Developing an alternate interaction device for domestic multimedia environment

Kalamullah Ramli

University of Wollongong

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Developing An Alternate Interaction Device for Domestic Multimedia Environment

A thesis submitted to the University of Wollongong in partial fulfilment of the requirements for the award of the degree of

Honours Master of Engineering (in Telecommunications Engineering)

by

Kalamullah Ramli

Bachelor of Engineering, Universitas Indonesia

August 1997

The School of Electrical, Computer, & Telecommunication Engineering
ABSTRACT

The continuing advances in digital storage, transmission and processing technology makes interactive multimedia within the reach of a network environment. This opens a wide range of services for accessing from the living room in a residential environment. These technological advances, however, create the need for a suitable user interface. The interface may be built into the users' television set or a stand-alone multimedia console that allows the viewer to selectively combine and switch between entertainment and information. The current VCR remote control for cable TV technology, which restricts the viewers to only 'surf' a limited number of channels, is becoming insufficient for the interactive multimedia TV.

This project investigated the provision an alternate user interaction device for the domestic multimedia environment. The development was focused on to how the device could take better advantage of users' natural capabilities rather than requiring users to learn to conform to the device's requirement. This is important because the individual viewer differs by age and skills. All abilities must be catered for when designing a device for controlling the Interactive Multimedia Television.
Statement of Originality

The work described in this thesis is entirely my own, except where due reference is made in the text.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed.

Kalamullah Ramli
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I would like to thank my supervisor, DR. H.W.P Beadle, for his support, guidance, assistance and encouragement. I am grateful for his patience in answering the many questions I had throughout this study, and explaining the concepts I did not understand. I would like also to acknowledge his effort in developing the initial code for VOD server (Sub-section 4.4.2)

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Kalamullah Ramli
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<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for International Interchange</td>
</tr>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
</tr>
<tr>
<td>pgmtopbm</td>
<td>Portable Grey Map Format to Portable Bitmap Format (UNIX application)</td>
</tr>
<tr>
<td>HDTV</td>
<td>High Definition Television</td>
</tr>
<tr>
<td>HEX</td>
<td>Hexadecimal Code</td>
</tr>
<tr>
<td>IMTV</td>
<td>Interactive Multimedia Television</td>
</tr>
<tr>
<td>ITV</td>
<td>Interactive Television</td>
</tr>
<tr>
<td>NTK</td>
<td>Newton Tool Kit</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
</tr>
<tr>
<td>pgmtopbm</td>
<td>Portable Grey Map Format to Portable Bitmap Format (UNIX application)</td>
</tr>
<tr>
<td>pnmraw</td>
<td>Portable Any Map (Raw Data) Format (UNIX application)</td>
</tr>
<tr>
<td>pnmscale</td>
<td>Portable Any Map Format Scaling (UNIX application)</td>
</tr>
<tr>
<td>ppmto pgm</td>
<td>Portable Pict Map Format to Portable Gray Map Format (UNIX application)</td>
</tr>
<tr>
<td>TSRC</td>
<td>Telecommunication Services Research Centre</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
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<tr>
<td>------</td>
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<tr>
<td>VCR</td>
<td>Video Cassette Recorder</td>
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<tr>
<td>VOD</td>
<td>Video On Demand</td>
</tr>
<tr>
<td>WIMP</td>
<td>Windows Icon Mouse Pointer</td>
</tr>
<tr>
<td>xse</td>
<td>X’s Event (X Window application)</td>
</tr>
<tr>
<td>xwd</td>
<td>X Window Dump (X Window application)</td>
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<tr>
<td>xwdtopnm</td>
<td>X Window Dump to Portable Any Map (X Window application)</td>
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<tr>
<td>xwpick</td>
<td>X Window Picker (X Window application)</td>
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Chapter 1

Introduction

1.1 Background

The emergence of Cable Modem and Asymmetric Digital Subscriber Line (ADSL) has made it possible for multimedia services to find their way into homes. Such services as interactive domestic entertainment and education services [COO95, HIC94, LIT94, SUT92] have come about through the use of satellite, cable, or terrestrial network. These developments have been marked by the convergence of the telecommunication, computer, and entertainment technologies, which in turn, creates the need for the development of suitable user interfaces and interaction devices for such services.

Digital multimedia services can be delivered for work or entertainment via the broadband network and set-top box. The dominant view of the telephone companies and many cable operators seem to be that the domestic multimedia system will have an architecture as depicted in Figure 1.1.
The STB is connected to a PC/TV set. The STB separates the data stream into its component units, e.g., MPEG-2 video, MPEG audio and private data, and sends them to the appropriate devices. For example, private data sent to the Central Processing Unit (CPU) may contain graphic menus for movies and games selection. This is processed by the CPU, sent to the graphics generator and used to realise processor generated graphics.

![Home Network Architecture](image)

**Figure 1.1 Home Network Architecture**

Users need a friendly user interface to find their way through all the service offered and communicate their requirements to the set-top box via a remote control. The request is sent through the return path to the control system which locates the required data in the storage server and presents it to the transmission system which delivers it to the set-top box for display on the TV set.

Upstream data from the TV set or the remote control transferred to set-top box.
The current problem that exists in the system is the TV screen resolution. A TV screen is appropriate for watching movie but not for displaying text. The introduction of high resolution TV displays or a more sophisticated remote control may overcome the poor TV screen capability to display text.

1.2 Motivation

The domestic Interactive Multimedia TV (IMTV) is likely to have a hypermedia interface where the content and the interaction mechanism are merged [DAV95, GEI95] and links are supported within and between text, images, video, audio, graphics and program media types [BEA97]. Interactivity can be fully be carried out at the multimedia document level (content searching, browsing, structure navigation, selective playback, etc.).

To interact with this user interface, a more advanced user input device than the present traditional VCR control is needed: one that can support selecting services in two (or three) dimensions and entering information for searches or inputting data. Several new devices such as a voice recognition device [GOO94], wireless keyboards and field mouse [ANT96], personal digital assistant (PDA)-based interaction device [ROB96], and other developing input devices, had been proposed to deal with this technology.

The purpose of this project is an attempt to investigate the provision of an alternative, usable interaction device for a multimedia system in a domestic setting. It involves the study, design and development of a prototype of the interaction device.
The interaction device is based on a hand-held Newton PDA touchscreen (touchpad). The touchpad acts as an uncommitted wireless remote control [BEA96a, GON96, INF, MAU96, ROB96] which allows the user interface to a particular piece of hypermedia to be separated from the program [SIB94, BEA96b] and loaded into the user interaction device, dynamically. The result is that the touchpad then presents only the required interaction information to the user in a particular situation nominated by the user. The interaction is provided by [BEA97]:

- pointing on the touchpad supporting current hyperlink interaction;
- moving the pointer on the touchpad supporting current mouse-based interaction;
- writing on the touchpad supporting text entry for queries and authentication;
- gesturing with the touchpad pointer supporting gesture-based input and interaction

The hypothesis examined in this thesis is that, by focusing on how an input device can be made to take advantage of basic human capabilities rather than humans needing to learn how to confirm with the device’s requirement, a usable interaction device can be developed. The touchscreen function employed in the interaction device has been shown experimentally to be more effective to the user than the traditional mouse for pointing tasks. In addition, the handwriting recognition-based input exploited from the Newton PDA feature has been found superior in some aspects of usability to the traditional keyboard in entering small amounts of text in data entry tasks. The device has also been shown to be more
appropriate for the domestic setting than current interaction devices such as, the wireless keyboard and the field mouse.

1.3 Objectives

The objectives of this project were:

1. to investigate the requirements of the interaction device for interactive multimedia system in a domestic setting;
2. to observe interaction devices that are appropriate for such an environment;
3. to design an alternate, usable interaction device for interactive multimedia system in a domestic environment;
4. to build a prototype of the interaction device;
5. to implement the interaction device into an emulation of interactive multimedia system; i.e., to prove that the device functions properly; and
6. to assess the usability level of the interaction device.

1.4 Report Outline

The report is divided into six chapters following two appendices.

Chapter 1 discuss the background and need for the project.

Chapter 2 reviews previous work on designing a user interface for multimedia systems, in particular, in a domestic setting. This was found to be lacking in two major aspects. None of the papers investigated the provision of an interaction device for the domestic multimedia environment. Also, none of the papers
observes the requirements of the interaction device for such an environment. The first aspect is the main objective of this project and, therefore, is the prime consideration throughout the project. The second aspect is addressed in Chapter 4.

Chapter 3 deals with the theoretical background on how to design a usable system or user interface. The design principles, considerations and guidelines are summarised, defined, or observed, from the literature and have been taken into account in designing the interaction device and its user interface. The statistical analysis and usability aspects that can be used to measure the usability level of the interaction device are also described in this Chapter.

The early design and prototyping process of the interaction device and its implementation into an interactive multimedia system emulator are described in Chapter 4. Several input devices which were suggested by some papers (outlined in Chapter 2) to be used in a domestic setting are examined against some requirements of the interaction device. A description on how the prototype of the interaction device was programmed and functioned in an interactive multimedia system test platform is also presented.

Chapter 5 deals with the evaluation process and discusses the findings. Section 5.2 presents the usability comparison between the device prototype, the wireless keyboard and the field mouse. The user testing is reported in Section 5.3. The results are also presented and discussed. The usability problem occurred during the test and the recommendation for system improvement are identified in that section. Using the result and recommendation from the first usability evaluation test, the system was re-designed and re-implemented to improve the overall performance. The process is described in Section 5.3. The results from the second
usability testing on the enhanced system are given and discussed in Section 5.4.

Section 5.5 presents the learning effect of the user experiments.

Chapter 6 outlines the conclusion of the project.

1.5 Contributions

This section lists the contributions contained in this project. The section where the relevant work is discussed is given.

1. Application of PDA-based input device as a controlling device for interactive TV that has been proposed in several research works [BEA96a, BEA96b, BEA95b, GON95]. Alternate development of this idea is contained in a paper by Robertson et. al. [ROB96].

2. Application of a new interaction technique, i.e., the remote touchscreen, for interactive PC/TV or Web TV technology. See Section 4.2.3. The original idea of this new technique was given in a paper by Beadle, et. al. [BEA96b]. It offers some significant advantages over a traditional touchscreen as described in Section 5.2.

1.6 Publication

Chapter 2

User Interface Design

for Domestic Multimedia Systems

2.1 Outline

This chapter is concerned with the scope and limitations of previous research on designing user interface for domestic multimedia setting. In Section 2.2 a variety of sources that recognise the important role of the user interface to support a highly usable system is drawn upon. The goals of user interface design and development are also identified. In Section 2.3, a literature review on user interface design, in general, and user interface design for interactive multimedia services, in particular, is discussed. The potential use of PC-TV technology and PDA-based interaction device are also observed. Some usability issues in designing user interface for domestic settings are considered in Section 2.4. Based on the reviews in the previous sections, inadequacies in previous work are identified in Section 2.5. The manner in which these inadequacies are addressed in
this project are also outlined. Section 2.6 summarises the discussion presented in this chapter.

2.2 User Interface Design Goals, Metric, and Evaluation

2.2.1 The Role of the User Interface in a System

The user interface is the central issue in human-computer interaction because users interact with a system through its interface. A research group of ten industrial representatives [NOL92] concluded that "if the interface is ineffective, the system's functionality and usefulness are limited; moreover, users become confused, frustrated, and annoyed". Therefore, as pointed out in other reports [BLU95, SZU95], over half of the total cost of new computer systems is spent on the design and development of the user interface.

In the past, system designers paid little attention to the 'human element'. User interface specialists designed user interfaces particularly to accommodate the weaknesses of the computer. They believed that the computer was non-adaptable and inflexible. Humans, however, were believed to be flexible and adaptable because they are able to study and read manuals and can be trained to perform whatever operations are required.

Today, however, computers are becoming ubiquitous [WEI93, WEI]. Computer users are not limited to those who are interested in programming or spending many hours before a computer screen exploring the features available. They are sometimes not even willing to attend software or hardware training sessions. Many are novices and, therefore, they are likely to rely on user interface designers
and human-computer interaction specialists to bridge the gap between deficiencies in the computer and their lack of expertise. As a result, the user interface designers and human-computer interaction specialists have significantly difficult tasks to empower users of various levels of ability to utilise computers, or systems, effectively and efficiently to accomplish their everyday goals.

The principal function of a user interface is to facilitate human-computer dialogue. A user interface to a computer system consists of two parts:

- **Interaction Styles**

  The interaction styles are the kinds of dialogues arranged by the user interface designer in mediating the user's control action and machine's/computer's work. Interaction styles hide the structure of interrelation between the input/output device operating systems, networks, and applications and let the user switches applications or services smoothly, without concern to the technical complexity. Interaction styles range from awkward command lines to virtual environment.

