant folder or filing cabinet. The advantage of using a metaphor is that the user can identify with the environment presented on the screen. Having a metaphor allows users to predict the outcome of their actions more easily.

Note that the metaphor can break down, however. What is the real-world equivalent of formatting a disk? Is there a direct analogy for the concept of 'undo'? Think of some more examples yourself.

RECOMMENDED READING

D. A. Norman, *The Psychology of Everyday Things*, Basic Books, 1988. (Republished as *The Design of Everyday Things* by Penguin, 1991.)
A classic text, which discusses psychological issues in designing everyday objects and addresses why such objects are often so difficult to use. Discusses the execution–evaluation cycle. Very readable and entertaining. See also his more recent books *Turn Signals are the Facial Expressions of Automobiles* [267], *Things That Make Us Smart* [268] and *The Invisible Computer* [269].

R. W. Bailey, *Human Performance Engineering: A Guide for System Designers*, Prentice Hall, 1982.
Detailed coverage of human factors and ergonomics issues, with plenty of examples.

G. Salvendy, *Handbook of Human Factors and Ergonomics*, John Wiley, 1997.
Comprehensive collection of contributions from experts in human factors and ergonomics.

M. Helander, editor, *Handbook of Human–Computer Interaction. Part II: User Interface Design*, North-Holland, 1988.
Comprehensive coverage of interface styles.

J. Raskin, *The Humane Interface: New Directions for Designing Interactive Systems*, Addison Wesley, 2000.
Jef Raskin was one of the central designers of the original Mac user interface. This book gives a personal, deep and practical examination of many issues of interaction and its application in user interface design.

M. Blythe, A. Monk, K. Overbeeke and P. Wright, editors, *Funology: From Usability to Enjoyment*, Kluwer, 2003.
This is an edited book with chapters covering many areas of user experience. It includes an extensive review of theory from many disciplines from psychology to literary theory and chapters giving design frameworks based on these. The theoretical and design base is grounded by many examples and case studies including a detailed analysis of virtual crackers.

4

PARADIGMS

OVERVIEW

- Examples of effective strategies for building interactive systems provide paradigms for designing usable interactive systems.
- The evolution of these usability paradigms also provides a good perspective on the history of interactive computing.
- These paradigms range from the introduction of time-sharing computers, through the WIMP and web, to ubiquitous and context-aware computing.

4.1 INTRODUCTION

As we noted in Chapter 3, the primary objective of an interactive system is to allow the user to achieve particular goals in some application domain, that is, the interactive system must be usable. The designer of an interactive system, then, is posed with two open questions:

1. How can an interactive system be developed to ensure its usability?
2. How can the usability of an interactive system be demonstrated or measured?

One approach to answering these questions is by means of example, in which successful interactive systems are commonly believed to enhance usability and, therefore, serve as *paradigms* for the development of future products.

We believe that we now build interactive systems that are more usable than those built in the past. We also believe that there is considerable room for improvement in designing more usable systems in the future. As discussed in Chapter 2, the great advances in computer technology have increased the power of machines and enhanced the bandwidth of communication between humans and computers. The impact of technology alone, however, is not sufficient to enhance its usability. As our machines have become more powerful, the key to increased usability has come from the creative and considered application of the technology to accommodate and augment the power of the human. Paradigms for interaction have for the most part been dependent upon technological advances and their creative application to enhance interaction.

In this chapter, we investigate some of the principal historical advances in interactive designs. What is important to notice here is that the techniques and designs mentioned are recognized as major improvements in interaction, though it is sometimes hard to find a consensus for the reason behind the success. It is even harder to predict ahead what the new paradigms will be. Often new paradigms have arisen through exploratory designs that have then been seen, after the fact, to have created a new base point for future design.

We will discuss 15 different paradigms in this chapter. They do not provide mutually exclusive categories, as particular systems will often incorporate ideas from more than one of the following paradigms. In a way, this chapter serves as a history of interactive system development, though our emphasis is not so much on historical accuracy as on interactive innovation. We are concerned with the advances in interaction provided by each paradigm.

4.2 PARADIGMS FOR INTERACTION

4.2.1 Time sharing

In the 1940s and 1950s, the significant advances in computing consisted of new hardware technologies. Mechanical relays were replaced by vacuum electron tubes. Tubes were replaced by transistors, and transistors by integrated chips, all of which meant

that the amount of sheer computing power was increasing by orders of magnitude. By the 1960s it was becoming apparent that the explosion of growth in computing power would be wasted if there was not an equivalent explosion of ideas about how to channel that power. One of the leading advocates of research into human-centered applications of computer technology was J. C. R. Licklider, who became the director of the Information Processing Techniques Office of the US Department of Defense's Advanced Research Projects Agency (ARPA). It was Licklider's goal to finance various research centers across the United States in order to encourage new ideas about how best to apply the burgeoning computing technology.

One of the major contributions to come out of this new emphasis in research was the concept of *time sharing*, in which a single computer could support multiple users. Previously, the human (or more accurately, the programmer) was restricted to batch sessions, in which complete jobs were submitted on punched cards or paper tape to an operator who would then run them individually on the computer. Time-sharing systems of the 1960s made programming a truly interactive venture and brought about a subculture of programmers known as 'hackers' – single-minded masters of detail who took pleasure in understanding complexity. Though the purpose of the first interactive time-sharing systems was simply to augment the programming capabilities of the early hackers, it marked a significant stage in computer applications for human use. Rather than rely on a model of interaction as a pre-planned activity that resulted in a complete set of instructions being laid out for the computer to follow, truly interactive exchange between programmer and computer was possible. The computer could now project itself as a dedicated partner with each individual user and the increased throughput of information between user and computer allowed the human to become a more reactive and spontaneous collaborator. Indeed, with the advent of time sharing, real human–computer interaction was now possible.

4.2.2 Video display units

As early as the mid-1950s researchers were experimenting with the possibility of presenting and manipulating information from a computer in the form of images on a video display unit (VDU). These display screens could provide a more suitable medium than a paper printout for presenting vast quantities of strategic information for rapid assimilation. The earliest applications of display screen images were developed in military applications, most notably the Semi-Automatic Ground Environment (SAGE) project of the US Air Force. It was not until 1962, however, when a young graduate student at the Massachusetts Institute of Technology (MIT), Ivan Sutherland, astonished the established computer science community with his *Sketchpad* program, that the capabilities of visual images were realized. As described in Howard Rheingold's history of computing book *Tools for Thought* [305]:

> Sketchpad allowed a computer operator to use the computer to create, very rapidly, sophisticated visual models on a display screen that resembled a television set. The visual patterns could be stored in the computer's memory like any other data, and could be manipulated by the computer's processor. . . . But Sketchpad was much more

> than a tool for creating visual displays. It was a kind of simulation language that enabled computers to translate abstractions into perceptually concrete forms. And it was a model for totally new ways of operating computers; by changing something on the display screen, it was possible, via Sketchpad, to change something in the computer's memory.

