A usability evaluation of navigation modes in interactive maps

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Abstract: The user interface of interactive maps consists of visual representation and operation interface. Visual representation is often in the form of a map and operation interface is the objects that are manipulated to control the visual representation. It is essential to understand whether the basic operation interfaces of interactive maps are compatible with the user's ability. The objective of this research is to investigate how operation interface of interactive maps affects usability. An interactive map consists of several functions of operation interfaces where pan and zoom are the most frequently used. The presentation of such operations can either provide continuous transitional feedback or not. Simulated testing on three different navigation modes was conducted: 1) continuous control with continuous display; 2) discrete control with continuous display; 3) discrete control with discrete display. The participants' total time of completing a task, frequency of button clicks, and subjective satisfaction were recorded and analyzed. The result shows that "continuous control with continuous display" is better in performance and also with higher subjective satisfaction. In conclusion, this study reveals some characteristics of operation interface that are not intuitively obvious and visible; however, they significantly affect usability of interactive maps. Appropriate navigation mode, such as one with continuous control and continuous display improves usability.

Key words: interactive map, operation interface, usability evaluation, navigation mode.

1. Introduction

The related issues of usability and operation interface are very important, because the target users of interactive maps are ordinary people without professional experience [2]. Norman [5] pointed out that the unfamiliarity of the conceptual model to an operation interface could result in misleading in operation. Users may feel frustrated and not interested in use. While designing operation interfaces of interactive maps, it is a critical issue whether operation interfaces can provide users the correct cognitive guidance or information feedback.

Information display controls are functions that control the image in a display frame, such as zoom and pan. Operation interface elements are interactive elements that respond to input, such as icon, button, and menu.

Operation methods are ways to operate the mouse, pen or other digitizers, such as click and drag. Navigation modes are the continuous or discrete characteristics of control and display. All above elements that an operation interface consists of could have effects on usability of the operation interface. This study conducted usability evaluation of navigation modes to expect the results can be as reference in development of interactive maps [7].

It is necessary to adjust information space by operation interface to estimate the distances and positions in the display of an interactive map [3]. In an analysis of interfaces for dealing information spaces that do not fit a single screen, it was found that the navigation approaches, such as scroll, pan and zoom, allow users to browse information spaces when it is necessary to maintain the original layout. Zoom enlarges or reduces a map to see it more clearly or to get a better overview. Pan repositions or re-centers the map to locate the target area [1]. Because users have to operate different controls for panning and zooming, the controls may interfere with each other [6].

Harrower and Sheesley [4] proposed criteria for functionality for evaluating pan and zoom. One is navigation modes of continuous versus discrete map browsing. A continuous (sequential) navigation forces users to browse through intermediate steps before getting the targets. A discrete navigation allows users to jump immediately to a new scale or location. For example, in the range of the scale in an interactive map, when users want to change zoom scale (from point A to B) (see Figure 1), a continuous navigation adopts "+" button to enlarge the map through immediate scales between point A and B continuously. A discrete navigation allows users to click point B directly, and the map will be re-rendered immediately in the new scale. If users are familiar with the structure and contents of the information space, a discrete navigation would be more efficient than a continuous navigation. If users are unfamiliar with the information space, they may need continuous navigation to browse through the entire information space. A discrete navigation may make some arbitrary guesses before reaching the target. In such condition, a continuous navigation could be more efficient than a discrete navigation [4].

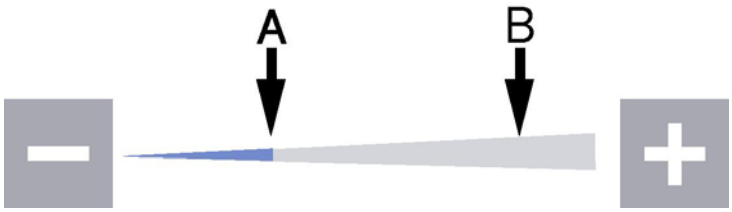

Figure 1. Zoom scale with operation buttons
Source: Harrower & Sheesley [4]

Although there are some discussions about continuous and discrete navigation in literature, little experimental evaluation on interface usability has been done. This study is based on the situation that users are unfamiliar with the information space. Simulated experiments were conducted to evaluate the usability of interfaces with continuous and discrete navigation modes.

2. Methods

It is found from some cases of interactive map that continuous display can be controlled with continuous or discrete control, but discrete display is compatible with only discrete control. The combination of continuous/discrete display and control make up three navigation models: 1) continuous control with continuous display; 2) discrete control with continuous display; 3) discrete control with discrete display.