- **Interaction Devices**

  One of the key successes of a system is also determined by how convenient the interaction device is to use as judged by the users. Basically, an input device is “a transducer from the physical properties of the world into logical parameters of an application” [BAE87]. The development of interaction devices has an ultimate goal: to make the human-computer interaction as natural as human-human interaction. Therefore, a great deal of effort has been expended in making computers understand the human voice, hand-gestures, and handwriting.
Above all, interaction styles and devices are application specific. There is no particular interaction style or device that is best for all applications. A keyboard, for example, is best for word processor applications. Virtual reality technology is the most suitable one for flight simulator schemes. However, neither of these two technologies is currently more appropriate than mouse for windows icon menus pointer (WIMP) based metaphor and direct manipulation interfaces.

Given the importance of the user interface to a system, the goals of user interface design are twofold:

1. to present an appropriate layout of dialogue and control (i.e., interaction styles) for specific application that will not confuse novices with the complexity of the system and, at the same time, will not be tedious for experts.
2. to select or develop a usable, more natural interaction device or a combination of several devices for a particular application.

When designing a user interface for a system, interactive system designers usually face two general issues [LIT94]:

1. how to develop an interactive system and at the same time ensure its usability;
2. how to demonstrate and measure the usability of an interactive system.

The first issue is addressed in Chapter 3 and 4, whereas the second issue is described in the following subsection and is implemented in Chapter 5.

2.2.2 Usability Aspect of The User Interface

The term usability is interchangeable with a number of other terms, such as user-friendly, perceived ease-of-use, perceived usefulness, or intuitive user interface. Usability is "a measure of the ease by which a system can be learned
or used, its effectiveness and efficiency, and the attitude of its users towards it” [PRE94].

Usability can be objectively recognised in terms of how well users can master and perform tasks on the system. It is the user, not the designer, who determines the level of usability of a product or device. Therefore, a goal in usability testing is to measure the level of user acceptance of a product or device.

The following subsections outline some approaches to measure the usability level of a product.

2.2.3 Usability: The Variety of Point-of-View

It is important to give user interface designers the qualitative or quantitative results of their efforts. A report [BEV94] lists three views on how usability could be generally measured:

1. in terms of ergonomic attributes of the product (product-oriented);
2. in terms of the mental effort and attitude of the user (user-oriented); and
3. in terms of how the user interacts with the product (interaction-oriented) with typical emphasis on either:
   - ease-of-use: how easy the product is to use
   - acceptability: whether a product can be used in the real world.
2.2.4 User Interface Evaluation Techniques

The level of usability of a system is usually measured and determined during the evaluation stage. Some methods can be used to evaluate the user interface. The descriptions of several evaluation methods are given below:

**Heuristic Evaluation** [MIL92, TRE94] is a method in which human-computer interaction experts are invited to observe the application in depth and find out those properties that may cause usability problems.

**Comparison against guidelines** [MAR91, MIL92] is an evaluation method in which engineers examine the application against published design guidelines that are closely related the application itself. For example, in designing a window-based user interface, choose the colours that do not harm the viewers [FOL90, MAR95].

**Cognitive walk-throughs** [MIL92, TRE94] is a method in which the engineers or designers compare their understanding of the target users' goals and expectations against the performance of the user interface. During a walkthrough, an individual engineer or the team, who are developing a product, "walkthrough" the specification, looking for discrepancies between what the interface actually performs and what the user would expect are noted and documented as features.

**Usability testing** [MAR91, MIL92, TRE94] is an experiment in which engineers run empirical tests in controlled situations reflecting the real-world. Data are gathered and analysed on problems that may arise during the experiments.
The comparison between each approach is summarised in Table 2.1.

Another evaluation method that has gained much attention from researchers [TRE94], and is incorporated in the evaluation stage of this project, is the comparison method evaluation. The observers usually compare the performance of a newly designed device with other devices that have been widely used. The result is then discussed to emphasise the advantages (or disadvantages) of the user interface or interaction device tested.

**Table 2.1 Comparison of Four Interface-Evaluation Techniques [MIL92]**

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heuristic Evaluation</td>
<td>Identifies the most problems</td>
<td>Requires several interface expert evaluators</td>
</tr>
<tr>
<td></td>
<td>Identifies more serious problems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Relatively informal procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td></td>
</tr>
<tr>
<td>Usability Testing</td>
<td>Identifies primarily severe problems</td>
<td>Requires interface expertise</td>
</tr>
<tr>
<td></td>
<td>Identifies problems that will irritate real users</td>
<td>High cost</td>
</tr>
<tr>
<td>Comparison Against Guidelines</td>
<td>Identifies recurring and general problems</td>
<td>Identifies relatively severe problems</td>
</tr>
<tr>
<td></td>
<td>Can be employed by software engineers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td></td>
</tr>
<tr>
<td>Cognitive Walkthrough</td>
<td>Helps define user goals and assumptions</td>
<td>Tidious</td>
</tr>
<tr>
<td></td>
<td>Can be used by software engineers</td>
<td>Identifies relatively few severe problems</td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td></td>
</tr>
</tbody>
</table>

In the evaluation stage of this project, the comparison method is performed to give a theoretical result of the usability aspect of the device (product-oriented approach). Usability testing is also used to get objective feedback from the actual users. The user-involved usability inspection method is believed to be the most accurate method for checking the usability level of a product or system [DUM93, TREU94, WIK95]. User preferences to two interaction devices, i.e. Newton-based
interaction device and keyboard-mouse combination, are compared in this test. Usability testing would reveal the mental effort and attitude of the user (user-oriented) toward the interaction device being tested. The testing can also be classified as an interaction-oriented evaluation because its result will indicate two important aspects of usability: ease of use and comfort.

2.3 User Interface Design Issues for Multimedia Services

2.3.1 Overview

In this section previous works on user interface design and evaluation are described. These works are reviewed in the light of their relevance to the emergence and evaluation of interaction styles and devices and are summarised in Table 2.2. Usability issues which arise with the development of interactive multimedia services are also discussed in this section, followed by a description of two newly-emerged interaction devices that have influenced the design and implementation of the user interface in this project.

Subsections 2.3.2 and 2.3.3 review the emergence of PDA-based interaction device and PC/TV unit as a combination input/output device for the future domestic multimedia system. The PDA-based interaction device and an emulation of PC/TV technology are incorporated in the design of the user interface in this project.

From the papers reviewed in
Table 2.2, the interaction devices candidate for domestic multimedia environment are:

- PC/TV unit
- voice-based input
- handwriting-based input
- wireless mouse (air mouse/field mouse) and wireless keyboard
- PDA-based input device

Table 2.2 Research on User Interface and the Evaluation Method Used

<table>
<thead>
<tr>
<th>Paper</th>
<th>Type of Work</th>
<th>User Interface</th>
<th>Evaluation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SEA91]</td>
<td>Improving touchscreen keyboard and compared it with other devices</td>
<td>Touchscreen Keyboard, Mouse, Traditional Keyboard</td>
<td>Comparison method, User-involved usability testing</td>
</tr>
<tr>
<td>[LOR93]</td>
<td>A comparison of keyboard-integrated pointing devices</td>
<td>keyboard-integrated trackball, keyboard-integrated roll bar, keyboard and trackball</td>
<td>Comparison method, User-involved usability testing</td>
</tr>
<tr>
<td>[MUR91]</td>
<td>Experimental evaluation of some existing interaction devices for pointing tasks</td>
<td>Mouse, Joystick, Joypad, Light-pen, Trackball, and Touch-screen</td>
<td>Comparison method, User-involved usability testing</td>
</tr>
<tr>
<td>[JAC94]</td>
<td>Examining that performance is improved when the perceptual structure of the task matches the control structure of the input device</td>
<td>Three-dimensional tracker, Mouse</td>
<td>Comparison method, User-involved usability testing</td>
</tr>
<tr>
<td>[KAR93]</td>
<td>Provide strong evidence that automatic speech recognition devices are superior to the conventional input devices</td>
<td>Speech-activated commands keyboard - for text entry, mouse - for direct manipulation</td>
<td>Comparison method, User-involved usability testing</td>
</tr>
</tbody>
</table>
2.3.2 **PC-TV Unit**

The computer and TV screen have been the most popular output device in recent times. However, multimedia applications are rapidly blurring the distinction between the computer and the television screen. American and Japanese computer industries are introducing PCs with tuner boards that allow for hooking up to a cable TV or antenna [ANT96, MAL94]. This has enabled the integration of the PC/TV screen. The architecture consists of digital set-top boxes and multimedia servers. The system operates within a client/server paradigm. It is the TV-sized screen that combines audio-video and multimedia computing in a complete system. The result is interactive multimedia television (IMTV): TV with the power of the computer.
As computer power and processes are integrated into the television, it becomes a two-way, interactive medium that allows viewers to select what they want to watch, and a time nominated by them. It is about giving viewers more control, new choices and new ways of communicating. It has also opened up the challenge in designing interaction styles and devices which are most appropriate for this relatively new technology.

2.3.3 PDA-based Interaction Devices

Mobility is one important factor that will affect current and future computing. The emergence of Personal Digital Assistants (PDAs) has made computers smaller, lighter, more mobile, and more intelligent. Some developers [MAU96, ROB96] have started to use this technology for real estate and stock exchange information systems. During the last Ford Australian Open '97 Tennis Championship, coaches employed this small interaction device as their assistant to record their player's statistics during a game. The NBC American news relayed by Channel 7 Australia (10th March '97), reported that the device is also used for military purposes. That is, it is used as the US soldiers' intelligence equipment for mapping the battle field.

Mauro [MAU96] developed a high performance user interface for a wireless, pen-based, hand-held computer for the New York Stock Exchange. His objective was to develop an effective electronic metaphor that would minimise negative transfers, improve user performance and reduce reporter training time. His aim was to create an electronic version of the paper-based process that would be fully compatible with the new NYSE information processing
infrastructure and business objectives. The report claimed that the product has improved data entry rates for reporting both trades and quotes on the floor of the exchange and eliminated the need for over ten million paper cards in the first year.

Another prototype of a multiple-device application consisting of a PDA that operates in conjunction with an interactive television was developed for real estate information services [ROB96]. In this application Newton is used off-line with the interactive TV. The project has some primary goals: supporting mobile users with the PDA, taking advantage of the high-quality display capabilities of a television; and utilising the resources of the broadband information network.

The users interact exclusively with the PDA. They can also control the information display on the television by executing graphic widgets on the PDA. The television responds to the action by presenting visual images and videos on its screen. In addition, during the house inspection phase, users can explore the selected house information stored in the PDA.

Robertson et. al. [ROB96] noticed that a likely use of PDA-based interaction device in the future, is to interact with cable television services.

However, when used as an interaction device which requires transferring data from a device to the Newton and vice versa (i.e., real-time, on-line applications), Newton is a bit slow [ROB97, RIS96, SAN94] particularly when the data transferred is in text format. Although the Newton itself is equipped
with the capabilities to transmit or receive other forms of data, no applications reported in literature transfers other format than text.

2.3.4 System Components for Domestic Multimedia Services

Some research [BAS93, GEL91, LIT94 MOS93] proposed that a typical interactive multimedia scenario consists of a local data-base and server connected to the customers' homes via communication network. The home equipment consists of a network interface coupled to a display. The user interacts with the system via a remote hand-held remote control or a computer keyboard.

The research project was concerned to the interaction device of the customer premises equipment (CPE) part of the interactive multimedia system (e.g., Web TV). Figure 2.1 illustrates a schematic of the CPE for home entertainment.

- Customer Premises Equipment (CPE)

To support interactive services, the equipment located at the customer premises must perform basic functions such as provide a network interface that is able to decode incoming signals and deliver them to the appropriate output device (e.g., display and speaker). In return, the network interface also translates user input from the remote interaction device to the appropriate signals for network transfer.
Given the wide range of services to be supported and the considerable functionality to be performed, some usability issues arise in designing multimedia user interfaces, particularly for the domestic environment. These issues are described in the following subsection.

### 2.4 Usability Issues for Domestic Multimedia User Interfaces

The role of user interface in a domestic multimedia environment is to assist users to select the services they want, and to interact easily with the system. There are four key usability issues that must be considered in designing multimedia user interface for domestic environment.
2.4.1 *The users*

The users of domestic multimedia entertainment range from novices to experts. The main problem with the various levels of users' skills is how to design a user interface that is not tedious for the expert but is easy enough for the novice to understand.

2.4.2 *Selection of interaction styles.*

With hundreds of television channels and many interactive services to choose from, one problem which arises is how to present an effective and efficient dialogue or interaction style in front of the viewers. Traditional paper TV guides will be unlikely to list all the services. In the traditional broadcast TV system, many stations broadcast their programs simultaneously and the user is the passive participant receiving what the service providers offer. This may be superseded.

2.4.3 *Choice of interaction device.*

The remote interaction device plays a key role in the usability of the interface. A report [COO95], pointed out that in existing systems, many keys are not used (e.g., colour and contrast), and key labels are not understood. Some basic design rules, revealed in the same report, are: it should have as few keys as possible, but include a pointing device, and should have a key layout that is easy to remember. In general, the choice of interaction device depends upon the interaction tasks that will be supported and the environment in which the interaction process exist; e.g., public or domestic environment.
2.4.4 Understanding of the system.

