Pen-Based User Interface Based on Handwriting Force Information

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Abstract. Pen-based computing attracts many researchers recent years. Pen-computer generally uses pen tip position and pen pressure information at present. Actually, the force between the pen tip and writing plate is a three-dimensional vector, which represents more important information in the process of writing. In this paper we firstly describe an innovative force sensitive device (F-Tablet) for pen-based computing, and it can acquire three perpendicular forces and position of the pen-tip simultaneously. The second part deals with problems of Pen-User Interface design based on this tablet. Experimental results show that this pen-user interface considers context awareness and some characteristics of user cognition. Furthermore the pen-user interface can complete most functions of keyboard and mouse.

Keywords: Pen-based computing, Pen-computer, Pen-User Interface, handwriting.

1 Introduction

Handwriting is an input modality that is very familiar to most users since everyone learns to write as he/she begins to study. As one of natural human forms of communication (e.g. handwriting, speech, and gesture), using pen to communicate with computer is becoming commonplace and pen-based computing has held promise for decades. It has a rich history of innovative hardware and software solutions as human computer interface (HCI) [1].

The earliest technology in pen computing can be traced back to 1957, when T. L. Dimond presented a device called "Stylator" which could read handwritten characters. After that, more tablet and stylus devices were developed for handwriting data acquisition on-line. Pen-based data acquisition devices include I-pen (Inductum) [2], Virtual Pen (GOU Lite) [3], E-Pen (InMotion) [4], N-scribe (Digital Ink) [5] and Compupen (Pen2Net) [6] etc. To tablet-based data acquisition device, Wacom tablets [7] and ePad-ink [8] are two commercially popular tablets on the market. Tablet PCs employ Wacom's authorized sensor technology [9]. All these handwriting devices have

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the common ability to acquire pen movement as sequences of pen tip positions in succession. Some of them have sensors for pen pressure and inclination information acquisition additionally. As we know Handwriting is the trajectory of the writing pen's contact movement on the writing surface driven by writing forces, So writing forces are one of the most important information of writing dynamics and many researches have been done on them. Crane and Ostrem developed a three-dimension force-sensitive pen to get the writing forces [10]. Shimizu developed an electrical pen using two-dimensional optical angle sensor to get writing forces [11]. But most devices can only get the writing pressure.

In this paper, we present an F-tablet as pen-computer interface input system. It can acquire kinematics and kinetics handwriting information of pen tip, including strokes of pen-up and pen-down, velocity and acceleration of pen-tip, three dimension forces of pen-plate contacting point and shape of character etc ïï ï ïïïIn the following Pen-User Interface based on F-Tablet is described in detail. The pen user interface is composed of two work mode: pen script mode and pen control mode. The former one mainly handles with pen input and the latter controls pen cursor move and activates pen click events. Thus it can implement most functions of keyboard and mouse.

2 F-Tablet

As handwriting is the process of human hand acting on contacting plate (such as paper) with pen, the writing information includes pen-tip trajectory, contacting force direction and amplitude. Up to now various pen-computing devices cannot acquire all those information simultaneously. In our design a force sensitive tablet named F-Tablet (Fig.1) is capable of capturing three perpendicular forces of the pen-tip to the contacting plane and torques in two directions directly with a multi-dimension force/torque sensor. Furthermore, with the specially designed structure, the static trajectory of the pen-tip on the writing plane and the other dynamic information such as the velocities, accelerations and slants of the pen-tip can be calculated indirectly [12]. The device is connected to computer via USB interface with a maximum sample rate of 120Hz. And there is no special requirement on the writing pen.

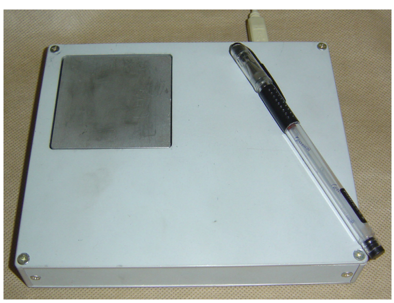


Fig. 1. Photo of the F-Tablet

When a pen writes on the input tablet at point p (Fig.2), force F can be decomposed into forces in three perpendicular directions $F_x(t_i)$ $F_y(t_i)$ $F_z(t_i)$. At the same time, $M_x(t_i)$ and $M_y(t_i)$ are also measured directly by the multi-dimension force/torque sensor. These five elements are all functions of time t_i. The coordinates ($x_p(\mathrm{t_i})$, $y_p(\mathrm{t_i})$) of the point p can be calculated from the equilibrium of moments. They can be expressed as (1):

$$\begin{aligned} x_p(\mathrm{t_i}) &= \frac{M_y(\mathrm{t_i}) - F_x(\mathrm{t_i}) \cdot h}{F_z(\mathrm{t_i})} \\ y_p(\mathrm{t_i}) &= \frac{-M_x(\mathrm{t_i}) - F_y(\mathrm{t_i}) \cdot h}{F_z(\mathrm{t_i})} \end{aligned} . \quad (1)$$

Where h denotes the distance between the input tablet and the origin of the coordinate.

