Improving Finger-click Recognition of a Wearable Input Device

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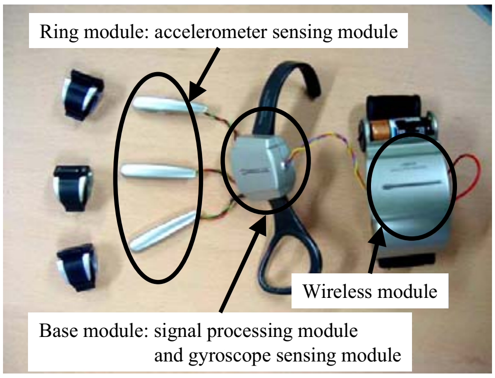
Abstract: In this paper, a finger-click recognition method is proposed to improve the recognition performance for finger-clicking of a wearable input device, called SCURRY™. The proposed method is composed of three parts including feature extraction part, valid click discrimination part, and cross-talk avoidance part. Two types of MEMS inertial sensors are embedded into the wearable input device to measure the angular velocity of a hand (hand movement) and the acceleration rates at the ends of fingers (finger-click motion). The experiment applied to the SCURRY™ device shows the improved stability and performance.

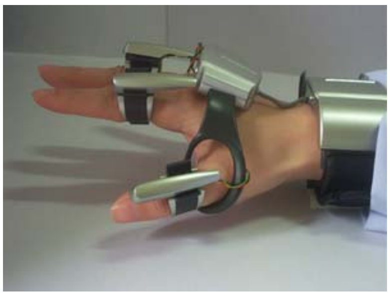
Keywords: Wearable Input Device, Initial Sensor, Finger-clicking, SCURRY™

1. INTRODUCTION

Although QWERTY type keyboards are still widely used in these days, it is true that they are too bulky and inconvenient for portable computing systems including wearable and mobile computing system. As a result, many input devices including a forearm mounted keyboard (FK), virtual keyboard (VK), and Kordic keypad (KK) [1] have been introduced in conjunction with the portable computing systems. Other researchers have studied various input devices. Twiddler input device [2] integrated with keyboard is also introduced. With the device, a human operator can input text entry as well as GUI event he wants. Ring and glove-like input devices are introduced which can input based on the chording combination of fingers [3]. In particular, the development of glove-like input devices has been an important role in the human-computing system symbiosis since its appearance. People have designing, building, and studying ways of getting computers to understand operator's hands directly, free from the limitations of intermediary devices. Gary Grimes of Bell Telephone Laboratories developed the Digital Data Entry Glove specially tailored to data entry using an alphabet of hand signs [4]. A low-cost glove named Power Glove is developed as a controller for Nintendo home video games [5]. Recently, accelerometer sensing glove (ASG) was developed by K. Pister et al. at UC-Berkeley based on accelerometers from commercial-off-the-component, which can detect and translate a human finger and motion into computer interpreted signals and gestures[6].



(a) Construction of SCURRY™



(b) The way to use SCURRY™

Fig. 1 SCURRY™, a wearable input device

A wearable input device (SCURRY™) which can be used as both keyboard and mouse, was introduced [7,8]. The system is a glove-like input device which can be worn on a human hand composed of a base module including one controller and two angular velocity sensors (gyroscopes) placed on the back of the hand and four ring-type modules (rings) including 2-axis acceleration sensor (accelerometer) worn on four fingers respectively (Fig. 1). Sensor, communication (transceiver and receiver), and controller are embedded into the base and rings, which allow the system to be compact and light.

In this paper, we propose a finger-click recognition method that can improve the recognition performance for finger-clicking of the wearable input device. The proposed algorithm is composed of three parts including feature extraction, valid click discrimination, and cross-talk avoidance. The experiments were conducted to verify the effectiveness and efficiency of the proposed method.

2. SCURRY™ SYSTEM

2.1 Hardware

A wearable input device, SCURRY™, has three function blocks, which are the sensing block, the signal processing block, and interface block. The sensing block consists of two kinds of sensors: two gyroscopes that sense the up and down, left and right movements of a hand and four accelerometers that sense the click motion of each finger of the hand. An RF transceiver with 2.4GHz in the interface block is capable of transmitting all the data sensed by the gyroscopes and accelerometers wirelessly to a target system (desktop PC, PDA, and etc.) which covers up to 10 [m] range. Signal processing is required to translate the sensed data obtained from the gyroscope and accelerometer into the input command the human operator intends (Fig. 2).

