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Design and feasibility study of an integrated pointing device apparatus for individuals with spinal cord injury

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Abstract

Despite the commercial availability of numerous computer-pointing devices, many severely disabled individuals still rely on customized equipment to operate computers. This study presents a novel Integrated Pointing Device Apparatus (IPDA) that integrates numerous commercial pointing devices. The novel IPDA, which complies with a standard USB 1.1 interface, is compatible with most tested computer-pointing devices and flexibly integrates commercial computer devices, tailoring them to suit individual needs. By using simple integrated circuit design and low-cost electronic components, this low-cost apparatus is easily maintained. The feasibility of the IPDA was evaluated by four subjects with high-level cervical (C4-5) spinal cord injury (SCI). Participants performed normal move-and-click and drag-and-drop tasks typically performed by computer pointing devices. Each participant not able to use a traditional computer mouse or trackball were able to operate a computer adequately with the IPDA and three including one operating a trackball with his chin, operated computers easily and smoothly. This feasibility study showed that the IPDA effectively integrates commercial pointing devices, thereby providing the possibility for some people with SCI to obtain computer operability. This study demonstrated the advantages of flexibility, low cost, and acceptable efficiency of the novel IPDA.

Keywords: Disability; Computer pointing device; Assistance device design

1. Introduction

Integrating technologies to develop special tools for people with disabilities is a goal in advanced countries (Vanderheiden, 1990). In Taiwan, more than 1000 people incur a spinal cord injury (SCI) annually (average age, 23.7 years). Of these, 19% graduated from at minimum junior college, and 58% graduated from junior or senior high school. According to their education levels, an estimated 500 people per year with SCI have a potential of obtaining computer-related employment via vocational rehabilitation programs of which roughly 2/3 have paraplegia/paraparesis with normal hand functions and do not rely on special devices to operate a computer. Most computer training classes in SCI rehabilitation centers in Taiwan, therefore, are designed for those with normal hand function. However, roughly 200 new cases annually with high-level cervical SCI and adequate education levels have severe hand or upper limb function limiting their ability to obtain computer-based employment. To enhance their employment opportunities through computer training programs, people with disabilities typically use special pointing devices while operating computers.

Because of extensive window and graphical user interfaces in computer operation systems, mice and other pointing devices are replacing traditional computer input keyboard tasks. A mouse may be easy for most people to

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operate; however, people with severe disabilities typically encounter mouse operation problems (Fujisawa et al., 1997; Rao et al., 2000). Those with high-level cervical SCI often have difficulty operating standard mice. Most have residual functions in the neck, shoulders, elbows or wrists, such as neck flexion, shoulder abduction, elbow pronation or wrist extension. Alternative devices controlled by the head/neck, shoulders, elbows or wrists may be more suited to the needs of such users.

Various computer-pointing devices have been developed to meet the needs of people with various physical disabilities (Shein et al., 1992). Devices designed for people with severe hand disabilities include infrared- or ultrasonic-based head-controlled interfaces (Gottschalk, 1993; Heuvelmans et al., 1990; Evans et al., 2000; Chen et al., 1999), optically controlled interfaces (Park and Lee, 1996; Lin, 2002), and several other interfaces such as footmouse, camera mouse, etc. (Springer and Siebes, 1996; Betke et al., 2002; Harwin and Jackson, 1990; Chen et al., 2003). Despite different methods for controlling various pointing devices, the basic operation of a cursor, such as clicking, double clicking, target acquisition, dragging and dropping, remains the same, permitting researchers to compare feasibility of various devices. Casali and Chase (1995) examined computer operation of 20 people with impaired upper limb/hand functions, demonstrating that some devices required considerable time for users to attain proficiency. Of those devices tested, some design attributes negatively affected user performance. Lin et al. (1992) showed that a head-controlled input device significantly reduced operating time. Several other studies objectively evaluated the efficacy of pointing devices (Walker et al., 1993; Radwin et al., 1990) to determine the suitability of human–computer interfaces. The criteria used in these evaluative studies are applicable for determining the suitability of input devices for people with disabilities.

Previous studies suggested that people with high-level SCIs can effectively use specially designed devices (Chen et al., 2003), however, the cost of such devices are usually considerably higher than commercially available mice or trackballs. Furthermore, special devices are often difficult to obtain or maintain and may further impede those with disabilities from obtaining such devices. This study presents a novel integrated pointing-device apparatus (IPDA) for people with high-level cervical SCI that facilitates the use of commercial computer mice and trackballs. The operational performance of four people with high-level SCI in using IPDA with common pointing devices was evaluated.

2. IPDA design

2.1. Design concept

Generally, operational efficiencies of standard mice are superior to those of common trackballs and special pointing devices, based on movement times for different pointing devices in target-acquisition tasks (Radwin et al., 1990; Card et al., 1978). Most people with cervical SCIs, who are unable to operate common computer mice and trackballs alone, can achieve acceptable operational efficiencies by combining a trackball with a separate button (IOSH, 2000). The design goal of the IPDA is to combine achievements of previous studies in developing an economical apparatus that can flexibly integrate commercial computer mice and trackballs, thereby tailoring the device to individual needs. To accommodate a wide variety of physical disabilities associated with cervical SCI, such an apparatus must allow for several combinations of pointing devices to improve individual operational performance.

Due to the varying physical abilities among people with cervical SCI and the variety of commercially available pointing devices, this study did not attempt to offer a device suited to all individual needs. Instead, the IPDA was mainly designed to allow users to operate standard pointing devices with any two body parts, such as hands, wrists, chin, etc. Moreover, the device should be able to customize a pointing device for different operational orientations without losing the compatibility to control cursor movements. For the first version of the IPDA, the following three applications for people with cervical SCI were considered:

(1) A person with SCI and poor physical control below the neck may not be able to operate a standard mouse owing to severely impaired hand functions. Under such a condition, the user can move the cursor by controlling a trackball with their chin. The user can also click external switches or buttons on a second computer input device with an upper limb/hand. The integrating functions of the IPDA allow a user with severely impaired hand functions to operate efficiently a computer (Fig. 1).

Fig. 1. Combining neck and hand function to operate input devices.