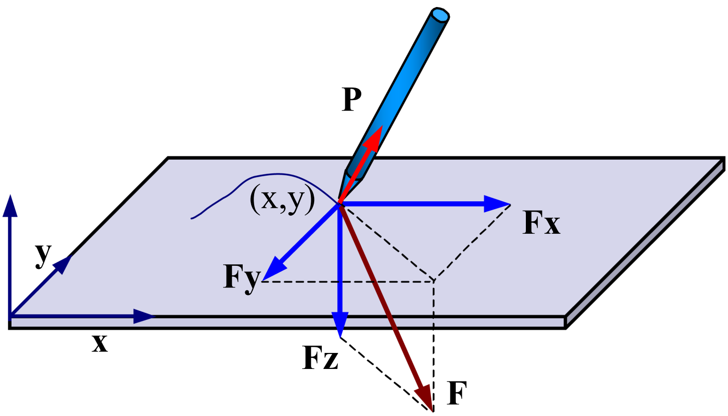


Fig. 2. Schematic Diagram of Force Action

Fig.3 displays the handwriting of Chinese "中" and its forces information acquired by the F-Tablet.

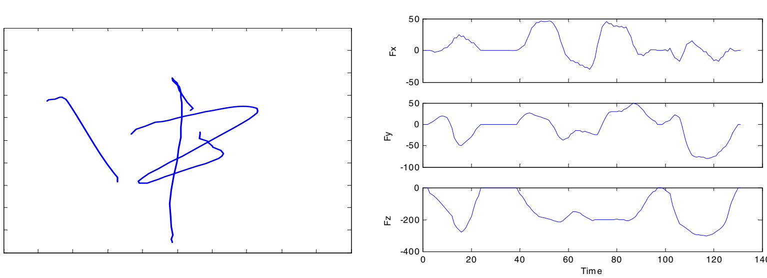


Fig. 3. The Chinese "中" by F-tablet and its force curves

3 Pen-User Interface

While markets or labs have invented various type pen-computing devices, computer users also need a bridge to help them interact with pen computers. This section will introduce the detailed design of our pen user interface. Given the merits and some disadvantages of F-Tablet, this paper would like to split the pen user interface into two parts. The first part mainly concerns on how to write characters naturally by the F-Tablet although the writing area is not big enough as Wacom or Hanwang, while the second one introduces how to implement pen clicks and pen cursor movement called pen control mode in this paper.

3.1 Pen Script Mode

In this mode, pen user interface mainly concerns on handwriting related. Authors divide the writing into five zones in this mode which is described in Fig.4. Each zone manages a specific task and the width of all zones except the largest zone is the 1/15th length of writing pad in below.

Zone one mainly enables users switch to pen control mode when users click. It is note that users need to click the zone one for a while at begin in order to filter noise signals or other error motions. Similarly, zone two, three and four need the same operations. The location of zone one has two choices in our pen user interface. The default is on the left side of the writing pad. Because most users are right hand privilege, the left side is rarely touched. Of course, if the user is a left hand privilege, the zone one location could also be set on the left side by users and the zone three will be set on the left side.

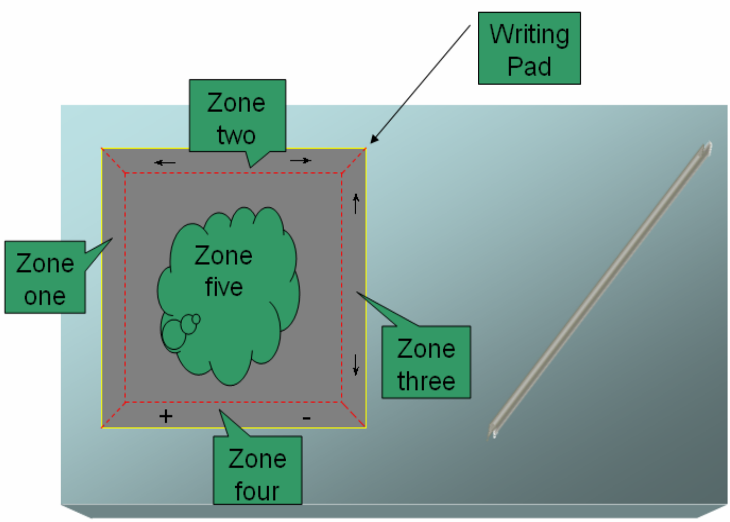


Fig. 4. Schematic Diagram of Zone Division of Pen Script Mode

Zone two takes charge of left or right slide of writing region and the left part of zone two makes writing region slide to left, while if users want the writing region slide to right, they could click the right one. Figure 4 shows the writing region which is a white square on the screen.