When interacting with the system, viewers need to be able to mentally visualise an accurate representation. Otherwise, they are likely to have problems to optimally, or easily, use the system.

These usability issues will be addressed further in chapter 3, 4, and 5. The next section describes some developments in interaction devices that would have a significant impact in designing an appropriate user interface for domestic entertainment.

2.5 Deficiencies and Development

In Section 2.2 two important goals for user interface design were described. In Section 2.3, previous work on user interface design and development was reviewed in the light of these goals, and the usability evaluation method used. Furthermore, in Section 2.4 user interface design issues for domestic multimedia settings were also surveyed. The following subsections describe the deficiencies found in previous work and how this project proposes to deal with these deficiencies.

2.5.1 Deficiencies of Previous Work

The following deficiencies were noted:

1. None of the papers exclusively addressed designing an interaction device for the domestic environment. Some [COO95, HIC94, LIT94], emphasised only the need for a more usable interaction device than the current VCR remote
control. Only one of the papers [ANT96] suggested alternate interaction
devices for such domestic environment but no design considerations and
evaluation results were reported.

2. None of the papers defined the requirements of an interaction device for
domestic settings. These requirements can be defined by taking into account
the characteristics of such an environment.

3. None of the papers gave any reasons for the choice of the interaction devices to
be incorporated in a domestic multimedia system.

4. None of the papers pointed out what interaction tasks (e.g. select-and-point,
text entry) must be supported by the interaction styles candidate for interactive
multimedia services. Consequently, the kinds of interaction styles that should
be employed in the user interface are not clear. One paper [MYE92], only
considered the use of the standard computer interfaces, i.e., menus and
windows, without explaining why this was done.

2.5.2 Developments in this Project

Each of the three deficiencies noted above is considered in the body of this
project.

1. The ultimate goal of this project is to design an interaction device for domestic
settings. The result is the provision of an alternate interaction device for the
environment where the traditional keyboard and mouse are not appropriate.

2. The requirements of the interaction device for domestic environment are
outlined.
3. Based on these characteristics, some interaction techniques that are appropriate for such an environment are observed, and selected to be employed into the interaction device being designed.

4. The interaction tasks that can support user interaction with interactive multimedia services are revealed. Hence, the appropriate interaction styles could be determined. One factor that is considered when selecting an interaction device is its ability to facilitate the interaction tasks or to support the interaction styles.

### 2.6 Summary

This chapter has reviewed research projects and literature that are related to the design of user interface for the domestic multimedia settings. It is clear that there is a need for alternative devices to control the domestic multimedia system. Several devices, presented in this chapter, have emerged to cope with this need. In the next chapter, the methodologies that would be used to develop an alternate device are reported.
Chapter 3

Designing For Usability:
A Practical Approach

3.1 Outline

This chapter is concerned with describing of how usability issues are addressed during the process of design. In Section 3.2, usability issues in designing user interface for interactive multimedia services, noted in Chapter 2, are addressed. Design principles and guidelines are also observed. These principles will be applied in the design and implementation stage of this report (Chapter 4). In Section 3.3, some design guidelines to be considered in order to employ, combine or integrate interaction devices are noted. In Section 3.4, the steps which are generally executed to design and build a user interface are specified. These steps will also be implemented in chapter 4 and 5. The theoretical background of the usability assessment used in the project (i.e., acceptance questionnaire and statistical analysis) is explained in Section 3.5. Seven usability factors to measure the user’s response to the questionnaire are described in Section 3.6.
3.2 Principles in Designing Usable Interface

It is not possible to design a usable system without reviewing design principles generally. Most of the principles considered here are derived from the practical experiments of previous works in the literature review (Section 2.2, 2.3 and 2.4).

3.2.1 Helping Users to Understand and Comfortably Use the System

At least three determinant should be looked at when considering the interaction between users and a system. That is, physical aspects, cognitive factors and mental model. All of these aspects are discussed below:

- Physical Aspects

This factor is concerned with the human physical limitations in operating input/output devices. Parameters that are generally considered in human-computer interaction are motor fatigue and the speed of hand and finger movements [COX90].

Motor Fatigue usually occurs due to poor mechanical design of a device; i.e., devices that require excessive muscular strength or that cause pain by requiring actions that are too small or too long for the muscles being used, or placing limbs in an unsupported positions too often or too long [COX90]. Fatigue can also be caused by sensory factors. That is, "excessive and strong stimuli, such as bright colours, intense light and loud noises, can cause sensory overloading as they bombard the perceptual system and demand attention" [SUT95]. Fatigue, in turn, affects error rates and user satisfaction (comfort) and indirectly
affects task time by lowering the attention span and slowing the reflexes [COX90].

Speed and hand movement affects task completion time and user satisfaction. Using keyboard and mouse, for example, requires users to move their hands between the devices. This takes time and is not comfortable for novices [MAY92].

Therefore, the device that is intended to be used as remote control device for the domestic multimedia system should be lightweight, and either a single or a combination of several devices. Viewers, however, are not likely to feel comfortable when they need more than one device to control the system. This would require them to control the devices in turn and frequently move their hands from one device to another.

- **Cognitive Factors**

Cognitive psychology with concerned to the process by which humans gain information and then transforms this information into knowledge [PRE94]. In the human-computer interaction field, cognitive psychology refers to the process of effective transfer of this information between the two parties involved in an interactive action, i.e., human and computer. To be effective, the interaction and information transfer should be designed by taking into account some natural human limitations such as limited short-term memory capacity and human attention span.

Humans recognise input from the outside world by means of five major senses; i.e., sight, hearing, touch, taste, and smell. The information humans obtain
through the senses is filtered into short-term memory. The selection is based on human attention; i.e., the concentration of human reason into one out of a number of competing stimuli or thoughts [PRE94]. Short-term memory is the working memory in which information is held temporarily, waiting for another processing activity such as handling input, selecting, retrieving, storing, planning, and preparing outputs. Short-term memory has limited capacity. Miller in 1956 [DIX93, PRE94], identified that humans can remember at any one time 7±2 pieces of information.

If the above information is used, a principle in designing usable user interface will be defined as:

The number of controls or dialogues to be represented in a system display should be designed to reduce cognitive load. Two ways of achieving this [PRE93] are by minimising memorisation (Miller’s rule) and minimising learning. Minimising learning could be accomplished by choosing meaningful names and symbols.

- **Mental Model**

A mental model is “an internal representation of a user’s current conceptualisation and understanding of a system” [MAY92]. This term is also known as mental representation.

Whenever humans learn to use a system, or interact the first-time with a new system, or device, in which some processes or mechanisms are invisible or unknown, they will form a mental model or representation. The mental model is important for two reasons [COX90]. Firstly, it guides users to predict the
appropriate procedure to obtain a desired outcome. Secondly, it provides a framework for understanding the behaviour of the system.

Usually a mental model is built using familiar analogy (i.e., learning by analogy) by referring to existing mental models of the real world, and then gradually learning and identifying (i.e., situated learning) the differences between the new system or device with their conceptual model. Some researchers [COX90, ERI95, LOV94, MAY92, PRE93, TRE92] noted that a highly successful approach in interface design is to capitalise on the user’s existing knowledge (e.g., by employing interface metaphor). Unfortunately, Lovgren [LOV94] noted that many of the interface metaphors he had seen are metaphors within the knowledge sphere of the designer, not the user.

Figure 3.1 depicts the relationship between the designer’s model and the user’s mental model. If the user’s model is successfully mapped onto the design’s model, the users would be able to use the system optimally as intended by the designer.

A user obtains information about the design model through the system image which is comprised of: the interface, its behaviour, and documentation. Therefore, if the system image fails to convey to the user the design’s model in a clear and obvious way, it is likely that the user will develop an incorrect or inaccurate mental model.

A report [MAY92] found that users also rely heavily on names and terminology in the interface to start forming a mental model of a system.
Based on the observation above, particularly from Mayhew [MAY92], two principles to help a user form a mental model correctly are noted:

1. employ well-known, widely accepted metaphors;
2. use relevant, appropriate names and terminology.

![Figure 3.1 Distinction between the design model, the user's mental model and the system image [PRE93]](image)

**3.2.2 Selection of Interaction Styles**

An interaction technique can be defined as “a way of using a physical input and output devices to perform generic tasks in human-computer dialogue” [ZIG96]. Most user interfaces employ more than one interaction styles, and none may be in its pure form [MAY92]. A major problem for the user interface designer is how to select appropriate interaction styles for the user interface being designed. In fact, there are many different interaction dialogues available to
perform the same tasks. To perform a select-and-point task, for example, designers can employ either traditional menus or a Windows Icon Mouse Pointer (WIMP)-based metaphor and direct manipulation. For data entry, fill-in-form interfaces or function keys interfaces (i.e., commands or objects are specified by pressing special keys on the input device) can be considered.

Given these reviews, two basic principles to choose appropriate interaction styles to represent on the display are identified:

1. Recognise the generic tasks to be performed. Generic tasks are low-level actions to perform in giving input to the system [ZIG96]. Some examples are: entering text or numeric value (data entry) and choosing an object or element from a set of options (select-and-point)

2. Understanding the trade-offs between the interaction styles before designing. That is, measuring desirable and undesirable features of each interaction style in any given situation.

### 3.2.3 Choice of Interaction Devices

The choice of interaction devices tightly corresponds to the selection of interaction styles. Three applicable principles to select interaction devices for a system are presented below:

1. Recognise the interaction styles to be supported. Keyboard or handwriting recognition technology, for example, are suitable to support fill-in-form interface. The mouse could be used to facilitate the WIMP-based metaphor and direct manipulation or menu interfaces.
2. Considering the environment where the interaction takes place. A voice recognition input device, for example, is noise sensitive; therefore, it is not suitable for a public environment.

3. Understanding the trade-offs between interaction devices for any given interaction styles in a particular environment.

In the following section a literature search provided some guidelines for an interaction device selection. These guidelines are applied in the design and implementation stage and also in the evaluation stage. The term guidelines "encompasses both the broad principles - which offer general advice and provide a sound foundation for a design - and the specific design rules - which direct details of design" [PRE93].

### 3.3 Applicable Guidelines for Employing and Combining or Integrating Interaction Devices

This section is concerned with guidelines to use an input or interaction device for specific applications in any particular situation. These guidelines, summarised from Mayhew [MAY92], are considered:

- Employ touch screen devices when the opportunity for adequate training is low, targets are large, discrete, and spread out, frequency of use is low, and the task requires little or even no text input.

- When combining two or more interaction devices, minimise the hand and eye movement involved in switching between input devices.
• Consider voice as an input device only under the following circumstances:
  1. the required vocabulary is small;
  2. the environment is quiet;
  3. if the user’s hand could potentially be occupied and mobility is required, or
     the user’s eyes are busy;
  4. the recognition error is low and the consequences of misrecognition is not
     crucial;
  5. low utilisation.

An interaction device should be simple. A beneficial concept of the principle of
simplicity is doing the most with ease. Don Norman, as illustrated in a paper by
Marcus [MAR91], noted some points that support this concept:
• determine the number of controls a device needs;
• the fewer the controls, the easier it is to use and the easier it is to find the
  relevant controls; and
• to make something look easy, minimise the number of controls.

Hence, the designer should remove all the unnecessary functions or controls.

When the demands on the interaction device are conflicting (i.e., no single optimal
device can be identified), two or more interaction devices could be combined or
integrated, to give optimal appropriateness. However, integrating one or more
input techniques in a compact device is better than combining two or more
interaction devices [JAC94, LOR93]. The reasons for this notion are:
  1. less hand movement is required because the devices share the same space;
  2. less desk space is required for the interaction device; and
3. users are free from carrying separate interaction devices.

Last, the device should have as few keys as possible, including a pointing device, and should have a key layout that is easy to remember [COO95].

The next section describes some stages that should be performed if a designer is to design a usable user interface. The first three steps are implemented in Chapter 4, whereas the last stage is carried out in Chapter 5.

### 3.4 User Interface Design Cycle

Human-Computer Interface Design is an empirical process. Waterworth [WAT92] pointed out that the idea of an iterative design-test-modify interface development is almost universally accepted as the only reliable route to a successful user interface. There are five stages in user interface design [WAT92, BRO89], as depicted in Figure 3.2.

#### 3.4.1 User/Task Analysis

The design should be based on an understanding of the task the user will perform with the system and whether the user interface is compatible with the physical and sociological environment in which the system will be used.

A users’ profiles should be observed. For example, who are the users, are they homogeneous or heterogenous (i.e., do they have different identifiable skills to meet), what are the skills, and what is the age range.
3.4.2 **Interface Design and Specification**

In this stage, designers make sure that all possible functionalities the users require are covered. Designers, however, are not supposed to implement unnecessary features.

![User Interface Design Cycle](image)

**Figure 3.2** User Interface Design Cycle [WAT92]

Designers can incorporate some general guidelines which are provided in literature as a good starting point. However, the guidelines should be made more specific and tailored to the context and constraints of the project.