Sketchpad demonstrated two important ideas. First, computers could be used for more than just data processing. They could extend the user's ability to abstract away from some levels of detail, visualizing and manipulating different representations of the same information. Those abstractions did not have to be limited to representations in terms of bit sequences deep within the recesses of computer memory. Rather, the abstractions could be made truly visual. To enhance human interaction, the information within the computer was made more amenable to human consumption. The computer was made to speak a more human language, instead of the human being forced to speak more like a computer. Secondly, Sutherland's efforts demonstrated how important the contribution of one creative mind (coupled with a dogged determination to see the idea through) could be to the entire history of computing.

4.2.3 Programming toolkits

Douglas Engelbart's ambition since the early 1950s was to use computer technology as a means of complementing human problem-solving activity. Engelbart's idea as a graduate student at the University of California at Berkeley was to use the computer to teach humans. This dream of naïve human users actually learning from a computer was a stark contrast to the prevailing attitude of his contemporaries that computers were a purposely complex technology that only the intellectually privileged were capable of manipulating. Engelbart's dedicated research team at the Stanford Research Institute in the 1960s worked towards achieving the manifesto set forth in an article published in 1963 [124]:

> By 'augmenting man's intellect' we mean increasing the capability of a man to approach a complex problem situation, gain comprehension to suit his particular needs, and to derive solutions to problems. . . . We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human 'feel for the situation' usefully coexist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids.

Many of the ideas that Engelbart's team developed at the Augmentation Research Center – such as word processing and the mouse – only attained mass commercial success decades after their invention. A live demonstration of his oNLine System (NLS, also later known as NLS/Augment) was given in the autumn of 1968 at the Fall Joint Computer Conference in San Francisco before a captivated audience of computer sceptics. We are not so concerned here with the interaction techniques that were present in NLS, as many of those will be discussed later. What is important here is the method that Engelbart's team adopted in creating their very innovative and powerful interactive systems with the relatively impoverished technology of the 1960s.

Engelbart wrote of how humans attack complex intellectual problems like a carpenter who produces beautifully complicated pieces of woodwork with a good set of tools. The secret to producing computing equipment that aided human problem-solving ability was in providing the right *toolkit*. Taking this message to heart, his team of programmers concentrated on developing the set of programming tools they would require in order to build more complex interactive systems. The idea of building components of a computer system that will allow you to rebuild a more complex system is called bootstrapping and has been used to a great extent in all of computing. The power of programming toolkits is that small, well-understood components can be composed in fixed ways in order to create larger tools. Once these larger tools become understood, they can continue to be composed with other tools, and the process continues.

4.2.4 Personal computing

Programming toolkits provide a means for those with substantial computing skills to increase their productivity greatly. But Engelbart's vision was not exclusive to the computer literate. The decade of the 1970s saw the emergence of computing power aimed at the masses, computer literate or not. One of the first demonstrations that the powerful tools of the hacker could be made accessible to the computer novice was a graphics programming language for children called LOGO. The inventor, Seymour Papert, wanted to develop a language that was easy for children to use. He and his colleagues from MIT and elsewhere designed a computer-controlled mechanical turtle that dragged a pen along a surface to trace its path. A child could quite easily pretend they were 'inside' the turtle and direct it to trace out simple geometric shapes, such as a square or a circle. By typing in English phrases, such as `Go forward` or `Turn left`, the child/programmer could teach the turtle to draw more and more complicated figures. By adapting the graphical programming language to a model which children could understand and use, Papert demonstrated a valuable maxim for interactive system development – no matter how powerful a system may be, it will always be more powerful if it is easier to use.

Alan Kay was profoundly influenced by the work of both Engelbart and Papert. He realized that the power of a system such as NLS was only going to be successful if it was as accessible to novice users as was LOGO. In the early 1970s his view of the future of computing was embodied in small, powerful machines which were dedicated to single users, that is *personal computers*. Together with the founding team of researchers at the Xerox Palo Alto Research Center (PARC), Kay worked on incorporating a powerful and simple visually based programming environment, Smalltalk, for the personal computing hardware that was just becoming feasible. As technology progresses, it is now becoming more difficult to distinguish between what constitutes a personal computer, or workstation, and what constitutes a mainframe. Kay's vision in the mid-1970s of the ultimate handheld personal computer – he called it the Dynabook – outstrips even the technology we have available today [197].

4.2.5 Window systems and the WIMP interface

With the advent and immense commercial success of personal computing, the emphasis for increasing the usability of computing technology focussed on addressing the single user who engaged in a dialog with the computer in order to complete some work. Humans are able to think about more than one thing at a time, and in accomplishing some piece of work, they frequently interrupt their current train of thought to pursue some other related piece of work. A personal computer system which forces the user to progress in order through all of the tasks needed to achieve some objective, from beginning to end without any diversions, does not correspond to that standard working pattern. If the personal computer is to be an effective dialog partner, it must be as flexible in its ability to 'change the topic' as the human is.

But the ability to address the needs of a different user task is not the only requirement. Computer systems for the most part react to stimuli provided by the user, so they are quite amenable to a wandering dialog initiated by the user. As the user engages in more than one plan of activity over a stretch of time, it becomes difficult for him to maintain the status of the overlapping threads of activity. It is therefore necessary for the computer dialog partner to present the context of each thread of dialog so that the user can distinguish them.

One presentation mechanism for achieving this dialog partitioning is to separate physically the presentation of the different logical threads of user–computer conversation on the display device. The *window* is the common mechanism associated with these physically and logically separate display spaces. We discussed windowing systems in detail in Chapter 3.

Interaction based on windows, icons, menus and pointers – the WIMP interface – is now commonplace. These interaction devices first appeared in the commercial marketplace in April 1981, when Xerox Corporation introduced the 8010 Star Information System. But many of the interaction techniques underlying a windowing system were used in Engelbart's group in NLS and at Xerox PARC in the experimental precursor to Star, the Alto.

4.2.6 The metaphor

In developing the LOGO language to teach children, Papert used the metaphor of a turtle dragging its tail in the dirt. Children could quickly identify with the real-world phenomenon and that instant familiarity gave them an understanding of how they could create pictures. Metaphors are used quite successfully to teach new concepts in terms of ones which are already understood, as we saw when looking at analogy in Chapter 1. It is no surprise that this general teaching mechanism has been successful in introducing computer novices to relatively foreign interaction techniques. We have already seen how metaphors are used to describe the functionality of many interaction widgets, such as windows, menus, buttons and palettes. Tremendous commercial successes in computing have arisen directly from a judicious choice of metaphor. The Xerox Alto and Star were the first workstations based on the metaphor of the office desktop. The majority of the management tasks on a standard

workstation have to do with file manipulation. Linking the set of tasks associated with file manipulation to the filing tasks in a typical office environment makes the actual computerized tasks easier to understand at first. The success of the desktop metaphor is unquestionable. Another good example in the personal computing domain is the widespread use of the spreadsheet metaphor for accounting and financial modeling.

