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Human-Computer Interaction
An Overview

Victor J. Demczuk

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HUMAN-COMPUTER INTERACTION
An Overview

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Information Technology Division
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DSTO-TR-0260

ABSTRACT

Technical Report

This report is a summary of current research and topical areas of interest in the Human Computer Interaction field.

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HUMAN-COMPUTER INTERACTION
An Overview

EXECUTIVE SUMMARY

This report is a summary of current research and topical areas of interest in the Human Computer Interaction field. It covers the areas of User acceptance of computer technology, human performance, human factors methods, usability, human factors standards, user interface software concepts, visualisation, and advanced interfaces.

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1. *INTRODUCTION*

This paper attempts to provide a overview of current Human-Computer Interaction (HCI) issues, and techniques. It is based on a literature search of relevant issues and personal opinion of what areas are significant.

The field of Human-Computer Interaction is very broad, incorporating fields such as psychology, software engineering, hardware design, asthetics and specific user domains. These fields must be successfully integrated for good HCI design to take place.

Systems that have been explicitly designed to be useable and affordable over their whole life cycle are expected to provide benefits in:- increased efficiency and effectiveness of individuals, increased efficiency and effectiveness of groups, increased user acceptance, increased job satisfaction, reduction in mission critical user errors, reduction of training costs, reduction in personnel requirements. The benefit of the approach described above is typified by the MANPRINT program adopted by the US DoD and UK MoD (Booher, 1990).

Computer systems are often only technically successful, but users may find them confusing to use, inconsistent, difficult to learn, and error prone. If users do not accept the introduction of systems, the systems cannot be used effectively.

2. *USER ACCEPTANCE OF COMPUTER TECHNOLOGY*

Any change in an environment, particularly if it impacts on people's primary tasks, will be seen as threatening by some people. Others may see the same situation as an opportunity for improved performance and advancement. An important question that needs to be answered, is what discriminates acceptance from rejection?

Rouse (1986) suggests that user acceptance is influenced on four dimensions. These dimensions include;

- users' perceptions of the impact of computers on quality of job performance,
- ease of use,
- impact on discretion and
- organisational and peer group attitudes to the introduction of computers.

Automation of functions by computer systems (particularly command and control systems), can involve one or more of the following functions:

- synthesis - the generation of alternatives,
- analysis - the evaluation of alternatives,
- decision - the selection among alternatives,
- control - implementation of alternatives and
- monitoring - observation of results.

The decision on which functions should be computerised should be made after analysis activities such as prescribed under MIL-H-46855 (see section 6.2). This should allow logical division of tasks between computers and humans.

Automation of functions need not be negatively perceived if the automated functions are **not** those over which users want discretion. Computerising of a function eliminates human involvement in that function. In contrast computer aiding may change behavioural requirements but does not eliminate them. The most common functions of automation are monitoring and control. Decision making may be found as computer-aided support. The work of (Adelman, 1986) covers decision making aids in command and control (C2) systems. The control in C2 systems are more complex than the monitoring and control requirements in say a power station.

Computerised synthesis and analysis systems in the form of "expert systems" have become available in a number of areas. They are automated in that they produce and analyse alternatives. Their autonomy is limited because they need to be used by knowledgeable professionals who can readily evaluate and pass judgement on the systems result. In effect the "expert assistant" can be corrected as needed. Successful systems tend to concentrate on analysis rather than synthesis with the interaction between the expert user and the computer producing the desired outcome.

In respect to the above five functions of automation in terms of discretion, it has been suggested that users are mainly concerned with opportunities to exercise skills, judgement, and creativity. Discretion relative to monitoring and control involves the opportunity to exercise skills such as landing an aircraft. Judgement is used in the decision function as in choosing among alternate courses. Discretion in regard to creativity involves the opportunity to synthesise or generate new alternatives.

Users may desire discretion for several reasons. They may not perceive the automation to be reliable or credible. This is a **performance** dimension of user acceptance. The computer system may require a function to be performed in a way that is inconsistent with users'

abilities and limitations. This is an **ease-of-use** dimension of user acceptance.

Beyond the performance and ease of use aspects, the need to "feel in control" and self-satisfaction are important individual needs. Computerisation need not be negative if the automated functions are **not** those over which users desire discretion.

Rouse suggests that it is the **perceived** impact of computerisation on user discretion that most strongly discriminates user acceptance.

2.1 *Impact on the system*

Interest in the introduction of computerised systems is based on the potential benefits. Bottom-up automation of task performance usually results in humans monitoring computerised systems. For example, information may be highly filtered and collated before humans make any decisions. This type of aiding may increase throughput, however it usually also lessens discretion in exercising skill. Top-down automation of job supervision, in terms of increased managerial or organisational control can be powerful and useful. System-wide benefits can be realised over local considerations. Ineffective and inefficient aspects of system operations can be quickly identified and resources can be dynamically reallocated.