The experiment referred You's [7] evaluation methods, and used simulated interactive maps with pan and zoom functions to conduct experiments. The simulated maps were constructed with grouped pan buttons and zoom scale. There were three types of simulated maps with navigation modes combined by display: continuous vs. discrete, and control: continuous vs. discrete. The three navigation modes were tested to evaluate overall usability. The dependent variables are the usability measured by user performance and subjective evaluation.

There were 36 participants, 18 male and 18 female, in the experiment. All participants were college students (undergraduate and post-graduate) from National Yunlin University of Science and Technology. The participants' total time of completing a task, frequency of button clicks, and subjective satisfaction were recorded and analyzed.

2.1 Materials and Setting

The simulated interactive maps were set for a small neighborhood area.

From the three navigation modes, 1) continuous control with continuous display; 2) discrete control with continuous display; 3) discrete control with discrete display, three types of simulated interactive maps were developed (see Table 1). The interface consists of grouped pan buttons and zoom scale (see Figure 2). Users can only differentiate them by using them.

Figure 2. Simulated interactive map interfaces

Table 1. Navigation modes of simulated interactive map

	Display (D)		Control (C)	
	Continuous (D1)	Discrete (D2)	Continuous (C1)	Discrete (C2)
M1	x		x	
M2	x			x
M3		x		x

Note: x denotes available function available

2.2 Equipment

Laboratory equipment is divided into hardware and software, as follows:

1) Hardware: The experiment was run on a 2.4G Hz Intel Pentium 4 computer with 1024Mb of RAM. The 17-inch LCD display was set to a resolution of 1280×1024 pixels. The input device was a standard Logitech 3-button mouse. All experimental software ran under the Windows XP operating system. The experiment was conducted in a computer laboratory (DC304) that was equipped with sufficient lighting and air-conditioning.

2) Software: The interfaces of simulated interactive map were created with an interface prototyping tool - Macromedia Flash (see Figure 2). The same fictitious map was used in all simulated interactive maps. The map frame covered an area of 650×530 pixels, and the simulated interface covered an area of 960×700 pixels.

2.3 Procedure

The experiment is a within-subject design. All participants tested three navigation modes. Maps for all three navigation modes shared the random point location layout. The order of test interfaces varied among the participants in order to counterbalance the effect of practice and/or fatigue.

There were 10 red points (labeled from Point 1 to 10) at different locations that acted as task targets in each interface. The tasks involved using simulated interfaces to find all 10 points. The red points appeared one at a time for participants to find. The search order is random, from point 1 to 10, for every participant. To prevent the participants from missing any of the points, the point of search is visible at all zoom scales.

The data of operation performance was collected, such as the time to find each target, the time of each step, the number of steps in using the function, and the correctness of code reading.

2.4 Questionnaire

Questionnaire referred the format from You et al. [7]. After each test of a different interface for tasks, each participant was asked to fill out a questionnaire as a subjective evaluation of interface use. The questionnaire was designed by the researchers to evaluate the satisfaction part of usability. The main purpose of the questionnaire was to determine user cognition and satisfaction both of which are not so explicitly measurable during interface testing. The questionnaire was filled out after testing each simulated map. Likert scale was used to get the data. The subjective evaluation was rated from 1 to 5, with 1 for strongly disagree and 5 for strongly agree. The statements in the questionnaire are listed as follows:

1. You understand direction of movement when you pan the map.
2. Map changing can help you quickly to find the destination.
3. The pan directions of the map match your cognition.
4. The pan function is easy to use.
5. You are satisfied with this navigation mode.

3. Results

3.1 Analysis of total time of accomplishing a task in navigation modes

Table 2 shows the user performances of total time used in locating targets. It appears that a continuous control with continuous display (M1) is more efficient than a discrete control with continuous display (M2) and a discrete control with discrete display (M3). Further statistical tests are necessary to verify the hypotheses.

Table2. User performance in time

Navigation modes (M)	N	M	SD
Continuous control with continuous display (M1)	36	137.611	25.120
Discrete control with continuous display (M2)	36	152.175	34.497
Discrete control with discrete display (M3)	36	160.825	35.396

Note: Units are in seconds.

To determine whether there are significant differences in the mean time among the three navigation modes, a repeated measures one-way ANOVA was used (see Table 3). Using a .05 significance level, the difference was significant ($p = .018 < .05$). After Scheffé's multiple comparison, the task completion time of M1 performance is better than M3 as well as M2, and there is significant difference between M1 and M3 ($p = .019 < .05$) (see Table 4).

