Various Techniques of Mode Changing with Stylus/Touch Interface

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ABSTRACT

Stylus for digital devices was initially designed as a surrogate to simulate pen actions on digital surfaces. As the technology develops, much more can be done on digital devices than on a normal paper. A stylus must perform multiple functions in order to utilize the power of the surface device sufficiently. This paper will discuss various techniques of changing mode that has been proposed, studied and test by people who've been working in the field. We will retrace their steps, take a close look at the study they've done and discuss the conclusions they've drawn. We will start with some of the older works done on the legacy machine which only accept stylus input. Several ways have been studied, tested and compared by Li et al [1]. We will start there and move on to new devices equipped with multi-touch enabled touch screens. Hinckley et al. showed an interesting yet reasonable combination of stylus and touch input on Microsoft Surface [7]. Vogel et al. and Harrison et al. also studied several intuitive approach of enabling multi-modal input on similar devices [4] [11].

Keywords

Stylus; touch; multi-modal; mode; pen; finger; input.

INTRODUCTION

Comparing to a classical paper, a digitized paper possesses much more advantage in terms of manipulating the content. To make operation on digital devices seemingly close to on an actual paper, a pen or stylus is quite the way to minimize the distinction. Since digital devices should outperform papers, a stylus can't just simply perform drawing operation. Commanding operations such as selecting, deleting and moving should also be among the functionalities of the stylus. In order to distinguish on function from another, it is necessary for the devices to change among different modes.

One simple idea is to allow an additional input source aside from the stylus. Most of the techniques Li et al. studied follow this idea [1]. The other idea is by deriving additional information from the stroke. This idea can take on different forms. Saund et al. studied the possibility of stroke gesture recognition, which is more practical on small screen devices [2]. While Vogel et al. and Harrison et al. tested the technique of changing mode by identifying what/which part is touching the screen [4][11].

Before multi-touch devices came along, it is practical to add extra input source, e.g. buttons and keys, to facilitate mode changing. As multi-touch technology became more and more available, one screen can act like multiple input sources. Based on the study Ruiz et al. on non-preferred hand mode manipulation, Hinckley et al. adapted such methodology on multi-touch surface which supports both stylus and finger input [7].

This paper will follow the timeline and focus on studies conducted on older devices initially. Although such devices are rarely seen nowadays, the methodologies applied to them are still instructive and can be migrated to newer devices. Then we will take a look at the studies on newer devices. This part will focus on how old techniques are modified to accommodate new technologies.

PEN/STYLUS INPUT DEVICES

The early type of pen-based devices, such as PDAs and Windows Tablet PCs, recognize only one input point from the screen. Some resistive touch screens support both finger touch and stylus touch while Windows tablets only allow stylus input. In all, only one touch point is allowed at a time on the screen. To study efficiency of different techniques of mode switching on this kind of devices, Li et al proposed and tested five different methods, from the most common ones to ones somewhat novel at the time [1].

Early Techniques [1]

The five techniques Li et al studied are the following. First, switching between modes by pressing and release a barrel button on the stylus; second, press and hold the stylus to utilize temporal information to switch modes; third, use non-preferred hand to press an additional button near screen; fourth, switching between modes by differentiating the downward pressure exerted on the stylus; fifth, flip the stylus to use the eraser end to indicate mode change.

They designed an experiment to fairly test all five techniques. 15 participants are asked to slice a piece of pie (see Figure.1). Before the experiment session, participants are required to take a training session in order to familiarize with the mechanism. In the experiment session, each participant has to perform 9 blocks of trials with each block consisting 5 slicing tasks on pies each of the 8 orientations.

From all 27,000 slicing tasks performed, they gathered and calculated the mean full cycle time and the mean time for mode switch of each technique. They have also counted and classified errors made by participants and surveyed the acceptance of each technique by participants.