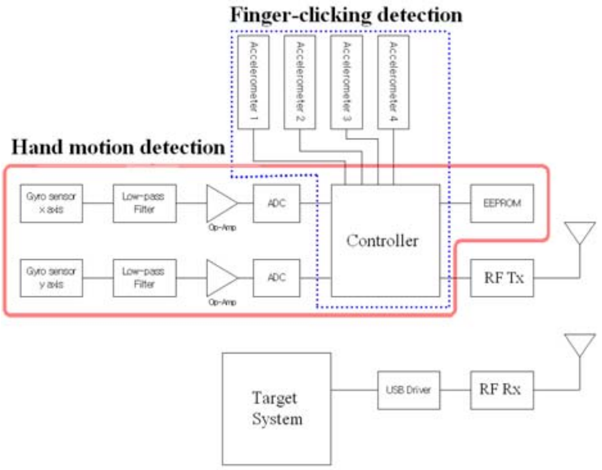


Fig. 2 Schematic diagram of SCURRY™ hardware.

2.2 Input Mechanism

A pointer is displayed on the screen while the human operator with SCURRY™ interacts with a target system. The pointer can be displayed with virtual keyboard in case that the device is used for a wearable keyboard. Through the finger-clicking and hand motion, the human operator can select any character, event, or operation on the virtual keyboard spatially without physical touch. As such, SCURRY™ can be used as a wearable mouse by allowing any three fingers to be operated as the left, middle, and right mouse buttons in similar manner as it allows the human operator to point and selects any character, event, or operation by both his hand motion and finger-clicking as a wearable keyboard (Fig. 3).

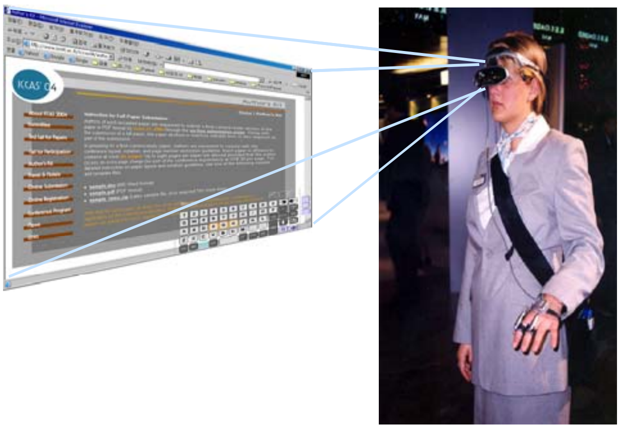


Fig. 3 The way of using SCURRY™.

2.3 Finger-click Recognition

The operator's input on the developed input device is motion and finger-clicking. As these two movements are obtained from the outputs sensed by the gyroscopes and accelerometers respectively, unintentional noises or cross-talks between the fingers or between the hand motion and the finger-clicking cause wrong or inaccurate data. The result degrades a recognition performance, even a wrong operation or recognition failure of the finger-clicking. For these reasons, the method for exact finger-click recognition is proposed composed of the three parts:

- *The feature extraction part* extracts the feature signal to determine whether the accelerometer output is generated by the finger-clicking with the operator's intention.
- *The valid click discrimination part* determines exactly which finger is clicked from all the accelerometer outputs.
- *The cross-talk avoidance part* allows the hand motion and finger-clicking not to be coupled by making them to be transferred separately after they are determined as the human intention.

2.3.1 Feature extraction

The operator's finger-clicking on the developed device is defined as the finger movement from left to right for the thumb, and from up to down (right hand) for the other fingers. It is difficult to determine the finger-clicking with the human operator's intention only from the accelerometer output in case the thumb movement is slow as the magnitude of the output is too small to be understood clearly. The finger-clicking by the middle finger's movement is more difficult to tell than that by the thumb one. Therefore, a feature extraction part is needed to extract the feature enough to determine whether the accelerometer output is generated by the finger-clicking with the operator's intention.