Table3. One-way ANOVA of user performance in time

Source of variation	F	*P*
user performance in time (seconds)	4.191	.018*

Note: * $p<.05$

Table4. Scheffé's multiple comparison of user performance in time

Source of variation (I) navigation modes	(J) navigation modes	*P*
(M1)	(M2)	.204
	(M 3)	.019*
(M2)	(M1)	.204
	(M3)	.568
(M3)	(M1)	.019*
	(M2)	.568

Note: * $p<.05$

3.2 Analysis of frequency of button clicking in navigation modes

Table 5 shows the user performances of button clicking used in locating targets. It appears that a continuous control with continuous display (M1) is more efficient than a discrete control with continuous display (M2) and a discrete control with discrete display (M3). Further statistical tests are necessary to verify the hypotheses.

Table 5. User performance in click

Navigation modes (M)	N	M	SD
Continuous control with continuous display (M1)	36	58.556	24.391
Discrete control with continuous display (M2)	36	177.667	43.706
Discrete control with discrete display (M3)	36	192.389	72.710

Note: Units are in times

To determine whether there are significant differences in the mean time among the three navigation modes, a repeated measures one-way ANOVA was used (see Table 6). Using a .05 significance level, the difference was

significant (p = .00 < .05). After Scheffé's multiple comparison, the task completion time of M1 performance better than M2 and M3. There is significant difference between M1 and M2 (p = .00 < .05), and M1 and M3 (p = .00 < .05) such as Table 7.

Table 6. One-way ANOVA of user performance in click

Source of variation	F	*P*
User performance in click (times)	74.652	.00***

Note: * p<.05, ** p<.01, *** p<.001

Table 7. Scheffé's multiple comparison of user performance in click

Source of variation	(I) navigation modes (J) navigation modes	*P*
(M1)	(M2)	.000***
	(M3)	.000***
(M2)	(M1)	.000***
	(M3)	.474
(M3)	(M1)	000***
	(M2)	.474

Note: * p<.05, ** p<.01, *** p<.001

3.3 Analysis of subjective evaluation

After a test of navigation mode experiment, we require the subjects to complete a questionnaire of subjective satisfaction immediately. The answers to the 5 statements in the subjective evaluation questionnaire were rated from 1 to 5. The higher the rating, the more preferred the navigation mode. Table 8 shows the subjective evaluation. To determine whether there are differences in the subjective evaluation among the three navigation mode, a repeated measure one-way ANOVA was used (see Table 9). Using a .05 significance level, the difference was significant (p < .05). In most questions, there are significant differences in the subjective satisfaction among the three navigation modes. Only in Questions 3 was not significant.

Table 8. Subjective evaluation

Question	Navigation modes	N	Mean	SD
1	M1	36	4.28	.91
	M 2	36	3.78	.96
	M 3	36	3.67	.99
	Total	108	3.90	.99
2	M1	36	3.92	1.16
	M 2	36	3.39	1.10
	M 3	36	2.94	1.26
	Total	108	3.42	1.23
3	M1	36	4.03	.98
	M 2	36	3.92	1.13
	M 3	36	3.72	.94
	Total	108	3.89	1.02
4	M1	36	3.78	1.12
	M 2	36	2.86	1.13
	M 3	36	2.89	1.19
	Total	108	3.18	1.21
5	M1	36	3.86	1.07
	M 2	36	3.28	.97
	M 3	36	3.28	.97
	Total	108	3.48	1.04

Note: Likert scale measure used in table (1-5), with 1 for strongly disagree and 5 for strongly agree..

Table 9. One-way ANOVA of subjective evaluation

Statements	F	*p*
1. You understand direction of movement when you pan the map.	4.197	.018*
2. Map changing can help you quickly to find the destination.	6.167 .	003**
3. The pan directions of the map match your cognition.	.830 .	439
4. The pan function is easy to use.	7.442 .	001**
5. You are satisfied with this navigation mode.	4.016 .	021*

Note: * p<.05, ** p<.01

Table 10 shows that there is significant difference in the subjective evaluation between M1 and M 3 (p = .09 < .05) for Question1. M1 is preferred to M3 in the compatibility of movement directions between the map and user's mental cognition.

In Question 2, there is significant difference in the subjective satisfaction between M1 and M3 (p = .00 < .05). Through continuous control with continuous display (M1), it is easy to find the targets. But discrete control with discrete display (M3) is not so easy to find the targets.

