Pen-Shaped Device for Handwriting on Wearable Computers

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Abstract

We develop the pen-shaped device which can input handwriting information for wearable computers utilizing the camera and pattern projection device attached on the pen. The measurement of the relative movement and orientation between the pen-shaped device and the drawing surface is achieved without special device or patterns on the drawing surface. The experiment using the prototype system shows the capability of the proposed method that any characters can be written on arbitrary surface.

Key words: Wearable Computer, Handwriting, Interface

1. Introduction

Handwriting information has high flexibility that enables us to represent various types of information, such as letters, drawings, figures, and so on. Since almost all papers can become the recording media for handwriting information, we can use handwriting information on all occasions in daily life. However, this convenience of handwriting information has a weak point that the papers on which some information has been written easily get scattered and lost.

Digitalize of handwriting information makes it possible to store this information in unified way and prevent to lose the information. Moreover, there are advantages of digitalization such as making a fair copy utilizing letter and figure recognitions, sharing information between distant sites, and so on. Foregoing researches proposed the methods in which a special device is attached on drawing surface [1,2], a special pattern is printed on drawing surface [3], and so on. However, these methods limit the environment of making handwriting information and spoil the convenience.

To input handwriting information properly, the position of the tip of a pen on the drawing surface and the switching information whether the tip of a pen is touching on the surface or not (figure 1). The acquisition of three-dimensional position on the drawing surface coordinates brings the above information simultaneously.

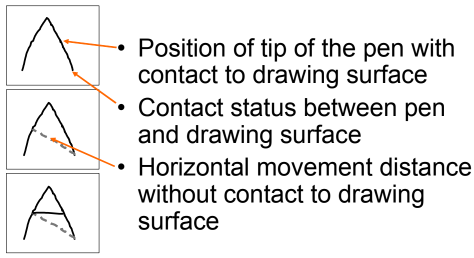

Fig. 1 Acquisition of Handwriting Information

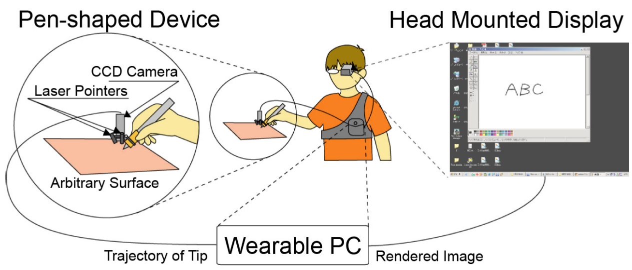

Fig. 2 System Overview

In this paper, we propose the pen-shaped device by which users can input handwriting information without special device or patterns on the drawing surface. The device equips a miniature camera and a projected laser pattern and the image processing on wearable computers brings the realization of the proposed handwriting device (figure 2).

2. Proposed Method

2.1 Digitalization of Handwriting Information

In this research, the three-dimensional position of the tip of the pen is acquired as the combination of the following two kinds of information.

- The horizontal movement distance of the pen-shaped device.

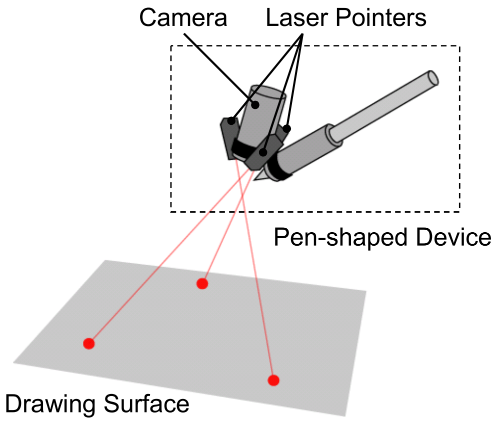

Fig. 3 Structure of Proposed Pen-shaped Device

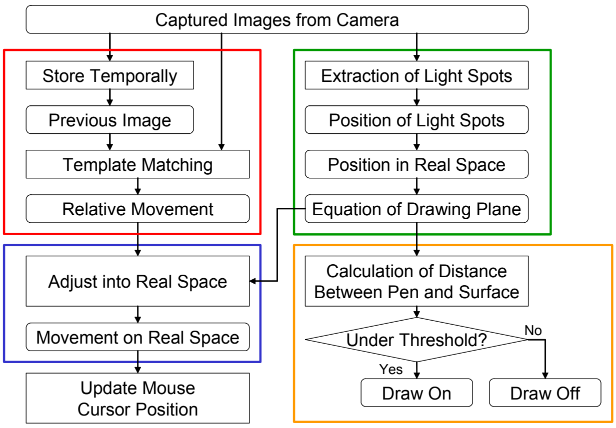

Fig. 4 Flow of Processing

- The height of the pen tip from the drawing surface.

To acquire these distances, we propose the measurement method utilizing the combination of projection of laser spots on the drawing surface and image processing for detection of laser spots and relative movement of the pen to the drawing surface. Figure 3 shows the components of the device. The processing of acquiring the requested information is shown on figure 4.

