User Experience Quality in Multi-Touch Tasks

Ioannis Leftheriotis
Ionian University
Tsirigoti sq. 7, Corfu, Greece
midmandy@gmail.com

Konstantinos Chorianopoulos
Ionian University
Tsirigoti sq. 7, Corfu, Greece
choko@ionio.gr

ABSTRACT
In this paper, we present an updated set of experimental tasks and measures for large multi-touch (MT) input devices. In addition to a multi-user condition, we have employed an updated set of tasks, as well as subjective measures for user enjoyment. In the first experiment (a target acquisition task with two moving targets), the MT was more efficient than the mouse. Surprisingly, we found that the reduced accuracy of MT did not affect the perceived usability, or the enjoyment of the users. In the second experiment (a multiple shapes docking task), the MT was again more efficient and enjoying than the mouse. In the two-user condition, we found that performance and enjoyment was always higher than the single-user conditions, regardless of input device and task. Besides the quantitative results, we observed that users employed diverse interaction strategies in the MT condition, such as bi-manual input. The proposed tasks and the results support the use of MT in entertainment applications (multimedia and video-games), collaborative work, and scientific visualizations with complex data.

Author Keywords: Multi-touch, large screen, task, mouse, multi-user, input, user experience.

ACM Classification Keywords: H5.m. Information interfaces and presentation: Miscellaneous.

General Terms: Design, Experimentation

INTRODUCTION
Multi-touch (MT) applications are not considered to be traditional WIMP (Windows, Icons, Menus, Pointer) applications. MT applications rely on multiple fingers, gestures, and in general, more natural interaction techniques (Figure 1). Therefore MT is a completely different input device compared to traditional input devices of the past. According to Buxton, "One solution I see, is that we will start building new classes of computational devices that are not constrained by the legacy applications that were designed for a very different style of interaction." (cited in [13]).

Previous research has compared traditional indirect-mapping input devices such as mouse with MT devices. For

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Figure 1: The majority of current MT applications regard actions such as drag, resize and rotate of photos: a) Microsoft Surface Collage application, b) Jeff Han manipulating pictures with two finger gestures [3], c) multiplayer MT demo on PyMT[4], d) MT navigation application[4].

example, Shanis et. al [14] tested MT against mouse and touchpad for speed, performance and wrist posture. They showed that cursor positioning was better with the mouse and that MT caused significantly less wrist extension than the touchpad, but was comparable to the mouse. Forlines et al. [2] have shown that MT is more efficient (i.e., less time) than mouse in target selection, but worse in shape matching. Wigdor et al measured accuracy of the Ripples MT system with traditional target selection tasks [6]. Overall, researchers have compared the MT to the mouse in the face of traditional computer tasks, such as single target acquisition and shape dragging.

In this research, we have developed a set of experimental tasks that are more suitable for a MT surface than a mouse. Previous experiments mainly relied on traditional tests that have been designed for a single pointing device, such as the mouse. For example, target acquisition is an established task since the early studies on input devices by Card and colleagues at Xerox PARC [1]. In contrast, Kin et al [8] conducted a multi-target selection experiment. There were multiple targets on the screen and users were asked firstly to touch targets serially and finally touch as many targets as they could in parallel. Here, the established experimental tasks have been adapted to the characteristics of a MT screen. However, the scaling or rotation of objects was not used in our experiments because it has already been studied extensively in the past (e.g. [2]). In the following sections, we present two user experiments that feature multiples shapes, moving targets, and multiple users. In addition to the traditional usability measures (time, accuracy, preference), we have also employed flow and enjoyment user experience constructs, which have not yet been considered by previous research.

EXPERIMENT 1 – TARGET ACQUISITION

The first experiment was a target acquisition task. Although there have been multiple targets in previous experiments and the measure of "target acquisition time" has been studied before, there has not been any report on a task that considers multiple moving targets. We have designed a task with moving targets because there are several research and commercial MT applications (e.g. [9], games, advertising setups) that provide moving elements as part of the UI. In our task, users had to hit two moving targets (Figure 3).