This stage has two purposes [COX90, MAR89]:

1. discussing the value of guidelines in the design process; and
2. developing the task definition by defining objectives, actions, and the model of how the system will work
3.4.3 Prototyping and Implementation

This is the process whereby the designer builds a prototype using several rapid prototyping tools, e.g., a Newton Tool Kit (NTK), X Window or Motif. Once a user-interface is designed, either a prototype or implemented solution on a screen, those individuals selected as participants are asked to perform some actions.

3.4.4 User Testing and Evaluation

Feedback from the participants used in the previous stage is then used to determine whether the goals of the user interface design have been satisfied. Otherwise, the designer must return to the second stage of the design (i.e., interface/interaction styles design and specification), to fit the user interface to the user’s requirements.

3.5 Usability Assessment Approach

A central function of modern statistics is statistical inference [JOH94, SIE88]. Statistical inference is concerned with two types of problems: the estimating of population parameters and testing an hypothesis. It is the latter which is the primary concern in this usability assessment stage of the project.

Once a prototype has been developed, an experiment is usually conducted to test the performance of the user interface or device. Data, in turn, are collected to enable the observer to make decisions concerning the hypothesis. The decisions may lead the observer to retain, revise, or reject the hypothesis.
The null hypothesis (H₀) is a hypothesis of "no effect" and is usually formulated for the express purpose of being rejected; i.e., it is the negation of the result being expected. If it is rejected, the alternative hypothesis (H₁) is supported. If the decision is about differences, H₀ is tested against H₁. H₁ constitutes the assertion of hypothesis that is accepted if H₀ is rejected.

### 3.5.1 Non-parametric Tests

- **Statistical Inference**

  Statistical inference is concerned with "how to draw conclusions about a large group of participants, or about events yet to occur on the basis of an observation of a few participants, or what has occurred in the past" [SIE88]. A common problem for statistical inference is to determine, in terms of a probability, whether significant differences exist between two samples.

  A group of statistical techniques of inference which make many reasonable assumptions about the nature of the population from which the observations or data are drawn, are called *parametric* [EAS, JOH94, SIE88]. For example, a technique of inference may be based on the assumption that the data were drawn from a normally distributed population or from populations having the same variances (\( \tau^2 \)). The conclusion produced is usually written as: "If the assumptions regarding the shape of the population distributions are valid, then it can be concluded that...".

  On the other hand, a number of techniques of inference which do not make stringent assumptions about the population from which the sample data are collected are called *non-parametric* [EAS, JOH94, SIE88]. Tests are performed
without reference to any parametric model. For example, when comparing two independent samples, the Wilcoxon Mann-Whitney test does not assume that the difference between the samples is normally distributed whereas its parametric counterpart, the two sample t-test, does. All tests invoking ranked or ordinal data, i.e. data that can be put in order, are non-parametric [EAS, JOH94, SIE88]. After using one of these techniques, the conclusion is usually written as: “Regardless of the shape of the populations, it can be concluded that...”.

- **Lickert Scale and Ordinal Data**

  A set of data is said to be ordinal if the values/observations belonging to it can be ranked (put in order) or have rating scale attached [POL95]. An ordinal set of data usually has a natural order. For example, a group of people were asked to taste a variety of chocolate on a rating scale of 1 to 5, representing strongly disliked, disliked, neutral, liked, strongly liked. A rating of 5 indicates more enjoyment than a rating of 4, a rating of 3 means more enjoyment than a rating of 2, etc., so such data are ordinal.

  Lickert scales [RUB94, TRE94] are scales on which the subjects or participants register or express their level of agreement of disagreement with a statement. The judgments are usually quantified on a range of a five to nine-point scale. The data collected from lickert scale-based questionnaires are ordinal.

### 3.5.2 The Level of Significance ($\alpha$)

Once the null hypothesis and alternative hypothesis have been stated, and the appropriate statistical test has also been selected, the next step is to specify a
level of significance (\( \alpha \)) and to select a sample size (\( N \)). \( H_0 \) is to reject in favour of \( H_1 \), if a statistical test yields a value whose associated probability of occurrence under \( H_0 \) is equal to or less than some small probability \( \alpha \). Stated differently, if the probability associated with the occurrence under \( H_0 \) (i.e. when the null hypothesis is true) of the particular value yielded by a statistical test is equal to or less than \( \alpha \), \( H_0 \) is rejected in favour of \( H_1 \) the operational statement of the research hypothesis. That probability is called the *level of significance*. Common values of \( \alpha \) are .05 and .01 [EAS, JOH94, POL95, SIE88].

There are two types of errors which may be made in arriving at a decision about \( H_0 \) (the null hypothesis):

- Type I error involves rejecting the hypothesis \( H_0 \) when it is, in fact, true;
- Type II error involves failing to reject the null hypothesis \( H_0 \) when, in fact, it is false.

The probability of committing a type I error is denoted \( \alpha \) (the level of significance). The larger the probability \( \alpha \), the more likely it is that \( H_0 \) will be rejected falsely, i.e., the more likely it is that a Type I error will be committed. The type II error is usually denoted \( \beta \).

Some of the usability factors described in sub-section 3.6 would be those assessed by users. The data collected from the user-involved usability experiment would then be analysed using the Wilcoxon-Mann-Whitney U test to test whether the hypothesis of the project is true.
3.5.3 The Confidence Interval

The interval within which we consider the hypothesis about the population parameter tenable is referred to as the confidence interval. Common confidence intervals are 95% and 99% (1-\(\alpha\) when \(\alpha = 0.05\) and 0.01 respectively) [LEV78, RUN91]. The confidence interval defines the precision and the reliability of the observed data. Reliability is concerned with the probability that the estimate is correct; and precision is the probability that the estimate is close to the target parameter.

3.5.3 The Wilcoxon-Mann-Whitney U Test

The Wilcoxon-Mann-Whitney U test [EAS, JOH94, POL95, SIE88] is one of the most powerful of the non-parametric tests. It can be used when the measurement in the research is not an interval scale [SIE88]. In the field of human-computer interaction, this test has been used in several research projects [ARCH95, MUR91, SEA91]. The following example from [LEV84] illustrates the use of the test.

- Approaching a Problem Using The Mann-Whitney U Test

Suppose that in a user interface project, a researcher wants to test the hypothesis that the users' acceptance level of two devices (A and B) are equal. The random sample of twenty five participants who give their subjective scores on five-point likert scale for both devices has produced the data shown in Table 3.1.

| Table 3.1 Device Scores Collected for Student |
To apply the Mann-Whitney U test for this problem, all the scores are ranked in order from lowest to highest. Table 3.2 accomplishes this.

Table 3.2 accomplishes this.

![Table 3.2 Devices' Scores Ranked from Lowest to Highest](image-url)
In this case, both \( n_1 \) and \( n_2 \) are equal to 15.

The symbols for Mann-Whitney U test are:

\( n_1 = \) number of items in sample 1; i.e., number of participants at Branch A;

\( n_2 = \) number of items in sample 2; i.e., number of participants at Branch B;

\( W_1 = \) sum of the ranks of the items in sample 1;

\( W_1 = \) sum of the ranks of the items in sample 1;

Table 3.33 adds the ranks from accomplishes this.

Table 3.2.

Table 3.3. Raw Data and Rank for Devices' Scores

<table>
<thead>
<tr>
<th>Device A</th>
<th>Rank</th>
<th>Device B</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
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<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>14</td>
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<tr>
<td>3</td>
<td>6</td>
<td>3</td>
<td>15</td>
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<tr>
<td>3</td>
<td>7</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>3</td>
<td>17</td>
</tr>
</tbody>
</table>
- **Special Properties of the U Test (Ties)**

In this example the thirteen scores ranked 6 until ranked 18, for example, had the value 3. In this case, it would be found that the average of their ranks $(6+7+8+...+18)/13 = 12$. Table 3.33 is modified into Table 3.44.

- **Calculating the U Statistic**

The U statistic, a measurement of the difference between the ranked observation of the two samples of device scores can be determined with:

\[
U = n_1 n_2 + \frac{1}{2} n_1 (n_1+1) - W_1
\]

\[
= (25) (25) + \frac{1}{2} (25) (26) - 566
\]

\[
= 625 + 325 - 566
\]

\[
= 384 \quad \leftarrow U \text{ Statistic}
\]

**Table 3.4 Raw Data and Rank for Devices' Scores (with Ties)**

<table>
<thead>
<tr>
<th>Device A</th>
<th>Rank</th>
<th>Device B</th>
<th>Rank</th>
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<tbody>
<tr>
<td>3</td>
<td>9</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>4</td>
<td>26</td>
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<tr>
<td>3</td>
<td>11</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>4</td>
<td>28</td>
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<td>3</td>
<td>13</td>
<td>4</td>
<td>29</td>
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<td>4</td>
<td>19</td>
<td>4</td>
<td>30</td>
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<td>36</td>
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<td>37</td>
<td>5</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

| Total Ranks | 481 | Total Ranks | 794 |

---

<table>
<thead>
<tr>
<th>Designing For Usability: A Practical Approach</th>
</tr>
</thead>
</table>

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**Designing For Usability: A Practical Approach**
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>2.5</td>
<td>2.5</td>
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<tr>
<td>3</td>
<td>12</td>
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<td>12</td>
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<td>41</td>
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<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Ranks</td>
<td>566</td>
<td>Total Ranks</td>
<td>711</td>
<td></td>
</tr>
</tbody>
</table>

If the null hypothesis that the $n_1+n_2$ observations comes from identical population is true, then this U statistic has a sampling distribution with a mean of:

$$
\mu_U = \frac{1}{2} n_1 n_2
$$

$$
= \frac{1}{2} (25) (25)
$$

$$
= 312.5 \Leftarrow \text{Mean of the U Statistic}
$$

and variance of:

$$
\tau^2_U = \frac{1}{12} n_1 n_2 (n_1 + n_2 + 1)
$$

$$
= \frac{1}{12} (25) (25) (51)
$$

$$
= 2656.25
$$


- Testing the Hypothesis

The sampling distribution of the U Statistic can be approximated by the normal distribution when both \( n_1 \) and \( n_2 \) are larger than 10 [JOH94, LEV84]. Therefore, to solve this problem, we can use the normal distribution and the \( z \) table to make the test. The researcher wishes to test at the 0.05 level of significance the hypothesis that these samples were drawn from identical populations.

\[ H_0: \mu_1 = \mu_2, \quad \text{null hypothesis: There is no difference between the two populations, so they have the same mean or median} \]

\[ H_1: \mu_1 \neq \mu_2, \quad \text{alternative hypothesis: There is a difference between the two populations; in particular they have different means or median.} \]

\[ \alpha = 0.05 \quad \text{level of significance for testing these hypothesis} \]

The researcher wants to know whether the mean acceptance score for the participants at either of the two device is preferred over the other. Therefore, this is a two-tailed hypothesis test. With \( \alpha = 0.05 \), the acceptance region takes up 0.475 of the area under the curve (see Figure 3.3.a). The table in Appendix A shows that the appropriate \( z \) value for an area of .475 is 1.96. The two limits of the acceptance region can be calculated in the following manner:

\[ \mu_U + 1.96 \tau_U = 312.5 + (1.96)(51.54) \]

\( \tau_U = 51.54 \quad \text{Standard Error of the U Statistic} \)
It can be seen from Figure 3.3.b below that sample U statistic does lie within the acceptance region (211.48 < 384 < 413.52). illustrates this test graphically. Thus, the null hypothesis of no difference is accepted and a conclusion reached that the participants have the same preferences for both devices.

![Figure 3.3](image)

**Figure 3.3** a) Two-tailed Hypothesis Test of a Proportion at the .05 level of significance [LEV84]

b) Two-tailed Hypothesis Test at the 0.05 Level of Significance (showing the acceptance region and the sample U Statistic)

Using statistic software called MINITAB [EAS, POL95], the results for the above example are:

```
MTB> mannwhitney x1 x2
Mann-whitney Confidence Interval and Test
X1   N = 25    Median = 4.000
X2   N = 25    Median = 4.000
```
Point Estimate for ETA1-ETA2 is 0.000
95.2 pct c.i for ETA1-ETA2 is (-1.000, -0.000)
W = 566.0
Test ETA1 = ETA2 vs ETA1 n.e ETA2 is significant at 0.1683
The test is significant at 0.1487 (adjusted for ties)
Cannot reject at α = 0.05

The purpose of this test is to observe whether or not the two populations differ in their preferences for either device (ETA1 = ETA2 vs ETA1 not equal ETA2). ETA (η) is the population median. The result shows that both samples have the (same) median value of 4, the sum of the ranks are 566 (equal to our calculation) and there is insufficient evidence to reject H0. That is, the test is significant at 0.1487, which is inside the acceptance region (see Figure 3.3.a). An adjustment due to ties is necessary because some ranks have the same scores.