2.2 Measurement of movement in camera coordinates

The camera attached on the pen captures an image of the drawing surface. Block matching method between a current image and a previous image is executed. The template is a central area of the previous image and the position of the template is detected by block matching. For finding the matched point, the proposed method adopt sum of squared difference (SSD) criterion. The distance between the detected position and a center point of the current image is considered as the relative

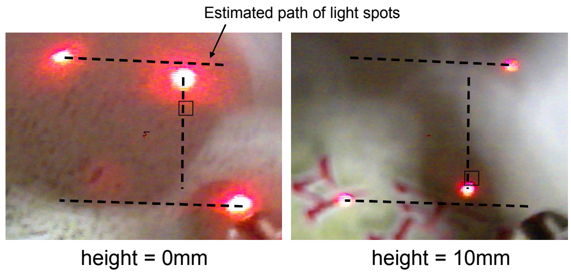

Fig. 5 Captured Images

movement distance in the camera coordinates.

2.3 Decision of equation of drawing surface

To calculate the movement on a real space from the movement distance in the image coordinates, the relative orientation of the pen-shaped device to the drawing surface is required. Decision of the equation of the drawing surface in the camera coordinates corresponds to the measurement of the relative orientation.

In this research, three laser pointers are attached on the pen-shaped device. These laser pointers produce the light spots on the drawing surface and the captured image contains these spots (figure 5). The proper image processing, which uses thresholding and labeling of continuous regions, makes it possible to extract the light spots from the captured image. Three-dimensional positions of the light spots are calculated by triangulation because the relative position and direction of the laser pointers are known. From a couple of positional information of light spots, the equation of plane in the camera coordinates is calculated.

2.4 Calculation of position in real space

The line between the center of the projection of the camera and the matched position (that is, the center point of the previous image) crosses the drawing surface. Using the equation of the drawing surface, we can calculate the crossing point. Then the length between the current center point and the previous crossing point is the horizontal movement distance on the drawing surface. The integration of horizontal movement distance brings the position of the tip of the pen.

2.5 Judgment of drawing status

The height between the drawing surface and the tip of the pen can be calculated utilizing the equation of the drawing plane. Since the position of the tip of the pen is known in the camera coordinates, the distance can be acquired using the general formula of the distance between a point and a plane in three-dimensional space. If the height is below the threshold value, the state of the pen is estimated as "drawing".

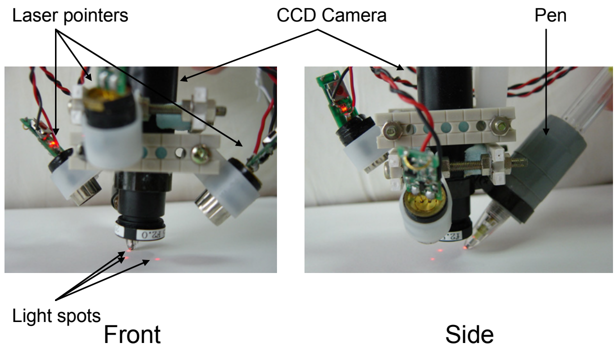

Fig. 6 Prototype System

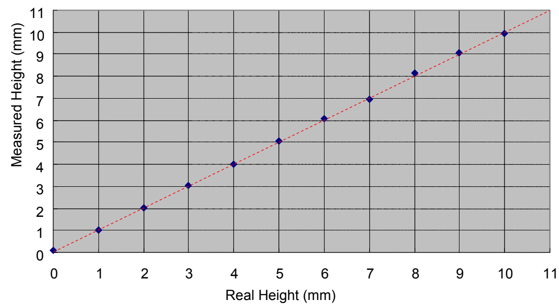

Fig. 7 Measured Heights (Lean: 0degrees)

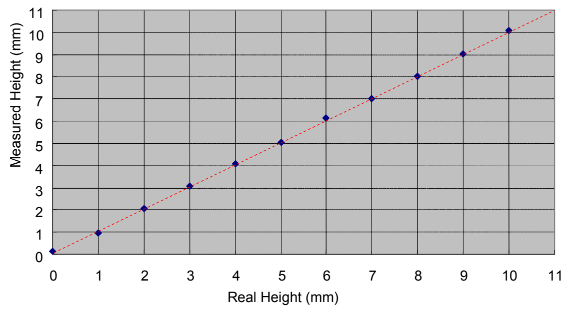

Fig. 8 Measured Heights (Lean: 10degrees)

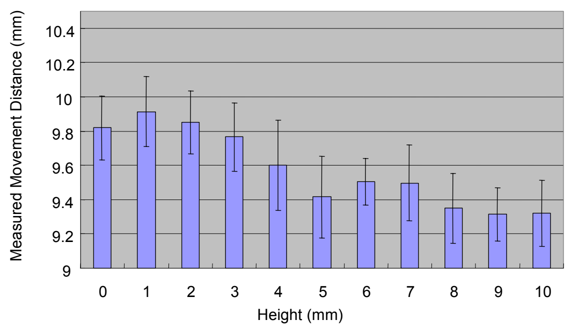

Fig. 9 Measured Movement Distance (Lean: 0degrees)