Very few will debate the value of a good metaphor for increasing the initial familiarity between user and computer application. The danger of a metaphor is usually realized after the initial honeymoon period. When word processors were first introduced, they relied heavily on the typewriter metaphor. The keyboard of a computer closely resembles that of a standard typewriter, so it seems like a good metaphor from which to start. However, the behavior of a word processor is different from any typewriter. For example, the space key on a typewriter is passive, producing nothing on the piece of paper and just moving the guide further along the current line. For a typewriter, a space is not a character. However, for a word processor, the blank space *is* a character which must be inserted within a text just as any other character is inserted. So an experienced typist is not going to be able to predict correctly the behavior of pressing the spacebar on the keyboard by appealing to his experience with a typewriter. Whereas the typewriter metaphor is beneficial for providing a preliminary understanding of a word processor, the analogy is inadequate for promoting a full understanding of how the word processor works. In fact, the metaphor gets in the way of the user understanding the computer.

A similar problem arises with most metaphors. Although the desktop metaphor is initially appealing, it falls short in the computing world because there are no office equivalents for ejecting a floppy disk or printing a document. When designers try too hard to make the metaphor stick, the resulting system can be more confusing. Who thinks it is intuitive to drag the icon of a floppy disk to the wastebasket in order to eject it from the system? Ordinarily, the wastebasket is used to dispose of things that we never want to use again, which is why it works for deleting files. We must accept that some of the tasks we perform with a computer do not have real-world equivalents, or if they do, we cannot expect a single metaphor to account for all of them.

Another problem with a metaphor is the cultural bias that it portrays. With the growing internationalization of software, it should not be assumed that a metaphor will apply across national boundaries. A meaningless metaphor will only add another layer of complexity between the user and the system.

A more extreme example of metaphor occurs with *virtual reality* systems. In a VR system, the metaphor is not simply captured on a display screen. Rather, the user is also portrayed within the metaphor, literally creating an alternative, or virtual, reality. Any actions that the user performs are supposed to become more natural and so more movements of the user are interpreted, instead of just keypresses, button clicks and movements of an external pointing device. A VR system also needs to know the location and orientation of the user. Consequently, the user is often 'rigged' with special tracking devices so that the system can locate them and interpret their motion correctly.

4.2.7 Direct manipulation

In the early 1980s as the price of fast and high-quality graphics hardware was steadily decreasing, designers were beginning to see that their products were gaining popularity as their visual content increased. As long as the user–system dialog remained largely unidirectional – from user command to system command line prompt – computing was going to stay within the minority population of the hackers who revelled in the challenge of complexity. In a standard command line interface, the only way to get any feedback on the results of previous interaction is to know that you have to ask for it and to know how to ask for it. Rapid visual and audio *feedback* on a high-resolution display screen or through a high-quality sound system makes it possible to provide evaluative information for every executed user action.

Rapid feedback is just one feature of the interaction technique known as *direct manipulation*. Ben Shneiderman [320, 321] is attributed with coining this phrase in 1982 to describe the appeal of graphics-based interactive systems such as Sketchpad and the Xerox Alto and Star. He highlights the following features of a direct manipulation interface:

- visibility of the objects of interest
- incremental action at the interface with rapid feedback on all actions
- reversibility of all actions, so that users are encouraged to explore without severe penalties
- syntactic correctness of all actions, so that every user action is a legal operation
- replacement of complex command languages with actions to manipulate directly the visible objects (and, hence, the name direct manipulation).

The first real commercial success which demonstrated the inherent usability of direct manipulation interfaces for the general public was the Macintosh personal computer, introduced by Apple Computer, Inc. in 1984 after the relatively unsuccessful marketing attempt in the business community of the similar but more pricey Lisa computer. We discussed earlier how the desktop metaphor makes the computer domain of file management, usually described in terms of files and directories, easier to grasp by likening it to filing in the typical office environment, usually described in terms of documents and folders. The direct manipulation interface for the desktop metaphor requires that the documents and folders are made visible to the user as icons which represent the underlying files and directories. An operation such as moving a file from one directory to another is mirrored as an action on the visible document which is 'picked up and dragged' along the desktop from one folder to the next. In a command line interface to a filing system, it is normal that typographical errors in constructing the command line for a move operation would result in a syntactically incorrect command (for example, mistyping the file's name results in an error if you are fortunate enough not to spell accidentally the name of another file in the process). It is impossible to formulate a syntactically incorrect move operation with the pick-up-and-drag style of command. It is still possible for errors to occur at a deeper level, as the user might move a document to the wrong place, but it is relatively easy to detect and recover from those errors. While the document is dragged,

continual visual feedback is provided, creating the illusion that the user is actually working in the world of the desktop and not just using the metaphor to help him understand.

Ed Hutchins, Jim Hollan and Donald Norman [187] provide a more psychological justification in terms of the *model-world metaphor* for the directness that the above example suggests. In Norman and Draper's collection of papers on user-centered design [270] they write:

> In a system built on the model-world metaphor, the interface is itself a world where the user can act, and which changes state in response to user actions. The world of interest is explicitly represented and there is no intermediary between user and world. Appropriate use of the model-world metaphor can create the sensation in the user of acting upon the objects of the task domain themselves. We call this aspect of directness *direct engagement*.

In the model-world metaphor, the role of the interface is not so much one of mediating between the user and the underlying system. From the user's perspective, the interface *is* the system.

A consequence of the direct manipulation paradigm is that there is no longer a clear distinction between input and output. In the interaction framework in Chapter 3 we talked about a user articulating input expressions in some input language and observing the system-generated output expressions in some output language. In a direct manipulation system, the output expressions are used to formulate subsequent input expressions. The document icon is an output expression in the desktop metaphor, but that icon is used by the user to articulate the move operation. This aggregation of input and output is reflected in the programming toolkits, as widgets are not considered as input or output objects exclusively. Rather, widgets embody both input and output languages, so we consider them as *interaction objects*.

Somewhat related to the visualization provided by direct manipulation is the *WYSIWYG* paradigm, which stands for 'what you see is what you get'. What you see on a display screen, for example when you are using a word processor, is not the actual document that you will be producing in the end. Rather, it is a representation or rendering of what that final document will look like. The implication with a WYSIWYG interface is that the difference between the representation and the final product is minimal, and the user is easily able to visualize the final product from the computer's representation. So, in the word-processing example, you would be able to see what the overall layout of your document would be from its image on screen, minimizing any guesswork on your part to format the final printed copy.

With WYSIWYG interfaces, it is the simplicity and immediacy of the mapping between representation and final product that matters. In terms of the interaction framework, the observation of an output expression is made simple so that assessment of goal achievement is straightforward. But WYSIWYG is not a panacea for usability. What you see is all you get! In the case of a word processor, it is difficult to achieve more sophisticated page design if you must always see the results of the layout on screen. For example, suppose you want to include a picture in a document you are writing. You design the picture and then place it in the current draft of your

document, positioning it at the top of the page on which it is first referenced. As you make changes to the paper, the position of the picture will change. If you still want it to appear at the top of a page, you will no doubt have to make adjustments to the document. It would be easier if you only had to include the picture once, with a directive that it should be positioned at the top of the printed page, whether or not it appears that way on screen. You might sacrifice the WYSIWYG principle in order to make it easier to incorporate such floatable objects in your documents.