Centralised control places pressure on individuals to keep pace with the system. Another problem is that global policies might not be understandable in local contexts. Humans in any one part of the system cannot exert effective control on that part of the system because they lack knowledge of the objectives and operations of the total system. This can decrease their abilities to operate as system components. This is particularly a problem in failure situations, because in all computerised systems, humans are the ultimate backup system.

2.2 *Impact on humans*

Some of the major effects of computerisation impact on the individual's tasks and behaviours. People tend to perceive change in terms of how it affects them personally rather than in more abstract terms. With increased computerisation humans in general will be:

- performing tasks **less**,
- watching and listening **more**,
- walking around and communicating face to face **less**,
- key pressing **more**,
- exercising much **less** discretion,

- coping with much **more** complexity.

The above trends have the potential for negatively effecting acceptance of computerisation by three types of perceived loss of discretion;

- loss of feeling in control,
- decreased self-satisfaction in task performance,
- decreased opportunity for person-person interaction.

An important question to be answered is, can computerisation be introduced without creating these perceptions?

It should be noted that not all operations are normal and routine. Unfamiliar and failure situations emerge, and humans are expected to intervene. Humans are social animals. They need to interact and this social interaction is an important medium of exchanging information.

2.3 *Impact on acceptance.*

Computerisation is accepted to the extent that it is favourably received and willingly used as intended. Acceptance has been found to **increase** with automation of tasks that humans cannot perform, distracting tasks, and tedious tasks. Acceptance also **increases** as staff gain experience with automation, and is greater for staff who have more status, responsibility and authority.

Acceptance has been found to **decrease** when the automated functions involve decision making when the costs of failure are high. It also **decreases** when staff have no discretion in selecting modes of automation and intervening when they feel it necessary.

2.4 *Operational Problems*

A major problem with computerisation is coping with system failure. Human errors in association with computerisation have been well documented. Computers do what they are told, even if the instructions are inappropriate. If humans do not have the means or the motivation to check what is happening, automation can "fly into the side of a mountain". Humans' concern that they might supply inappropriate inputs can lead to their avoiding automation or duplicating its efforts as a means of checking.

Humans can also be misled by automation. False alarms and missed warnings by automated systems can lead humans to be unaware of real situations. Fault-tolerant systems can progressively compensate for an increasingly degraded system and avoid "bothering" the operators until the situation is almost hopeless.

Humans exhibit consistently poor performance in monitoring complex systems. When the humans' primary role is simply watching, they have a difficult time remaining vigilant and interpreting what they see. As a result, they are ill-prepared to detect that intervention is necessary and subsequently to act appropriately. This can also lead to diffusion and abandonment of responsibility.

Beyond vigilance and interpretation problems, humans have difficulty acquiring and retaining abilities they hardly ever use. Automation often causes loss of skills in experts. People can feel increasingly remote from their tasks, particularly if previously those tasks involved social interactions.

2.5 *Shifting the emphasis*

The use of computer technology should be a means to an end. Thus computerisation should be objectives-driven rather than technology-driven. User acceptance can be affected by manipulating perceived impact on discretion, i.e. making computer use optional.

2.6 *Recommendations*

Research should be conducted on the perceived impact that discretion plays on user acceptance. The various roles such as commander and analyst should be studied to determine what discretionary tasks they consider important. Computerisation is accepted to the extent that it is favourably received and willingly used as intended. It should be objectives-driven rather than technology-driven.

3. *THE HUMAN IN HCI*

In order to better design human-computer interfaces, we need a good understanding of what are the human capacities and limitations. This can relate to either individual or group performance.

3.1 Individual performance data.

Two types are available; basic data from experimental psychology, and applied data from human factors research. References such as Boff & Lincoln (1988) and Helander (1988) are good sources of performance data.

Individual performance data: There are three areas of basic research.

(1) **Perception** - visual, auditory, other senses. As an example the legibility of text is a visual perception issue.

(2) **Cognition** - memory, problem solving, learning. As an example reading a block of text and extracting its meaning, is a cognitive activity.

(3) **Motor behavior** - pointing, typing, speaking. As an example scrolling though a large text document using a keyboard or a mouse is a motor activity.

3.2 Group performance data:

The main questions asked are;

(1) How does group behaviour differ from individual behaviour?

(2) What factors influence group behaviour?

The disciplines usually involved in group studies are; sociology, social psychology, anthropology, and management science. It is usual because of the complexity of interactions to consider applied problems rather than the basic simple tasks that are often considered in individual performance research.

