
AccPen: Using Smartphone with Accelerometer to Interact as Pen

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Abstract

Smartphone has become a commodity device that makes life convenient whereas its capability of user interaction is often limited by its small touch screen. Employing built-in accelerometer to reconstruct gesture motions is considered as a promising solution for gesture interaction. However, the inability to separate unintentional movement from gesture motion, which often misleads the gesture recognition systems, limits the application of those acceleration-based methods. We present AccPen, a method that using smartphone as a pen for gesture interaction on physical surfaces, such as walls and tables. We utilize the high frequency portion of acceleration signals caused by friction when using the AccPen to write on physical surfaces to detect intentional gestures and reconstruct a representation of the gesture trajectory for gesture recognition. We conduct a study with 10 participants and present robust gesture recognition with an average accuracy of 92.22% across surfaces of desktops, wall, and paper.

Author Keywords

Pen interaction; acceleration signal; segmentation; trajectory reconstruction; gesture recognition.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See

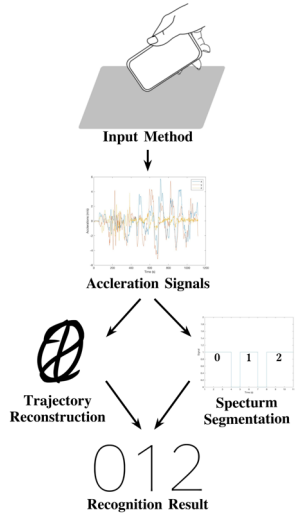


Fig 1 AccPen employs smartphone with built-in accelerometer to write on surface as pen.

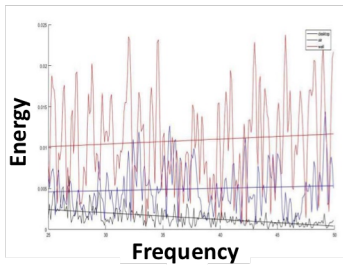


Fig 2: Demonstration for the high frequency portion (25-50 Hz) of acceleration signal spectrum when using AccPen to writing on desktop (blue), on wall (red), and in air (black).

Introduction

Small screen device such as smartphone and smart watch enables the portability and flexibility of the device but limits the capability of gesture interaction. Acceleration-based approaches are promising for gesture interaction due to its advantages of environment robustness, low power consumption, and low cost. However, the inability of the existing acceleration-based methods is to separate unintentional movements from gesture input, which is also named the Midas problem. Many approaches have been proposed to resolve the Midas problem, such as using special hanging on gesture [1]. We present AccPen, a method that use a smartphone to write as an ordinary pen and utilize the acceleration signal for gesture segmentation and recognition. In contract with the existing work that utilizing built-in accelerometer for air gesture, we employ smartphone to write on physical surfaces, such as desktop and wall. We conducted a preliminary study to explore the performance of our system. Generally, this paper makes the following contributions:

- We demonstrate the feasibility of utilizing vibrations caused by friction to address the Midas problem when using smartphone as pen for gesture interaction on physical surfaces.
- We present AccPen, a gesture recognition method that reconstructs gesture motion by built-in accelerometer on smartphone.
- We found that surfaces have effect on gesture recognition accuracy. For example, writing on wall is significant better than on paper.

Related Work

Previous acceleration-based gesture interaction work has adopted various methods to avoid or solve the Midas problem. One of those methods is to change the writing way of characters or break up the characters into some basic strokes which can be completed by one single stroke. For example, Agrawal et al. proposed a prototype called PhonePoint-Pen, which constructed six basic strokes and asked the users to write according to a set of strokes, and then employing a predictive stroke-tree to reconstruct strokes, letters, and words [1, 3]. Those template-based methods partly minimize the probability of detecting unconscious movements as gestures, but they do not completely address the Midas problem, because the unconscious movement can still be detected as a base strokes. In general, the Midas problem in gesture input is not well solved in the past studies. Detecting the beginning and the ending of a gesture input in low cost and high accuracy way is still an unaddressed problem.

