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Thesis Title:

Novel User Interfaces Using Gaze Tracking, Facial Feature Detection and Rear Touch

Thesis Outline:

In this thesis, with the aim of providing the innovative interactions for computer gaming, novel methods of using an image sensor, namely vision technology, as part of the human-machine interaction are proposed. In addition, the use of rear touch sensor is studied and not only the method for cursor control but also utilizing rear touch gestures for command control are evaluated. Especially, the proposed system with the combined use of vision technology and rear touch proves the practical single-handed navigation of hand-held devices. This thesis consists of four parts, gaze tracking, facial feature tracking, rear touch operation, and combined use of facial feature detection and rear touch.

Fundamental motivation is emerged as how gaze estimation can be utilized effectively regarding an application to games. In games, precise estimation is not always important in aiming targets but an ability to move a cursor to an aiming target accurately is also significant. Incidentally, from a game producing point of view, a separate expression of a head movement and gaze movement sometimes becomes advantageous to expressing sense of presence. A case that panning a background image associated with a head movement and moving a cursor according to gaze movement is a representative example. On the other hand, widely used technique of POG estimation is based on a relative position between a center of corneal reflection of infrared light sources and a center of pupil. However, a calculation of a center of pupil requires complicated image processing, and therefore, a calculation delay is a concern, since to minimize a delay of inputting data is one of the most significant requirements in games. In the first study, a method to estimate a head movement by only using corneal reflections of two infrared light sources in different locations is proposed. Furthermore, a method to control a cursor using gaze movement as well as a head movement is proposed. By using game-like-applications, proposed methods are evaluated and, as a result, a competitive performance to conventional methods is confirmed and an aiming control with lower computation power and stress-less intuitive operation is obtained.

Although purposeful results are obtained in the first study, the need of infrared light sources and glasses mounted with a camera imposes a burden on a user. Moreover, the remarkable deterioration of the usability, which happens when the estimated POG is deviated from the actual POG, is the essential problem of the gaze estimation. From this reason, to find the alternative technology to achieve the similar functionality by the easier method than estimating POG strictly precisely is the prime motive to the next study. In the second study, we propose the techniques using the facial feature detection applied for cursor control and zoom on mobile

devices. In detail, nose movement is used to control cursor movement, and zooming is achieved by detecting the apparent distance between the left and right eyes. Techniques are implemented on the portable gaming device, and the cursor positioning and object zooming accuracy with single-handed operation is evaluated.

In the research of the single-handed operation of mobile devices, the use of rear touch aroused curiosity. In the third study, we conducted the basic study of cursor control performance by rear operation. To improve single-handed operation of mobile devices, the use of rear touch panel has potential for user interactions. The operational control is assumed to be simply achieved through drag and tap of the index finger on a rear surface. Since a user has to hold the handheld device firmly with the thumb and fingers, a movable range of the tip of an index finger is limited. This restriction requires a user to perform several times of dragging actions to reach a cursor to the long distance target. Considering such kinematic restriction, a technique optimized for rear operation is proposed, wherein not only the position but also the velocity of fingertip movement is regarded. Movement time, the number of dragging operation, and the throughputs of the proposed technique have been evaluated in comparison with the generic technique using Fitts's law. Experiments have been conducted to perform the target selection in the form of reciprocal 1D pointing tasks with ten participants. The combinations of two ways of holding the device (landscape and portrait) and two directions of dragging (horizontal and vertical) are considered. As a result, the proposed technique achieved the improvements of from 5 to 13% shorter movement time, from 20 to 40% higher throughputs and no deterioration of the number of dragging even for the longer distance targets. In addition, the further analysis addressed that there exists the advantageous combinations of the way of holding and the direction of dragging, which would be beneficial for better design of single-handed user interactions using rear touch.

Finally, interests reached the practical use cases of hand-held devices. The cursor navigation is only a part of them, and scroll or zoom functions are also required. To achieve these functionalities, command control mechanism is also an essential. Then, an advanced idea of the combined use of facial feature detection and rear touch occurs. As the final study, to establish practical single-handed operation of mobile devices, rear touch panel operation to control commands and facial feature detection to control cursor position are proposed. Operational control is achieved through finger chord gestures on a rear touch panel, and nose movement is used to control cursor movement. Zooming is achieved by detecting the apparent distance between the left and right eyes in conjunction with a finger chord gesture. Movement time, error rates, and the throughputs of these techniques in comparison with the conventional single-handed front touch panel thumb operations are assessed using Fitts's law. Experiments have been conducted to evaluate two operation modes, selection and zooming, in the form of

reciprocal 1D pointing tasks with ten participants. For the target selection task, the proposed technique achieved 10% (0.23 s) shorter movement time and 4.1% smaller error rate than the conventional method on average. Especially for long distance targets, the performance of the conventional method became remarkably inferior due to the limit of reach of the thumb, whereas the proposed technique achieved much less deterioration and obtained expected performance because the cursor could reach anywhere on the display. For the target size adjustment task, the proposed technique achieved 6% (0.15 s) shorter movement time than the conventional method, and obtained a comparable error rate of less than 4%. Consequently, we could demonstrate the techniques that make single-handed select and zoom operations available anywhere on a large-sized tablet device with no blockage of the display.