# Developing a User Interface Device for Domestic Multimedia Environment

**Kalamullah Ramli*, Peter Beadle**, Bagio Budiardjo***

* Dept. of Electrical Engineering, University of Indonesia, Kampus UI Depok 16424

** School of Electrical, Computer & Telecommunications Engineering, University of Wollongong, NSW 2522, Australia

*Abstract*

*Traditional ways of interacting with multimedia applications fail in a domestic setting because the user interaction devices typical of a desktop multimedia system (mouse, keyboard, joystick, high resolution screen) are currently unavailable or are impractical. We have investigated, prototyped, and evaluated an alternate interaction device based on a handheld touchpad device that we believe is practical in a domestic environment where people interact with Multimedia content for education and entertainment in a lounge room like setting. We have evaluated the usability level of the device in human trials and found that it performs better than keyboard-mouse combination, which is one of the most widely used interaction device today.*

## 1. Introduction

Human-computer interaction currently focuses on the computer. Humans must adapt their behaviour and skills to the computers peculiarities to achieve a desired goal. In some situations this is acceptable; in others, particularly the domestic use of computing and communications technology, it is not.

The emergence of the Cable Modem and Asymmetric Digital Subscriber Line (ADSL) technology makes interactive domestic entertainment and education services feasible [1, 2, 3, 4]. At home, Interactive Multimedia TV (IMTV) is likely to have a hypermedia interface where the content and the interaction mechanism are merged [5, 6] and links are supported within and between text, images, video, audio, graphics and dimensions by selecting links to follow. They also needs to enter information for searches and authentication for applications such as electronic banking and shopping. Current computer-focused interaction devices, such as traditional TV and VCR remote control, wireless keyboard and trackball combinations [7], and others are inadequate for interaction with hypertext and hypermedia based content in a domestic setting typically because of their size and cumbersome interaction without a firm support based. A more sophisticated interaction device is required; one that can specify location or direction in two dimension, support text entry, and operate in a lounge-room environment.

We have investigated and prototyped an alternate interaction device for domestic environment. The device is based on a handheld touchscreen (touchpad) Newton Personal Digital Assistant (Newton PDA). The touchpad acts as an uncommitted graphical remote control [8, 9, 10, 11, 12] and allows the user interface to a particular piece of hypermedia or an application program to be separated from the program [13, 14] and loaded into the user interaction device dynamically. The touchpad then presents only the required interaction information to the user in any particular situation.

Interaction is provided by:

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

Future work will couple the touchscreen to a SmartBadge [15, 16, 17], a badge based [18, 19] location and environment sensor to allow location based interaction and orientation sensing further increasing the richness of the domestic interaction device.

The hypothesis is that, by focusing on to how an input device can be made to take advantage of the human basic capabilities rather than the human learning on how to confirm with to the device requirement, we have developed a usable interaction device. The touchscreen function employed in the interaction device is expected be more likeable to the users than traditional mouse for pointing tasks. In addition, the handwriting recognition-based input exploited from the Newton PDA feature is likely superior in some aspects of usability to the traditional keyboard in performing small amount text in data entry tasks. The device is also believed to be more appropriate for the domestic setting than competing interaction devices like wireless keyboard and fieldmouse.

## 2. Usability Issues

There are several key issues that must be considered in the design of user interface device for domestic settings.

The users. The users of domestic multimedia entertainment are ranging from novices to experts. The main problem with the various levels of user's skill is how to design a user interface that is not tedious for expert and is also easy to use and understand for novices.

Choice of interaction device. The remote interaction device plays a key role in the usability of the interface. A report [1] 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, including 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 will be supported and the environment where present the interaction process; e.g., public or domestic environment.

Understanding of the system. The system should be built to allow viewers holding accurate mental representation. Otherwise, they are likely to have problems to optimally, or easily, use the system.

## 3. Design Considerations

With mobility as their reasons, the new generation of personal digital assistants (PDAs) support two natural interaction techniques, i.e. touchscreen and handwriting input with stylus. Another feature is their programmable intelligent communicator part.

Considering the usability issues for domestic hypermedia, the following factors should be considered.