During our initial exploratory experiments our MT display found to have tracking problems. As a consequence it was unable to track moving objects and thus mixed results were produced. In an effort to solve this issue the MT surface tracking system was improved. It became more accurate and thus allowed fast dragging of objects without losing the blobs at a rate of more than 95%.

Apparatus

The experimental set-up was based on FTIR technology [3], which is supplied by Nortd[1] labs (Figure 2). Community Core Vision[2] was employed to transform the video input from the camera to tracking data and events. We used the PyMT[4] toolkit to develop the MT applications.

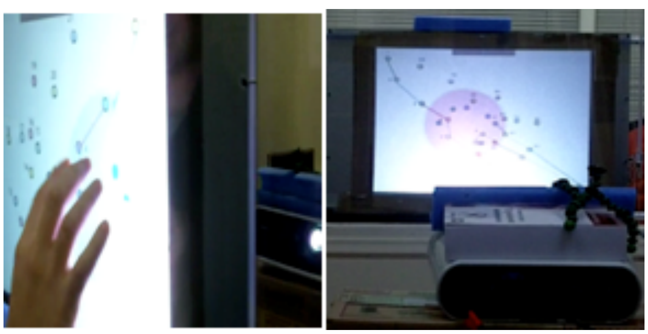

Figure 2: Our installation: a 25 inch vertically placed FTIR MT surface, a Sony 1024x768 projector and a Unibrain infrared camera.

System Implementation

During the design and implementation of our experimental set-up we realized that this is a fragile installation. There are a number of devices that need to be precisely calibrated and moreover, there are factors such as ambient lighting, for example, that could influence the performance, accuracy and robustness of our installation. There are mapping issues between the projected image and the surface that the user touches, or even positioning or focusing the camera correctly. Nevertheless, we managed to establish a robust set-up (Figure 2) that did not affect the performance of the users.

Although the majority of MT systems are positioned in a horizontal axis we decided that we wanted to have a vertical MT surface. As it is shown in [10], vertical displays have the advantage of being able to accommodate larger groups of people. Our main motivation for a vertical installation is that we would like to use it in a classroom, where a teacher shows images or interacts with applications in order to improve the educational procedure. Thus, the MT surface was positioned vertically and users were asked to sit in a chair in front of the MT screen and interact in a natural way as comfortable as possible. Image was back-projected and there was no use of mirrors since the installation was vertical.

Both in MT and mouse condition the same screen was used. Subjects were sitting on a chair placed in front of the MT screen at about 1 meter distance. A mouse (with BlueTrack tracking technology – 1000 dpi) was used along with a mouse pad. Since the analysis of the screen was 1024x768 and the size of the screen that was used was 25 in, the mouse cursor was bigger than the size of a typical cursor on a Desktop pc with Mac OS X. However, since the distance between the users and the screen was relatively larger than the typical distance between a user and his desktop pc, there were no users complaining about locating the mouse cursor or about its size in general. The tracking speed of the mouse was placed in the middle of the scale (five out of ten) on the system preferences of the Mac OS X environment and users were asked whether the mouse sensitivity/tracking speed was satisfying.

Participants

Seven users took part in the study (five females, two males). They were recruited from the department of Informatics and given a bonus of half grade in HCI lesson for their time. The age ranged from 19 to 34 years with an average of 27.23 years (SD = 7.79). All participants, but one who was ambidextrous and used primarily his right hand, were right-handed. Three of them had used a large MT surface before. Four of them were familiar with MT technology as they held one or more MT mobile devices (iPhone, iPod etc.).

Task

At the beginning of each task, targets are still. Users are asked to touch/click on the targets being as accurate and fast as possible. To complete the target acquisition task users should have hit fifty targets. The system is automatically storing the number of efforts and the time needed to hit all fifty targets. That is the time saved is the interval between the first and the fiftieth hit and the number of efforts derives from the sum of the fifty successful hits of the targets along with the number of the unsuccessful

[1] Nortd labs, Website: http://labs.nortd.com/touchkit/

[2] NUI Group Community. Community Core Vision (CCV) software, Website: http://ccv.nuigroup.com/.

ones. In the event of hitting all fifty targets, a green screen with a message "task completed" is being shown.