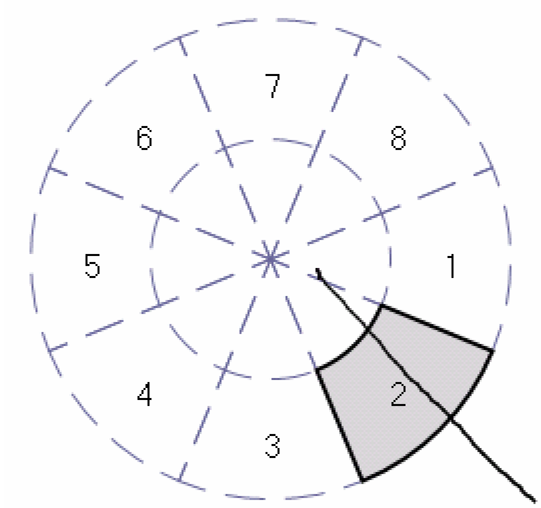

Figure 1 [1]. Pie Slice Task, the participants are asked to slice from inner rim to outer rim and two pieces left must be of relatively the same size.

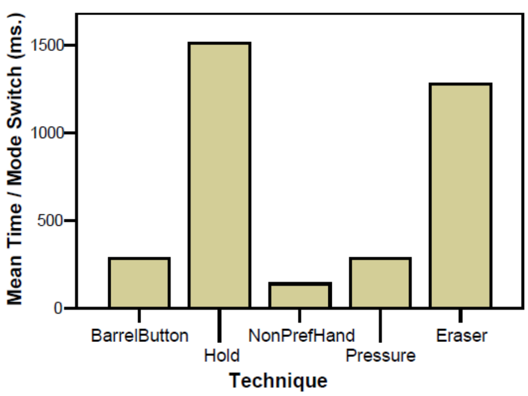

Figure 2 [1]. Mean time taken to switch mode with five techniques.

The conclusion they've drawn from the statistical study of the data gathered is that Non-preferred Hand mode switching is the most efficient technique yet introduced the least errors (Figure 2). The participants also nominated Non-preferred Hand to be the best in learning, using, accuracy, speed and fatigue. As the most common solution, Barrel Button showed a fairly promising result in the experiment. Although the pressure-based method showed a moderate level of performance, they concluded that improvement can be made by using personalized pressure space. Press and Hold performed the worst among all five in the experiment, but it is still widely used at the time cause of least requirement of the hardware support (purely handle by software).

Non-preferred Hand Mode [3] [5] [6]

Based the conclusion drawn by Li et al, Ruiz et al conducted a series of studies on Non-preferred Hand mode switching and changing.

Since Non-preferred Hand mode is among the most efficient ways of switching mode with stylus input [1], Ruiz et al designed the initial experiment quite like the one in the previous work done by Li et al. 12 participants are asked to perform bisecting tasks even simpler than the pie slicing task. This is to reduce amount of effort required from participant to perform the task correctly in spatial sense and focus on whether it is perform in the right mode. The temporal measurements are more delicate than the previous work, contain initiation and stroke time, both are recorded rather than calculated. The study mainly focused the effect of allowing temporal overlap of the mode switching action and drawing action.

From the data gathered, by allowing concurrent actions of drawing and mode switching, the total time consumed has a statistically significant decrease [5]. Another observation is that there is no significant temporal difference between moded gesture time and unmoded gesture time whether parallelism is allowed [5].

After this work, they further the study on the scalability of Non-preferred Hand Mode. Since all five fingers of the off-hand can be utilized, the experiment is expanded to up to 4 modes instead of 2.The task for subjects remained the same as bisecting 2 vertical lines. Test subjects consist both right-handed and left-handed to ensure fairness.

The result matches the previous work as allowing parallelism reduces time consumption. The concurrent technique not only shortened the time gap between mode changed and pen down but also reduced the time needed for cognitive planning time for activating a mode [3]. But concurrent technique no longer remained cost free as number of modes increased [3]. The time consumption and number of modes are positively correlated and possibly follows the Hick-Hyman law.

The later work focused on the speculation from the scalability test that the planning time and number of modes follow the Hick-Hyman law. Again the same experiment is expanded to accommodate 4, 6 and 8 modes. The experiment result indicated that the mathematical model they built by Hick-Hyman law can accurately predict the time to perform a non-preferred hand mode change given the number of modes, which is less than 8 [6].