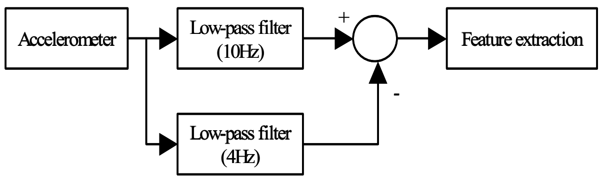


Fig. 4 Block diagram of the feature extraction part composed of two low-pass filters

The feature extraction part is composed of two low-pass filters, but it is different from general band-pass filter typically composed of one low-pass filter and one high-pass filter in the sense that the feature signal is obtained by using two low-pass filters with the heuristically chosen cut-off frequencies (4Hz and 10Hz for the device in this paper). By filtering the accelerometer outputs, the feature signal is extracted based on the latency between the two filtered outputs and the subtraction amount of them. Fig. 4 shows the block diagram of the feature extraction part composed of two low-pass filters.

2.2 Valid click discrimination

Other fingers except the thumb are moved together and affected each other when any finger-clicking is generated. Accelerometer outputs can be generated from the fingers which are not valid finger-clicking and thus misunderstood as the feature signals of the corresponding individual fingers. This is the cross-talk generated between fingers.

To avoid the cross-talk, a part to discriminate the valid click among many accelerometer outputs is needed for the algorithm. The proposed valid click discrimination part is the conditions to help determining which finger is clicked from all the accelerometer outputs including the cross-talk between the fingers. Fig. 5 shows the schematic diagram of the condition used for the valid click discrimination. By the condition as shown in the figure, the finger-clicking can be discriminated as the valid click if the feature value extracted from the accelerometer output of the finger is greater than the threshold value (the threshold for finger-clicking detection in the figure) and lasts longer than T_H, the duration threshold. In addition,

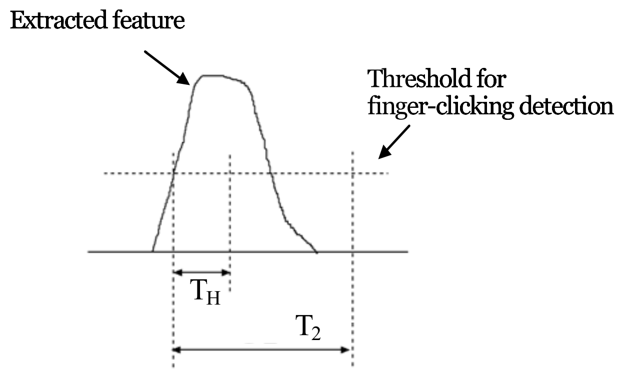


Fig. 5 The condition used for the valid click discrimination.

once the feature signal (extracted feature in the figure) is determined as the valid finger click by the finger-clicking, the other feature signals generated during T_2 are ignored to avoid potential wrong operation caused by either noises or the another cross-talk between the hand motion and finger-clicking which will be explored in the following part.

2.3 Cross-talk avoidance

Operator's finger-clicking on the developed device also affects the hand motion resulting in generating the gyroscopes output in the base module affixed to the back of the human hand. These outputs by the gyroscope may generate a click at a different position which is not the position when he generates the finger-clicking.

As such, the unintentional output generated by the gyroscopes for the duration of T_{D1} as shown in the figure makes it misunderstood as the input, thus another point is selected. This is a typical cross-talk between the finger-clicking and the hand motion which degrades the recognition performance or cause the recognition failure of the finger-clicking. By the threshold conditions such as T_1, T_2, and T_{D2} of the cross-talk avoidance proposed in the previous section, the finger-clicking can be performed.

The movement is assumed to be ready for the pointing or clicking if it stays in a specified position or area for the duration of the predefined time, T_1: it becomes a mode to wait