Some existing work has used acceleration sensor to identify objects [2, 4]. Ward et al. collected acceleration and sound signals by wearing an acceleration sensor and a microphone on the arm to categorize operating tools in a factory workshop [4]. In addition, Laput et al. found that the accelerometer on the wristband can be used to identify different objects that can emit active vibration [2]. Inspired by those work, we propose a method that captures acceleration signals caused by vibration of friction when we are using smartphone to write on a plane. Different with Laput's work, we utilize the high frequency portion of vibration to detect writing movement, by which can address the Midas problem when using smartphone to write on physical surfaces.

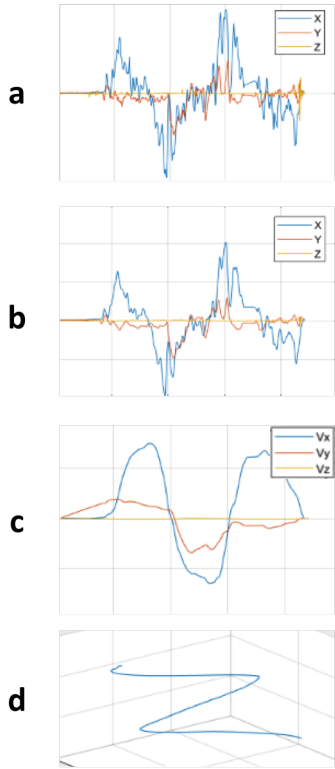


Fig 4: Demonstrations for trajectory reconstruction process. (a) Raw acceleration signals, (b) acceleration signals after kalman filter, (c) velocity calculated by acceleration signals, and (d) trajectory constructed.

Design of AccPen

Like the usual pen based interaction, AccPen employ smartphone to write on physical surface, such as desktop and wall. As shown in Figure 1, the acceleration signals are captured with sampling rate of 100 Hz by the AccPen system. On one side, the acceleration signals are used gesture segmentation by spectrum analysis. On the other side, the acceleration signals are used for trajectory reconstruction. And then the segmented trajectories are finally used for gesture recognition.

Spectrum Segmentation

When interact with AccPen, the part of trajectory writing on surface is considered as intentional gesture while the part in air is considered as unintentional movement. Therefore, gesture segmentation is a very important part before gesture recognition. Figure 2 shows an intuitionistic differences of spectrum energies on 25-50 Hz when using a smartphone to write on desktop, on wall, and in air. To detect the gesture states (writing on surface or movement in air), we employ a hamming window of 0.5 second with 80% overlap to analyze the acceleration signals, and then generate frequency spectra by performing a FFT on the acceleration signal for each hamming window. We use spectrum frequency from 25 to 50 Hz as the high frequency portion and use an empirical value of spectrum energy on 0.05 as threshold for detection.

Trajectory Reconstruction

Before calculating the movement trajectory from acceleration signals, we need to remove the gravity component in all directions. We used both the acceleration signals and orientation signals to calculate the base acceleration signals without gravity. In the

trajectory generation stage, the shift distance of smartphone, which indicates the hand movement when the smartphone being hold in hand, can be calculated by the double integral of the acceleration. By this way, the gesture trajectory is reconstructed from acceleration signals.

Gesture recognition

After the trajectory of gesture was reconstructed, we employed a recognizer named \$1 Recognizer for gesture recognition [5]. The \$1 Recognizer is a 2-D recognizer designed for rapid prototyping of gesture-based user interfaces. In machine learning terms, \$1 is an instance-based nearest-neighbor classifier with a Euclidean scoring function, i.e., a geometric template matcher.

Preliminary study and Evaluation

We make a survey on 26 participants to collect opinions about what kind of physical surface people would like to use when they interact with AccPen. The following is the final list of most welcome six surface along with the number of vote: desktop (21), paper (17), wall (13), skin (10), cloth (9), and ground (8). After that, we recruited 10 participants with their ages ranged from 21 to 26 (mean = 23). Participants are shown how to operate with AccPen, and then asked to select 5 characters in alphabetic list by themselves and then write them on desktop, wall, and paper. By this way, we collected 135 samples (5 characters * 3 surfaces * 9 participants).