Figure 3: Target acquisition application: Users were asked to touch the two moving targets with their fingers on the first condition, or click on them with mouse on the second.

Targets on the screen are moving with constant speed (approximately 100 pixels or 5 cm per second) Targets appear in random places near one side of the screen (i.e. left part of the screen) and are moving to the opposite side (i.e. right part of the screen). Users have to touch the targets with their fingers or click on them with their mouse. Whenever a user touches a target, a counter that counts the succeeded efforts is increased, that target disappears and a new target is created near one side of the screen. Whenever user fail to touch a moving target an image of a broken piece of glass is shown as a negative feedback to the user (Figure 3) and the total efforts are increased too. The target is moving until the user touches it, or until it reaches the other side of the screen, where it stops moving. We chose the speed of moving targets, so that all users could hit them before they reached the end of the screen.

The task of selecting multiple moving targets is representative in MT surfaces. Moreover, this application could be used with one hand, with two hands, or with two users collaboratively.

Procedure

In the beginning of the experiment we screened users for previous experience with MT devices. Then, the application was presented to them. They were asked to interact with the MT screen for as long as they needed to feel comfortable. In the experiment there were targets that were 48x48 pixels (2.4x2.4 cm). But in order for user to feel familiar with the MT surface a variety of different sizes of targets were shown as a warm up procedure. The total number of targets that were hit prior to the main experiment for familiarizing purposes was 150 targets for each condition (mouse or MT) per user. We waited for users to feel comfortable with the task before the beginning of the experiment.

Four users started the experiment with the MT and the other three started with the mouse. Users were asked to be as accurate and as fast as possible during the experiment. The total number of targets that were used during the experiment was 50 targets for each condition (mouse or MT) per user. In the end of this task two users were asked to work together on the MT screen for hitting 50 more targets.

After each condition the subjective quality questionnaires were given to users. In particular, we employed the flow state scale [7], the PQ, and HQS questionnaire form [5]. All questions were rated on a 7-point scale, ranging from 1 (strongly disagree) to 7 (strongly agree). In the end of this experiment a preference questionnaire was given to users and they were asked to reply which condition they preferred, and in which condition they felt they were more accurate or faster.

Results

In agreement to other works [2,12], it seems that MT has better performance in target acquisition, even when there are two moving targets on the screen. As it is depicted in table 1 users needed 37.4 seconds (std = 2.7) to hit 50 targets with MT while they needed 50.4 (std = 7.8) seconds to click on the targets with the mouse. The quantitative results of the study are indicative of the performance differences between an indirect and a direct input device. Moreover, the qualitative results (user observation) indicate a preference to use an MT as a single touch direct input device. Nevertheless, the MT condition has been also evaluated in the two-user condition, which would not be possible without multiple touches.

Experiment 1: Target acquisition	Average Time	Standard Deviation
MT	37.40	7.8
Mouse	50.47	2.7
MT 2 users	24.50	4.3

Table 1: In the two moving targets acquisition task MT performs better.

The average mark for flow questionnaire was 5.29 out of seven (std=0.83) for mouse and 5.94 out of seven (std=0.58) for MT, for the two moving targets acquisition task. As far as the Hedonic Quality-Stimulation (HQS) rankings is concerned, MT obtained 5.1 while mouse obtained 2.8 out of seven. Finally, MT was rated with 5.7 on Pragmatic Quality (PQ) whether mouse was rated with 3.2 out of seven (Figure 4). All in all, MT not only performed better considering time but users were able to understand that they were performing better too.

Experiment 1: efforts	Average Efforts	Standard Deviation
MT	59.8	2.8
Mouse	53.4	1.3
MT 2 users	55.5	2.1

Table 2: In the two moving target acquisition task, considering selection errors MT proves to be less accurate than mouse.