Worked exercise

Discuss the ways in which a full-page word processor is or is not a direct manipulation interface for editing a document using Shneiderman's criteria. What features of a modern word processor break the metaphor of composition with pen (or typewriter) and paper?

Answer

We will answer the first point by evaluating the word processor relative to the criteria for direct manipulation given by Shneiderman.

Visibility of the objects of interest

The most important objects of interest in a word processor are the words themselves. Indeed, the visibility of the text on a continual basis was one of the major usability advances in moving from line-oriented to display-oriented editors. Depending on the user's application, there may be other objects of interest in word processing that may or may not be visible. For example, are the margins for the text on screen similar to the ones which would eventually be printed? Is the spacing within a line and the line breaks similar? Are the different fonts and formatting characteristics of the text visible (without altering the spacing)? Expressed in this way, we can see the visibility criterion for direct manipulation as very similar to the criteria for a WYSIWYG interface.

Incremental action at the interface with rapid feedback on all actions

We expect from a word processor that characters appear in the text as we type them in at the keyboard, with little delay. If we are inserting text on a page, we might also expect that the format of the page adjust immediately to accommodate the new changes. Various word processors do this reformatting immediately, whereas with others changes in page breaks may take some time to be reflected. One of the other important actions which requires incremental and rapid feedback is movement of the window using the scroll button. If there is a significant delay between the input command to move the window down and the actual movement of the window on screen, it is quite possible that the user will 'overshoot' the target when using the scrollbar button.

Reversibility of all actions, so that users are encouraged to explore without severe penalties

Single-step undo commands in most word processors allow the user to recover from the last action performed. One problem with this is that the user must recognize the error before doing any other action. More sophisticated undo facilities allow the user to retrace back more than one command at a time. The kind of exploration this reversibility provides in a word processor is best evidenced with the ease of experimentation that is now available for formatting changes in a document (font types and sizes and margin changes). One problem with the ease of exploration is that emphasis may move to the look of a document rather than what the text actually says (style over content).

Syntactic correctness of all actions, so that every user action is a legal operation

WYSIWYG word processors usually provide menus and buttons which the user uses to articulate many commands. These interaction mechanisms serve to constrain the input language to allow only legal input from the user. Document markup systems, such as HTML and LaTeX, force the user to insert textual commands (which may be erroneously entered by the user) to achieve desired formatting effects.

Replacement of complex command languages with actions to manipulate directly the visible objects

The case for word processors is similar to that described above for syntactic correctness. In addition, operations on portions of text are achieved many times by allowing the user to highlight the text directly with a mouse (or arrow keys). Subsequent action on that text, such as moving it or copying it to somewhere else, can then be achieved more directly by allowing the user to 'drag' the selected text via the mouse to its new location.

To answer the second question concerning the drawback of the pen (or typewriter) metaphor for word processing, we refer to the discussion on metaphors in Section 4.2.6. The example there compares the functionality of the space key in typewriting versus word processing. For a typewriter, the space key is passive; it merely moves the insertion point one space to the right. In a word processor, the space key is active, as it inserts a character (the space character) into the document. The functionality of the typewriter space key is produced by the movement keys for the word processor (typically an arrow key pointing right to move forward within one line). In fact, much of the functionality that we have come to expect of a word processor is radically different from that expected of a typewriter, so much so that the typewriter as a metaphor for word processing is not all that instructive. In practice, modern typewriters have begun to borrow from word processors when defining their functionality!

4.2.8 Language versus action

Whereas it is true that direct manipulation interfaces make some tasks easier to perform correctly, it is equally true that some tasks are more difficult, if not impossible. Contrary to popular wisdom, it is not generally true that actions speak louder than words. The image we projected for direct manipulation was of the interface as a replacement for the underlying system as the world of interest to the user. Actions performed at the interface replace any need to understand their meaning at any deeper, system level. Another image is of the interface as the interlocutor or mediator between the user and the system. The user gives the interface instructions and it is then the responsibility of the interface to see that those instructions are carried out. The user–system communication is by means of indirect language instead of direct actions.

We can attach two meaningful interpretations to this language paradigm. The first requires that the user understands how the underlying system functions and the

interface as interlocutor need not perform much translation. In fact, this interpretation of the language paradigm is similar to the kind of interaction which existed before direct manipulation interfaces were around. In a way, we have come full circle!

The second interpretation does not require the user to understand the underlying system's structure. The interface serves a more active role, as it must interpret between the intended operation as requested by the user and the possible system operations that must be invoked to satisfy that intent. Because it is more active, some people refer to the interface as an *agent* in these circumstances. We can see this kind of language paradigm at work in an information retrieval system. You may know what kind of information is in some internal system database, such as the UK highway code, but you would not know how that information is organized. If you had a question about speed limits on various roads, how would you ask? The answer in this case is that you would ask the question in whatever way it comes to mind, typing in a question such as, 'What are the speed limits on different roads?' You then leave it up to the interface agent to reinterpret your request as a legal query to the highway code database.

Whatever interpretation we attach to the language paradigm, it is clear that it has advantages and disadvantages when compared with the action paradigm implied by direct manipulation interfaces. In the action paradigm, it is often much easier to perform simple tasks without risk of certain classes of error. For example, recognizing and pointing to an object reduces the difficulty of identification and the possibility of misidentification. On the other hand, more complicated tasks are often rather tedious to perform in the action paradigm, as they require repeated execution of the same procedure with only minor modification. In the language paradigm, there is the possibility of describing a generic procedure once (for example, a looping construct which will perform a routine manipulation on all files in a directory) and then leaving it to be executed without further user intervention.

The action and language paradigms need not be completely separate. In the above example, we distinguished between the two paradigms by saying that we can describe generic and repeatable procedures in the language paradigm and not in the action paradigm. An interesting combination of the two occurs in *programming by example* when a user can perform some routine tasks in the action paradigm and the system records this as a generic procedure. In a sense, the system is interpreting the user's actions as a language script which it can then follow.

4.2.9 Hypertext

In 1945, Vannevar Bush, then the highest-ranking scientific administrator in the US war effort, published an article entitled 'As We May Think' in *The Atlantic Monthly*. Bush was in charge of over 6000 scientists who had greatly pushed back the frontiers of scientific knowledge during the Second World War. He recognized that a major drawback of these prolific research efforts was that it was becoming increasingly difficult to keep in touch with the growing body of scientific knowledge in the

literature. In his opinion, the greatest advantages of this scientific revolution were to be gained by those individuals who were able to keep abreast of an ever-increasing flow of information. To that end, he described an innovative and futuristic information storage and retrieval apparatus – the *memex* – which was constructed with technology wholly existing in 1945 and aimed at increasing the human capacity to store and retrieve connected pieces of knowledge by mimicking our ability to create random associative links.

