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A handwriting input method based on the thermal cue of the fingertip

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ABSTRACT

This paper proposed a handwriting input method based on the thermal cue of the fingertip. During writing or drawing movements of a fingertip on the surface of a temperature sensitive panel, the thermal exchange happened between the fingertip and the panel. In this method, the temperature values of the thermistor array in the temperature sensitive panel could be recorded and the fingertip moving trajectories could be tracked. Thus the handwriting characters written by the fingertip could be recognized. With this method, we then designed a handwriting prototype device with a 16 × 8 thermistor array in the row–column fashion covered its temperature sensitive panel. Finally, digital character input experiments on the handwriting device were performed. The experiment results verified the validity and the feasibility of the handwriting input method based on the thermal cue of the fingertip.

1. Introduction

Many handwriting input technologies have been developed based on sensors such as electromyography (EMG) sensor [1], vision sensor [2], inertial-measurement-unit [3], tilt-acceleration sensor [4], optical angle sensor [5], capacitive sensor [6], piezoresistive sensor [7], and writing force sensor [8,9]. In these technologies, pen-based computing technologies have been used successfully in handheld computers to replace traditional human–computer interaction (HCI) interfaces such as keyboards and mouse [2]. The normal piezoresistive panels were sensitive to the resistive change caused by different touch pressure, which required specialized pens to interact with digitizers. The normal piezoresistive panels showed a good speed in detecting the handwriting of the specialized pens. However, the specialized pen had the risk of misplace or loss. The capacitive touch panels featuring multi-touch finger-input are more popular for they enable the user to input directly on the panel without any intermediate devices, such as stylus [2]. So the capacitive touch panels are more convenient. The capacitive touch panels are sensitive to the distributed capacitance of the finger, but it may fail to work normally when the panels are wet. Thus more handwriting input methods for HCI interfaces are desired.

In this paper, we propose an attractive handwriting input method based on the thermal cue of the fingertip for the handwriting input devices. This paper is organized as follows: Section 1 introduces existing handwriting input devices. Section 2 provides the principle of the proposed method and the design of its prototype device. Section 3 presents experiment results and discussion. Finally, Section 4 provides conclusions.

2. Handwriting input method and its prototype device

2.1. Principle of the handwriting input method based on the thermal cue of the fingertip

Thermal perception was very important for us to recognize the thermal properties of different objects [9,10]. As thermal perception, temperature sensor array provided us the thermal properties of objects, thus it had been used to recognize the objects shape and the contact area distribution [11–17]. Due to dynamic response speed, size, and rapid detection method limit, less temperature tactile sensor array had been reported. Castelli [18] designed an 8 × 8 tactile sensor array within 18 mm × 18 mm to discriminate thermal properties of contact objects, in which copper resistor was used as the temperature sensor. Li [19] designed a non-scanning tactile sensor array with rapidly response character, in which piezoelectric resonators were used as temperature sensing elements. Takao [20,21] designed a 6 × 6 monolithic silicon smart tactile image sensor with strain and temperature perceiving

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function in 3.04 mm × 3.04 mm. Yang [22] designed a 32 × 32 temperature and tactile sensing array using PI-copper films within 160 mm × 160 mm, which could recognize the big size objects with different shape. Wu [23] designed an 8 × 16 temperature sensing tactile device within 16 mm × 32 mm. In this paper, we are about to detect the input trajectories based on the thermal cue of the fingertip's handwriting.

When the fingertip contacted with the surface of the object for example the temperature sensitive panel of a handwriting input device as shown in Fig. 1(a), the thermal response curves were shown as in Fig. 1(b). In most cases, humans lived in a comfortable environment with its ambient temperature (T_a) below their basal body temperature (T_0). By natural heat exchange, the fingertip's temperature was between T_a and T_0 and it was close to T_0. So the fingertip's temperature was higher than the environmental temperature in most cases. During contacting, the temperature of the surface on the handwriting input device increased while the temperature of the surface on the fingertip decreased rapidly. While the fingertip separated from the handwriting input device, the temperature of the surface on the handwriting input device dropped slowly to T_a for air cooling and the temperature of the surface on the fingertip returned to a temperature close to its T_0. Thus the thermal response curves of the separating were different from those of the contacting as shown in Fig. 1(b). During contacting and separating between the fingertip and the panel, the temperature response curves of the thermistors in the sensitive panel were affected by many factors such as the movement speed, the temperature difference, and the thermal resistance. The thermal resistance was mainly affected by the surface materials and surface morphologies of the fingertip and the panel. Between the fingertip and the panel, the thermal resistance was also affected by the varied pressure which changed the surface morphologies and the contact area.