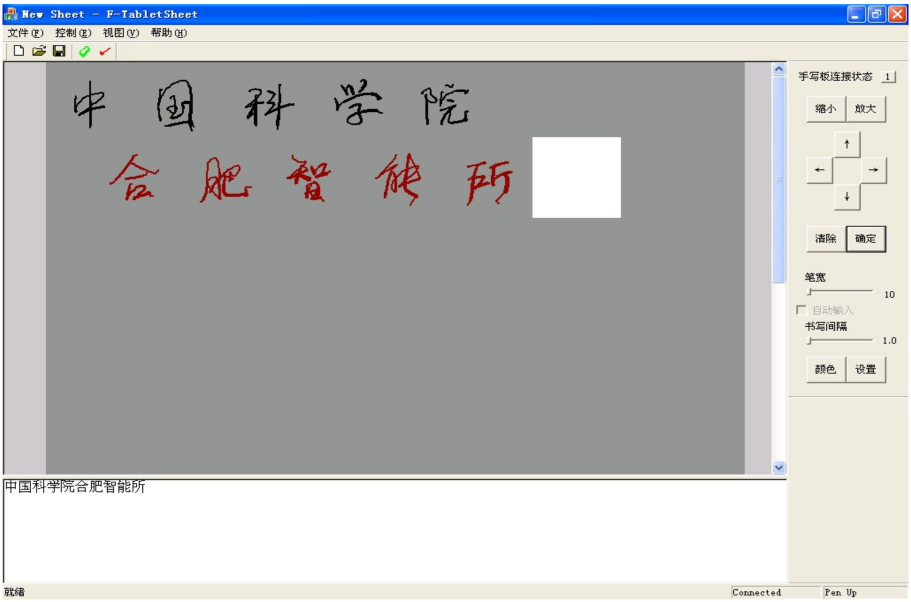
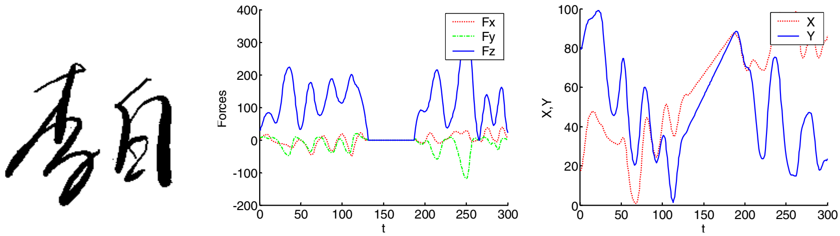


Fig. 5. Writing Region

Zone three is responsible for up or down slide of writing region on the screen shown as Fig.5. Like zone two, the upper part of zone three enable the writing region slide up and the lower region offers the contrary function.

Additionally, considering the number of activation of zone three is more than zone one and the right hand privilege users are much more than left hand privilege people, a default set looks like Fig.4. At the same time, if a user is a left hand privilege, the pen user interface also provides interface to exchange zone one and zone three.

Zone five is the main region since handwriting is input here. This paper utilizes coordinates and forces of pen tip to input the handwriting on the screen. When users write on the F-Tablet, the real time coordinates and forces of pen can be captured, so handwriting can be easily rendered based on the real time coordinates. Unfortunately, this type of handwriting has no any aesthetic perception and does not look like Chinese character. Hence, in order to render handwriting more beautiful, this paper uses z-axis force (F_z) to embody the blackness and width degree of strokes. Users write more powerful, stokes of handwriting will be more black and clearly. Fig.6 shows Chinese characters and corresponding 3-Axis force and 2-dim coordinate curves. From the shape of the character, we can see that not only the trajectory of the pen, but also the writing style of the writer is recorded.