The memex was essentially a desk with the ability to produce and store a massive quantity of photographic copies of documented information. In addition to its huge storage capacity, the memex could keep track of links between parts of different documents. In this way, the stored information would resemble a vast interconnected mesh of data, similar to how many perceive information is stored in the human brain. In the context of scientific literature, where it is often very difficult to keep track of the origins and interrelations of the ever-growing body of research, a device which explicitly stored that information would be an invaluable asset.

We have already discussed some of the contributions of 'disciples' of Bush's vision – Douglas Engelbart and Alan Kay. One other follower was equally influenced by the ideas behind the memex, though his dreams have not yet materialized to the extent of Engelbart's and Kay's. Ted Nelson was another graduate student/dropout whose research agenda was forever transformed by the advent of the computer. An unsuccessful attempt to create a machine language equivalent of the memex on early 1960s computer hardware led Nelson on a lifelong quest to produce *Xanadu*, a potentially revolutionary worldwide publishing and information retrieval system based on the idea of interconnected, non-linear text and other media forms. A traditional paper is read from beginning to end, in a linear fashion. But within that text, there are often ideas or footnotes that urge the reader to digress into a richer topic. The linear format for information does not provide much support for this random and associated browsing task. What Bush's memex suggested was to preserve the non-linear browsing structure in the actual documentation. Nelson coined the phrase *hypertext* in the mid-1960s to reflect this non-linear text structure.

It was nearly two decades after Nelson coined the term that the first hypertext systems came into commercial use. In order to reflect the use of such non-linear and associative linking schemes for more than just the storage and retrieval of textual information, the term *hypermedia* (or *multimedia*) is used for non-linear storage of all forms of electronic media. We will discuss these systems in Part 4 of this book (see Chapter 21). Most of the riches won with the success of hypertext and hypermedia were not gained by Nelson, though his project Xanadu survives to this day.

4.2.10 Multi-modality

The majority of interactive systems still use the traditional keyboard and a pointing device, such as a mouse, for input and are restricted to a color display screen with some sound capabilities for output. Each of these input and output devices can be considered as communication channels for the system and they correspond to

certain human communication channels, as we saw in Chapter 1. A *multi-modal* interactive system is a system that relies on the use of multiple human communication channels. Each different channel for the user is referred to as a modality of interaction. In this sense, all interactive systems can be considered multi-modal, for humans have always used their visual and haptic (touch) channels in manipulating a computer. In fact, we often use our audio channel to hear whether the computer is actually running properly.

However, genuine multi-modal systems rely to a greater extent on simultaneous use of multiple communication channels for both input and output. Humans quite naturally process information by simultaneous use of different channels. We point to someone and refer to them as 'you', and it is only by interpreting the simultaneous use of voice and touch that our directions are easily articulated and understood. Designers have wanted to mimic this flexibility in both articulation and observation by extending the input and output expressions an interactive system will support. So, for example, we can modify a gesture made with a pointing device by speaking, indicating what operation is to be performed on the selected object.

Multi-modal, multimedia and virtual reality systems form a large core of current research in interactive system design. These are discussed in more detail in Chapters 10, 20 and 21.

4.2.11 Computer-supported cooperative work

Another development in computing in the 1960s was the establishment of the first computer networks which allowed communication between separate machines. Personal computing was all about providing individuals with enough computing power so that they were liberated from dumb terminals which operated on a time-sharing system. It is interesting to note that as computer networks became widespread, individuals retained their powerful workstations but now wanted to reconnect themselves to the rest of the workstations in their immediate working environment, and even throughout the world! One result of this reconnection was the emergence of collaboration between individuals via the computer – called computer-supported cooperative work, or CSCW.

The main distinction between CSCW systems and interactive systems designed for a single user is that designers can no longer neglect the society within which any single user operates. CSCW systems are built to allow interaction between humans via the computer and so the needs of the many must be represented in the one product. A fine example of a CSCW system is electronic mail – *email* – yet another metaphor by which individuals at physically separate locations can communicate via electronic messages which work in a similar way to conventional postal systems. One user can compose a message and 'post' it to another user (specified by his electronic mail address). When the message arrives at the remote user's site, he is informed that a new message has arrived in his 'mailbox'. He can then read the message and respond as desired. Although email is modeled after conventional postal systems, its major advantage is that it is often much faster than the traditional system (jokingly referred

to by email devotees as 'snail mail'). Communication turnarounds between sites across the world are in the order of minutes, as opposed to weeks.

Electronic mail is an instance of an asynchronous CSCW system because the participants in the electronic exchange do not have to be working at the same time in order for the mail to be delivered. The reason we use email is precisely because of its asynchronous characteristics. All we need to know is that the recipient will eventually receive the message. In contrast, it might be desirable for synchronous communication, which would require the simultaneous participation of sender and recipient, as in a phone conversation.

CSCW is a major emerging topic in current HCI research, and so we devote much more attention to it later in this book. CSCW systems built to support users working in groups are referred to as *groupware*. Chapter 19 discusses groupware systems in depth. In Chapter 14 the more general issues and theories arising from CSCW are discussed.

4.2.12 The world wide web

Probably the most significant recent development in interactive computing is the world wide web, often referred to as just the web, or WWW. The web is built on top of the internet, and offers an easy to use, predominantly graphical interface to information, hiding the underlying complexities of transmission protocols, addresses and remote access to data.

The internet (see Section 2.9) is simply a collection of computers, each linked by any sort of data connection, whether it be slow telephone line and modem or high-bandwidth optical connection. The computers of the internet all communicate using common data transmission protocols (*TCP/IP*) and addressing systems (*IP* addresses and *domain names*). This makes it possible for anyone to read anything from anywhere, in theory, if it conforms to the protocol. The web builds on this with its own layer of network protocol (http), a standard markup notation (such as HTML) for laying out pages of information and a global naming scheme (uniform resource locators or URLs). Web pages can contain text, color images, movies, sound and, most important, hypertext links to other web pages. Hypermedia documents can therefore be 'published' by anyone who has access to a computer connected to the internet.

The world wide web project was conceived in 1989 by Tim Berners-Lee, working at CERN, the European Particle Physics Laboratory at Geneva, as a means to enable the widespread distribution of scientific data generated at CERN and to share information between physicists worldwide. In 1991 the first text-based web browser was released. This was followed in early 1993 by several graphical web browsers, most significantly Mosaic developed by Marc Andreesen at the National Center for Supercomputer Applications (NCSA) at Champaign, Illinois. This was the defining moment at which the meteoric growth of the web began, rapidly growing to dominate internet traffic and change the public view of computing. Of all the 'heroes' of interactive computing named in this chapter, it is only Berners-Lee who has achieved widespread public fame.