From the works done, Non-preferred Hand mode changing showed a promising performance and a wide possibility of application. It outperformed other techniques and rated with highest popularity [1], the possibility of scaling to multiple modes is also quite promising with parallelism allowed [3]. With chording key mapping introduced, the scalability of Non-preferred Hand Mode can be further enlarged [6].

MULTI-TOUCH DEVICES

As the multi-touch screen got widely accepted in the past few years, the industry shifted its focus from traditional Windows tablet with only pen input to pad-like tablets with multi-touch enabled screens that takes finger and stylus input. More ideas emerged as in controlling devices in a more comfortable and ergonomic manor. Multi-touch gesture is one of the most common solutions for delivering different commanding actions. Hinckley et al proposed the technique that combines touch and pen actions [7].

Pen Plus Touch [7] [8]

The initial study is the foundation of the design, which is the study on how people work with physical tools and paper. Several behaviors, such as tucking the pen, hold while writing and piling, are summarized and classified to serve as design attributes. The prototype systems are built on the core idea that pen writes, touch manipulates and pen plus touch yields new tools [7].

By differentiating finger and pen input, mode change is done seamlessly without the need of an explicit switch. But this raised issues when user expected the job of pen and finger can be interchangeable. In the pilot design, each selected object has an overlaid radial menu which is handled by pen input. The users constantly try to click the menu buttons with their fingers and introduce mistakes. The combinations of finger and pen input can be assigned to different jobs according to the situation. In the prototype system, holding with finger and tap with pen is clipping/grouping, holding with finger and drag with pen is duplicating and many more complicated cases are adopted.

Actions	Pen	Touch
Sketch	✓	×
Select Object	✓	✓
Move Object	×	✓
Camera Gestures	×	✓
Activate Widgets	✓	✓

Figure 3 [8]. Roles of pen and finger touch.

Different from the strict separated roles for pen and touch, Lopes et al designed a model that allows some actions be done by both input source (Figure 3) [8]. To evaluate this approach, a base model with only pen input is set up and 10 users are invited to test on both models. According to the result, the average time spent in camera almost halved, from 9 seconds to 5 (Figure 4), indicating a significant advantage of combining finger and pen actions. The users mostly preferred to operate camera gestures with non-preferred hand, which correspond to the work by Li et al [1]. Majority of the users are in favor of the combined model according to the preference questionnaire.

Based on the pilot design of systems utilizing such techniques, a number of more sophisticated systems are developed with much more detailed assignment of finger gestures. More gestures are classified and assigned with operational functionalities. Such systems include NEAT, design and studied by Frisch et al [10], which performs layout management and Pointable, designed and test by Banerjee et al [9], which addresses reachability issues on large touch screen.

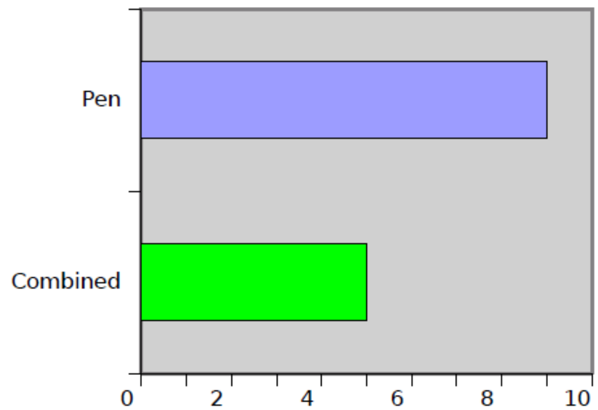

Figure 4 [8]. Average time consumed in camera mode.

Despite the possibilities of much broader application of combining pen and touch input, several issues have to be addressed when implementing such systems. Since touching requires zero activation force, activated upon contact, it is very likely to introduce false input [7]. When writing, the resting palm will almost definitely cause accidental input. Accidental touch of the screen will most probably happen when using both hands. Fingers may rest on screen if performing a hold gesture for too long. Issues like above, if not addressed properly, are most likely to cause trouble in the application of touch plus pen technique.

