Cursor Control using Smartphone in Large Display Space

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Abstract—**We present a novel approach as a smartphone based interface that enables the users to control the cursor position in large display space. In the proposed method, computational techniques using image processing and accelerometer processing methodology serves as the core engine for fine cursor control. Unlike previous positioning mechanisms based on image processing, the proposed system is free from restraint of movement with velocity. For the implementation of our system, we combine the block matching algorithm for optical flow with three-axis acceleration to improve an accuracy and clutch.**

Keywords*—*smartphone; large display; optical flow; accelerometer;

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1 Introduction

In the recent digital media era, we can see easily various usages of a large displays in many places, such as art works in museum, big store, and commercial displays on street. However, due to the size of display, there are some challenging issues about how to control it efficiently or how to utilize it. In order to give customers more convenient interfaces or manipulations on the displays, a lot of researchers are trying to suggest that how user can handle the displays. Especially, the control of large display is one of the attentive areas on Human Computer Interaction.

To manipulate the large display, we focus on smartphone. The smartphone is now given over to the related researchers for its versatility and multi modalities because it provides easy solution to manage favourite contents, camera, accelerometer sensor, and WI-FI network. Hence we apply these useful functions to furnish user-friendly solution of cursor control for large display.

We exploit a complementary sensor-fusion technique that combines image and sensor processing for the effective control method of large display. The technique enables user not only to handle the cursor everywhere, but also to use it comfortably with less limitation of movement.

We treat the image and the acceleration to detect movement of smartphone. The previous method for point estimation in mobile phone uses optical-flow algorithm[1]. This system can detect relative movement based on comparison of sequential images captured from camera. But the optical flow algorithm based location estimation cannot measure arm or hand velocity of users. From this problem, we take advantages of accelerometer with optical flow together to overcome the restricted information from image processing and make it possible to control accurately the cursor on the large display.

Fortunately, recent smartphones have an accelerometer sensor which is capable to calculate the change in velocity over time. Thus, we utilize the additional methods by accelerometer sensor processing[2,3]. These methods can recognize some gestures and detect shake motion from three-axis acceleration data. The acceleration algorithm considers the rough trajectory of device, but it needs another sensor such as gyro sensor or complex algorithm for accuracy.

For this reason, we determine to develop a technique which applies image processing and accelerometer sensor processing to compensate both defects of them. The technique is based on optical flow algorithm and combines the magnitude of three-axis accelerations to present the arm velocity of user.

2 Algorithm for user-friendly control

The proposed method deals with the image and the acceleration to detect location of smartphone for cursor control. The input images are sequential image data from camera and the acceleration is a data measured by the three-axis accelerometer on every sampling time. In order to treat the image data and the acceleration data, we use two algorithms, optical flow and magnitude of acceleration.

2.1 Optical Flow

Optical flow is the pattern of apparent motion of objects in visual scene caused by the relative motion between a camera and the scene[4]. It tries to calculate the motion between two image frames which are taken at time t and t+Δt at every pixel position.

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We take advantages of the block matching method[5] to compute the optical flow. The block matching method is simpler and faster than other complicated algorithm, so it is a suitable method for smartphone environment, since the capacity of existing smartphone is not enough to perform the complex process. The basic theory of block matching method is that the intensity blocks of image are approximately constant at least a short duration. If intensity block I(x, y, t) will have moved by Δx, Δy and Δt between the two image frames, then this can be expressed as

$$I(x, y, t) \approx I(x + \Delta x, y + \Delta y, t + \Delta t) \tag{1}$$

where Δx, Δy are the displacements of the image at (x, y, t) after time Δt.

The block matching for the proposed method divides the two frames, the current and previous frame, into blocks of intensity. The blocks of current frame are compared with blocks of previous frame as predefined scan range. To compare between the two blocks, we apply L1 norm. Let c is a block in current image frame and p is a block in previous image frame, and then difference of two blocks are defined as

$$d(c, q) = \sum_{i=1}^{n} |c_i - q_i| \tag{2}$$

where d(c, q) is the difference of two blocks, n is a size of block and c_i, q_i are pixel values in each block. Then, we choose the most similar block with current one in previous frame and decide the orientation for each block of current frame.

After the comparing process, we can get two orientation fields with regards to x-axis and y-axis. The orientation fields denote the vectors that are orientation of each block. If the frame size is 176×176 and the block size is 16×16, then we are able to get 121 blocks and 121 related vectors with orientation fields.