Basic tasks tend to be "unreal" tasks, but can have a large degree of experimental control and no prior knowledge is needed. Applied tasks may be either "toy" or trivial tasks, parts of real tasks (e.g. reading menus) or real tasks (e.g. observations in the workplace). Less control is needed for part-tasks, they require prior knowledge, and may have large individual differences. "Real" tasks usually mean minimal control, extensive prior knowledge, and many confounding variables. Sanders (1991) makes the point that simulation technologies are becoming

sophisticated enough to be able to analyse complex tasks in a rigorous manner.

Areas where computer support is sought are often complex and not amenable to simple analysis. Research is ongoing to determine methodologies appropriate in dealing with complex systems.

3.4 Recommendations

A core competency in human performance analysis needs to be maintained in ITD to support HCI research.

4 *HUMAN FACTORS METHODS*

In this context a method is a regular, definite procedure for obtaining a desired result. The desired result is a computer system which is acceptable to the user.

The universal experience of system development is that systems should be designed for the users. Commercial organisations have lost many millions by purchasing systems that do not quite fit their requirements - and some commercial organisations did not survive the experience.

Over the years a number of methods have become available to HCI practitioners to aid in the design of useable systems. These include:-

(1) User requirements elicitation methods

  (a) Rapid Prototyping and/or Storyboarding

  (b) Requirement Elicitation Techniques

(2) Usability testing

In formal systems analysis there are numerous techniques available for capturing system and some which address user requirements. In the field of HCI these have not generally been taken up. The major cause of their inapplicability to the human end of the system could be their lack of flexibility which demands expression of requirements in system related terms. The results may be comprehensible to systems analysts and programmers but rarely so to users.

4.1 Observation

In rapid prototyping and usability testing, human performance on system tasks is usually observed or measured. There are a number of aspects that are considered in an experimental evaluation of a system. They include:- performance time, time to learn, errors, satisfaction, "think-aloud" protocols.

If the measures are relevant and conditions generalizable then useful results are possible. It is useful for understanding the work process and identifying "critical" incidents. It is currently popular to make use of "Usability laboratories" to conduct these observation techniques. The cost-effectiveness of these laboratories may be debatable.

4.2 *Modeling*

Used for performance prediction, simulation of human performance, complexity demonstrations. A good example of a modelling technique is the GOMS (Goals, Operators, Methods, Selection rules) methodology. It provides prediction of sequence of operations, performance time, learning time, but is weak on error prediction.

4.3 *Engineering*

In an attempt to move from the "art" of human-computer interaction to a more rigorous methodology, a number of tools/techniques have been developed or adapted from other fields.

(1) **Expert design**. Intuitive design and evaluation based on experience may reside in an individual designer, or a case library.

(2) **Standards, guidelines and rules**. Various documents are available eg MIL ISO, UK, which tend to be generally stated and imposed in some formal manner. They can be very useful in enforcing in a legal way some minimum human factor requirements.

(3) **Usability inspection methods**. There is family of techniques such as heuristic evaluation, feature inspection, consistency inspection. (Nielson, 1993)

(4) **Walkthroughs**. Similar to software design walkthroughs. Cognitive walkthroughs - focus on cues in the environment. (Lewis, Polson, Wharton, & Rieman (1990)). Programming walkthroughs - primarily language design, focus on knowledge necessary for use. (Bell, Rieman, & Lewis (1990)).

(5) **Formal methods**. Task action grammar, State-Transition networks, PIE interaction modeling, User action notation.

(6) **Claims analysis.** Comparible to reverse engineering. Examine features for psychological claims embodied in its design, e.g menus embody claim that recognition is easier than recall.

There is still a need to support iterative design, prototyping and evaluation. This allows users to interact with the complexity of systems and highlight un-anticipated problems.

4.4 *CORE*

A controlled requirements expression (CORE) was developed jointly by SD-Scicon and British Aerospace as a more flexible approach to systems design and is not specifically aimed at computer systems design. CORE requires the definition of the problem and the subsequent reduction of this to a number of viewpoints. The viewpoint of users can be accommodated in the CORE analysis.

CORE has been successfully used by UK MoD, British Aerospace (UK), British Aerospace (Australia) and British Telecom in systems definition studies.

4.5 *Recommendations*

The HCIL should maintain a watching brief on standards and methodologies in the Human Factors area so as to be able to recommend their use where appropriate. More effort could be expended in providing support to the analysis phase of projects so as to be influential as early as possible.

5. *USABILITY*

5.1 *Introduction*

Usability is often considered to be the end-users definition of system **quality**.