Whilst the internet has been around since 1969, it did not become a major paradigm for interaction until the advent and ease of availability of well-designed graphical interfaces (browsers) for the web. These browsers allow users to access multimedia information easily, using only a mouse to point and click. This shift towards the integration of computation and communication is transparent to users; all they realize is that they can get the current version of published information practically instantly. In addition, the language used to create these multimedia documents is relatively simple, opening the opportunity of publishing information to any literate, and connected, person. However, there are important limitations of the web as a hypertext medium and in Chapter 21 we discuss some of the special design issues for the web. Interestingly, the web did not provide any technological breakthroughs; all the required functionality previously existed, such as transmission protocols, distributed file systems, hypertext and so on. The impact has been due to the ease of use of both the browsers and HTML, and the fact that *critical mass* (see Chapter 13) was established, first in academic circles, and then rapidly expanded into the leisure and business domains. The burgeoning interest led to service providers, those providing connections to the internet, to make it cheap to connect, and a whole new subculture was born.

Currently, the web is one of the major reasons that new users are connecting to the internet (probably even buying computers in the first place), and is rapidly becoming a major activity for people both at work and for leisure. It is much more a social phenomenon than anything else, with users attracted to the idea that computers are now boxes that connect them with interesting people and exciting places to go, rather than soulless cases that deny social contact. Computing often used to be seen as an anti-social activity; the web has challenged this by offering a 'global village' with free access to information and a virtual social environment. Web culture has emphasized liberality and (at least in principle) equality regardless of gender, race and disability. In practice, the demographics of web users are only now coming close to equal proportions in terms of gender, and, although internet use is increasing globally, the vast majority of websites are still hosted in the United States. Indeed, the web is now big business; corporate images and e-commerce may soon dominate the individual and often zany aspects of the web.

4.2.13 Agent-based interfaces

In the human world agents are people who work on someone's behalf: estate agents buy and sell property for their customers, literary agents find publishers for authors, travel agents book hotels and air tickets for tourists and secret agents obtain information (secretly) for their governments. Software agents likewise act on behalf of users within the electronic world. Examples include email agents which filter your mail for you and web crawlers which search the world wide web for documents you might find interesting. Agents can perform repetitive tasks, watch and respond to events when the user is not present and even learn from the user's own actions.

Some agents simply do what they are told. For example, many email systems allow you to specify filters, simple *if then* rules, which determine the action to perform on certain kinds of mail message:

If Sender: is bank manager
Then Urgency: is high

A major problem with such agents is developing a suitable language between human and agent which allows the user to express intentions. This is especially important when the agent is going to act in the user's absence. In this case, the user may not receive feedback of any mistake until long after the effects have become irreversible; hence the instructions have to be correct, and believed to be correct.

Other agents use artificial intelligence techniques to learn based on the user's actions. An early example of this was Eager [83]. Eager watches users while they work on simple HyperCard applications. When it notices that the user is repeating similar actions a small icon appears (a smiling cat!), suggesting the next action. The user is free either to accept the suggestion or to ignore it. When the user is satisfied that Eager knows what it is doing, it can be instructed to perform all the remaining actions in a sequence.

Eager is also an example of an agent, which has a clear *embodiment*, that is, there is a representation of Eager (the cat icon) in the interface. In contrast, consider Microsoft Excel which incorporates some intelligence in its sum (Σ) function. If the current cell is directly below a column of numbers, or if there is a series of numbers to the left of the current cell, the sum range defaults to be the appropriate cells. It is also clever about columns of numbers with subtotals so that they are not included twice in the overall total. As around 80% of all spreadsheet formulae are simple sums this is a very useful feature. However, the intelligence in this is not embodied, it is diffuse, somewhere in 'the system'. Although embodiment is not essential to an agent-based system it is one of the key features which enable users to determine where autonomy and intelligence may lie, and also which parts are stable [107].

We have already discussed the relationship between language and action paradigms in human–computer interaction. To some extent agent-based systems include aspects of both. Old command-based systems acted as intermediaries: you asked them to do something, they did what you wanted (if you were lucky), and then reported the results back to you. In contrast, direct manipulation emphasizes the user's own actions, possibly augmented by tools, on the electronic world. Agents act on the user's behalf, possibly, but not necessarily, instructed in a linguistic fashion. But unlike the original intermediary paradigm, an agent is typically acting within a world the user could also act upon. The difference is rather like that between a traditional shopkeeper who brings items to you as opposed to a shop assistant in a supermarket who helps you as you browse amongst the aisles. The latter does not prevent you from selecting your own items from the shelves, but aids you when asked.

In fact, the proponents of direct manipulation and agent-based systems do not see the paradigms as being quite as complementary as we have described them above. Although amicable, the positions on each side are quite entrenched.

4.2.14 Ubiquitous computing

Where does computing happen, and more importantly, where do we as users go to interact with a computer? The past 50 years of interactive computing show that we

still think of computers as being confined to a box on a desk or in an office or lab. The actual form of the physical interface has been transformed from a noisy teletype terminal to a large, graphical display with a WIMP or natural language interface, but in all cases the user knows where the computer is and must walk over to it to begin interacting with it.

In the late 1980s, a group of researchers at Xerox PARC, led by Mark Weiser, initiated a research program with the goal of moving human–computer interaction away from the desktop and out into our everyday lives. Weiser observed:

> The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

These words have inspired a new generation of researchers in the area of *ubiquitous computing* [369, 370]. Another popular term for this emerging paradigm is *pervasive* computing, first coined by IBM. The intention is to create a computing infrastructure that permeates our physical environment so much that we do not notice the computer any longer. A good analogy for the vision of ubiquitous computing is the electric motor. When the electric motor was first introduced, it was large, loud and very noticeable. Today, the average household contains so many electric motors that we hardly ever notice them anymore. Their utility led to ubiquity and, hence, invisibility.

How long in the future will it be before we no longer notice the interactive computer? To some extent, this is already happening, since many everyday items, such as watches, microwaves or automobiles, contain many microprocessors that we don't directly notice. But, to a large extent, the vision of Weiser, in which the computer is hardly ever noticed, is a long way off.

To pursue the analogy with the electric motor a little further, one of the motor's characteristics is that it comes in many sizes. Each size is suited to a particular use. Weiser thought that it was also important to think of computing technology in different sizes. The original work at PARC looked at three different scales of computing: the yard, the foot and the inch. In the middle of the scale, a foot-sized computer is much like the personal computers we are familiar with today. Its size is suitable for every individual to have one, perhaps on their desk or perhaps in their bedroom or in their briefcase. A yard-sized computer, on the other hand, is so large that it would be suitable for wide open public spaces, and would be shared by a group of people. Perhaps there would be one of these in every home, or in a public hallway or auditorium. On the opposite side of the scale, an inch-sized computer would be a truly personal computing device that could fit in the palm of a hand. Everyone would have a number of these at their disposal, and they would be as prevalent and unremarkable as a pen or a pad of sticky notes.