There are some interesting results with regard to the accuracy and the multi-user condition. Most notably, the mouse proved to be more accurate. In order to hit 50 targets with MT, users had approximately 60 efforts, and thus a success rate of 83% while in mouse condition they needed only 53 efforts and thus their access rate was 94%. In addition, the two users' condition showed that two users outperform one user as it was expected. Two users prove to be more than two times faster (24.5 sec) than one user using mouse but not twice as fast as the condition with one user using MT (table 2). Additionally, as far as the number of efforts to hit all the targets, they are almost equal to one user MT condition. Therefore, increasing the number of users on an MT does not proportionally increase the efficiency, but it improves the accuracy per user. During the tasks users were not guided on how they should hit the targets. Almost all users, apart from two experts, used only their dominant hand to touch the targets.

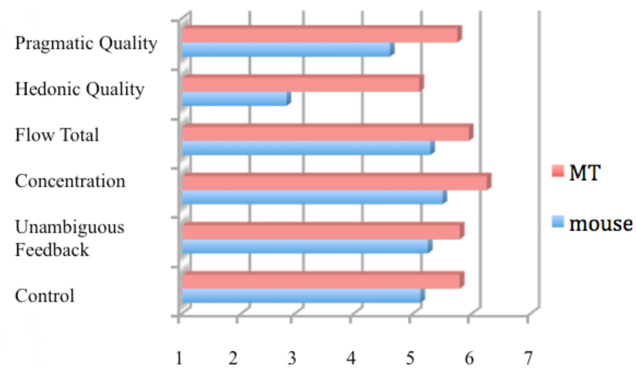

Figure 4. Target acquisition task: Questionnaires results.

Discussion

Although there have been previous studies comparing input devices showing that MT performs better in target acquisition, it is shown that even when there are two targets on the screen moving constantly the MT outperforms mouse significantly. Additionally, users seemed to enjoy the MT condition in target selection more than the mouse condition. Apparently, they could estimate correctly that they performed in less time with the MT. In addition, users felt that they were in-control with the MT surface. In the two-user condition, it was obvious that they enjoyed more due to their facial expressions and the fact that they were involved more by deploying strategies in order to improve their time while they were playing. Nevertheless, the two-user condition was not as efficient as expected. We observed that issues such occlusion or cluttering the display with multiple moving hands are responsible.

EXPERIMENT 2 – SHAPE DOCKING

Instead of using a simple docking task with one shape, repeatedly, as in [2], we considered that a MT screen offers more than one finger touches. Thus, there was more than one shape on the screen. This could increase the cognitive and motor load, but it could guide in interesting results as far as the multitasking (two users or two hands) is concerned on a MT surface. In our second experiment the setup of the first experiment was used. In order to conduct our experiment, six new (different from the first experiment) users were recruited from the local university. Their average age was 27 years old and they were all males with a previous experience in MT technology (mostly with MT mobile devices).

Task

At the beginning of each task, twenty-two shapes such as triangles or rectangles appear on the screen in random places. There are eleven colored and eleven white shapes. Note that the eleventh shape is the trigger to the counter of the task completion time. The time to dock ten shapes is finally measured. Each colored shape has its twin white shape. The main purpose is to match all the colored shapes with their corresponding white ones. Thus, users are asked to move each colored shape over its identical white one. Once this happens, these two shapes disappear. It is not necessary for the user to position precisely the colored shape above the white one that matches. There is a threshold of ten pixels (or 0.5 cm) (as in [11]) that allows the shapes to disappear when they come into proximity. Only colored shapes can be moved. In addition, users are able to move more than one shape simultaneously either with one or two hands. The system gives feedback for each touch. A small yellow circle appears (Figure 5) around the spot where the finger touches the screen for every touch.