As shown as Figure 5, our experimental evaluation shows that this approach achieve an average of 92.22% (90% on desktop, 100% on wall, and 86.67% on paper) with characters gesture across 10

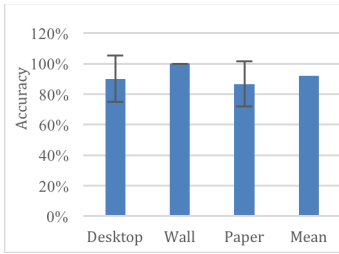


Fig 5: Gesture recognition accuracy when using AccPen to write on desktop, wall and paper.

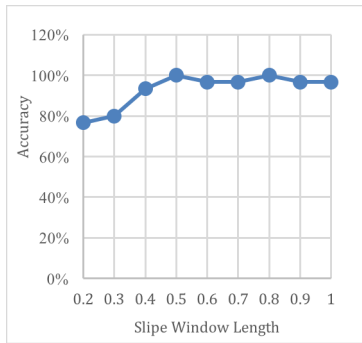


Fig 6: The gesture recognition accuracies when different hamming windows are employed.

participants. T-TEST shows that writing on wall is significant better than writing on paper ($p < 0.05$), writing on desktop is marginal better than on wall ($p = 0.10$). This high recognition accuracy shows that detecting intentional gesture by acceleration spectrum is feasible for gesture interaction and our system proposed in this paper is high performance and robust.

We also conduct a study on hamming window length that participants using AccPen to write on desktop, wall, and paper when different hamming windows are applied. As shown in Figure 6, we found that the gesture recognition accuracy is rising when the hamming window is from 0.2 to 0.5 seconds, and then keep generally stable in a rather high level. Considering that shorter hamming window means faster detection speed, a hamming window of 0.5 second is recommended in our study.

Conclusions and Future Work

We present AccPen, a gesture interaction system that employing smartphone with built-in accelerometer to write as pen on physical surface. Like usual pen based interaction, AccPen provides natural haptic feedback. We found that it is feasible to utilize the high frequency portion of acceleration signal for gesture segmentation when writing on desktop, wall, and paper. The system shows promising gesture recognition accuracy of 92.22% in our 10-hparticipants' preliminary study. However, several unaddressed problems revealed future research opportunities: 1) whether the system perform better if the acceleration sampling rate is higher than 100 Hz, such as 500 Hz or higher; 2) whether the system can use other gesture recognizer to replace the \$1 Recognizer, such as support vector machine and decision tree; 3) whether the writing space and speed have significant effect on the gesture

segmentation and recognition; In addition, we also want to explore the feasibility of our system when applying on smart watch and user is using finger to write on desktop.

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References

1. Agrawal S, Constandache I, Gaonkar S, et al. 2011. Using mobile phones to write in air. International conference on mobile systems, applications, and services, 15-28.
2. G. Laput, R. Xiao, and C. Harrison. 2016. ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers. Proceedings of the 29th Annual Symposium on User Interface Software and Technology, 321-333.
3. T. Miyagawa, Y. Yonezawa, K. Itoh, and M. Hashimoto. 2014. Handwritten pattern reproduction using 3D pen acceleration and angular velocity. The transactions of the Institute of Electronics, Information and Communication Engineers. 83: 1137-1140.
4. J. A. Ward, P. Lukowicz, G. Troster, and T. E. Starner. 2006. Activity recognition of assembly tasks using body-worn microphones and accelerometers. IEEE Transactions on Pattern Analysis and Machine Intelligence, 28(10), 1553-1567.
5. Wobbrock, Jacob O., Andrew D. Wilson, and Yang Li. 2007. Gestures without libraries, toolkits or training: a \$1 recognizer for user interface prototypes. User interface software and technology, 159-168.