

**DETECTING, CLASSIFYING, AND
INTERPRETING INPUT EVENTS BASED ON
STIMULI IN MULTIPLE SENSORY DOMAINS**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

[0001] The present application claims priority under 35 U.S.C. §119(e) from U.S. Provisional Patent Application Serial No. 60/337,086 for "Sound-Based Method and Apparatus for Detecting the Occurrence and Force of Keystrokes in Virtual Keyboard Applications," filed Nov. 27, 2001, the disclosure of which is incorporated herein by reference.

[0002] The present application is related to U.S. patent application Ser. No. 09/502,499 for "Method and Apparatus for Entering Data Using a Virtual Input Device," filed Feb. 11, 2000, the disclosure of which is incorporated herein by reference.

[0003] The present application is further related to U.S. patent application Ser. No. 10/115,357 for "Method and Apparatus for Approximating a Source Position of a Sound-Causing Event for Determining an Input Used in Operating an Electronic Device," filed Apr. 2, 2002, the disclosure of which is incorporated herein by reference.

[0004] The present application is further related to U.S. patent application Ser. No. 09/948,508 for "Quasi-Three-Dimensional Method and Apparatus To Detect and Localize Interaction of User-Object and Virtual Transfer Device," filed Sep. 7, 2001, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0005] 1. Field of the Invention

[0006] The present invention is related to detecting, classifying, and interpreting input events, and more particularly to combining stimuli from two or more sensory domains to more accurately classify and interpret input events representing user actions.

[0007] 2. Description of the Background Art

[0008] It is often desirable to use virtual input devices to input commands and/or data to electronic devices such as, for example personal digital assistants (PDAs), cell phones, pagers, musical instruments, and the like. Given the small size of many of these devices, inputting data or commands on a miniature keyboard, as is provided by some devices, can be time consuming and error prone. Alternative input methods, such as the Graffiti® text input system developed by Palm, Inc., of Santa Clara, Calif., do away with keyboards entirely, and accept user input via a stylus. Such schemes are, in many cases, slower and less accurate than typing on a conventional full-sized keyboard. Add-on keyboards may be available, but these are often cumbersome or impractical to attach when needed, or are simply too large and heavy for users to carry around.

[0009] For many applications, virtual keyboards provide an effective solution to this problem. In a virtual keyboard system, a user taps on regions of a surface with his or her fingers or with another object such as a stylus, in order to interact with an electronic device into which data is to be entered. The system determines when a user's fingers or stylus contact a surface having images of keys ("virtual

keys"), and further determines which fingers contact which virtual keys thereon, so as to provide input to a PDA (or other device) as though it were conventional keyboard input. The keyboard is virtual, in the sense that no physical device need be present on the part of surface that the user contacts, henceforth called the typing surface.

[0010] A virtual keyboard can be implemented using, for example, a keyboard guide: a piece of paper or other material that unfolds to the size of a typical keyboard, with keys printed thereon to guide the user's hands. The physical medium on which the keyboard guide is printed is simply a work surface and has no sensors or mechanical or electronic component. The input to the PDA (or other device) does not come from the keyboard guide itself, but rather is based on detecting contact of the user's fingers with areas on the keyboard guide. Alternatively, a virtual keyboard can be implemented without a keyboard guide, so that the movements of a user's fingers on any surface, even a plain desktop, are detected and interpreted as keyboard input. Alternatively, an image of a keyboard may be projected or otherwise drawn on any surface (such as a desktop) that is defined as the typing surface or active area, so as to provide finger placement guidance to the user. Alternatively, a computer screen or other display may show a keyboard layout with icons that represent the user's fingers superimposed on it. In some applications, nothing is projected or drawn on the surface.

[0011] Camera-based systems have been proposed that detect or sense where the user's fingers are relative to a virtual keyboard. For example, U.S. Pat. No. 5,767,842 to Korth, entitled "Method and Device Optical Input of Commands or Data," issued Jun. 16, 1998, describes an optical user interface which uses an image acquisition system to monitor the hand and finger motions and gestures of a human user, and interprets these actions as operations on a physically non-existent computer keyboard or other input device.

[0012] U.S. Pat. No. 6,323,942 to Bamji, entitled "CMOS-compatible three-dimensional image sensor IC," issued Nov. 27, 2001, describes a method for acquiring depth information in order to observe and interpret user actions from a distance.

[0013] U.S. Pat. No. 6,283,860 to Lyons et al., entitled "Method, System, and Program for Gesture Based Option Selection," issued Sep. 4, 2001, describes a system that displays, on a screen, a set of user-selectable options. The user standing in front of the screen points at a desired option and a camera of the system takes an image of the user while pointing. The system calculates from the pose of the user in the image whether the user is pointing to any of the displayed options. If such is the case, that particular option is selected and an action corresponding with that option is executed.

[0014] U.S. Pat. No. 6,191,773 to Maruno et al., entitled "Interface Apparatus," issued Feb. 20, 2001, describes an interface for an appliance having a display, including recognizing the shape or movement of an operator's hand, displaying the features of the shape or movement of the hand, and controlling the displayed information, wherein the displayed information can be selected, indicated or moved only by changing the shape or moving the hand.

[0015] U.S. Pat. No. 6,252,598 to Segen, entitled "Video Hand Image Computer Interface," issued Jun. 26, 2001,