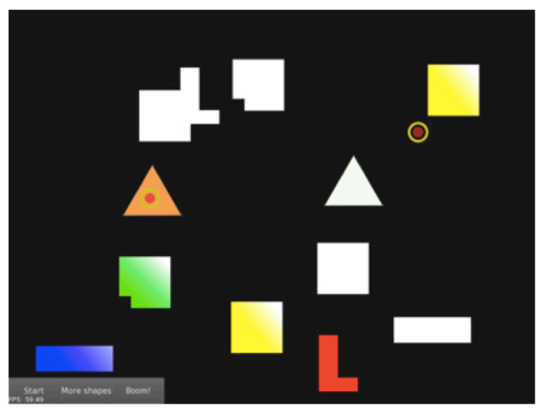

Figure 5. Object docking task: Users were asked to move the colored shapes to the white matching ones in order to dock and disappear.

Design and procedure

In this experiment users were asked to match the colored shapes with the white ones. The size of each shape was 50x50 pixels (or 2.5x2.5 cm apart from the blue bar shape which was sized 60*20 pixels or 3x1 cm).

The application was firstly presented to users. They were asked to interact with the MT screen for as long as they needed to feel comfortable in dragging subtasks. Additionally, larger sized shapes were used in order to make users feel familiar with the dragging subtask on the MT screen, which were followed by shapes the same size as the experiment. When users felt familiar with the dragging subtask (after matching plethora of shapes) we were ready to begin the experiment. It was a within group experiment with three conditions, MT, mouse, two users MT just as multiple target acquisition experiment. In order to minimize the learning effect, we have employed random assignment to the treatments: three users started firstly the experiment with the MT condition and the other three users started with the mouse. Users were informed that they should be as accurate and as fast as possible. In the task, there were eleven colored shapes to be matched with their corresponding white ones. The time needed to match all the shapes on the screen was measured. The time counter started when the first shape match occurred, measuring the time to match ten shapes.

After the experiment the flow and enjoyment questionnaire were given to the users just as in the target acquisition experiment. In the end of this experiment a preference questionnaire was given to users and they were asked to reply which condition they preferred, mouse or MT and in which condition they felt they were more accurate or faster.

Results

As it is shown in table 3, MT outperformed mouse in the shape-matching task, considering completion times. In order to dock 10 colored shapes to the 10 white ones users needed 17.94 seconds with MT and 22.19 with mouse.

Experiment 2: Shape Matching	Average Time	Standard Deviation
MT	17.94	0.36
Mouse	22.19	2.80
MT 2 users	10.16	0.44

Table 3. Shape matching task: MT proves to be faster than mouse. Two users on MT are almost two times faster than with the mouse.

According to the questionnaires, users preferred the MT instead of the mouse again (table 4). As it can be seen from Figure 6, the average mark from flow (derived from concentration, unambiguous feedback and control) questionnaire was 5.4 out of 7 for mouse and 6.3 for MT condition. As far as the HQS rankings is concerned, MT obtained 5.17 while mouse obtained 3.63 out of seven. On the other hand, MT was rated with 5.9 on PQ whether mouse was rated with 5.7 out of seven. Although those two ratings are very close with each other, we suppose that this happens due to the fact that Pragmatic Quality is based on user experience and we consider users much more experienced in the use of mouse.

Experiment 2: Shape Matching Questionnaire	Mouse	MT
Preferred	3.33	7.0
Fast	3.50	7.0
Entertaining	2.83	7.0
Effective	4.16	6.5

Table 4. Shape matching task: Users seem to prefer MT condition much more.

All in all, MT not only performed better considering time but users were able to understand that they were performing better too. But as we can see both from the table 4 and the HQS (Hedonic Quality) in Figure 6, the greatest difference between the input devices appears to be related to the entertainment factor.