There is an increasing number of examples of computing devices at these different scales. At the foot scale, laptop computers are, of course, everywhere, but more interesting examples of computing at this scale are commercially available *tablet computers* or research prototypes, such as an interactive storybook (see Figure 4.1). At the yard scale, there are various forms of high-resolution large screens and projected displays as we discussed in Chapter 2 (Section 2.4.3). These are still mainly used as output-only devices showing presentations or fixed messages, but there is

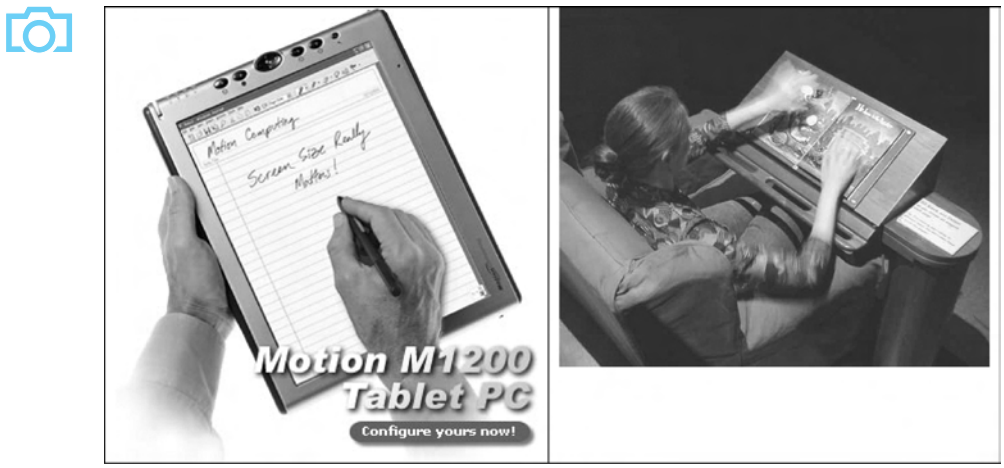
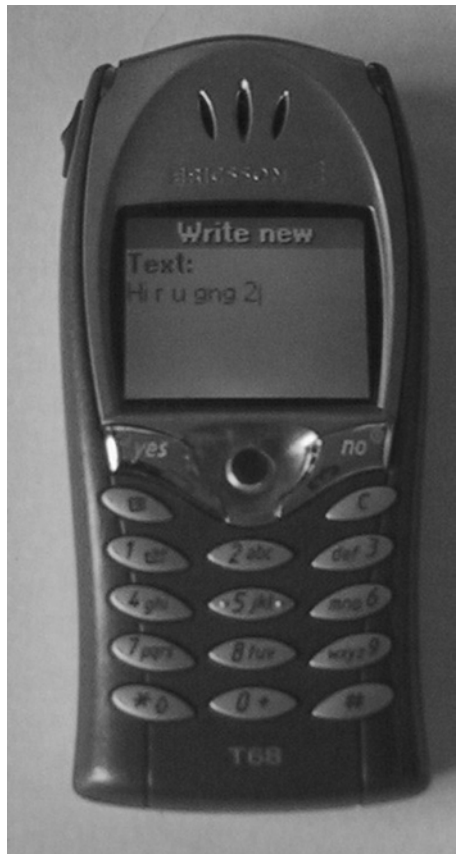


Figure 4.1 Examples of computing devices at the foot scale. On the left is a tablet computer – a Tablet PC from MotionComputing (Source: Motion Computing, Inc.). On the right is a research prototype, the Listen Reader, an interactive storybook developed at Palo Alto Research Center (picture courtesy Palo Alto Research Center)

Figure 4.2 The Stanford Interactive Mural, an example of a yard-scale interactive display surface created by tiling multiple lower-resolution projectors. Picture courtesy François Guimbretière

increasing use of more interactive shared public displays, such as the Stanford Interactive Mural shown in Figure 4.2. At the inch scale, there are many examples, from powerful, pocket-sized *personal organizers* or *personal digital assistants* (PDAs) to even smaller cellular phones or pagers, and many pocket electronic devices such as electronic dictionaries and translators (see Figure 4.3). There are even badges whose position can be automatically tracked.



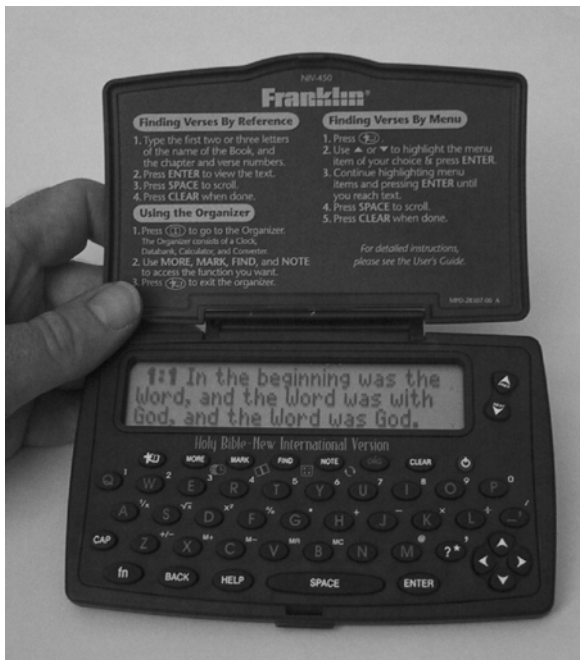


Figure 4.3 Example inch-scale devices. From left to right, a PDA, a mobile phone and pocket-sized electronic bible. Source: Top left photograph by Alan Dix (Palm Pilot Series V), bottom left photograph by Alan Dix with permission from Franklin Electronic Publishers, photograph right by Alan Dix (Ericsson phone)

This influx of diverse computing devices represents the *third wave of computing*, in which the ratio of computers to human drastically changes. In the first wave of computing, one large mainframe computer served many people. In the second wave, the PC revolution, computing devices roughly equalled the number of people using them. In the third wave, the devices far outnumber the people. It is precisely because of the large ratio of devices to people that Weiser and others note the importance of minimizing the attention demands of any single device.

Many different technologies are converging to make the dream of ubiquitous computing possible. These technologies include wireless networking, voice recognition, camera and vision systems, pen-based computing and positioning systems, to name a few. What all of these technologies provide is the ability to move the computer user away from a desktop, allow interaction in a number of modes (voice, gesture, handwriting) in addition to a keyboard, and make information about the user (through vision, speech recognition or positioning information) available to a computational device that may be far removed from the actual user.

Ubiquitous computing is not simply about nifty gadgets, it is what can be done with those gadgets. As Weiser pointed out, it is the applications that make ubiquitous computing revolutionary. In Chapter 20, we discuss some examples of the applications that ubiquitous computing makes possible, including the way this is becoming part of everyday life in places as diverse as the home, the car and even our own bodies. The vision of ubiquitous computing – first expressed by Weiser and grounded in experimental work done at Xerox PARC – is now starting to become reality.