The last line in the Mann-Whitney confidence interval and test result (Cannot reject at α = 0.05) will not appear if H0 is rejected. In this case, the test is likely to be significant at the value of less than 0.05 and the sample median is different. The preference is given to the sample with the higher median.

3.6 The Usability Factors to Measure

There are seven well-known usability factors to be assessed by the actual users in this project. A description of each factor is given below:

3.6.1 Comfort

Comfort, represents the users' subjective assessment of the physical aspect of the device. For example, Murata [MUR91] and Loricchio [LOR91] noted that
although a direct device (e.g., touchscreen, lightpen) is faster to operate than an indirect device (e.g., mouse, keyboard, joystick), all of these induced fatigue of the shoulder, hand, neck and arm. This usability factor has been used in determining the usability level of a device in several research project [ARC95, MUR91].

### 3.6.2 Ease of Use

Ease of use deals with the user’s mental effort to understand and easily use a system. Sometimes, familiarity with a particular device affects the user’s assessment of this factor. Traditional keyboard, as one of the most widely used input devices today, is found to be easier to use for students than touchscreen keyboard [ARC95, SEA91]. However, for pointing tasks, the lightpen is easier to use for pointing an object than other more familiar indirect pointing device such as the mouse or trackball [MUR91].

### 3.6.3 Error Rate or Less Likelihood of Making Mistakes

This usability factor is usually measured in the number of error made by the subject during an experiment. A research experiment [KAR93] found that there are no significant differences between voice input and mouse-based input for word processing in regard to error rates. Another report [JOH89], pointed out that keyboard-based input produced much less error than voice-based input. For the pointing task, a report [MUR91], concluded that the error rate for the light pen is the smallest compared to touchscreen, joystick, mouse, trackball, and joycard.
This usability factor can also be recognised by asking users to express their subjective feeling on "the less likelihood of making mistakes" question [ARC95]. In the latest case, the user might be asked to give scores to the device or user interface being tested.

3.6.4 Naturalness

Naturalness is related to the normal manner of human-human interaction. Hand gestures [BAU93, MAY92, PRE94], voice recognition [JOH89, KAR93, MAY92, PRE94] are two of the most natural forms of human-human communication used.

3.6.5 Accuracy in Pointing

An experiment [MUR91], found that a mouse is more accurate as a pointing device than a joystick. Another researcher [SEA91], conducted a usability experiment on a touchscreen keyboard mounted at three angles (i.e., 30°, 45°, 70°) from the horizontal. He notified that a 30° angle resulted in the most accurate pointing.

3.6.6 Ease of Correcting Mistakes

The window-based application, correcting typing mistakes by using a mouse, i.e. block the word or sentence and then press ‘space’ or ‘delete’ keys, is likely to be easier than using ‘backspace’ or ‘delete’ keys in the keyboard. An experimental trial [KAR93] found that correcting mistakes is likely to be even faster using the voice command.
3.6.7 Speed of Entering Data

A report [KAR93] noted that speech input is faster for word processing applications than the keyboard-mouse combination. Another work [SEA91] compared the speed of entering data using a touchscreen, a mouse, and a traditional keyboard. A touchscreen and a mouse were used and a QWERTY keyboard was presented on the screen. Data was entered by selecting keys on that keyboard. It was found that a keyboard was the fastest device in entering the data, but that a touchscreen is faster than a mouse.

3.7 Summary

In order to design a user friendly user interface, some principles and guidelines should be followed. In this chapter, user interface design principles and guidelines that will be incorporated in the design of PDA-based interaction device have been given. It has been shown that the process of design should also follow the four-stages of the user interface design cycle in order given. A non-parametric statistic inference and Mann-Whitney U Test described in this chapter is one way to analyse the data collected from the user trial. Last, seven usability factors that need to be observed in the evaluation stage (Chapter 5) have also been explained here. In the next chapter, the process of design and implementation are reported.
Chapter 4

A User Interaction Device for Domestic Hypermedia System

4.1 Outline

This Chapter presents the user interface design stage. In Section 4.2, the user/tasks analysis are performed to outline the design considerations. By taking into account some specific characteristics of the domestic environment, the requirements of the interaction device for such an environment are identified and the appropriate interaction devices are selected. Section 4.3 describes the implementation of the Newton-based user interface. The user interface components and their representations are presented. An explanation of how the prototype was developed, programmed and then implemented to interact with an interactive multimedia terminal emulator, is given in Section 4.4. Section 4.5 summarises the chapter.
4.2 Design Considerations and Specification

In selecting the interaction device to be used in the domestic environment, it is important to take into account the situations in the particular setting and the tasks that need to be facilitated.

4.2.1 The Output Device

- **PC/TV System**

Two reports noted the emergence of PC-TV technology. A paper [MAL96], reported a PC that could receive television programmes, and another report [ANT96] noted the release of a TV as the first convergence device that combines audio/video and multimedia computing. An example of this is Gateway 2000’s Destination PC/TV. It tethers 31-inches (diagonal) Mitsubishi VGA-only monitor to a computer. Any video source (broadcast, cable, satellite, VCR, laserdisc, or videogame) is fed into the video card in the computer. Other instances are Olivetti PC/TV, Web TV and Pippen.

The Destination is operated by either one of two wireless devices. The first device is a full sized keyboard with a touchpad that a user can slide a finger on to control the screen pointer. The other is a handheld remote control that Gateway calls a Field Mouse. Further, Antonoff [ANT96], noted that “the most compelling use for Destination is the ability to visit a World Wide Web address mentioned on TV while simultaneously watching the program. Using the wireless keyboard and the Microsoft Internet Explorer 2.0 browser software bundled in the system, I was able to get onto the Web and open a window of concert dates related to a band being
featured on one of the cable channels”. At this time, the PC/TV screen is likely to be the most suitable output device for the domestic multimedia environment.

This potential output device for interactive multimedia services would be emulated in the test platform.

However, there are several usability problems with the input devices for this technology, i.e., the Wireless Keyboard and the Fieldmouse, were identified. The size of wireless keyboard is too big for a remote control and it still requires a hard flat surface to operate accurately. The field mouse requires a more awkward hand-eye co-ordination than a traditional mouse because the distance between the user and PC/TV is large and the user has to wave the field mouse around in the air.

4.2.2 The Requirements of Interaction Device

- **Convenient to be used**

  A living room, as an example of the domestic environment, is intended as a place to relax. The interaction device should support this intention. Virtual reality-based input, for example, require a users to use a helmet mounted display and a special glove. It suffers from a lack convenience for the user, in particular, the novices. Therefore it is inappropriate for such an environment.

- **Provide a (more) Natural Means of Interaction**

  If the interactive TV is present in the home, people with various levels of skills (from novices to experts), a wide range of ages (from children to the elderly), a and diverse range of education and work experience backgrounds, may watch and have control of the TV. The interaction device should be one which is natural for human
to use. Therefore, voice-, gestures- and handwriting-based input are some potential candidates for domestic environment.

Keyboard-based interaction devices, which presume typing skills and need users to be familiar with the layout, for example, are difficult to use in such an environment. Indirect pointing devices such as a mouse and a trackball require hand-eye coordination which seems awkward for novices or first-time users.

- Tolerate Noise

At home, viewers are likely to put their multimedia entertainment devices in the living room. Many family activities take place here, such as conversations, both serious and idle chatter, and children use it for playing games. The living room is like a public environment. It is almost impossible to avoid noise in such a room. Therefore an interaction device that is intolerant to ambient noise such as a voice-based input device is not likely to be suitable for this environment.

- Support Mobility: A Remote, Handheld Device

Viewers are not likely to be willing to control an interactive system, such as interactive TV, while sitting, or standing in one position for any length of time [ANT96]. They may want to control the system while resting on the sofa, or lying on the floor, or even while sitting at the dining room table. In addition, when interacting with the TV, viewers need to protect their eyes by maintaining a particular distance from the screen while controlling or viewing the TV screen. The distance is 4 to 6H (H: display height) for an ordinary television and from 2 to 3H when considering High Definition Tele-Vision (HDTV) [ARI93]. The widely used
A current VCR remote control is an example how a handheld remote device is suitable for such an environment.

A hand gesture-based input, however, cannot support the required mobility. It demands users sit or stand in a particular position, so that their gestures can be tracked properly by the system’s camera. In addition, the handgesture-based input requires users to memorise a set of gesture commands that the computer recognises. This is awkward and inconvenient for the novice. Cultural sensitivity of gesture is also an issue. Different cultures may have their own set of gestures to communicate with others.

Due to their inability to support this requirement, the traditional mouse and the keyboard are also unsuitable for such an environment. The traditional touchscreen-based input is inappropriate too, because it does not support mobility or allow users to sit or stand further than an arm’s reach away.

- **Facilitating Select-and-Point and Data Entry functions**

  The interaction techniques that should be supported by the user interface for multimedia services include [BEA97, BEA95, COO95, HIC94, LIT94] :

  - browsing and navigating;
  - menu driven interface;
  - search based inquiries (to allow users to find specific information);
  - data entry (e.g., to support remote banking and other electronic commerce applications); and
  - hypermedia links to other information.
All the interaction techniques listed above can be supported by hypermedia interfaces. Further, these types of interaction techniques can be classified into two generic tasks; i.e., select-and-point tasks and text entry tasks. Therefore, the proposed interaction device should be able to support the select-and-point and text entry tasks.

4.2.3 The Choice of Interaction Device

Given the above requirements, it is likely that a successful, secure interaction device will combine aspects of the following technologies.

- **Handwriting-based Input**

Writing is natural and basic to humans. Typing is a more difficult and a learnt skill. Nevertheless handwriting-base input technology suffers from the following problems:

- user dependence (handwriting style)
- character set dependent (e.g., Japanese characters, Thai characters)
- requirement to train the system

Due to these limitations, pen-based handwriting recognition devices are mostly appropriate for fill-in-form type interfaces and other applications requiring small quantities of text input.

Provided that the interaction device for the domestic multimedia setting should support the data entry tasks which are only likely to require small quantities of text input (e.g., electronic banking and shopping applications), and can also provide for
a natural form of human interaction, it was decided to employ this technology to support data entry tasks.

- **Touchscreen-based Technology**

  Touchscreen technology allows users to input information or commands by touching a particular part of the screen. The most significant advantage of this technology is that the input device is also the output device. It is not necessary to learn how to use it. Moreover, pointing to an object is a natural activity. No additional skills are needed to use a touchscreen.

  However, it suffers from the lack of precision. This is because the human finger may be too large to point to small icons, menus or hypermedia links. Consequently, the error rates increase. Further, the user's arms are likely to become fatigued if the scheme is used for any length of time. It also does not support mobility because the user needs to stand or sit in front of the screen. Lastly, the user cannot maintain the appropriate distance necessary for eye protection.

  Nevertheless, some of these drawbacks could be solved by the following approaches:

  1. **The use of stylus.** Precision problems could be solved by the use of a stylus to point an object. This, in turn, would decrease the error.

  2. **The use of programmable tablet-like device.** The last two drawbacks (mobility and remote access) could be solved by employing a tablet-like device that could be programmed to display the same image as being displayed on a TV/computer screen. It is remote touchscreen.
Given that the touchscreen provides the most natural interaction technique for pointing tasks, it was decided to employ a remote touchscreen function in the Newton-based interaction device (the Newton is a touchpad with stylus).

- **PDA-based Interaction Devices**

  PDA is a wireless, handheld, programmable device that is well equipped with communication facilities (through wired connection or infra red), handwriting recognition capabilities and a virtual keyboard. In addition, the device could be programmed to act as an intelligent programmable content sensitive remote control used to interact with the service content being presented on the TV screen. Therefore, it was decided to incorporate the handwriting-based input and remote touchscreen functions into the Newton-based user interface.

  After selecting the interaction techniques to be employed in the Newton-based interaction device, three more tasks had to be completed:

  1. Designing the Newton-based user interface; and
  2. Prototyping and Implementing the interaction device into an interactive system
  3. Measuring its level of usability

### 4.3 Designing The Newton-based User Interface

In its most rudimentary stages, the design process involved breaking up the control device into the different interface components which are to be employed. As suggested by the guidelines in Chapter 3, well-known metaphors are employed. The use of
metaphors means “expressing the unknown in terms of the known” [HJE97]. The desktop metaphor of the Macintosh user interface, probably the most popular one, uses a symbol of a desktop to illustrate the working of the computer. Using interface metaphors eases the cognitive load of the user and, therefore, makes the system easier to use.

The following components of the Newton-based user interface were isolated:

- Touchscreen Area
- Handwriting Input Area
- Connect/Disconnect Button
- Sending Button

The function of each of these components is discussed individually in this sub-section. Figure 4.1 depicts the Newton-based User Interface Prototype. It is the full-sized picture that was scanned from the actual device.

4.3.1 Screen Metaphor for Touchscreen Function

It was decided to employ a screen metaphor on the Newton user interface. This is an interface area that would display an image or picture transferred from the remote TV screen. To help the users build their mental model correctly the title “Screen” was placed on the top of the area.