In Question 4, there is a significant difference between M1 and M2 (p = .00 < .05) and between M1 and M3 (p = .00 < .05). For easy-to-use panning, M1 is preferred to M2 and M3.

In Question 5, initial analysis was significant, but post comparison analysis was not significant. The difference between M1 and M2 (p = .00 < .053) and between M1 and M3 (p = .00 < .053) are very close to significant. Generally speaking, the navigation mode of M1 is preferred the navigation modes of M2 and M3.

Table 10. Scheffé's multiple comparison of subjective evaluation

	Source of variation	(I) mode (J) mode	*P*
1.	(M1)	(M2)	.09
		(M3)	.03*
	(M2)	(M1)	.09
		(M3)	.89
	(M3)	(M1)	.03*
		(M2)	.89
2.	(M1)	(M2)	.17
		(M3)	.00**
	(M2)	(M1)	.17
		(M3)	.28
	(M3)	(M1)	.00**
		(M2)	.28
4.	(M1)	(M2)	.00**
		(M3)	.00**
	(M2)	(M1)	.00**
		(M3)	1.00
	(M3)	(M1)	.00**
		(M2)	1.00
5.	(M1)	(M2)	.05
		(M3)	.05
	(M2)	(M1)	.05
		(M3)	1.00
	(M3)	(M1)	.05
		(M2)	1.00

Note: * p<.05, ** p<.01

4. Discussion

This study evaluated the usability of interfaces with different navigation modes. The results showed there was significant difference in task completion time and there was partial significant difference in times of button use and subjective satisfaction. The result shows that the navigation mode with *continuous control* and *continuous display* (M1) is best in user performance and also with highest subjective satisfaction. The order of both user performance and subjective satisfaction is M1, M2, and M3. The result is consistent with what Harrower and Sheesley [4] has proposed. If users are unfamiliar with the information space, a continuous navigation could be more efficient than a discrete navigation.

In operating interfaces with continuous display (M1, M2), users can see the response of the maps and understand the conceptual model of moving frame. But in operating interfaces with discrete display (M3), users may perceive the change of map image as movement of the map. The inference is compatible with the result of satisfaction evaluation in You et al. [7]. It is reasonable it will help users to find targets on a map more efficiently with continuous display, because there is no confusion between moving frame and moving map.

Considering operation of button clicking, the order is the same, M1, M2, and M3. Only M1 adopts continuous control. M2 and M3 adopt discrete control. It is not necessary to click repeatedly with continuous control. Users can complete the tasks with lesser effort.

In subjective satisfaction evaluation, there are three questions that get significant. They are as follows: Question 1: You understand direction of movement when you pan the map, Question 2: Map changing can help you quickly to find the destination, and Question 4: The pan function is easy to use. In Question 1, there is significant difference between M1 and M3. Most participants understood moving direction clearly while operating M1, but not so clearly while operating M3. It is possible that the continuous display of M1 can show participants the moving direction. But with the discrete display of M3, users may mistake that map itself moves, not the map frame. That is why M1 got better satisfaction than M2 and M3.

In Question 2, there is significant difference between M1 and M3. It is obvious the characteristic of map image changing is very different between M1 and M3. The continuous changing of map image in M1 provides good relationship to navigate between original and new map image. The discrete changing of map image in M3 may not help to navigate smoothly for lack of visual guide.

In Question 4, there is significant difference between M1 and M2 and between M1 and M3. One possible explanation for this is that the difference between continuous control and discrete control. With continuous control, repeated clicking is not necessary. It may help lower the load on muscle and bones and prevent fatigue in hand.

5. Conclusion

In this study simulated testing on three different navigation modes was conducted. Usability data including user performance and subjective satisfaction were recorded and analyzed. The findings provide empirical evidence

for the usability of continuous navigation modes, including display and control. They will help as practical guides in designing interactive maps.

There findings are summarized as follows:

1) In limited map area, the navigation mode with *continuous control* and *continuous display* has good usability in both user performance and subjective satisfaction.
2) The continuous display provides good relationship to navigate. Discrete display may not help to navigate smoothly for lack of visual guide. Although it can jump to new image quickly, the result is not easy to predict in advance.
3) Continuous control can omit repeated clicking. It may help lower the load on muscle and bones and prevent fatigue in hand.

Many technologies have been developed to deal with the problem of detail and overview in HCI domain, especially for the mobile devices with small display and control. All such solutions have the property of navigation mode, continuous or discrete. To lower the learning effort and time, the visibility of navigation mode may become a problem for better usability. It could be an important issue in future research.

6. References

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