Domestic Setting. The characteristic of domestic setting is similar to public environment. Noises are unavoided. Viewers are not likely to watch while sitting on the desk [7]. Therefore traditional keyboard and mouse are not appropriate. The interaction device for such an environment should be a hand-held device which does not require an additional hard flat surface.

Human Basic Capabilities. The device was designed by taking into account human basic capabilities. Amongst the interaction device technologies that natural to human are voice, hand-gestures, touchscreen. For pointing tasks touchscreen is the most natural one. Despite its natural form of interaction, hand-gesture input is lack of comfort and non self-revealing. It requires wearing a glove and being linked to the computer, or, in a video-based hand-gesture tracking case, users must stay firm in one position to get their hand-gestures tracked properly by the system. User also must know the set of gestures that the system recognises. For data entry tasks, voice recognition input is out of selection because of the noise sensitive nature of the technology. Although not as natural as the technologies mentioned earlier, handwriting recognition is more natural than typing. People learn to write earlier than type.

The user of Interface Metaphors. Metaphor philosophy is to express the unknown in terms of the known. It exploits the users' current knowledge in order to help to form their mental model correctly. The use of related terms or title can also help. The display of the interaction device is comprised of a screen metaphor with "SCREEN" title for touchscreen function and a paper metaphor with "TEXT INPUT" title for handwriting-based input.

## 4. Prototype

The touchpad has been constructed from a Newton PDA and a HTML viewer. The HTML viewer runs on a computer in the network and renders HTML pages. A proxy program takes the rendered pages {Figure 1}, converts them and sends them to the touchpad for display {Figure 2}..


Figure 1 A Rendered Pages


Figure 2 A Result of System's Interaction on The Newtons' Side

User actions (current pointer position and text entered through the handwriting recognition capability of the Newton) are transmitted to the proxy which then converts coordinate system and text, and forwards the messages to the HTML viewer (Figure 3). The user-interface to the application or media stream is presented as a series of HTML pages. User actions are implemented as a collection of CGI programd (remote procedure calls) attached to links the HTML pages.

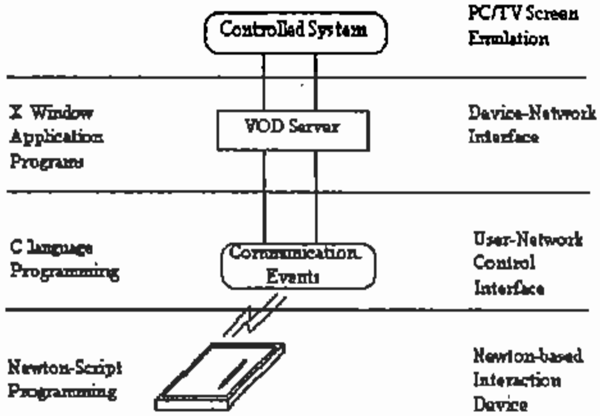


Figure 3 System Architecture

The touchpad-based interaction device acts as a remote touchscreen. As a result, it removes at least three of the traditional touchscreen (i.e. pointing directly to the TV/PC screen) disadvantages:

- The requirement to stand or sit within hand-reach distance.
- The risks to human eyes (related to the distance from the screen).
- The lack of mobility.

A symple example is presenting an interactive movie guide. The guide page contains the text names of the movies on offer as hyperlinks. The guide page is rendered and displayed on the touchpad. When a user selects a link the selection event is relayed back to the HTML viewer through the proxy. The link in the HTML page is then followed causing a CGI program to start the movie playing the users' IMTV connection. An HTML based data stream associated with the movie can then be displayed on the touchpad to give the user interactive control of the movie playback and potentially non-linear access to the movie content.