The purpose of usability design effort is to minimise the extra effort imposed on users by;

- mapping work onto functions
- learning and remembering commands
- learning and remembering how to operate devices
- perceiving and comprehending displays
- mapping system status onto work goals
- making and recovering from errors
- keeping track of multiple work states

Usability design involves an analysis of requirements, then a preliminary design, building a prototype, evaluating the effectiveness of relevant tasks on the prototype, then iterating around the design-prototype-evaluation cycle as needed until usability criteria have been satisfied.

5.2 *Objective criteria*

To determine an objective Usability criteria, a methodology such as described in Demczuk (1987) can be employed. It requires the definition of the range of user tasks in terms of effectiveness, learnability, flexibility and attitude. Although it does not specifically mention Usability US Military Specification MIL-H-46855B provides a methodology for determining objective criteria.

If objective Usability requirements are defined, it becomes possible to specify these in a contract that is legally enforcable. It also provides a rational way to compare relative performance of competing tenders. It also becomes possible to have an objective way of measuring the increase/decrease in efficiency of future enhancements. Since it is defined in task terms, it is independent of the technology enabling the task.

5.3 *Usability Standards*

There has recently been considerable work in the European Economic Community on Usability Standards. A Draft International Standard ISO DIS 9241-11 "Ergonomic requirements for office work with visual display terminals (VDTs):- Part 11: Guidance on Usability" has been produced. It has as its definition of Usability "The extent to which a product can be used by specified users to achieve specified goals with **effectiveness, efficiency** and **satisfaction** in a specified context of use." This standard emphasises the need for objective usability criteria.

Within ISO 9241-11 the context of measurement must match the context of use, which is broken up into **users, task, equipment**, and **environment**. Information needs to be collected under each heading so as to define the context. The nature of the product, the tasks being specified and the breadth of the context all interact to determine which measures will be used.

By specifying the above information in a contract, users can be more confident that they will get what they ask for. Contract disputes are minimised because of the visibility of requirements.

5.4 *Usability Tools*

Bevan and MacLeod (1994) provide a good description of Usability tools such as MUSiC which have come out of an ESPRIT project on Usability. They make the point that Usability is a property of a whole system. It is the quality of use in a particular context. The **effectiveness** can be defined in terms of the extent to which the intended goals of use of the system are achieved. For example the goal may be to transcribe a two page document into a specified format. A measure of effectiveness could be the number of spelling mistakes and the number of deviations from the correct format. The **efficiency** can be defined in terms of the consumption of resources such as time, money, and mental effort needed to achieve the intended goals. For example, if the desired goal was

production of a report, then economic efficiency would be the number of usable copies printed, divided by the resources used on the task such as labour hours, process costs and materials consumed. The **satisfaction** is the extent to which the user finds the system acceptable. Satisfaction can be specified and measured by attitude rating scales.

5.5 Recommendations

Objective usability criteria should be developed for all human-computer interface systems. If contractural issues arise standards such as ISO DIS 9241-11 and MIL-H-4685B should be used. Expertise should be gained in the use of emerging usability standards and tools.

6. HUMAN FACTORS STANDARDS

A standard is a document that specifies a particular way of working.

There is a temptation to regard standards as absolutes and, in the field of HCI, this has resulted in developers suggesting that standards inhibit progress. This was certainly the case in the early days of creating HCI standards when they attempted to describe what should appear on the screen under given circumstances. For example, the following is based on an existing ISO Standard:-

Viewing Distance = 0.5m

Char height = 3.2 mm

Char Width = 2.24 mm

Stroke width = 0.36 mm

Horiz. Spacing (min) = 0.36 mm (or 1 pixel - whichever >)

Line Spacing (min) = 0.72 mm (or 2 pixel - whichever >)

Note that if applied to the personal organiser or hand held input terminal (eg. used in stock control) this will cause design problems.

Developing standards are phrased in terms of the user performance required of the system.

6.1 *ISO 9241: Ergonomics Standards for Office Work with Visual Display Terminals*

Core elements of this standard are specified in terms of the performance of the user and not in terms of absolute values. The emphasis has been shifted from the means of achieving an aim, to determining how well the aim has been achieved. ISO 9241 consists of 19 parts;

(1) General Introduction

(2) Guidance on task requirements

(3) Visual display requirements

(4) Keyboard requirements

(5) Workstation layout and postural requirements

(6) Environmental requirements

(7) Display requirements with reflections

(8) Requirements for displayed colours

(9) Requirements for non-keyboard input devices

(10) Dialogue principles

(11) Usability statements

(12) Presentation of information

(13) User guidance

(14) Menu dialogues

(15) Command dialogues

(16) Direct manipulation dialogues

(17) Form filling dialogues

(18) Question and answer dialogues

(19) Natural language dialogues

6.2 *US MIL-H-46855B: Human Engineering Requirements for Military Systems, Equipment and Facilities.*

This specification defines the requirements and methods used for applying human engineering to the development and acquisition of military systems, equipment and facilities. It includes the work to be accomplished by contractors in conducting a human engineering effort

integrated with the total system and development effort. It is a very useful document to include in contractual specifications, as it puts the onus on the contractor to do the human engineering work. It has been used successfully in the JORN project.

