A Novel F-Pad for Handwriting Force Information Acquisition

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Abstract. This paper presents a novel pad for handwriting force information acquisition. The pad named F-Pad (force-pad) is capable of capturing both the dynamic handwriting information and the static trajectory of the writing pen. With the core part of the multi-dimension force/torque sensor, the F-Pad can capture the 3-D forces and 2-D torques directly. And with the specially designed structure, other dynamic and static information such as the velocities, accelerations, handwriting shape and slants can be got indirectly. Ordinary pens can be used to write on the pad and the pad provides a real-time visual feedback to gain a natural writing feeling. Basic experiments in which characters are written demonstrate the possibility of handwriting force information detection.

Keywords: Force pad, handwriting force information, visual feedback.

1 Introduction

Biometrics, an identification technology that is used to prevent unauthorized access to all kinds of e-data is often effective in identification. Data from physical biometrics such as fingerprints, hand geometry and iris scans, behavioral biometrics such as signature, voiceprint, gait and mannerisms, and chemical biometrics such as DNA and body odor have been acquired and analyzed for security applications [1].

Handwriting, as one kind of biometrics, not only expresses our idea, but also represents the writer's identity, which can be used for application like signature verification. And because of the long history of handwriting and the convenience of the pen and papers, we are all accustomed to having a signature signed on files to be used as a basis of comparison for verifying our signature [2][3]. So far, Many researchers have developed scientific works on signature. For example, Rejean Plamondon has studied the models and the dynamic characters of signatures; Sargur N. Srihari has done much work on the static handwriting information. Communication Intelligence Corporation has developed transaction and communication enabling technologies for electronic signatures, handwritten biometric signature verification, data security, and

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data compression. Anoto Pen, Wacom, LCI SMARTpen and some other companies have all provide solutions for signature identification/verification.

Generally, the handwriting analysis can be studied using the dynamic handwriting signals, static handwriting signals or both the dynamic signals and the static signals at the same time. As the dynamic signals are apparently much harder to be imitated by others than the static signals, a wide variety of hardware devices have been devised for capturing the dynamic handwriting signals. An accelerometer pen is used to capture the two direction accelerations and pressure in the z-axis. A dual axis accelerometer is used to get the signature's dynamics. The Smart Pen is used to capture forces on the pen-tip in three directions and angles of the pen-shaft in two dimensions (relative to the writing surface) [4]. A "digital pen" is used for detecting z-axis pressure [5]. An electrical pen using two-dimensional optical angle sensor is developed to get writing forces [6]. A Kinetic pen is used for detecting the hand-pen contacting force information [7]. A "force-based pen" using five off the-shelf 1-D force sensors is designed to detect 3-D forces between the pen's tip and the paper [8].

Although these systems have exhibited promising results in their own application areas, they do not provide a natural interaction style and all handwriting information, such as strokes of pen-up and pen-down, velocity and acceleration of pen-tip, 3-D forces of pen-plate contacting point and shape of character etc. In order to resolve such problems, we propose a novel force pad named F-Pad which is capable of capturing all handwriting information and providing a natural writing feeling.

For this purpose, the F-Pad concept is illustrated at first and then the conditioning process for handwriting signal is specified in the next section. The working principles of the F-Pad for handwriting signal capture is described in section 4. Then the experimental results are presented and discussed in part 5. Finally, conclusions about the pad and some future work are given in the last part.

2 F-Pad Concept

Handwriting, which is produced by human hand acting on contacting plate (such as paper) with pen, provides useful information, such as pen-tip trajectory, contacting force direction and amplitude. It is ideal to acquire all those information simultaneously.

In our design, the F-Pad is capable of collecting handwriting force information with a multi-dimension force/torque sensor. And with these force information and a special design, the F-Pad can calculate and get other handwriting information, such as tracks of writing, pen-tip trajectory and so on.

Fig.1 shows an internal view of the F-Pad. It mainly consists of 5 parts. Part 1 is the conditioning circuit which processes the signals from the sensor, Part 2 is a multi-dimension force/torque sensor, Part 3 is a LCD which displays the real-time writing tracks as a visual feedback, Part 4 is a pen-contacting plate for writing, and Part 5 is the digital processing circuit which completes the pen computing and the logic control of the whole system.