## 5. Evaluation Result

The device is compared with several competing device to identify the potential advantages and disadvantages of the device in a domestic setting. The result are summarised below:

Newton-based Interaction Device (handwriting and touchscreen)

*Advantages*

- support select-and- point and text entry

- eliminate the need for user learning
- handwriting is more natural than typing
- can be used as virtual wireless keyboard

*Disadvantages*

- heavier - introducing fatigue
- delay for image transfer

**Filed Mouse**

*Advantages*

- light - less fatigue

*Disadvantages*

- support only select-and-point
- requires hand and eye co-ordination
- requires visual accuity

**Wireless Keyboard with Integrated Trackball**

*Advantages*

- support select-and-point and text entry

*Disadvantages*

- large and heavy, leading to fatigue
- inconvenient to store
- requires hand and eye co-ordination (trackball)
- presumes typing skills

## 5.1 User-involved Usability Experiment

The experiment is used 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;

The experiment was divided into two generic tasks:

**Select-and-Point Tasks:** The aim of this task is to compare the Newton and the mouse in performing select-and-point function. The subjects were free to do whatever they want. They navigate and browse the hypermedia interface, reading or watching whatever they want. 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.

**Data Entry Tasks:** This part of the experiment compares the keyboard and the Newton in performing data entry task. The subjects were asked to write down or type their names, occupations and comments about the Newton-based interaction device in a fill-in form interface. Data entry tasks require 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, amount of money to withdraw or save, etc.

### 5.1.1 Subjects

Forty-three volunteers served as subjects in the first experiment. Fourty of them were using keyboard-integrated pointing device daily. There were three novices amongst them. None of subjects had used Newton before.

### 5.1.2 Equipment

Two kinds of input devices were used in the experiment: keyboard-mouse combination and Newton PDA as Multipurpose Input Device. All input devices are connected to the PC running linux.

### 5.1.3 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). Using each of input devices (i.e., Newton and keyboard-integrated pointing device), each subject interacted with the TV screen emulator user interface, locating any information or entertainment they wanted to see. In the second task, the subjects wrote their personal information and comments on the Newton user interface and send the data to the remote screen.

After completing each of these tasks, the subjects were requested to fill in a questionnaire with responses on a five-point Lickert scale, containing 11 questions about the input devices just tested. The users' preferences to the newton were compared to their preferences to the mouse and keyboard. The subjective feeling is gauged by their responses to particular questions.

## 5.2 Results and Discussion

During the data analysis stage, the preferences were detected using Wilcoxon-Mann-Whitney confidence interval and test [20, 21, 22, 23]. MINITAB [22] statistic program was used to perform the calculation. The first hypothesis ($H_0$) was that users have no preferences between the Newton and the mouse or keyboard. The alternate hypothesis ($H_1$) was that the users preferred one device over the other (depends on their median value). The confidence interval of 95% and level of significant $\alpha = 0.05$ and $\alpha = 0.01$ were used. The differences found with $\alpha = 0.01$ is more significant than with $\alpha = 0.05$. By using $\alpha = 0.01$, the probability of type I error (rejecting the null hypothesis falsely) is made smaller.

Table 1 and Table 2 summarise the results. The hypothesis were:

$H_0$: $\mu_1 = \mu_2$, Users have no preferences, the medians are equal.

$H_1$: $\mu_1 \neq \mu_2$, Users prefer one device, which has a greater median, than the other.

$H_1$ constitutes the assertion of hypothesis that is accepted if

$H_0$ is rejected. However, the decision depends on whether

the difference is significant or not.

Table 1 Result for select-and-point tasks

| Usability Factors | N | Significant at | Significant Level | Preference |
|---|---|---|---|---|
| Comfort | 43 | 0.0001 | ** | Newton |
| Ease of Use | 43 | 0.0001 | ** | Newton |
| Less Mistakes | 43 | 0.0002 | ** | Newton |
| Naturalness | 43 | 0.0004 | ** | Newton |
| Accuracy | 43 | 0.0001 | ** | Newton |

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

**Newton vs Mouse**: From five usability aspects observed, the test showed that significant differences exist in five aspects. (Table 1).

The Wilcoxon-Mann-Whitney U test shows that the device leads Mouse in all five usability aspects {Figure 4}. 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 earlier design).