Next, we exploit a weight matrix to alleviate errors, which are caused by contour of image frame because the contour is susceptible to a little movement. Thus, we implement the center-weighted matrix to give higher weight to adjacent block to center than peripheral blocks. For example, if we get the orientation field for 25 blocks, then the weight matrix W is demonstrated as

$$W = \begin{bmatrix} 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.1 & 0.2 & 0.2 & 0.2 & 0.1 \\ 0.1 & 0.2 & 0.8 & 0.2 & 0.1 \\ 0.1 & 0.2 & 0.2 & 0.2 & 0.1 \\ 0.1 & 0.1 & 0.1 & 0.1 & 0.1 \end{bmatrix} \tag{3}$$

We calculate the sum of all vectors after applying the weight matrix and define the global movement of current image frame.

2.2 Accelerometer Processing

Accelerometer measures acceleration that is a change in velocity over time. The basic theory is that as a consequence an accelerometer at rest relative to the Earth's surface will indicate approximately 1g upwards[6]. Following this theory, we can easily know the movement if the acceleration value is not equal to 1g.

The method for accelerometer estimates the magnitude of three-axis acceleration every sampling time T. The magnitude of three-axis acceleration is defined as

$$M = \sqrt{x^2 + y^2 + z^2} \tag{4}$$

where M is a magnitude and x, y, z are value of acceleration for three-axis. Then, we determine the current state of movement such as move or stop using threshold specified by experiment. This can be expressed as

$$S(t) = \begin{cases} move, & \text{if M} \geq \text{threshold} \\ stop, & \text{otherwise} \end{cases} \tag{5}$$

where S(t) is state at sampling time t. Also we work out the relative velocity through contrast with magnitude of prior sampling time. In other words, the current velocity is increased if it is bigger than the prior magnitude.

2.3 Complementary Method

As previously stated, we have described two basic algorithms, optical flow and accelerometer processing. The two basic algorithms compose the proposed method for user-friendly cursor control.

First, we carry out the block matching for optical flow, and then compute the global movement of current image frame. The global movement is defined as a vector, so it shows the progress of moving orientation of user or smartphone. However, the optical flow based global movement cannot measure arm or hand velocity of users. Because this weakness may make the users to be restricted in fast motion of arm or hand, we solve the issue by checking a current acceleration value.

We search the current state of movement using computed magnitude, and then, run the different routine dependent on current state, defined as move and stop. If the state is move, current velocity is reckoned by the magnitude. Using this velocity, we determine the final displacement of cursor. That is, the proposed method enables users to change the position of cursor according to velocity freely. On the other hand, if the state is stop, we utilize the new threshold to examine the slow motion. Even though the state is stop, the smartphone might not be stationary. Therefore, to prevent the missing several slow motion of user, the global movement is given through the new threshold. As a result, the proposed method can communicate clearly with users who want either slow or fast motion. The overall procedure of the complementary method is described in Fig. 1.

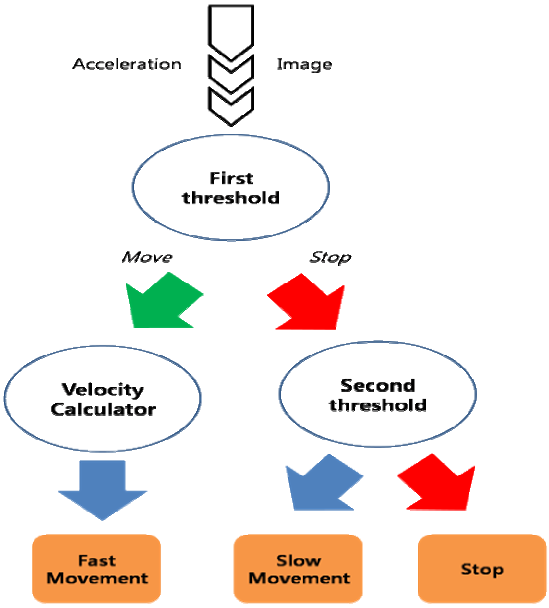

Fig. 1 Overall procedure of the proposed method

3 Implementation on smartphone

Ideally, one technique should be able to operate well under most, if not all conditions. This was the primary motivating objective for design of the proposed method. In this section, we describe the specification of the proposed method to achieve this objective and example of cursor control for large display.

3.1 Design and Specification

The proposed method is a cursor positioning system using smartphone for large display space. It allows relative positioning. Locations of smartphone are mapped to a larger display. To invoke the proposed method, user just needs to touch the display and moves the smartphone in the air. Also the proposed method uses cursor acceleration using accelerometer sensor. We implemented the proposed system on a Samsung SPH-M8400 smartphone with WI-FI network.

In detail, first, the proposed method joins a large display through WI-FI network. Next, users touch the display of smartphone and they can manipulate the cursor in large display. Then, the cursor in large display is moved as motion of smartphone, wave in air and also the smartphone exhibits now x, y coordinates and velocities. Finally, if users want to finish the control, then they only have to touch the screen of smartphone again. In Fig. 2, a prototype of the proposed system on smartphone is shown.

Fig. 2 A prototype of the proposed system on smartphone. The green ball expresses now relative position of smartphone.