4.3.2 Paper Metaphor for Handwriting Input Function

It was decided to use paper metaphor because it was believed that almost everyone today, particularly in developed countries, has experienced writing on paper. To
help users form their mental model correctly, the sentence “Your Text Here” is used to guide users where to write their text.

Figure 4.1 The Newton-based User Interface Prototype with Connect Button Active

4.3.3 Button Metaphors for Connect/Disconnect, Sending Functions

Following the guidelines in Chapter 3, the minimum number of controls to be incorporated into the Newton-based user interface needs to be determined. Unlike other types of interaction devices, which are dedicated only as an input device, the Newton is a multipurpose device. It was originally developed as an intelligent personal digital assistant and, therefore, is not automatically connected
to the PC-TV. It was decided for the prototype that the Newton-based user interface should provide "connect" and "disconnect" virtual button (again, buttons are metaphors) to allow users to initiate and release the connection with the remote end. Instead of having two separate buttons for these actions, the Newton-based user interface employs only one virtual button. The button acts as a "connect" button if the connection has not been initiated, and is altered to as a" disconnect" button once the connection has been made.

![Figure 4.1 The User Interface with Virtual Keyboard and Disconnect button Active](image_url)

**Figure 4.1** The User Interface with Virtual Keyboard and Disconnect button Active

**Error! Reference source not found.** (CONNECT button active) and Figure 4. Illustrate this alteration respectively. In addition, the Newton-based user
interface also requires a “sending” button to allow users to send text to the remote end once the Newton interpret their handwriting correctly. The last technique also allows user for editing and correcting if need.

4.4 Prototyping and Implementation

The following sections describe the first stage of prototyping and the system implementation. The first user trial will determine whether or not this system works properly. There might be a second stage of design, prototyping and system implementation if necessary.

4.4.1 Prototyping the Newton-based User Interaction Device

The Newton was programmed with the object-oriented, dynamic language NewtonScript with pascal-like syntax. Programming for Newton is done using the Newton Tool Kit (NTK), the development environment for Newton, on a Macintosh or window-based computer.

• How the prototype was programmed and works

The Newton-script views that underlie the prototype are depicted Figure 4.3. The prototype consists of five visible views, Touchscreen view, Text Input view, Connection Status Button view and Sending Text Button view, and one invisible communication view. The communication view is programmed to send/receive data to/from the remote end. The data to be forwarded to the remote end is sent from either the Touchscreen view (x,y position) or the Text Input view (text). The data received is then sent to the Touchscreen view.
The Touchscreen view is programmed as the touchscreen component. It receives image raw data from the Communication view. The raw data are then transferred into image format and displayed on the screen. This view is also responsible for detecting user tapping on a particular position on the screen (it may be where the object or menu exists) and then soon send the position to the remote end through the Communication view.

The Text Input view is programmed to accept text translated from the user's handwriting. The text remains buffered here until the send button is tapped by the user.
The *Sending Text Button view* is programmed to detect user tapping and then calling the *Communication view* class to send data (text) that the *Sending Text Button view* inherits from the *Text Input view*.

The Connection Status Button view is responsible to call the communication view for establishing and releasing connection to the remote end.

### 4.4.2 System Implementation

Based on the Customer Premises Equipment (CPE) of the interactive multimedia system shown in Figure 2.1 [LIT94, GEL91], the system was implemented into several layers as depicted in Figure 4.4.

![Figure 4.4 The Interaction System Layering](image)

- **The PC-TV Screen Emulation**

  The interaction device prototype has been designed and programmed to interact compatibly with PC-TV (or Web TV) terminal emulator run either on
Macintosh, PC, or UNIX machine. In the experiment, the Web TV user interface was emulated using the Arena Web Browser running on PC based Linux operating system. This web browser displays TSRC's (Telecommunication Services Research Centre, University of Wollongong) hypermedia interface experiment (http://jupiter.tsrc.uow.edu.au/experimental/tsrc/tsrc.html). Figure 4.5 depicts the actual user interface on the PC/TV side.

![Web Browser Image on TV](image)

**Figure 4.5** Web Browser Image on TV

- **Device-Network Interface**

  The device to network interface is controlled by a Video-on-Demand (VOD) server. It is a UNIX Shell Script program that runs C communication programs, and several X Window and UNIX applications consecutively. VOD server controls the flow of data between the PC/TV Screen Emulator and User-
Network Control Interface. For example, it runs an `xwd` program to grab the rendered pages on the PC screen, converts them using UNIX applications and then sends the image file into the Newton through the communication program. In return, again through the communication application, it receives point (x,y) or text from the Newton and generates mouse or keyboard x-events to access the web browser.

Table 4.1 lists the programs controlled by the VOD server to transfer images to the Newton and to send back the user actions to the PC/TV screen emulator.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Application Programs</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows Grabbing</td>
<td>xwd, xwdtopnm (X Window apps)</td>
<td>grab the rendered pages and convert them into pnm file</td>
</tr>
<tr>
<td>File Conversion</td>
<td>pnmscale, ppmtopgm, pgmto-pbm, pnmraw (UNIX apps)</td>
<td>generate an ASCII pbm file</td>
</tr>
<tr>
<td></td>
<td>pbmtohex (C program)</td>
<td>convert ASCII pbm into ASCII HEX file</td>
</tr>
<tr>
<td>Communication with the Newton</td>
<td>tonewt (C program)</td>
<td>transfers file to the Newton.</td>
</tr>
<tr>
<td></td>
<td>Fromnewt (C program)</td>
<td>sends user actions to the PC</td>
</tr>
<tr>
<td>Sending Events/User Actions</td>
<td>xse (X Window app)</td>
<td>generates mouse and keyboard x-events</td>
</tr>
</tbody>
</table>

- **User-Network Control Interface**

User actions are captured by the Newton, processed using NewtonScript program and send back to the PC and VOD server through C-based communication program.
• Newton-based Interaction Device

The Newton was programmed to accept images sent from the remote end. The result is that the Newton displays the same image or picture as on the remote TV emulator. To simplify the endpoint communication program, the Newton is set to accept only the ASCII HEX file from the remote end. The ASCII file is then converted into real HEX. This HEX data is used to convert into a bitmap file before the image can be displayed on the Newton screen.

Users can point to an object or write any text directly on the Newton screen, just as in a touchscreen. The Newton captures the x,y co-ordinate or text in the screen and sends back the two dimensional positions or text to the remote end. If it is a link, the remote server would connect to the information source intended.

The VOD emulator (i.e., the shell script program) detects if there is a packet coming from the Newton and execute a C-based communication program to read a text stream from the PDA and translate it into a packet containing the appropriate keyboard-events format. X events are generated based on this packet. If the Newton sends numeric stream, keyboard numeric events are generated to send all characters to the Arena web browser.

Figure 4.6 illustrates results of the user-device-network interaction process on the Newton-based interaction device.
4.5 Summary

Detailed descriptions of the Newton-based interaction device have been given in the preceding sections of this chapter. Looking at the user interface structures of the interaction device it is clear that it provides the functions covering most usability aspects of the user interface design and principles for domestic multimedia setting. In the next chapter, the usability trial carried out to collect the data from the real users are reported.

Figure 4.6 Web Browser Image on The Newton-based User Interface
Chapter 5

Iterative Design-Test-Modify

Interface Development

5.1 Outline

This chapter presents the iterative process of the development of the Newton-based interaction device. Section 5.2 presents the theoretical advantages and disadvantages of the each function of the interaction device over other devices that are capable of performing similar functions. The results from the first user-involved usability experiment of the interaction device are presented in Section 5.3 and the usability problems detected in the first experiment are outlined. The process to enhance the performance of the user interface system is described in Section 5.4. The result from the second user-involved usability experiment is given and discussed in Section 5.5. The Chapter is summarised in Section 5.6.
5.2 Preliminary Result

Considering the design principles and guidelines outlined in Section 3.2 and 3.3, then the preliminary result of the theoretical-based evaluation of the device is as presented in Table 5.1. In this evaluation, the performance of the Newton-based interaction device is compared with the fieldmouse and wireless keyboard. These two latter devices have been used previously in the domestic multimedia environment [ANT96].

**Table 5.1 Preliminary Result of the Evaluation**

<table>
<thead>
<tr>
<th>Newton-based Interaction Device (handwriting and touchscreen)</th>
<th>Fieldmouse</th>
<th>Wireless Keyboard (integrated with trackball)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>• support select-and-point and text entry</td>
<td>• support select-and-point and text entry</td>
</tr>
<tr>
<td></td>
<td>• eliminate the need for user learning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• handwriting is more natural than typing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• can be used as virtual wireless keyboard</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>• more heavy than fieldmouse - fatigue</td>
<td>• heavy, big size - fatigue, inconvenient</td>
</tr>
<tr>
<td></td>
<td>• introduces delay for image transfer</td>
<td>• requires hand and eye co-ordination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• requires hand and eye co-ordination (trackball)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• presumes typing skills</td>
</tr>
</tbody>
</table>

In addition, the Newton-based interaction device provides a remote touchscreen interaction technique. As a result, it removes at least three of the traditional touchscreen (i.e. pointing directly to the TV/PC screen) disadvantages. These are:

1. The requirement to stand or sit within hand-reach distance;
2. The risk to human eyes (related to the distance from the screen);

3. The lack of mobility.

5.3 User-involved Usability Experiment

Based on the objectives of this thesis, the goals of the user-involved experiment are:

1. To test the hypothesis of the project that the newton-based interaction device with its two basic functions (i.e. remote touchscreen and handwriting-based input) is more usable than the combination of keyboard and mouse for hypermedia user interface applications.

2. To measure the user acceptance level of the Newton-based interaction device in the light of several usability factors such as: comfort, ease of use, less error prone, naturalness, accuracy in pointing objects or selecting menus, ease of correcting mistakes and speed of entering data;

3. To recognise the subjective feeling of the users about the Newton-based interaction device. This can be obtained by studying the participants' comments on the performance of the Newton-based interaction device.

The experiment was divided into two generic tasks:

1. Select-and-Point Tasks: The aim of this task is to compare the Newton and the mouse in performing select-and-point functions. The participants were free to do whatever they wanted. They navigated and browsed the hypermedia interface, read or watched whatever they wanted. In a multimedia setting, all viewers are likely to want to entertain themselves by watching movies or
reading newspapers or magazines. Therefore they may have no specific task in mind when they start ‘surfing’ the interactive TV.

2. **Data Entry Tasks:** This part of the experiment compares the keyboard and the Newton in performing data entry task. The participants were asked to write down or type their names, occupations and comments about the Newton-based interaction device in a fill-in form interface on the screen. Data entry tasks require a small amount of typing or handwriting. This task is necessary as it anticipates that the applications supported by an interactive TV may include electronic home shopping and banking. This may mean customers are required to fill in their names, account number, amount of money to withdraw or save, etc.

### 5.3.1 Participants

Twenty-five volunteers served as participants in the first experiment. Their skills ranged from expert to novice and, of these, twenty-three participants were using keyboard-integrated pointing device daily. Two were novice users. None of the participants, however, had used Newton before. To recognise the level of expertise of the participants, they were asked to complete a user profile form (Appendix B). Figure 5.1 below shows how a user controls the system during the user experiment. In fact, user can sit about 3 m away from the screen (not shown in the picture).
5.3.2 Interaction Devices

Two kinds of input devices were used in the experiment: a keyboard-mouse combination and a Newton PDA as multipurpose input device. All input devices were connected to the PC running linux.

5.3.3 Procedure

At the beginning of the experiment, the observer gave each participant a tutorial on how to use the Newton and keyboard-mouse combination (important for novices). At the beginning of the experiment, the observer gave each participant a tutorial on how to use the Newton and keyboard-mouse combination (important for novices). The tutorial given was mainly on how to use stylus to select object or write words on the Newton screen. For novice
participants, the tutorial on how to use keyboard for entering data and mouse for selecting and pointing object is also necessary. Observer did not talk much but asked the participants to try to use the interaction device for 5 minutes.

Using each of input devices (i.e., Newton and keyboard-integrated pointing device), each participant interacted with the TV screen emulator user interface, locating any information or entertainment sources they wanted to watch. The content presented on the TV emulator is Telecommunication Software Research Center (TSRC) multimedia set-top box user interface experiment.

In the second task, the participants wrote their personal information and comments on the Newton user interface and send the data to the remote screen. The Newton handwriting recognition setting is turned on to the guest mode. By doing so, the participant does not need to train the Newton his/her individual handwriting style.

The participants were sitting 3 metres away from the screen when using the Newton-based device for controlling the multimedia system.