Novel Methodologies

Input Source Identification and Classification [4] [11]

In the work of Li et al, one of the techniques studied is flipping the pen to use the eraser side to invoke mode change. Though this technique was the slowest of all five, it still can be applied in scenarios that speed is not the primary concern. The limit of the previous model is that it can only apply to two modes, inking and eraser. Inspired by artists' manipulation of conté crayons, Vogel et al design a sketch system that simulates the process and replaced the pen with a digital conté which invokes multiple modes.

The digital conté crayon is built of a cuboid shape. Each of its corners is installed with an IR led light. The interface that the conté operates on would capture individual input of contacting corners and use the spatial relevance of multiple inputs to identify the contact type. Seven possible modes can be invoked directly depending on the hand grips (Figure 5). In this system, rather than a normal crayon, which performs only drawing in various thickness, operations perform by edge or side contact are assigned with commanding actions. Short edge is associated with shape drawing rather than freeform drawing, medium edge performs lasso operation, end of the crayon invokes a radial menu which allows finger touch to select commands, attribute palettes and guideline tools will appear when thick and thin side of the crayon is placed on the interface.

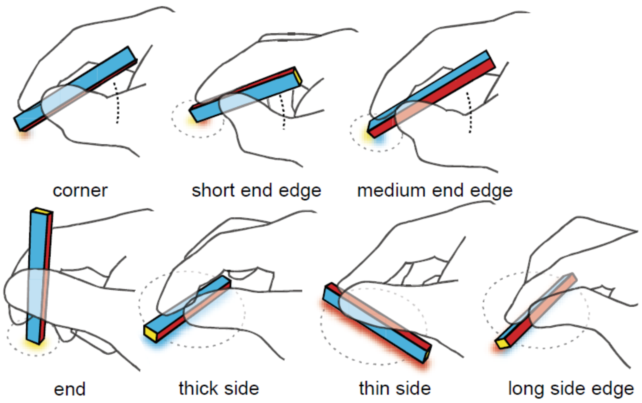

Figure 5 [4]. Different crayon contact types.

Apart from directly invoked modes, simple combination use of the edge and corner can trigger more modes. In this system, initial contact with the short edge combined with following actions done by corner would invoke writing mode. The digital ink dispensed in this mode will be processed by text recognition engine and replaced by text labels. Finger touch is also heavily utilized in guideline and alignment operation.

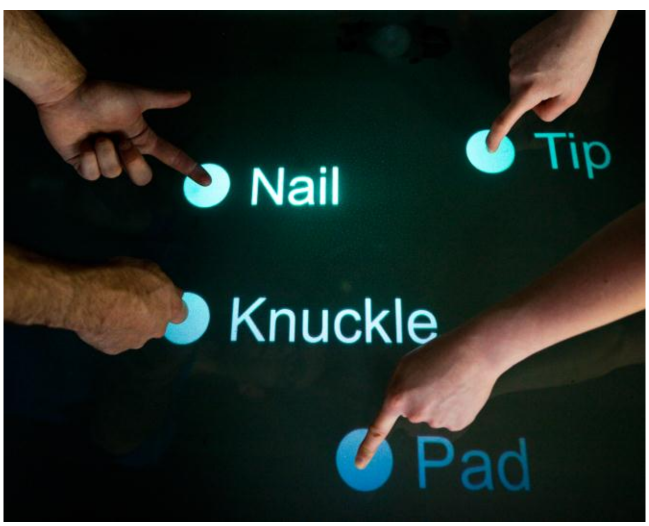

Figure 6 [11]. Different types of finger contact.

Harrison et al explored further possibilities of the above approach. Not only should the interface be able to identify different tangibles, but also different body parts, mainly hand parts. From this idea, they developed the system TapSense which is able to distinguish nail, knuckle, tip, pad touch and etc. (Figure 6). Different tangible contacts are also allowed to be programed in the system and enhanced the system's customization capability.