4.2.15 Sensor-based and context-aware interaction

The yard-scale, foot-scale and inch-scale computers are all still clearly embodied devices with which we interact, whether or not we consider them 'computers'. There are an increasing number of proposed and existing technologies that embed computation even deeper, but unobtrusively, into day-to-day life. Weiser's dream was computers that 'permeate our physical environment so much that we do not notice the computers anymore', and the term ubiquitous computing encompasses a wide range from mobile devices to more pervasive environments.

We can consider the extreme situation in which the user is totally unaware of interaction taking place. Information can be gathered from sensors in the environment (pressure mats, ultrasonic movement detectors, weight sensors, video cameras), in our information world (web pages visited, times online, books purchased online), and even from our own bodies (heart rate, skin temperature, brain signals). This information is then used by systems that make inferences about our past patterns and current *context* in order to modify the explicit interfaces we deal with (e.g., modify default menu options) or to do things in the background (e.g., adjust the air conditioning).

We already encounter examples of this: lights that turn on when we enter a room, suggestions made for additional purchases at online bookstores, automatic doors

and washbasins. For elderly and disabled people, assistive technologies already embody quite radical aspects of this. However, the vision of many is a world in which the whole environment is empowered to sense and even understand the context of activities within it.

Previous interactive computation has focussed on the user explicitly telling the computer exactly what to do and the computer doing what it is told. In *context-aware computing* the interaction is more implicit. The computer, or more accurately the sensor-enhanced environment, is using heuristics and other semi-intelligent means to predict what would be useful for the user. The data used for this inference and the inference itself are both fuzzy, probabilistic and uncertain. Automatically sensing context is, and will likely always remain, an imperfect activity, so it is important that the actions resulting from these 'intelligent' predictions be made with caution. Context-aware applications should follow the principles of *appropriate intelligence*:

1. Be right as often as possible, and useful when acting on these correct predictions.
2. Do not cause inordinate problems in the event of an action resulting from a wrong prediction.

The failure of 'intelligent' systems in the past resulted from following the first principle, but not the second. These new applications, which impinge so closely on our everyday lives, demand that the second principle of appropriate intelligence is upheld. (There is more on using intelligence in interfaces on the book website at /e3/online/intelligence/)

Arguably this is a more radical paradigm shift than any other since the introduction of interactive computing itself. Whereas ubiquitous computing challenges the idea of *where* computers are and how apparent they are to us, context-aware computing challenges *what it means to interact* with a computer. It is as if we have come full circle from the early days of computing. Large mainframes were placed in isolation from the principle users (programmers) and interaction was usually done through an intermediary operator. Half a century later, the implicit nature of interaction implied by sensing creates a human–computer relationship that becomes so seamless there is no conscious interaction at all.

This shift is so radical that one could even say it does not belong in this chapter about paradigms for interaction! In fact, this shift is so dramatic that it is unclear whether the basic models of interaction that have proved universal across technologies, for example Norman's execution–evaluation cycle (Chapter 3, Section 3.2.2), are applicable at all. We will return to this issue in Chapter 18.

4.3 SUMMARY

In this chapter, we have discussed paradigms that promote the usability of interactive systems. We have seen that the history of computing is full of examples of creative insight into how the interaction between humans and computers can be

enhanced. While we expect never to replace the input of creativity in interactive system design, we still want to maximize the benefit of one good idea by repeating its benefit in many other designs. The problem with these paradigms is that they are rarely well defined. It is not always clear how they support a user in accomplishing some tasks. As a result, it is entirely possible that repeated use of some paradigm will not result in the design of a more usable system. The derivation of principles and theoretical models for interaction has often arisen out of a need to explain why a paradigm is successful and when it might not be. Principles can provide the repeatability that paradigms in themselves cannot provide. However, in defining these principles, it is all too easy to provide general and abstract definitions that are not very helpful to the designer. Therefore, the future of interactive system design relies on a complementary approach. The creativity that gives rise to new paradigms should be strengthened by the development of a theory that provides principles to support the paradigm in its repeated application. We will consider such principles and design rules in detail in Chapter 7 and more theoretical perspectives in Part 3.

EXERCISES

4.1. Choose one of the people mentioned in this chapter, or another important figure in the history of HCI, and create a web page biography on them. Try to get at least one picture of your subject, and find out about their life and work, with particular reference to their contribution to HCI.

4.2. Choose one paradigm of interaction and find three specific examples of it, not included in this chapter. Compare these three – can you identify any general principles of interaction that are embodied in each of your examples (see Chapter 7 for example principles)?

4.3. What new paradigms do you think may be significant in the future of interactive computing?

4.4. A truly ubiquitous computing experience would require the spread of computational capabilities literally everywhere. Another way to achieve ubiquity is to carry all of your computational needs with you everywhere, all the time. The field of *wearable computing* explores this interaction paradigm. How do you think the first-person emphasis of wearable computing compares with the third-person, or environmental, emphasis of ubiquitous computing? What impact would there be on context-aware computing if all of the sensors were attached to the individual instead of embedded in the environment?

RECOMMENDED READING

H. Rheingold, *Tools for Thought*, Prentice Hall, 1985.
An easy to read history of computing, with particular emphasis on developments in interactive systems. Much of the historical perspective of this chapter was influenced by this book.

T. Berners-Lee, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web*, Harper, 2000.
The history of the world wide web as told by its inventor Tim Berners-Lee makes interesting and enlightening reading.

M. M. Waldrop, *The Dream Machine: J.C.R. Licklider and the Revolution That Made Computing Personal*, Penguin, 2002.
A readable biography of Licklider and his pioneering work in making computing available to all.

T. Bardini, *Bootstrapping: Douglas Englebart, Coevolution and the Origins of Personal Computing (Writing Science)*, Stanford University Press, 2000.
Biography of another great pioneer of interactive computing, Doug Engelbart and his work at Stanford.

J. M. Nyce and P. Kahn, editors, and V. Bush, *From Memex to Hypertext: Vannevar Bush and the Mind's Machine*, Academic Press, 1992.
An edited collection of Bush's writing about Memex, together with essays from computing historians.

M. Weiser, Some computer science issues in ubiquitous computing, *Communications of the ACM*, Vol. 36, No. 7, pp. 75–84, July 1993.
Classic article on issues relating to ubiquitous computing, including hardware, interaction software, networks, applications and methods.

A. Dix, T. Rodden, N. Davies, J. Trevor, A. Friday and K. Palfreyman, Exploiting space and location as a design framework for interactive mobile systems, *ACM Transactions on Computer–Human Interaction (TOCHI)*, Vol. 7, No. 3, pp. 285–321, September 2000.
Explores the space of context sensitive designs focussed especially on location.

There are also a number of special journal issues on ubiquitous, sensor-based and context-aware computing in *ACM TOCHI*, *Human–Computer Interaction* and *Communications of the ACM* and dedicated journals such as *IEEE Pervasive* and *Personal Technologies Journal*.