After completing each of these tasks, the participants were asked to fill in a questionnaire (see Appendix C) with responses on a five-point Lickert scale, containing 11 questions about the interactive feeling of the input devices just tested. The users’ preferences to the Newton are compared to their preferences to the mouse and keyboard. The subjective feeling is gauged by their responses to particular questions.
5.3.4 Data Analysis

During the data analysis stage, the preferences were detected using Wilcoxon-Mann-Whitney confidence interval and test. The first hypothesis (H₀) was that users have no preferences between the Newton and the mouse or keyboard. The alternate hypothesis (H₁) was that the users preferred one device over the other (depending on their median value). The confidence interval of 95% and level of significant α = 0.05 and α = 0.01 were used. The differences found with α = 0.01 is more significant than with α = 0.05 because by using α = 0.01 the probability of type I error (rejecting the null hypothesis falsely) is made smaller.

The hypothesis were:

H₀: μ₁ = μ₂, Users have no preferences, the medians are equal.

H₁: μ₁ ≠ μ₂, Users prefer one device, which has a greater median, over the other. However, the decision depends on whether the difference is significant or not.

H₁ constitutes the assertion of hypothesis that is accepted if H₀ is rejected.

5.3.5 Result and Discussion

- Newton vs Mouse

From five usability aspects observed, the test showed that significant differences exist in three aspects. Table 5.2 presents the calculation result.
Table 5.2 User Interfaces’ Questionnaire Result (Newton vs Mouse)

<table>
<thead>
<tr>
<th>Usability Factors</th>
<th>N</th>
<th>Significant at</th>
<th>Significant Level</th>
<th>Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>25</td>
<td>0.168</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Ease of Use</td>
<td>25</td>
<td>0.034</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Less Mistakes</td>
<td>25</td>
<td>0.041</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Naturalness</td>
<td>25</td>
<td>0.152</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>25</td>
<td>0.044</td>
<td>*</td>
<td>Newton</td>
</tr>
</tbody>
</table>

*: significant if $\alpha = 0.05$; NS: Not Significant at either $\alpha$’s (0.05 or 0.01)

The users felt that the Newton (touchscreen function) was easier, less error prone, and more accurate in pointing object than the mouse. In two other usability factors, the difference was not significant (i.e., above $\alpha = 0.05$). Therefore the Newton and the mouse shared the same preferences. The results of the usability testing are shown in Figure 5.2.

**Figure 5.2 Usability Performance in Select-and-Point Tasks**

- **Newton vs Keyboard**

  From the six usability aspects observed, the hypothesis $H_0$ was applied in four usability factors, i.e., ease of use, less likelihood of making mistakes, naturalness and speed of entering data.
Users felt more comfortable using Newton and, also, it was easier for correcting mistakes. The users only need to scrub the wrong text in case of error. Two novice participants indicated that they felt writing on a Newton-based interaction device was more natural for them than typing.

The calculation result is presented in Table 5.3.

Table 5.3 User Interfaces’ Questionnaire Result (Newton vs Keyboard)

<table>
<thead>
<tr>
<th>Usability Factors</th>
<th>N</th>
<th>Significant at</th>
<th>Significant Level</th>
<th>Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>25</td>
<td>0.049</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>25</td>
<td>0.617</td>
<td>NS</td>
<td>---</td>
</tr>
<tr>
<td>Less Mistakes</td>
<td>25</td>
<td>0.372</td>
<td>NS</td>
<td>---</td>
</tr>
<tr>
<td>Naturalness</td>
<td>25</td>
<td>0.088</td>
<td>NS</td>
<td>---</td>
</tr>
<tr>
<td>Ease of Correcting</td>
<td>25</td>
<td>0.003</td>
<td>**</td>
<td>Newton</td>
</tr>
<tr>
<td>Speed of Entering Data</td>
<td>25</td>
<td>0.113</td>
<td>NS</td>
<td>---</td>
</tr>
</tbody>
</table>

*: significant if $\alpha = 0.05$; **: significant if $\alpha = 0.01$; NS : Not Significant at either $\alpha$’s

Figure 5.3 shows the comparative usability performance of the devices. It can be seen that the Newton is more usable in two aspects than the keyboard.

Figure 5.3 Usability Performance in Data Entry Tasks

Nevertheless, eight participants (i.e., about 30% of the participants) expressed their subjective feeling, by filling in the comment space in the questionnaire
form, that although the Newton-based interaction device was easier to use, it was quite slow when transferring the image. They believed that the superiority of the Newton-based interaction device would be greatly enhanced if the transfer time was reduced.

5.3.6 Usability Problem

A usability problem with the current prototype as indicated from the first user experiment and observation by researchers is the transfer delay. The major delay introduced in the transfer process came from two sources:

1. The time needed to grab the windows and transfer them into the ASCII Portable Bitmap Format (PBM). The file format that is compatible with the current Newton-based user interface.

2. The time taken to send the ASCII PBM file to the Newton. Character sending is likely to be the major cause of the delay.

Table 5.4.a shows the processing time for each stage of the image transfer.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Application Programs</th>
<th>Processing Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows Grabbing</td>
<td><code>xwd, xwtopnm</code></td>
<td>17</td>
</tr>
<tr>
<td>File Conversion</td>
<td><code>pnmsetle</code></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><code>ppmtopgm, pgmtpbm, pnmraw, pbmtophex</code></td>
<td>1</td>
</tr>
<tr>
<td>File Transfer</td>
<td><code>tonewt</code></td>
<td>50</td>
</tr>
</tbody>
</table>

As a comparison, performance time of the mouse and keyboard is given in Table 5.4.b.
Table 5.4.b Performance Time of Mouse and Keyboard

<table>
<thead>
<tr>
<th>Interaction Device</th>
<th>Task</th>
<th>Performance Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>Select and Pointing</td>
<td>5 secs *</td>
</tr>
<tr>
<td>Keyboard</td>
<td>Entering Text (1 line)</td>
<td>3 – 5 secs **</td>
</tr>
</tbody>
</table>

* including rendering image from remote site
** depends on the level of expertise of users (novice or expert)

The remaining sections of this chapter describe the process prototype re-development, system enhancement and the second usability experiment.

5.4 System Implementation: The Improvement

The user interface development process has to return to the design stage. Because the design of the prototype has properly conformed to the design principles and guidelines, there must be an improvement in the system implementation.

5.4.1 Newton Binary Communication

Setting the Newton endpoint communication to accept binary transfer (i.e. data are sent as raw bytes) has increased the transfer performance. When transferring ASCII text, as the system did in the previous prototype, some layer of the communication element sends a stream of bytes that represent the text. The sending layer encodes a string, sends the data, and the receiving layer decodes it. These overhead steps slowed the communication process. Sending strings was accomplished with XON/XOFF flow control. Communication interface on the PC end waits for the Newton to complete the decoding process before sending the next data. This scheme produces 50 seconds transfer delay.
By sending binary data, the encoding/decoding step is skipped, and only the number of bytes to be sent or received needs to be specified. The size of binary file is eight times smaller than the ASCII file. On the Newton end, the raw data are treated either as a binary object or an array of bytes. However, to be able to display image directly from the raw bytes the Newton Bitmap Format (See Table D.1 in Appendix D) must be understood.

Some major changes have been made in the NewtonScript program. The endpoint or the Communication view has been changed to accept binary data or bytes instead of strings. The hardware flow control is used. Some methods (or subroutine in PASCAL term) are not used. There is no need to transfer ASCII hex into real hex. A new method is created to append the proper header information (bytes # 1-16, Table D.1 in Appendix D) to the binary data.

### 5.42 PC/TV Emulator Improvement

On the PC side, a C-based communication program is changed to accept binary transfer. Another significant improvement for the system performance is the replacement of two X Window applications (i.e. *xwd* and *xwdtopnm*) with one application, *xwpick*, that produces raw data directly. Since the Newton can now accept the binary files the number of file conversion applications involved in the process is reduced.

Table 5.5 depicts the overall improvement on the performance of the system.
Table 5.5 The System Performance Comparison

<table>
<thead>
<tr>
<th>Stages</th>
<th>Application Programs</th>
<th>old system</th>
<th>new system</th>
<th>old system</th>
<th>new system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows Grabbing</td>
<td>xwd</td>
<td></td>
<td>xwpick</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>xwdtopnm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>File Conversion</td>
<td>pnmscale</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ppmtoptopgm</td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pgmtopbm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pnmraw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pbmtohex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>File Transfer</td>
<td>send_data</td>
<td>50</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Transfer Delay</td>
<td></td>
<td>72</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The transfer delay is now equivalent to the performance time of the mouse (see Table 5.4.a): 5 seconds. The difference is in the time consumed to convert the image into the binary format (10 seconds).

The most significant enhancement in the improved system is the capability of the Newton-based interaction device to accept binary data. The most significant enhancement is the capability of the Newton-based interaction device to accept binary data. The file transfer stage is 10 (ten) times faster. The speed of file transfer is likely to be faster for the new version of Newton PDA. The Newton MP 110 used in this system can only allocated 1 KB data for transfer. For example, with Newton O.S 2.0, MP 120 can accept 4 KB per transfer [ROB97].

The use of xwpick has saved the processing time 11 seconds. This is almost three times faster than the old system. The newly enhanced system performs almost 5 (five) times better than the old system; i.e. 72 secs : 15 secs.
5.5 User-Involved Usability Experiment: The Second Test

The second test of the user-involved usability experiment is similar to the first test except for the number of participants.

5.5.1 Participants

Forty-three volunteers served as participants in the second experiment. There were twenty new participants and none had used Newton before. Twenty-three had participated in the first test and were using the Newton for the second time. Forty-one participants were used to work with keyboard-integrated pointing and the rest two are novice users, device daily. The learning effect would also be observed.

5.5.2 Result and Discussion

The data analysis is performed in the same way as in the first experiment.

- Mouse vs Newton

Table 5.6 shows the calculation for the select-and-point tasks.

<table>
<thead>
<tr>
<th>Usability Factors</th>
<th>N</th>
<th>Significant at</th>
<th>Significant Level</th>
<th>Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>43</td>
<td>0.0001</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>43</td>
<td>0.0001</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Less Mistakes</td>
<td>43</td>
<td>0.0002</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Naturalness</td>
<td>43</td>
<td>0.0004</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Accuracy</td>
<td>43</td>
<td>0.0001</td>
<td>*</td>
<td>Newton</td>
</tr>
</tbody>
</table>

*: significant if $\alpha = 0.05$; **: significant if $\alpha = 0.01$; NS: Not Significant at either $\alpha$'s

The Wilcoxon-Mann-Whitney U test shows that, after the improvement, Newton leads Mouse significantly in all five usability aspects. Another important fact of this experiment is that none of the subject had complaint
about the performance of the Newton-based interaction device, in particular the
transfer speed (which had been a major complaint in the first experiment).
Figure 5.4 depicts the usability performance comparison between the two
devices.

![Usability Factors Comparison: Newton vs Mouse](image)

**Figure 5.4 Usability Factors Comparison: Newton vs Mouse**

- **Newton vs Keyboard**

  The Wilcoxon-Mann-Whitney U test indicates that the Newton-based
  interaction device is now superior to the keyboard in four of the six usability
  aspects observed. The Newton-based interaction device is more comfortable,
easier to use, more natural, and easier for correcting mistakes. No significant
differences were found in ‘less likelihood of making mistakes’, and ‘speed of
entering data’ aspects.

Table 5.7 shows the calculation for the text entry tasks.
Table 5.7 Interface Comparison Questionnaire Result (Newton vs Keyboard)

<table>
<thead>
<tr>
<th>Usability Factors</th>
<th>N</th>
<th>Significant at</th>
<th>Significant Level</th>
<th>Preferences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td>43</td>
<td>0.002</td>
<td>**</td>
<td>Newton</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>43</td>
<td>0.014</td>
<td>*</td>
<td>Newton</td>
</tr>
<tr>
<td>Less Mistakes</td>
<td>43</td>
<td>0.074</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Naturalness</td>
<td>43</td>
<td>0.001</td>
<td>**</td>
<td>Newton</td>
</tr>
<tr>
<td>Ease of Correcting</td>
<td>43</td>
<td>0.001</td>
<td>**</td>
<td>Newton</td>
</tr>
<tr>
<td>Speed of Entering Data</td>
<td>43</td>
<td>0.601</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

*: significant if $\alpha = 0.05$; **: significant if $\alpha = 0.01$; NS: Not Significant at either $\alpha$'s

Figure 5.5 depicts the usability level comparison between the two devices.

Although the median comparison shows that the Newton-based interaction device offers less likelihood of making mistakes than the keyboard, the Wilcoxon-Mann-Whitney U test (Table 5.7) recommends not to reject the null hypothesis. Therefore, for this usability aspect, it is considered that the Newton-based interaction shares the same preferences with the keyboard.

A general comment expressed by most of the participants about the two usability aspects in which the device does not lead the keyboard is that they are used to the keyboard because they use the keyboard for text entry or word
processor daily. The virtual keyboard is also quite slow for them because they have to wait for the newton to complete the process (i.e., to translate a letter) every time they touch a letter in the virtual keyboard. In addition, the Newton needs some time to recognise their handwriting. Last, they thought that the Newton’s handwriting recognition errors had affected their score for the device.