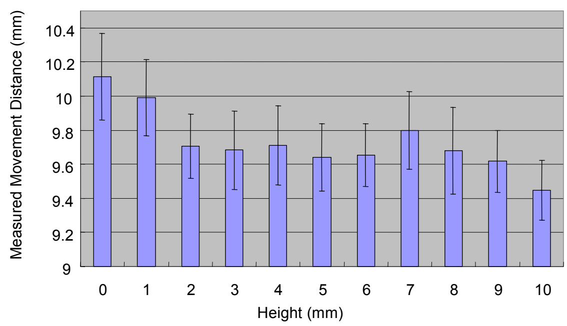

Fig. 10 Measured Movement Distance (Lean: 10degrees)

3. Experiment

3.1 Prototype system

The proposed method was implemented using a note PC (CPU: Pentium M 1.5GHz, memory: 1GB) and a miniature CCD camera (Watec WAT-240R). The prototype system is shown in figure 6. The viewing angle is about 90 degrees and the minimum distance between the drawing surface and the camera is about 10mm. The size of captured image is 360x240 pixels and a frame rate of processing on the prototype system is 10-15 frames/sec.

To evaluate the proposed method, we executed the following experiments with the prototype system.

3.2 Experiment for acquisition of distance form the drawing surface

The distance between the drawing surface and the pen was measured as changing the distance. The aim of this experiment is the inspection of accuracy of measurement distance. And there are two settings of camera orientation: 0 degrees and 10 degrees lean. The results are shown in figure 7 and figure 8. The error is suppressed under 0.1mm when the distance between the drawing surface and the tip of the pen changes from 0 mm to 10 mm.

3.3 Experiment for acquisition of movement length

We have to know whether the adjustment of moving length works well when also the pen is lifted off from the drawing surface. The distance from the drawing surface is fixed. And there are two settings of camera orientation: 0 degree and 10 degree lean. Then we moved the pen horizontally 10mm and compared the result from the system as the physically measured result. The results are shown in figure 9 and figure 10. The average of moving length is 9.3-10.1 mm.

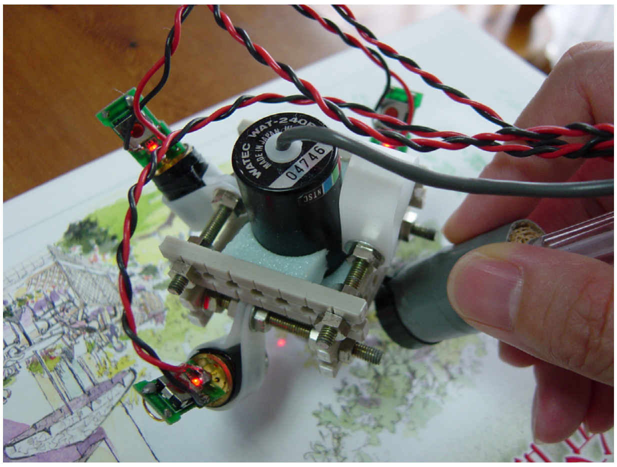

Fig. 11 Use of Prototype System

3.4 Experiment of drawing letters

We drew Japanese letters using the prototype system (figure 11). In figure 12, the left one shows the real movement of the tips of the pen utilizing a carbon paper and the right one shows the traces from the prototype system. The size of the character is about 5mm.

4. Discussion

The consideration of relative positional relationship between the drawing surface and the pen enables the device to acquire the movement length accurately even when the tip of the pen is off from the drawing surface. And during drawing, the slight change of the lean angle of the pen occurs. However, from the measurement of relative orientation between the pen and the drawing surface, relative movement length can be adjusted properly. After that, the characters which have the opportunity of moving the pen in the air can be drawn in the ordinary way.

The prototype system sometimes failed the judgment of drawing status at ends of a stroke. These failures are considered as the result of simple judgment method utilizing only the current height of the pen tip. The consideration of changing rate of the height makes it possible to detect the change of drawing state more accurately.

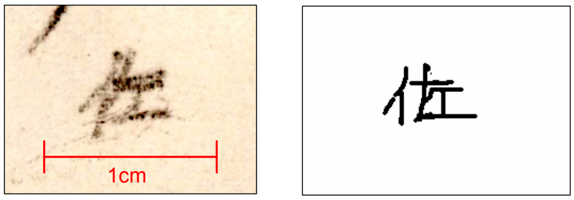

Fig. 12 Result of Drawing Character

5. Conclusion

We proposed the pen-shaped device which can input handwriting information without any external device utilizing the camera and pattern projection device attached on the pen. The experiment using the prototype device shows the capability that any characters can be written without any external devices. We considered this feature is suitable for building input device for wearable computers which will be utilizing "anytime" "anywhere".

Acknowledgments

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[3] Anoto Pen: http://www.anoto.com/