Although this system, unlike previous sketch systems, is only a demonstration prototype with no real world application, possibility of implementation on daily devices is indeed discussed. Similar to the approach by Vogel et al, pad touch serves as the normal selecting and dragging command, and knuckle touch or tip touch serves as command in alternative modes. The functionality of the single button can also be overloaded by differentiating input source, e.g. pad touch can be forward and tip touch is backward. Overloading a button is quite reasonable on devices with limited screen size.

The problem with TapSense comparing to Conté is that as the number of classification increases, the accuracy of the classifier significantly drops, especially with a general classifier. Unlike a digital crayon, no one's finger is identical to another's and touches of the same finger can vary from time to time. Accuracy is the primary concern when implement finger overloading and user adaptive classifier should always be considered [11].

Grips and Gesture [12]

Similar to the Conté design, another idea to overload the pen is proposed by Song et al. The approach is based on the normal practice of handling a pen or paint brush, however the signal used to identify grips originated from touching the pen itself rather than the operation interface in the Conté system. The pen is specially designed with the body covered by capacitive sense material.

From the ergonomic study of hand grips of pen in performing different tasks, several grips are classified. Tripod grip is used in precise writing and drawing, relaxed tripod grip for less precise drawing, sketch grip for sketching, tuck grip for hand operation, wrap grip for brushing and etc. Finger contacts are further classified as static and dynamic. In a stable grip, static contact remain relatively constant as the majority of the pen weight rest on these contact point, dynamic contact, however, can move from time to time. Dynamic contact, typically from index finger and thumb, is used for gesturing and precision control.

In the prototype design, tripod grip invokes paint mode, relaxed tripod changes the mode to highlighting, sketch grip dispenses scattered ink dots and wrap grip is used for page turning. When drawing, index finger can swipe on the pen barrel to adjust ink size or double tap the barrel for radial menu. Swiping after a self-intersecting ink trace will select content in the ink trace. Swiping with thumb when performing wrap grip would flip pages back and forth.

A usability experiment was conducted for mode switching with double tap and swipe. A pen with two barrel buttons is used as baseline. The experiment results showed that mode switching time is lowest with the first barrel button, swiping and double tap followed closely behind respectively, second barrel button is the slowest as user has to rotate the pen to reach the button (Figure 7). Though temporal advantage is shown in the experiment, the touch pen did not outperform pen with barrel buttons in error control as expected. Much higher false negative rate is observed due to unrecognized gestures. Slightly higher false positive rate is expected and observed for double tap due to frequent grip adjustment during experiment.

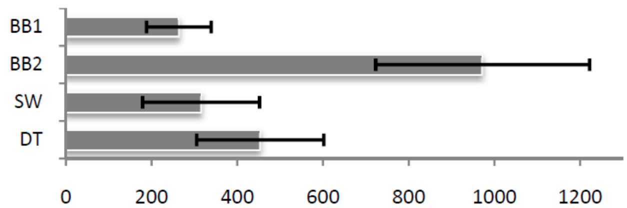

Figure 7 [12]. Mean time taken to change mode with buttons and touch gestures.

Song et al also proposed possibility of more sophisticated pen combining other sensors like gyro scope, pressure and motion sensor. Improvements can be made on the software as well to boost gesture recognition success rate.

SUMMARY

In this paper, we reviewed the works, from past few years, in facilitating mode change on touch/pen devices. We've discussed older methodologies on legacy devices and pointed out the ideas that inspired following works. On newer devices such as MS Surface, we've seen many novel techniques, like Pen + Touch and Conté, accommodating the multi-touch technology. Some of the works remained experimental while others are much closer to industrial application. Nonetheless, all designs provided inspirational guidance for future works in the area.

FUTURE WORK

Despite the promising results from the usability tests of the novel techniques, a common issue is shared by all designs utilizing multi-touch interface. Touch input requires zero activation force, i.e. an input is present upon contact. Accidental or false input is very likely to occur during operations. Some of the false input can be avoid by training user or experience accumulation, while some are originated from the nature of the gesture, e.g. resting palm when writing, can't possibly be removed. Another issue is the gesture recognition success rate. Effort devoted on this issue should have a significant impact on the false negative rate with finger touch input. Future works can be established addressing these above issues.

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