5.5.3 Learning Effect

Twenty-three of the forty-three participants of the second test are first test participants. They have only used the Newton once before and, therefore, have gained a learning experience from the first trial. This approach leads to question whether the user interface of the Newton-based device is easy to learn and easy to remember. The latter is the matter of retaining ‘how to use the device’ in the users’ memory or how long this knowledge is retained in the users’ memory.

In the Newton versus Mouse experiment, the improvement on the result of the usability testing is due to two dominant factors:

1. The speed of data transfer directly influences comfort and indirectly affects ease of use, less mistakes, and naturalness (i.e., once the user feel the device is too slow then they are not likely to give high score for the rest of usability factors). This fact is collected from the additional comments the users wrote on the questionnaire.

2. The human learning capability affects the ease of use, number of mistakes, and naturalness.
Accuracy is affected by the directness of the interaction. That is, touchscreen is a direct device whereas the mouse is an indirect device. 

Table 5.9 shows the accomplishment.

<table>
<thead>
<tr>
<th>Usability Factor</th>
<th>First Test Result</th>
<th>Second Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
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<td>NS</td>
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<tr>
<td>Ease of use</td>
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<tr>
<td>Less Mistakes</td>
<td>0.041</td>
<td>*</td>
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<td>NS</td>
</tr>
<tr>
<td>Accuracy</td>
<td>0.044</td>
<td>*</td>
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</table>

In the Newton versus the Keyboard experiment, the improvement on the result of the usability testing is caused by two dominant factors:

1. The speed of data transfer directly influences comfort and data entry speed, and indirectly affects the ease of use, less number of mistakes, and naturalness. That is, once the user feel the device is too slow then they are not likely to give high score for the rest of usability factors)

2. The human learning capability affects ease of use and naturalness.

There are several additional notes for lessening the number of mistakes and the ease of correcting mistakes factors. Correcting writing mistakes in the Newton device is as easy as scrubbing out the words or sentences. It is easier than
correcting mistakes using ‘delete’ or ‘←’ keys in the keyboard. However, the accuracy of the handwriting recognition of this device is the problem for the ‘less of mistakes’ factor, particularly when the guest mode is used. The latter affects the speed of entering data (many word mistakes and correction might occur before sending the text).

Table 5.9 shows the achievements.

Both of the tables show that Newton-based user interaction device is easy to learn and easy to remember.

Table 5.9 Comparison Between the Two Tests (Newton vs Keyboard)

<table>
<thead>
<tr>
<th>Usability Factor</th>
<th>First Test Result</th>
<th>Second Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
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<td>*</td>
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<td>Less Mistakes</td>
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<td>Ease Correcting</td>
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<td>Data Entry Speed</td>
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</table>

5.6 Summary

The user interface evaluation result has been given. The speed of the Newton-based interaction device has negative impacts on the users' satisfaction in the first testing. The second experiment proved that when the system works much faster the advantages of the Newton-based interaction device over the combination of
keyboard and mouse become apparent to the participants. The user interface of the
Newton-based device has also contributed to the users' higher acceptance level. In
the next chapter the overall achievements of the research project are concluded.
Further directions for research in this area and recommendations for human-
computer interaction community are also given.
Chapter 6

Conclusions

• A prototype of a wireless non-committed interaction device has been successfully developed that caters to the two modes of generic interaction tasks (i.e., select-and-point and data entry). The device supports remote touchscreen and handwriting-based input functions.

• The project has been shown to have two main contributions:
  1. The development of a prototype of usable interaction device for domestic hypermedia systems.
  2. The application of a new interaction technique, i.e., remote touchscreen, that combines a touchscreen technology and a mobile interaction device.

• The theoretical result of the evaluation (Section 5.2) shows that the Newton-based interaction device has a higher level of usability than the currently available wireless keyboard-trackball combination, field-mouse/air-mouse or dedicated remote control systems for the domestic multimedia environment.

• In a quantitative human study almost all the usability factors examined showed that a hand-held Touchpad based non-committed user interaction device
provides a higher users' level of acceptance than traditional keyboard-mouse combination in a laboratory-controlled experiment. The details are:

* The remote touchscreen function of the Newton-based interaction device is preferred over the mouse for select-and-point tasks (Sub-section 5.5.2). The device is superior to the mouse in five usability aspects tested: comfort, naturalness, ease of use, accuracy and less likelihood of making mistakes. The advantage can be considered more valuable when it is noted that all, except two novices, use a mouse regularly but were only using the Newton for the first time (20 Subjects) or for the second time (23 subject).

* The handwriting-based input function of the Newton-based interaction device is also proved more usable for data entry tasks that require small amount of text input than keyboard (Sub-section 5.5.2). The device is better than the keyboard in four of six usability aspects tested: comfort, ease of use, natural, and ease of correcting mistakes.

• These results provide important guidance to the designers of Internet Appliances for the domestic market and to the designers of domestic Interactive TV and hypermedia systems on how a PDA can be considered as an alternate user interface device for hypermedia applications.

• Although the Newton performance time satisfies the expectation (i.e., equivalent with the mouse performance time), the overall system performance time is still quite slow, in particular for real time applications. The improvement can be made if exists an application program that can immediately convert the image file into Newton-binary format in one shot. This
conversion is currently done through several steps which takes about 10 seconds. This would be a challenge for further research.

- The usability experiments used traditional keyboard-mouse combination as comparison devices. Further practical observation can be made to examine the prototype against the field mouse and wireless keyboard.

- The prototype has been developed and examined using a wired cable. It is referred to as a wireless non-committed communication. Actually the Newton PDA has the infra red communication features that enables a fully wireless communication. Further investigations are needed to check whether similar results are obtained when the latter mode is used.

- Further work could also include other application areas such as games interfaces and other mobile interaction systems.
References


[BEV94] Nigel Bevan, Jurek Kirakowski, Jonathan Maissel, *What is Usability?*,


[DIX93] Dix, A., Finlay, J., Abowd, G., Beale, R., *Human Computer Interact-


Publishers B.V, 1988, pp. 495-519


[SIE88] Siegel, S., Castellan, J.N.Jr., Nonparametric Statistic for The Beha-


[WEI] Weiser Mark, Ubiquitous Computing,

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weiser/ubiHome.html.


APPENDIX A

Areas Under the Standard Normal Probability Distribution between the Mean and Positive Values of Z

**APPENDIX TABLE 1**

Areas under the Standard Normal Probability Distribution between the Mean and Positive Values of $z^*$

![Diagram showing areas under the standard normal curve]

**EXAMPLE:** To find the area under the curve between the mean and a point 2.2 standard deviations to the right of the mean, look up the value opposite 2.2 in the table; .4861 of the area under the curve lies between the mean and a $z$ value of 2.2.

<table>
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## User's Profile Form

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<td>Name</td>
<td></td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
</tr>
<tr>
<td>rarely: one to three times; often: more than three times, but irregular; regularly: daily, weekly, etc.</td>
<td></td>
</tr>
<tr>
<td>♦ Have you ever used Newton PDA?</td>
<td>never, rarely, often, regularly</td>
</tr>
<tr>
<td>♦ Have you ever use keyboard and mouse?</td>
<td>never, rarely, often, regularly</td>
</tr>
<tr>
<td>♦ Can you type?</td>
<td>yes: fast, no, slow</td>
</tr>
<tr>
<td>♦ Have you ever used touchscreen device?</td>
<td>never, rarely, often, regularly</td>
</tr>
</tbody>
</table>

**For observer only:** novice non-novice
APPENDIX C

Usability Questionnaire

Select-and-Point Tasks

1. This interaction device is comfortable.

   Mouse
   least 1 2 3 4 5 most

   Newton
   least 1 2 3 4 5 most

2. I feel at ease with this interaction device

   Mouse
   least 1 2 3 4 5 most

   Newton
   least 1 2 3 4 5 most

3. The Less likelihood of making mistakes

   Mouse
   least 1 2 3 4 5 most

   Newton
   least 1 2 3 4 5 most
4. This interaction device is natural to my capabilities

Mouse

least 1 2 3 4 5 most

Newton

least 1 2 3 4 5 most

5. Accuracy in pointing object or selecting menus

Mouse

least 1 2 3 4 5 most

Newton

least 1 2 3 4 5 most

6. Additional Comments

................................................................................................................................................
................................................................................................................................................
................................................................................................................................................
................................................................................................................................................
................................................................................................................................................
Text Entry Tasks

1. This interaction device seems comfortable.

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<tr>
<td>5</td>
<td>most</td>
<td>most</td>
</tr>
</tbody>
</table>

2. I feel most at ease with this interaction device

<table>
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<th>Newton</th>
</tr>
</thead>
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<tr>
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3. The likelihood of making mistakes

<table>
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4. This interaction device is natural to my capabilities

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5. Ease of correcting keying/writing mistakes

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6. Speed of entering data

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7. Additional Comments

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D.1 Programming Features of The Newton [MEY95, KEE94]

The Newton was programmed with the object-oriented, dynamic language NewtonScript with Pascal-like syntax. NewtonScript is a descendant of Self. Self consists of objects and no class. The static nature of classes is replaced by inheriting from prototypes. Prototypes are more dynamic than class because they can be altered together at run-time together with inheritance. The prototypes are objects themselves and ordinary objects are simply copies of prototypes with a pointer to their origin. By doing so, the difficulty with class that are instances of metaclass, etc., is therefore removed.

All objects in NewtonScript are frames. A frame is an unordered collection of named slots and somewhat similar to a C struct or Pascal record. They are different in that frames are truly dynamic, i.e., slots can be added or removed at any time. The slots are accessed by their name. The slot values can be simple integers or strings, or they can be frames or NewtonScript functions.
Programming for Newton is done using the Newton Toolkit (NTK), the
development environment for Newton, on a Macintosh or Window-based
computer. NTK manages the entire life cycles of an application: we create projects,
layout templates, build an application, download to the Newton, and debug all
within the NTK. It also shows a representation of a Newton Display and a palette
of user interface elements that can be dragged to the display. The code is edited in a
Smalltalk-like browser. All visible and invisible user interface elements, be it
button, title, or data, are views. Views are frames with special properties that are
inherited from the Newton's prototype framework. The views we see on the
Newton are created at the run time by the Newton view system. The Newton view
system gets the information it needs to create the views based on templates we
make in NTK.

The NewtonScript inheritance model deals with objects. These objects may inherit
from other objects. Inheritance is implemented in NewtonScript by slots that
contain pointer to other frames (=objects). There are two kinds of inheritance:

- **Parent Inheritance.** It is used to represent the hierarchical structure of the
  views and implemented by the _parent slot of a view frame, e.g., a
  RadioButtonCluster containing several RadioButtons. The _parent slot points to
  another frame from which the object inherits.

- **Proto Inheritance.** It is done by via a slot named _proto slot. This inheritance
  mechanism gives access to the Newton's prototype framework where each user
  interface element is implemented by inheriting from other elements.
Figure D.1 depicts a simple application. The base view is a plain white slip view that floats above other views; this view also contains two child views. Each child view contains text. The first child view (i.e., myStaticTextView) contains “Enter Name”, and the other child (i.e., myInputLineView) has the text “K. Ramli”. The left hand side of Figure D.1 shows the three views as they are displayed upon the Newton. The right hand side shows the view frames in the Newton Application Memory Heap (frame heap) that underlie what you see on the Newton.

Figure D.1 A simple application and the views that underlie it [APP].

D.2 NewtonScript Application Communications [APP]

The most common type of communication that most applications do is routing through the In/Out Box. It is the highest-level NewtonScript interface. It is an application that is visible to the Newton user as icons in the Newton Extras
Drawer. The Newton built-in applications use this interface for e-mail, beaming, printing, and faxing.

As an alternative, applications can use the endpoint interface to control endpoint objects. The endpoint interface is a lower-level NewtonScript interface. It has no visible representation to the Newton user. Although programming endpoint interface is one of the most difficult parts of NewtonScript programming [ROB97, RIS96, SAN94] it is suited for real-time communication needs such as database access and terminal emulation and, therefore, is used in this project.

Moreover, if the endpoint is to accept raw data, we must understand the Newton Bitmap Format. Table D. 1 describes the Newton 1.x ROM Bitmap Format.

<table>
<thead>
<tr>
<th>Bytes #</th>
<th>Data-type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>long</td>
<td>ignored</td>
</tr>
<tr>
<td>4-5</td>
<td>word</td>
<td># bytes per row of the bitmap data</td>
</tr>
<tr>
<td>6-7</td>
<td>word</td>
<td>ignored</td>
</tr>
<tr>
<td>8-9</td>
<td>word</td>
<td>top offset of the bitmap</td>
</tr>
<tr>
<td>10-11</td>
<td>word</td>
<td>left offset</td>
</tr>
<tr>
<td>12-13</td>
<td>word</td>
<td>bottom offset</td>
</tr>
<tr>
<td>14-15</td>
<td>word</td>
<td>right offset</td>
</tr>
<tr>
<td>16-end</td>
<td>bits</td>
<td>pixel data, 1 for “on” pixel, 0 for “off”</td>
</tr>
</tbody>
</table>