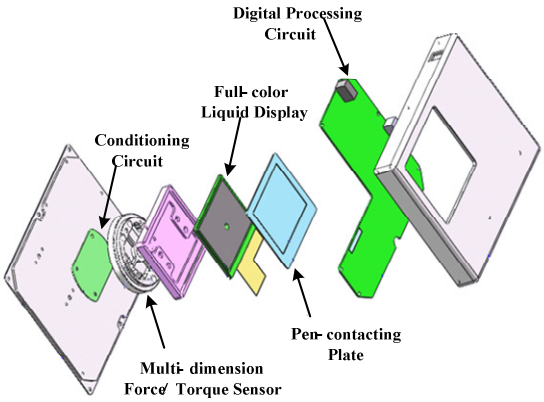


Fig. 1. Internal view of the F-Pad

The special display module is applied in the F-Pad to achieve a natural writing feeling. The screen, which can make the writer see how he/she signs immediately, implements a kind of function that helps people adjust their handwriting attitude and control their writing force to get a good handwriting performance.

3 Conditioning Design

The signal conditioning design is responsible for performing any required conditioning of the analog input signal to achieve digitizing and computing. The output of the condition is a stream of digitized data that can then be processed numerically by the rest of the system.

Results from our research shows that the upper limit of the frequency of handwriting is about 20Hz and the maxim writing force is about 5N, so the F-Pad is designed to measure forces between 0~25N(for the strongest signers), and the system resonance frequency is 200Hz(for capturing the dynamic handwriting signal without distortion)..

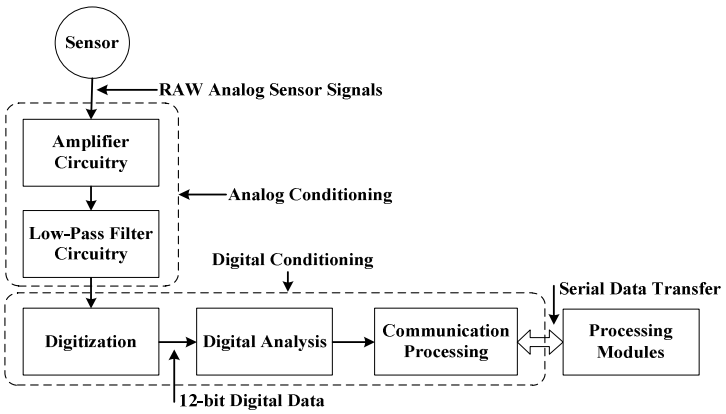


Fig. 2. Dataflow diagram of the conditioning design

The purpose of the conditioning design is to provide a digitized handwriting force signal which is representative of the handwriting produced by hand-pen movements for the F-Pad. To achieve this, the conditioning design has to extract from the multi-dimension force/torque sensor signals those components that correspond to hand-pen movements while ignoring irrelevant signal components. Additionally, the analog conditioning and the digital conditioning should be designed respectively in order to reduce the affect between analog signals and digital signals. Fig.2 shows a dataflow diagram of the F-Pad conditioning design, and the working procedure is presented as follows.

First the raw analog signals from the multi-dimension force/torque sensor are amplified to big enough to be sampled. As the signals have different measurement range, we adjust the operational amplifier suitably so that the maxim force or torque doesn't cause any saturation and the small signals can be observed at the same time. After that, a Low-Pass filtering circuit is used to band-limit the frequency content to let signals with frequency between 0 and 20Hz get across.

Then the filtered analog signals are quantized using a 12-bit analog-to-digital converter. The 12-bit converter is required to gain a high resolution (0.6mV LSB in F-Pad system) to meet the quantization requirement for all signers. After digitizing the analog signals, a data analysis component is proposed to process the digitized signals and transfer the results to a communication processing module. The communication processing module packets the digitized data and sends the data to other external system components via a bus interface which is realized by USB in the F-Pad.

4 Working Principal

The working principle can be learned from Fig.3. When a pen writes on the plate, force F, which is produced at the every track point(i.e. at the point P), can be decomposed into forces: Fx(ti), Fy(ti), Fz(ti) , which denote the force acting in X axis, Y axis and Z axis directions, respectively. At the same time, the torques Mx(ti) and My(ti) are exerted on the input pad. These five force elements are all functions of time ti and can be measured directly by the multi-dimension force/torque sensor. The coordinates of the point P can be calculated from the equilibrium of moments. They can be expressed as (1):