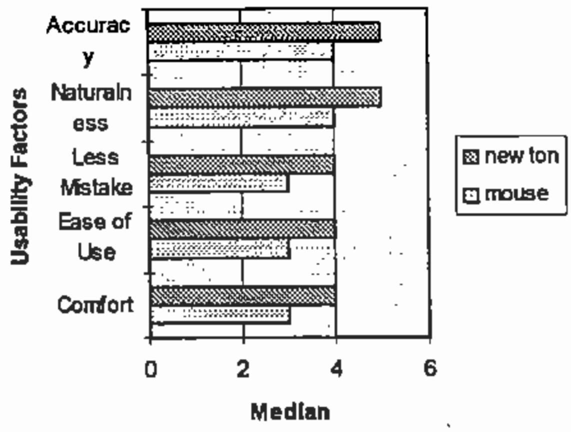


Figure 4 Usability Factors: Newton vs Mouse

Table 2 Result for data entry

| Usability Factors | N | Significant at | Significant Level | Preferences |
|---|---|---|---|---|
| Comfort | 43 | 0.002 | ** | Newton |
| Ease of Use | 43 | 0.014 | * | Newton |
| Less Mistakes | 43 | 0.074 | NS | ------- |
| Naturalness | 43 | 0.001 | ** | Newton |
| Ease of Correcting | 43 | 0.001 | ** | Newton |
| Speed of Data Entry | 43 | 0.601 | NS | ——— |

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

**Newton vs Keyboard**: Table 1 shows the calculation for the text entry tasks. The Wilcoxon-Mann-Whitney U test indicates that the Newton-based interaction device is now superior to keyboard in four of six usability aspects observed {Figure 5}. Then Newton-based interaction device is more comfort, easier to use, more natural, and more easy for correcting mistakes. No significant differences found in less likelihood of making mistakes, and speed of entering data. Although the median comparison shows that the Newton-based interaction device offers less likelihood of making mistakes than keyboard, the Wilcoxon-Mann-Whitney U test (Table 5.7) recommends not to reject the null hypothesis. Therefore, for this usability aspect, we consider The Newton-based interaction shares the same preferences with keyboard.

General comment expressed by the most of the subjects about the two usability aspects in which the device cannot lead the keyboard is that they are used to keyboard because they use keyboard for text entry or word processor daily. They are more familiar with keyboard. Virtual keyboard is also quite slow for them because they can only touch one key per time compared to ten-keys for the fast typist. In addition, The Newton needs an amount time to recognise their handwriting. Last, They expressed that the Newton's handwriting recognition errors affect their score to the device.

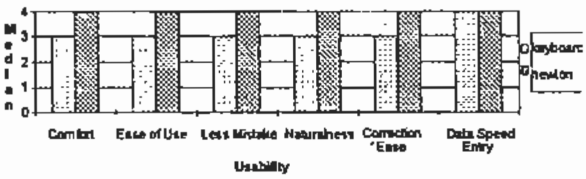


Figure 5 Usability Factors: Newton vs Keyboard

### 5.3 Notes on Learning Effect

The human trials was performed two times. The last was performed after several improvements to the system. Twenty-three of the fourty-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.
3. Accuracy is affected by the directness of the interaction. That is, touchscreen is a direct device whereas the mouse is an indirect device.

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).

## 6. Conclusions and Future Works

In almost all usability factors examined, it appears that a handheld touchpad based a non-committed user interaction device provides higher level of usability to currently available wireless keyboard/trackball, air-mouse/field-mouse or dedicated remote-control systems in a domestic Multimedia setting. Three novices expressed that they feel the touchpad is more natural and easier for them.

The higher level of user acceptance can be considered since almost all participants used the touchpad for the first time while they are keyboard and mouse users.

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.

## 7. References


[1] Cooper, R.L.W., Jourdan, P., Ferrier, C., Tazine, N.E., A User Interface for Multi-channel Television, *International Broadcasting Convention, Conference Publication*, September, 1995.

[2] Hicks, J.A., Chappel, M.A., Consumer Interactive TV: What Comes After the Digital Set-Top Box/TV Combination?, *IEEE*, 1994.

[3] Thomas D.C. Little, Dinesh Venkatesh, Prospects for Interactive Video-on-Demand, *IEEE Multimedia*, Fall 1994.