6.3 US MIL-STD-1472: Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

This USA standard presents general human engineering design criteria for military systems, equipment and facilities. It covers the "nuts and bolts" aspects of systems. It includes a specific section on the user-computer interface. Projects such as AUSTACCS and JORN have made use of this standard, with some "tailoring" for Australian requirements.

6.4 MIL-HDBK-759A: Human Factors Engineering Design for Army Materiel.

This handbook is a compendium of general data and detailed criteria for human factors engineering of Army materiel.

6.5 UK DEF STAN 00-25: Human Factors for designers of equipment. (12 Parts)

This standard, which is still under review contains the following parts:-

(1) Introduction

(2) Body size

(3) Body strength and stamina

(4) Workplace design (interim)

(5) Stresses and hazards (interim)

(6) Vision and lighting

(7) Visual displays

(8) Auditory information (interim)

(9) Voice communication (interim)

(10) Controls

(11) Design for maintainability (interim)

(12) Systems (interim)

The standard is considered as a permissive guideline, rather than mandatory. Its usefulness as a contractual document is therefore limited in a legal sense.

6.6 ANSI/HFS 100-1988: American National Standard for Human Factors Engineering of Visual Display Terminal Workstations.

This standard specifies requirements for visual display terminals.

6.7 Recommendations:

ITD should maintain a watching brief on standards in the Human Factors area so as to be able to advise on their use. ITD should also investigate other TTCP countries' Human Factors procurement practices (such as the USA and UK MANPRINT initiative) to ensure that human factors is considered at all stages of the ADF's procurement process. This should be achieved by mandating Human Factors activities and deliverables which should be undertaken throughout the life cycle.

7. USER INTERFACE SOFTWARE CONCEPTS

7.1 Separation of interface from application

The designer of an interactive system has a large number of methodologies available with which to build the required interface. Software Engineering techniques can be used to not only design but also specify and maintain the code for systems. An attempt to optimise the **process** of design is useful. The ideal of a design methodology is that of a procedure which leads to a good design (Baecker & Buxton, 1987).

A useful technique to support design/construction/maintenance is that of dialogue independence. This is where the human-computer interface is kept logically separate from the underlying application. There is an analogy to data independence in DBMS. This enables design decisions affecting only the dialogue to be isolated from computational software. It supports different roles and expertise, where interface specialists and graphic designers can concentrate on the interface, while algorithim and database designers can concentrate say on the database design.

Foley & Wallace (1974) divide the design process into 4 levels:- conceptual, semantic, syntactic, and lexical with separate design, specification, and implementation for the four levels.

(1) Conceptual Design levels: - basic entities and operations, it may not explicitly appear in the code.

(2) Semantic - application or client level. Implements the actual functions performed by the system.

(3) Syntactic - sequence of abstract events or tokens that occur in the dialogue.

(4) Lexical - describes hardware actions that correspond to each input and output token. Covers low level details such as function key assignments, display layout, output formats.

7.2 *Interaction techniques*

Basic interaction styles common now include: - command language, question and answer, form-based, menu, natural language, direct manipulation.

Emerging and future techniques will include: - virtual reality, pen-based, gesture based, outline/information hiding and visualisation, agents.

7.3 *User Interface Management system (UIMS)*

The user interface can be considered as the software that sits between the functional part of the application and the end user. The UIMS is a set of tools that can be used in managing the user interface. It encompasses the Syntactic and Lexical levels of interaction.

The tools that are available vary from those that support screen design, through to those that support an interaction style.

(1) Toolkits such as Motif, Macintosh toolbox, SunView, and XView usually contain a library of reusable routines for implementing interface features. They may be of two basic types- procedural or object oriented. Their basic components are a set of "widgets" or "intrinsics". They generally support a standard "look-and-feel".

(2) Interactive builders use direct manipulation techniques for specifying direct manipulation interfaces. They plug together components with pre-defined interactive behaviour. Examples are : - UIM/X, Windows/4GL, NeXT Interface builder, X-designer.

(3) Screen mockup and prototyping tools vary from the simplest ones which control a "slide-show" of non-interactive screens. The more sophisticated are like UIMS but without the ability to call separate application programs e.g.Dan Briklin Demo program, MacroMind Director, Hypercard.