While sliding on the surface of the handwriting input device, the fingertip heated part of the surface on the handwriting input device. The temperature of the part on or close to its moving trajectory would increase or decrease with the approaching to or the moving away from the fingertip. While the fingertip was sliding, the position currently contacted by the fingertip had a fast heating rate. While the fingertip stopped sliding and kept at the same place, the position currently contacted by the fingertip would have the maximum temperature. So the moving trajectory of the fingertip could be recognized by detecting the position of the thermal cues such as the fastest heating rate, and the maximum temperature. If the handwriting input device had a surface covered with the temperature sensors, it could detect the moving trajectories of the fingertip with its thermal cue.

2.2. Handwriting input prototype device design

The handwriting input prototype device based on the proposed method was shown in Fig. 2. It was composed of a temperature sensitive panel, an Isolated Drive Feedback Circuit (IDFC), a microprogrammed control unit (MCU) with an embedded 8 channels 10 bits Analog-to-Digital Converter (ADC) and a RS232 port connected to the personal computer. The temperature sensitive panel on the up surface of the handwriting input device was composed of a 16 × 8 sensor array. The distance between two adjacent thermistors was 5 mm in X or Y, thus the surface of the temperature sensitive panel was 82 mm × 42 mm in area, which was close to the sensitive area of the capacitive panel on a mobile phone. The surface of the sensor array was parallel with the XY plane of the handwriting input device. The temperature sensors used in the handwriting input device were the NTC-103F950 thermistors with a size of 2 mm × 2 mm × 2 mm, which had a negative temperature coefficient. To minimize the connected complexity, the 16 × 8 resistive temperature sensors were connected in a row–column fashion with all the sensor elements having one end connected to a row line and the other end connected to a column line. So the interconnect line number of the 16 × 8 resistive sensor array was 24. But the row–column fashion caused the effect of the resistive crosstalk. Thus the precision resistance values of the resistive elements in the sensor array were difficult to approach in common method. We adopted the IDFC [23] with the sample resistor connected to the ground as shown in Fig. 3(a) to detect these resistance values of thermistors in the array with a small resistive crosstalk.

In the case that the resistance values of the multiplexers' channel resistors (R_c was the column channel resistor, R_r was the row channel resistor) were zero and the op-amp was ideal amplifier in the IDFC, we could acquire an ideal simplified measurement Circuit (Circuit B) as shown in Fig. 3(b). In the Circuit B, a precision constant voltage (V_I) was loaded on the EBT (R_{xy}) and the sample resistor (R_S), thus the voltage (V_{SG}) on R_S could be calculated as Eq. (1). As V_I and R_S were known, the V_{SG} could be measured by ADC, so the effective equivalent resistance (R_{SG}) of the EBT could be acquired. Thus the temperature on the element in the sensitive panel could be measured. In the experiments, V_I was 5 V and R_s was 10 kΩ.

$$V_{SG} = \frac{R_s}{R_s + R_{xy}} V_I = \frac{R_s}{R_s + R_{SG}} V_I \quad (1)$$

For a good measurement performance of the IDFC, it was necessary that the resistances value of the column multiplex switches and the row multiplex switches were small enough to be negligible

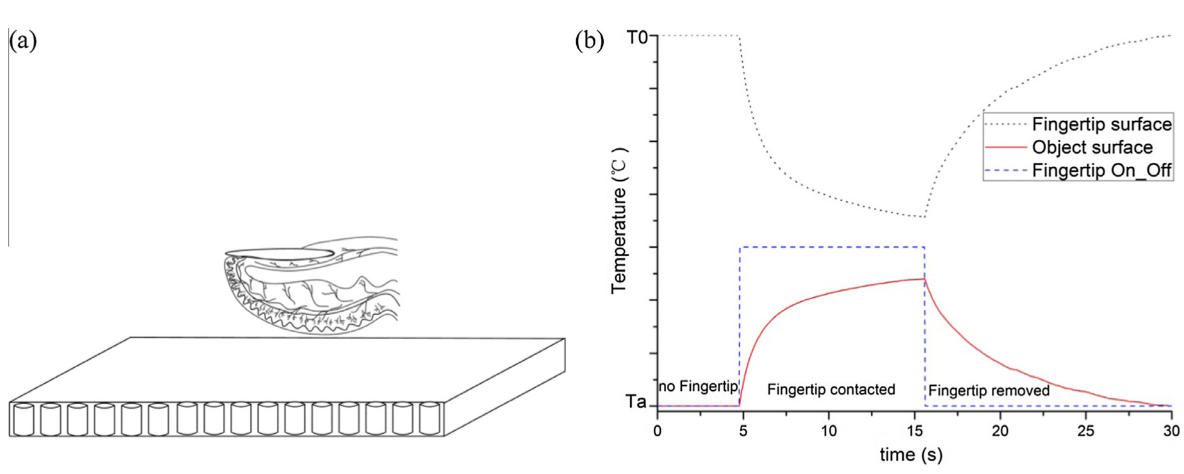

Fig. 1. The fingertip contacting with and removing from the object's surface: (a) the contacting model; (b) the thermal response curves.