[4] Sutherland, J., Litteral, L., Venkatesh, D., Prospects for Interactive Video-on-Demand, *IEEE Communication Magazine*, Vol.30, No.7, July 1992, pp. 36-41.

[5] Davenport, G., Martauga, M, ConText an Associative Media Browser, *Proc. Multimedia '95*, ACM, 1995, pp.377.

[6] Geissler, J., Surfing the Movie Space Advanced Navigation in Movie-Only Hypermedia, *Proc. Multimedia '95*, ACM, 1995, pp. 391-400.

[7] Antonoff, Michael, It's a Computer! It's a TV! Actually, It's Both, Stereo Review, August 1996, pp.30-36.

[8] Beadle, H.W.P., Gonzales, R., A Video Coding Based Mobile Multimedia Terminal, *Proc. Picture Coding Symposium*, Melbourne, 1996, pp. 509-514.

[9] Gonzales, R., Beadle, H.W.P., "Video Display Encoding for Mobile Multimedia Terminals", Proc. 7th Int'l Workshop on Packet Video, Brisbane, March, 1996, pp. 163-168.

[10] InfoPad Homepage, http://infopad.EECS.Berkeley.EDU/.

[11] Mauro, Charles, New York Stock Exchange Hand-held Device, *Interactions ACM*, pp. 19-25, May-June 1996.

[12] Robertson, S., Wharton, C., Ashworth, C., Franzke, M., Dual Device User Interface Design: PDAs and Interactive Television, Proceedings of HCI '96, ACM, pp. 79-88, 1996.

[13] Jacob, R.J.K, Sibert, L.E., McFarlane, D.C., Mullen, M.P., Jr., Integrality and Separability of Input Devices, *ACM Transactions on Human-Computer Interaction*, Vol. 1 no. 1, pp. 3-26, March1994.

[14] Beadle, H.W.P., Gonzales, R., Judge, J., Experiments with Domestic Hypermedia Information Systems, *Proc. 8th IEEE Workshop on Local and Metropolitan Area Networks*, Postdam, Germany, Aug. 1996

[15] Beadle, H.W.P., Harper, B., Maguire, Jr., G. Q., and Judge, J., Location Aware Mobile Computing, Proc. IEEE/IEE international conference on Telecommunications (ICT'97), Melbourne, 2-4 April '97.

[16] Beadle, H.W.P., Maguire, Jr., G.Q., Smith, M.T., Environment Aware Computing and Communication Systems, Proc. International Symposium on Wearable Computers, Cambridge, Massachusetts, October '97, Submitted.

[17] Beadle, H.W.P., Maguire, Jr., G.Q., Smith, M.T., Smart Badge: It Beeps, It Flashes, It knows When You Are Hot and Sweaty, Proc. International Symposium on Wearable Computers, Cambridge, Massachusetts, October '97, Submitted.

[18] Active Badge Homepage, Olivetti Oracle Cambridge Research Lab. http://www.18.oc.co.uk/ab.html

[19] Weiser, Mark, Some Computer Science Issues in Ubiquitous Computing, *Communications of the ACM*, Vol. 36 no. 7, 1993, pp. 75-85.

[20] Murata, Atsuo, An Experimental Evaluation of Mouse, Joystick, Joycard, Lightpen, Trackball and Touchscreen for Pointing: Basic Study on Human Interface Design, *Human Aspect in Computing: Design and Use of Interactive Systems and Work with Terminal*, H.J Bullinger (ed), Elsevier Science Publishers B.V., pp. 123 - 127, 1991.

[21] Johnson, Richard A., Miller's and Freund's Probability and Statistics for Engineers, Prentice Hall, 1994.

[22] Pollet, Phil, Nonparametric Methods and Tests,http://www.math.uq.oz.au/~pkp/teaching/ms213/11-nonp

[23] Sears, Andrew, Improving Touchscreen Keyboards: Design Issues and Comparison with Other Devices, *Interacting with Computers: the Interdisciplinary Journal of Human-Computer Interaction*, Vol. 3 no. 3, 1991, pp. 99-122, Butterworth Scientific Ltd. 1991.