7.4 *Recommendations*

The use of User Interface Management Systems should be promoted as widely as possible to facilitate dialogue independence. The payoff will be in better interface specification, design, construction and maintenance.

8. VISUALISATION

8.1 Introduction

Visualization involves the use of visual representations to facilitate the communication of knowledge. Knowledge in a computer is often in an incomprehensible form and needs to be translated to a representation that is meaningful to a human.

Visualization can be divided into 3 areas;

(1) **Numerical data display**, which seeks to summarize sets of numbers. For data sets of two dimensions, simple graphs can be used. For increasing dimensions, more elaborate display techniques such as colour , shape, 3-D, , movement, time, transparency, and texture can be used.

(2) **Real-world situations or models**. A flight simulator is an example of this type of visualization. A map can be considered an example of a visualization of the real-world. Virtual Environments are also an example.

(3) **Structural or organisational information**. The directory structure of a computer or the order-of-battle (ORBAT) of a military organization are typical examples.

8.2 Attributes

The increase of computer power in recent times has facilitated considerable work in computer visualization of large datasets. A number of modes can be used to communicate information on a display screen.

(1) **Colour**. A number of discrete colours can be used to define particular characteristics (such as green for vegetation on a map), or a range of data values (such as red defining say numbers from 10-20 in a data set). The limitation is an interaction between hardware constraints on numbers of available colours, and perceptual differentiation of the various colours.

(2) **Shape**. The relationship between data sets can be represented by shape and spatial relationships. The NetMap paradigm uses the size and position of circles to convey information about the inter-relationship of large data sets.

(3) **Three-dimensions**. The illusion of depth can be added to displays by the use of techniques such as polarised or shutter glasses. Pseudo 3D such as perspective drawings are also employed. The addition of the depth information can help to differentiate data, or to improve the simulation of a real-world situation (e.g. in a flight simulator).

(4) **Movement**. This can be used in at least two ways. The first is with the use of animation where objects move around the display in meaningful ways. An example might be the progress of an enemy force symbol across a military map. Another use of movement is the coding of the movement of an object to a range of data values. For example a column in a bar chart might vibrate. The column may represent an average value and the variability is related to the amplitude of vibration.

(5) **Time**. This is often used in conjunction with animation to represent aspects of a situation such as velocity, locations at particular times, existences of phenomena. For example the animated display of a hurricane weather pattern shows its spatial and temporal locations, as well as its size/life.

(6) **Transparency**. This can be used in visualization of data sets when linked to a range of values of a particular dimension. For example a 3-D model of a city may represent changing smog levels over time by the transparency of the smog layer over the city.

(7) **Texture**. This can be used as a visual characteristic to visualize another dimension of a data set. For example 4 degrees of roughness may represent 4 ranges of data values(e.g. density). This roughness can be applied to colour values which represent another dimension of data (e.g. vegetation).

(8) **Virtual environments**. These allow the visualization to represent data in a model that exists only inside the computer. For example the safe flight path of an aircraft might be represented as a "road" in the sky that can be flown by the aircraft. Virtual reality models which allow the user to be fully "immersed" in the environment are an ultimate visualization.

8.3 Recommendation:

Research into visualization can maximise the effective use of display devices. It provides a tool for coping with the large amounts of data that can be made available by electronic means. This research should take place as a matter of high priority as the widespread introduction of information systems will increase the amount of electronic data that can be accessed, without necessarily the display tools to efficiently interpret the data.

9. *ADVANCED INTERFACES*

9.1 Hand-held computers:

The Apple Newton hand-held computer is a good example of hand-held computer technology. It holds the promise of being a user-friendly device for people who are not computer literate.

The hand-held computer weighs a half-kilo, has a large display, a handwriting recognition capability, sound output, a potential for speech recognition and an intelligent assistant that can interpret complex commands and perform a number of combined operations. It incorporates software that anticipates the user's intentions. For example, if the phrase "call jim" is written and the Intelligent Assistant icon is tapped, the program opens the address book. On selecting the correct Jim the unit calls the appropriate telephone number. The unit communicates to other units and computers via an infra-red link.

In the military context, what could happen is that a staff officer leaves his home office to brief the commander. A device like the Newton could carry briefing notes and graphics that can be shown to the commander, as well as recording notes that can be taken while in discussion with the commander. This type of device could be beneficial in a high-level command and control environment.

9.2 Audio Interfaces:

(a) Speech input/output: Speech input and output is a very natural interface. Practical synthesisers are available now. Speech recognisors are still only available in narrow domains. It is expected that they will continue to slowly improve.

Speech analysis holds the promise of unobtrusive stress monitoring which could be used in performance assessment of command and control systems.