3.2 Freedom of Movement in Large Display Space

To evaluate the performance of the proposed method, we imitate an old artwork, Painting Melody[7], based on large display. The artwork generates the sound if visitors draw the picture using colour pens on the sketchbook. Also it presents a flying butterfly as trajectory of the pen.

The imitated work is comprised of server and client system. The server system is created in Max/MSP/Jitter and takes charge of main function which receives the input data from client. Then, it presents the butterfly on the large display and plays the midi sounds. The client system, our proposed system, sends the position of smartphone to the server. So the imitated work is able to use the smartphone like as a pen in charge of drawing on sketchbook directly. If the visitor is moving the smartphone, then the butterfly on the large display is also moving as same and the speaker is generating the sound mapped to position of screen. The imitated work for the proposed system is illustrated in Fig. 3.

We identified the proposed method that can freely move the object with large display space in all velocity of user movement. However, the proposed system lacks a convenient manipulation about absolute positioning. So we will improve the current technique in order to include all positioning function.

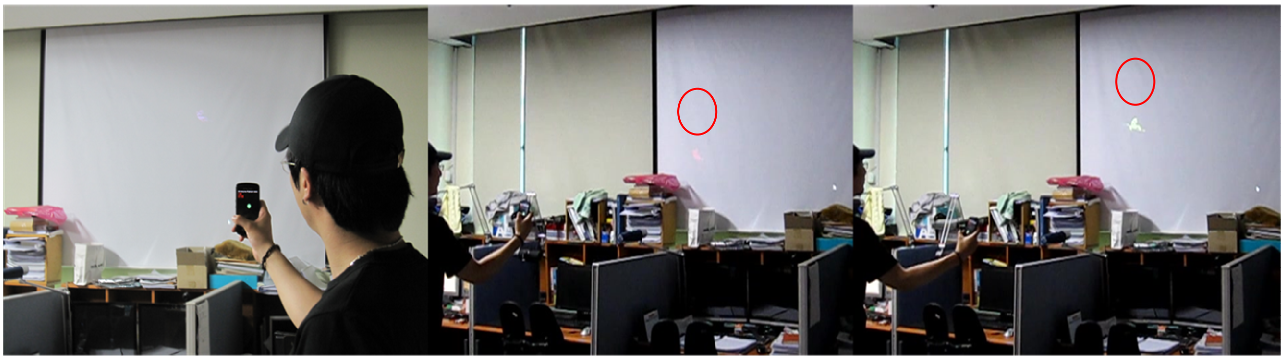

Fig. 3 An imitated work for the proposed system: The left image shows installation of the imitated work. The butterfly in the red circles of middle and right images is moved by movement of smartphone.

3.3 Additory Joy in Game

During the imitated work, we rediscovered the possibility of the proposed system for games. For example, we try to play the Starcraft, one of the most popular games, with our cursor control method. First, we add two buttons on display of smartphone for left and right click like as mouse. In addition, now acceleration value and travelling direction vector are showed on display for delicate control. Also the modified prototype previews the input image from camera instead of green ball which symbolizes relative position of smartphone. Fig. 4 indicates the scene of playing Starcraft with our proposed system.

The example lets users feel an interest in more active operation that is moving their smartphone in the air, but it is necessary to give supplementary functions about complex command in games. So we should expand the technique about acceleration such as tilt sensing to remedy this shortcoming and make a user interaction game on large display in the subsequent studies.

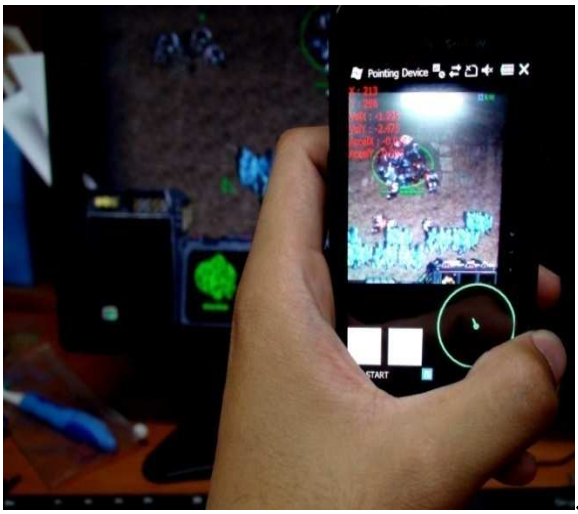

Figure 4Example of the proposed system;

4 Discussions

The proposed method is a novel technique for Human smartphone interaction based cursor positioning on large display space. We combined image processing and accelerometer processing for user-friendly control. Block matching based optical flow algorithm and accelerometer are used to estimate the cursor position without less limitation of movement. However, the proposed method is just about relative positioning yet. In our future work, we will add a gesture-function interaction to guide more comfortable handle.

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