(a) (b) (c)

Fig. 6. 3-Axis force (b) and 2-dim coordinate(c) curves of Chinese Handwriting (a)

3.2 Pen Control Mode

Every graphic user interface user is familiar with mouse or cursors with which users could control computers visually. Considering clicks and cursors are still effective in most selection/check events, this paper on one hand inherits the advantages of clicks and cursors, on the other hand, provides users much usabilities for avoiding so many switches between mouse and keyboard when in the graphic user interaction. Hence, the next work has to complete is to implement the pen clicks (double clicks) and pen cursor movement.

Because all information of F-Tablet has only one communication channel, it is very important to recognize pen click information, pen cursor movement signal or other usable information exactly. This paper proposes the design as below. Firstly, authors divide the script pad into four regions as Fig.7 describes. In that way, according to the pen tip position, pen user interface could reorganize and do what users want exactly.

Like pen script mode, the zone width except zone four is the 1/15th length of writing pad.

Zone one enables users switch to pen script mode as the function of zone one of pen script mode.

The functions of zone two and zone three are similar. As human beings are not good at drawing erect lines, it is difficult when human beings want to control the pen cursors move erectly. In addition, in some fine control situations, noise of F-Tablet can not be neglected. According to that, the pen cursor can only slide left or right direction horizontally with a stable slide rate similar as the ←or→ key on keyboards when users click the left or right part of zone two. Similarly, zone three provides a stable rate, vertical up or down direction slide as ↑ or ↓key works.

Zone four mainly completes pen clicks, namely pen double clicks, and pen cursor movement. The idea of pen clicks is simple. If F-Tablet senses two or more than two clicks in a short given time, double click action will be executed. The event of clicks can be detected when the value of F_z is higher than pre-defined threshold.

It is not difficult to complete pen cursor move. Depending on (2) and the velocities of pen to move the cursor, the pen user interface can control the cursor easily.

$$\begin{aligned} CursorPos.x &= Cursorpos.x + ratio * \Delta x \\ CursorPos.y &= CursorPos.y + ratio * \Delta y \end{aligned} \quad . \tag{2}$$

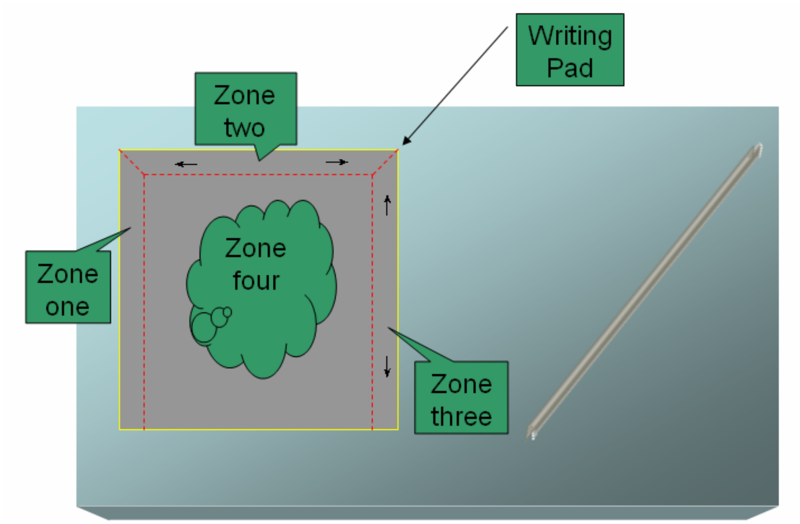


Fig. 7. Schematic Diagram of Zone Division of Pen Control Mode

Where *ratio* is a given threshold and Δx , Δy are calculated by the distances and velocities of pen.

By the way, the ratio is not fixed because when user moves pen cursor fast, generally speaking, they want the cursor reach the region they expect soon. Therefore, the faster velocity of cursors is, the higher the ratio value is.

However there emerges a problem. The two actions, including pen double clicks and pen cursor controls are coupling, as a result, the pen user interface has to separate the action accurately. Fortunately, pen double clicks and pen cursor control action are easy to be separated since a double click is a low-high-low-high-low signal procedure while pen cursor moves just a low-high-low procedure. The extra low-high-low signal provides pen user interface enough information to discriminate from pen double clicks and pen cursor move.

4 Conclusion

The paper describes the F-Tablet, which can acquire the kinematics and kinetics information of human handwriting, including strokes of pen-up and pen-down, pen nib trajectory and three-axis forces of pen tip directly and simultaneously. Then a new pen user interface has been designed based on the merits and some disadvantages of F-Tablet. With this interface, users not only can control pen clicks and pen cursor movement but also input handwriting naturally. The experimental results show that the interface is effective and natural. Next step in our work, we will pay more attention on the potential advantages of pen computing in relation to applications.

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