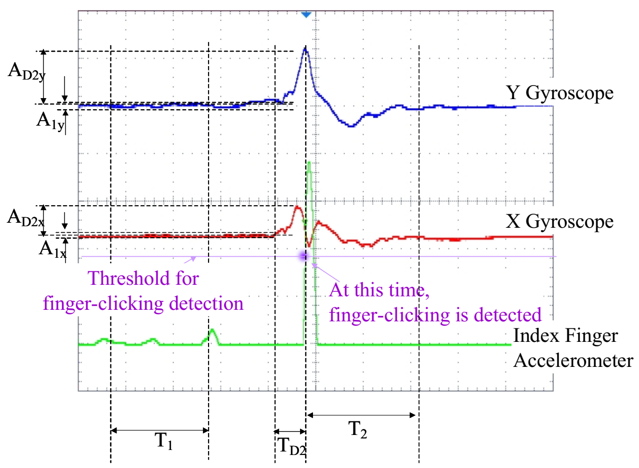


Fig. 6 Outputs of the gyroscopes and accelerometer by the hand motion and finger-clicking of the index finger.

for the finger-clicking for the duration of T_{D2} from the time when the gyroscopes outputs get larger than the predefined amount of threshold values (A_{1x} and A_{1y}). If the clicking is not generated, afterwards the movement is used for the pointing. When the clicking is generated, other clickings and all the movements except the generated clicking are disabled for the duration of the predefined time (T_2) to avoid the cross-talks which may be generated between fingers, or between the finger-clicking and hand motion (Fig. 6).

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

A GUI testbed as shown in Fig. 8 is introduced to examine how the entire proposed algorithm including the three parts verified respectively in the above improves the recognition performance of the finger-clicking.

The testbed generates a target circle with 15 pixel radius at random position. Five subjects participated in the test composed of 4 sets with 20 per one trial (total 80 for each subject). The task is given to see whether the human subjects on the developed device, SCURRY™, can point the

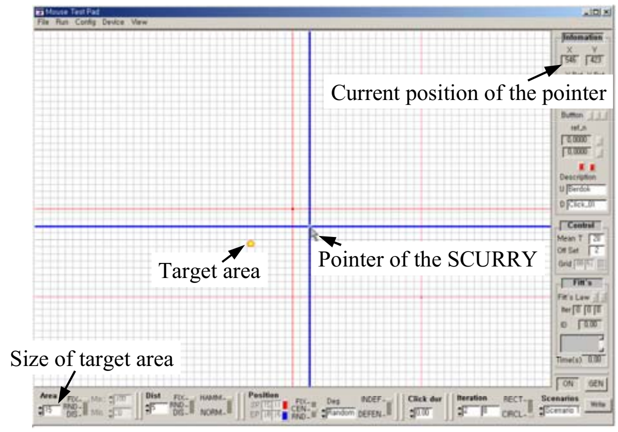


Fig. 7 A GUI testbed to examine the performance of the finger-clicking

Table 1. The experimental results of the finger-click recognition without the proposed algorithm

Trial No.	No. of Successful Task				
	Subject A	Subject B	Subject C	Subject D	Subject E
1	16	15	15	17	13
2	16	12	18	18	14
3	17	11	12	15	17
4	14	12	16	18	14

Table 2. The experimental results of the finger-click recognition with the proposed algorithm

Trial No.	No. of Successful Task				
	Subject A	Subject B	Subject C	Subject D	Subject E
1	18	17	17	19	17
2	20	13	16	19	16
3	17	16	19	20	15
4	19	16	17	18	17

random-made target position (the target area in Fig. 7) and generates the finger-clicking on it in given time (pointing and clicking) In case that the human operator can make the finger-clicking successfully on the circle within the given time, the finger-clicking is counted as the successful operation. On the other hand, it is considered as the failure and not counted in the case finger-clicking is made outside of the circle or exceeding the given time.

Table 1 shows the experimental results of the finger-click recognition without the proposed algorithm and Table 2 shows the experimental results with the proposed algorithm. The average and standard deviation as the successful finger-click recognition are improved to 17.3 (86.5%) and 1.437 respectively with the proposed algorithms: the average and standard deviation as the successful finger-click recognition are 15 (75.0%) and 1.668 respectively without the ones. About 15% of performance improvement for exact finger-click recognition is achieved with the proposed algorithm.

4. CONCLUSIONS

A finger-click recognition method composed of the three parts (feature extraction, valid click discrimination, and cross-talk avoidance) was proposed to improve the recognition performance for the finger-clicking on SCURRY™. Observed environment is designed to examine how the entire proposed method including the three parts verified respectively in the above improves the recognition performance of the finger-clicking. The experimental results proved that the performance of the finger-clicking is improved by the proposed method.

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