(b) Nonspeech audio: Sound is a natural medium for conveying information about:-

(i) physical events (did the dropped glass bounce or shatter?),

(ii) invisible structures (tapping on a wall to find a stud),

(iii) dynamic change (as we fill a glass we hear when the liquid has reached the top),

(iv) abnormal structures (a faulty engine sounds different to a normal one) and

(v) events in space (footsteps warn us of the approach of a person).

Earcons have been proposed as the audio equivalent to visual icons. Sounds with particular characteristics can provide feedback as to processes. For example a background audio cue could let the user know the status of a print job on a network without looking at a screen or walking down to a remote printer.

These interfaces are available now, they only need to be implemented in prototype systems and demonstrated to the service clients.

9.3 *Gesture interfaces*

Devices such as the Data Glove provide the user with an input device with a large number of degrees of freedom, and, consequently, many uses.

(1) In virtual environments the glove is used for navigation, ie. pointing causes the user to move through the environment in the pointed direction. Objects can also be picked-up and moved by hand movements. Gestures are a natural interface in a 3D environment.

(2) For disabled people, these devices have been interfaced to speech synthesisers by means of sign language for the gloved hand. A similar possible military application could be a replacement for a keyboard for a user in a NBC suit.

(3) In combination with other interfaces such as speech recognition, gestural commands such as "Put that there" become practical. In that interface, though a combination of pointing and spoken commands, objects are created, named, moved, copied and erased.

The hardware to research gesture interfaces is available now; the importance of research in this area should be considered.

9.4 *Virtual Environments*

The following application areas stand to gain significantly from developments in Virtual Environment (VE) technology:

(1) **Data or Model Visualisation**. Scientific visualisation can be used for extracting understanding from large data spaces. Stereoscopic imaging combined with intuitive control over point of view frees the user to concentrate on the data rather than the computer interface.

Augmentation is an extension of data visualisation. The image presented to the user is a combination of a computer-generated image and the view of the real world around the user.

(2) **Designing and planning**. A primary characteristic of design activities is the iterative *analyse-refine* cycle which takes place as the model evolves. Because a strength of VE is the capability for direct

manipulation of objects within the virtual space, design activities should benefit from this activity. There are already applications for architectural design and surgical planning using VE technology.

(3) **Education and Training**. Computer models of real-world systems can be presented through a virtual environment. Given the constraint of limited fidelity, the user can interact with the virtual system as though it were the real thing. In addition to simulating the real world, the rules governing a real world can be altered. In this way the effect and importance of various physical parameters can be studied and the training focus can be on cognitive skills rather than the specifics of a particular environment.

(4) **Teleoperations**. VE can be applied to situations where an environment is too hazardous for a human, but a tele-sensor/operator may enter. As an example, the exploration of the sunken Titanic was accomplished primarily through teleoperations.

(5) **Psychological Test Beds**. VEs can produce physically unrealisable stimulus environments that are uniquely useful for testing theories of human perception and manual control. This includes research into visual, auditory, and haptic or touch stimuli, and its effects, both short term and long-term, on the user of a VE.

(6) **Entertainment and Artistic applications**. Given the amount of public and media interest in VE technology, there is an economic potential for entertainment that calls itself "virtual reality". It is the area of fastest growth in the VE field.

The basic activity of artists is to create space - whether physical, mental, visual or emotional. As VE technology becomes more widely accessible, it is reasonable to expect that artists will begin to explore the unique possibilities of virtual environments.

(7) **Communications and Collaboration**. Virtual environments coupled with high-speed networks and distributed computation provide a common neutral space where communication, negotiation and collaboration can take place. The ability for two or more people in separate locations to meet inside a virtual space and work toward a common goal has the potential to revolutionise the way collaborative work is done.

9.5 Virtual Environment problem areas

The particular deficiencies and needs of the virtual environment are:-

(1) **Hardware, software and interface issues**. 3D Audio interfaces appear to be useable and of reasonable cost. Display devices are of low resolution and expensive. This should improve over the next few years. Graphics processors are still too slow and too costly. VE requires very large amounts of computing power. The question

becomes "what is the minimum power necessary for a particular task?"

(2) **Model engineering.** Building of non-trivial models takes considerable effort. The virtual environment represented in the video "Battle of 73 Easting" cost about $1.5 million.

(3) **Psychological measurement techniques and metrics.** There is a need to measure human cognitive performance which is difficult and an active area of research.

(4) **Simulator sickness.** It is expected that as VE becomes more realistic and people spend longer in VE's, people will increasingly show the adverse physical symptoms known as simulator sickness.

9.6 Natural Language interfaces.

These are becoming available to connect to databases. One example is "Natural Language" from Natural Language Inc. They translate English sentences into SQL commands which can query and retrieve a database for information. The interface is usually tailored to a particular domain and database, which constrains the scope of discourse.