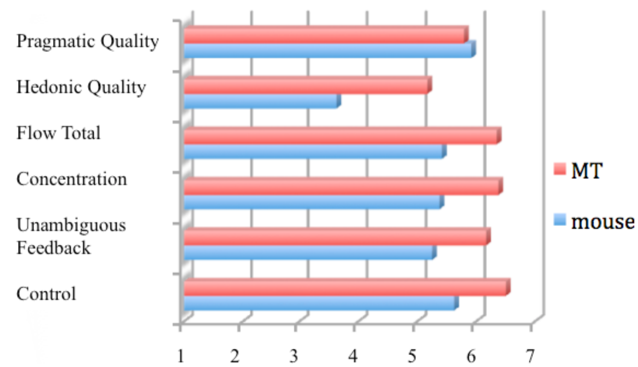

Figure 6. Object docking task: Questionnaires results

As in experiment one almost all users enjoyed more the two users condition. Two users MT condition (Figure 7.c) improved significantly the task completion time but again two users where not two times faster than one user with MT.

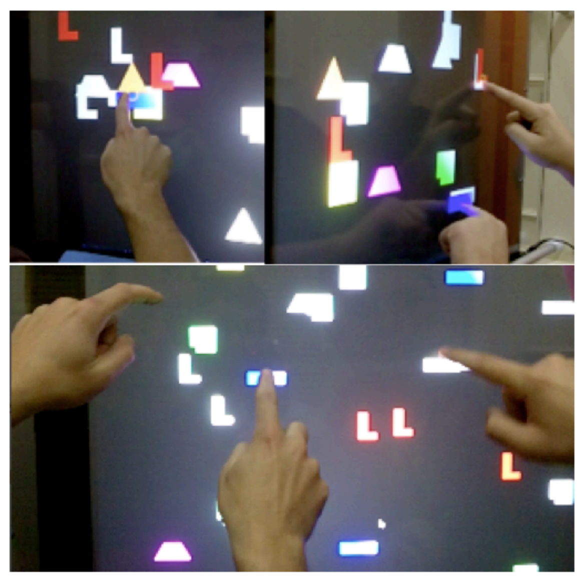

Figure 7. a) One user, dominant hand. b) One user, bimanual interaction, c) Two users, both using both their hands.

Discussion

In this experiment, most of the users used primarily their dominant hand (Figure 7.a) but sometimes users tried to use both hands. Moving shapes with both hands seems to be easy but trying to dock them with their white respective ones proved to be difficult (Figure 7.b). Although accuracy was not measured directly in log files due to the fact that there was a 10 pixels threshold (0.5 cm), users seemed to be accurate in matching shapes except from when they tried to do it simultaneously with both their hands.

MT surfaces not only proved to be faster in dragging task but produced feelings of enjoyment of interaction, improved control and in general an entertaining atmosphere.

CONCLUSION

In this research, we examined the potential of MT surfaces by conducting two laboratory experiments with a relatively small number of users. The results from more users would probably improve the reliability of the study, but we would not expect any significant difference in its validity because the measurements are focused on the differences between experts' pointing and dragging performance. Actually, the original mouse comparative study [1] had only four users and established that a small number of users are enough as long as there is sufficient training and multiple repeated tasks (i.e. expert users). Moreover, we extended established experimental tasks and measures for input device comparisons, in order to compare MT and multi-user conditions. In particular, we introduced user tasks that are suitable for MT applications, such as multiple moving target acquisition and multiple objects docking. The tasks might seem artificial when compared to real applications, but those tasks are atomic and unique for every MT user interface. Regardless of how advanced the UI is, the user has to reach for multiple screen elements and to move them around. Thus, the tasks were suitable for our experiment, because they stand for basic user actions. Moreover, additional measurements such as flow or enjoyment were employed to highlight the benefits of MT.

In those two experiments, we figured out that the MT surface and its tracking system plays the most important role when measuring enjoyment and effectiveness of the MT surface. The system must be as accurate as possible in detecting finger blobs because users' opinion is really influenced. Thus the improved tracking system we had in the experiments allowed having more valuable results.

Finally, we believe that since MT surfaces have some unique attributes, an updated set of measures such as engagement of the user, in-control feeling or flow should be applied. Correlations between traditional measures such as performance or accuracy and the updated set of measures proposed should be investigated in order to evaluate applications dedicated for MT surfaces. Finally, we argue that future MT and multiuser systems should be evaluated with respect to collaboration effectiveness.

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