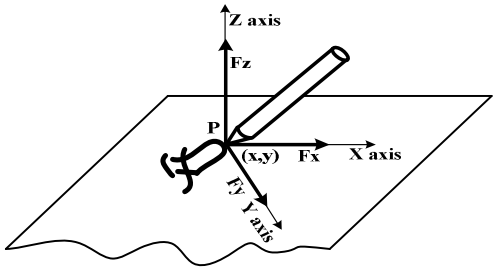


Fig. 3. Schematic Diagram of Force Action

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

Where h denotes the distance between the pen-contacting plate and the origin of the coordinate of force sensor; i = 0, 1, 2, ... The velocities and accelerations are the derivative of the two coordinates, which can be expressed as (2) and (3).

$$\begin{aligned} \mathrm{v}_x(t_j) &= \frac{x(t_j) - x(t_{j-1})}{\Delta t} \\ \mathrm{v}_y(t_j) &= \frac{y(t_j) - y(t_{j-1})}{\Delta t} \end{aligned} \tag{2}$$

$$\begin{aligned} \mathrm{a}_x(t_k) &= \frac{v_x(t_k) - v_x(t_{k-1})}{\Delta t} \\ \mathrm{a}_y(t_k) &= \frac{v_y(t_k) - v_y(t_{k-1})}{\Delta t} \end{aligned} \tag{3}$$

Three research groups are working on force-based systems and, although these systems are among those which have led to the best research results, several improvements must still be made to develop a commercial system.

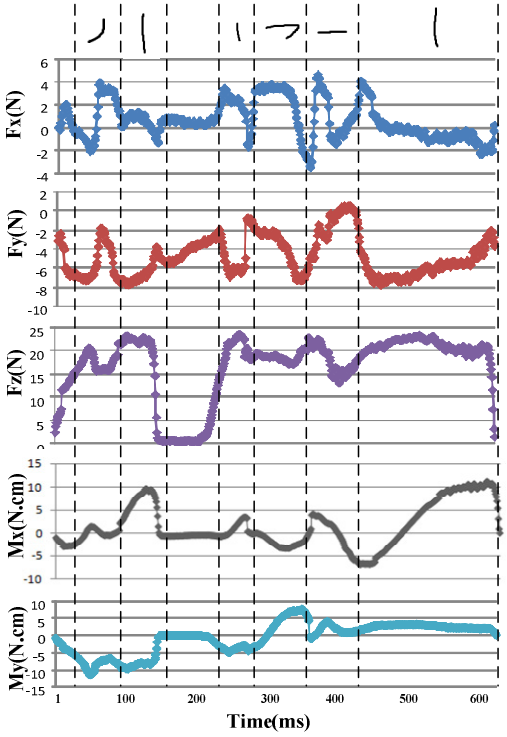
5 Experimental Results

To validate the properties of the novel force pad, a detection experiment is designed and tested. Because the forces and torques are measured by the pad, so there is no requirement on the writing pen. An ordinary pen is used to write a Chinese character on the input glass. The conditioning circuit gets the sensor output signals and transmits them to the processing module through USB interface. The processing module computes the writing trajectory information using (1) and sends the results to the display module. Graphic test software is developed to draw the tracks to give a visual feedback on the display module when writing.

Fig.4 shows the shape of the Chinese character on the LCD and 3-D forces and 2-D torques during writing. 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 can be displayed at the same time when writing. The velocities and accelerations are calculated with (2) and (3) respectively. Other handwriting information such as the angle between the writing pen and the input tablet can also be calculated from the three perpendicular forces.

From the experiments results, we can find that the designed F-Pad can get all handwriting information, including strokes of pen-up and pen-down, velocity and acceleration of pen-tip, 3-D forces of pen-plate contacting point and shape of character.

(a)



(b)

Fig. 4. Experiment Result:(a) Handwriting of a Chinese Character "仲",(b) Force and Torque information of the Character "仲"

6 Conclusions

In this paper, a novel pad named F-Pad for handwriting force information acquisition is introduced. The F-Pad can get all handwriting information, including strokes of pen-up and pen-down, velocity and acceleration of pen-tip, 3-D forces of pen-plate contacting point and shape of character etc directly or indirectly. And there is no special requirement for the writing pen. A pen-like tool is enough for handwriting input. Particularly, with the special display module, the F-Pad can provide a natural interactive feeling when writing and can even be used as a development tool for children to improve their writing skills.

Experimental results show that the F-Pad is indeed capable of obtaining forces, trajectory, velocities and acceleration signals of the pen-tip. The further work is to do some research work on handwriting analysis and signature verification using one kind or several kinds of the signals captured with the force pad.

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