Language is a social phenomenon. The language interaction that is normal between humans is still not possible with a computer. Users of natural languages need to understand the limitations of the interface. The major limitation with present systems is that they process only one question at a time.

9.7 Graphical Query interfaces

These can be used to query and interact with databases. They present the user with a visual representation, or Data Model of the host database. One example is GQL (Graphical Query Language) from Andyne Computing Ltd.

The user clicks on the diagram to indicate the tables containing the information to be retrieved and the relationships which should apply. The user builds up a query by clicking on the attributes to be displayed and entering any appropriate conditions.

This type of interface does require the user to have more database expertise than the natural Language type interface. However it does provide a visual representation of the data model, so a more complete picture of complex inter-relationships is possible.

9.8 Information Interfaces

The pervasive networks that are being proposed will strain the capabilities of present day user interfaces like Windows, the Macintosh and Motif window-manager, because they are designed to deal with

between 100-500 resources, and in the future computers will have access to millions of resources.

Hypermedia promises to provide efficient techniques to present information. However navigation through the information space can be a problem. Handcrafted links between information can be very complex. The issue of information "chunk size" is important and raises the question of how does one cope with multiple information spaces? Information is not brought to the user; rather the user has to go to different places in the dataspace to get information. As an explorer in a potentially world-sized information space, the user will need help.

One way to cope with information overload is to ignore detail and concentrate on relationships between information groups, ie. look for larger patterns. Some tools are being developed to support this. An example is the Knowledge Finder text retrieval software. The user has control over the quality/relevance searching strategy. When the text is retrieved, a visual picture is given of how relevant that text is compared to the other possible retrievals.

The MIT Information and Object Lens project which uses intelligent assistants to sort electronic mail and other information is an example of what is possible in coping with very large information spaces. It uses semi structured templates, rule-based processing and an object-oriented database to represent information about messages, people, tasks and products.

In the past users had to adapt to computers. With the computing power now available, and increases in the future, it should be possible to adapt the computer to the user, ie. make the computer and user better collaborators. To do this the computer must be able to make inferences about the user, which will mean building a user model. A major hurdle is that people can change their actions dramatically in a short period, so any model must be adaptive.

9.9 Interface Agents

Interface agents can be defined as a computer based intelligent entities, that act on behalf of the user in a computer-based environment. There is a familiarity in the use of a living-organism metaphor in terms of cognitive accessibility and communication style. Their usefulness can range from managing mundane tasks, like scheduling, to handling customised information searches that combine both filtering and the retrieval of alternate representations.

Agents, like anything else, can be well or poorly designed. A good one will do what the user wants, informing the user what he/she wants to know about what it is doing, and giving back control on demand. Good interfaces usually allow for more than one way of interaction. Users should have agents by choice, and those who do not want to use them should have alternative choices.

Psychologically, humans are quite good at relating and communicating with other humans. When a machine or animal is anthropomorphised, a human personality is not invoked in all its detail and complexity. Only the traits that are useful in a particular context are invoked. Humans expect computers to perform with *responsiveness* and have the *capacity to perform actions.* These are qualities of agency. Agents provide expertise, skill and labour, particularly for tasks that are too complex for simple algorithmic solutions or for complete parametric specification by the human user.

A military example might be for an Intelligence workstation where a naval collation clerk agent might collect and store all data that referred to sea activities. A more general example might be for a postman agent to organise the electronic mail for a particular user.

Research needs to be done on user needs for agents to answer questions such as; what are the qualities of a task that make it a good candidate for an agent-like interface, how do we select the appropriate traits for a given agent, and do non- computer literate users relate better to agents than skilled computer users?

9.10 Recommendations

In the next 10 years it is predicted that user interfaces will consist of large, wall-size displays in 2D and 3D for group viewing, desktop and handheld displays for single user viewing, personal glasses for virtual environments. Multimedia, multi-dimensional interaction, multiple agents and metaphors, speech input, portable access to telecommunications with people and computers will all be standard. These the user interaction with these various new technologies and techniques should be researched now so they may be best incorporated in future command and control and other information systems.

10. CONCLUSION

This document has attempted to cover a number of issues of relevance to the field of Human-Computer Interaction. It is a dynamic and rapidly changing field and users, designers and procurers of information systems need to be aware of the capabilities and pitfalls of human-computer interactions. A regular update of the field, such as this document tries to achieve can be of value. It is important that the field be continually monitored to evaluate emerging techniques and technologies so that they may best be integrated into information systems.

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HUMAN-COMPUTER INTERACTION
An Overview

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19. Abstract

This report is a summary of current research and topical areas of interest in the Human Computer Interaction field.