Developing a Scanning Assistive Input Device for the Severely Disabled to Operate the Computers and Mobile Devices

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Abstract

The severely disabled such as amyotrophic lateral sclerosis and cerebral palsy often have different states and varying degrees of disease, and then the operation way of the assistive devices for the severely disabled to operate the computers and mobile devices is quite different. Thus, to develop a suitable assistive input device for severely disabled in operating computers and mobile devices is very important. In this study, a scanning assistive input device (SAID) is developed for severely disabled. To meet the user's physical condition, an assistive input switch with different assistive input interfaces is developed to ease severely disabled in inputting commands. To help severely disabled in operating the computers or mobile devices, the SAID control box is designed to recognize and execute the input commands. To ease the operation of SAID, the function indicator lights prompt is applied as the input interfaces. The experimental results showed that the proposed SAID can effectively help severely disabled in operating computers or mobile devices. Thus, the proposed approach can help severely disabled in daily life.

Keywords: Scanning assistive input device, Severely disabled, Assistive input switch, Control box, Function indicator lights prompt

1 Introduction

Computers and mobile devices such as tablets and smart phones have become an indispensable necessity in daily lift. However, the subjects with severe disabled such as amyotrophic lateral sclerosis (ALS) and cerebral palsy (CP), who often have different states and varying degrees of disease, is very difficult to use the computers and mobile devices. Therefore, developing an assistive device can effectively help severely disabled in operating computers or mobile devices.

ALS is a disease that causes the death of neurons that control voluntary muscles and CP is the most common movement disorder in children. Subjects with ALS or CP are characterized by stiff muscles, muscle twitching, and progressive weakness due to reduced muscle size [1-4]. Thus, for subjects with ALS or CP, the abilities of sensation, vision, hearing, swallowing, and speaking would be seriously degraded.

The severely disabled may begin with weakness in the arms or legs, or difficulty speaking or swallowing. About half of the affected people have at least mild difficulties in thinking and behavior, and most people will feel pain. Most people will eventually lose the ability to walk, hands, talk, swallow, and breathe. Recently, the developing of computers and mobile devices such as tablets and smart phones greatly change the lifestyle of people. Accessing computers and mobile devices can easy people in communicating with others or getting information. For normal users, the keyboard or mouse are the necessary devices in operating computers and mobile devices. Due to the limits of severely disabled, they are very difficult in operating computers and mobile devices by using the keyboard or mouse. Therefore, developing an assisting device to help subjects with severe disabled in accessing computers or mobile devices can greatly improve their quality of life.

To help severely disabled in operating computers or mobile devices, many assistive mechanisms that mimic the functionality of input devices had been developed. Struijk et al. [5-6] developed the inductive tongue computer interface to help disabled people in operating computers. The inductive tongue computer interface applied a current with fixed frequency and fixed amplitude, and the number of turns of each coil was the only parameter that made it possible to determine which coil was activated. This could give false detections since the difference in the number of turns of the coils was relatively small.

Liu et al. applied eye-controlled device, which uses cameras to track pupil movement from the captured images of the user's eyes, as the assist input interface [7]. But it is very difficult to distinguish the control command and the reading function for the eye

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movements. The infrared head-operated joystick based head-controlled devices had be proposed to simulate the functions of a mouse [8-11]. Su and Chung adopted speech recognizer to transfer voices to keyboard signals [12-13]. Unfortunately, the head-controlled devices and speech recognizer are easily affected by surrounding noise. The users need muscles to control these kinds of assistive input devices, thus, it is unsuitable for severely disabled.

To reduce the needs muscles for controlling the assistive input devices, the physiological signals including electrooculography (EOG) switch [14-17], electromyography switch [18-20], and electroencephalogram [21-27] had been selected as the interfaces. These approaches can acquire the physiological signals and transform it to the corresponding commands by using different types of electrode pads. However, these signals would be always affected by age, muscle development, motor unit paths, skin-fat layer, gesture styles, eye blinks, and neck movements. Therefore, the performance of these assistive input devices would be severely degraded. Thus, the value of these types of assistive input devices would be greatly reduced in practical applications.

Wu et al. designed the Morse code to represent the text or commands and then the severely disabled can used less muscles to use the assistive input devices [28-29]. The experimental results showed that the Morse code based assistive input devices can help severely disabled to quickly input the text. However, ALS or CP always cause subjects to have excessive limb tension due to nervousness and pressure. In these cases, the severely disabled cannot apply Morse code based assistive input devices to use computers or mobile devices for long-time use. For severely disabled, a suitable assistive interface, which can be used for long-time use, would be very helpful.

In this study, a scanning assistive input device (SAID) is proposed to help severely disabled in operating computers or mobile devices. The proposed scanning assistive input device composes three parts: an assistive input switch, a control box, and the function indicator lights. To meet the user's physical condition, an assistive input switch is developed to help users to input the commands. To quickly select the commands for severely disabled, a two status transform architecture is designed. To help user in operating computers or mobile devices, the SAID control box is used to recognize and execute the input commands. To ease the operation of SAID, the function indicator lights prompt is adopted to help severely disabled. Therefore, the proposed SAID is able to help severely disabled to operate the computers or mobile devices.

The remainder of this paper is organized as follows. Section 2 describes the proposed SAID, which includes assistive input switch and control box. Section 3 presents the experimental results to evaluate the performance of our approach. Finally, conclusions are drawn in Section 4, and possible improvements for the future development of this work are discussed.

2 The Scanning Assistive Input Device

In this study, SAID is proposed to help subjects with severe disability (as shown in Figure 1). The proposed SAID composes three parts: an assistive input switch, a control box, and the function indicator lights. First, the function indicator lights prompt is adopted to help the users to ease the operation of SAID. Second, an assistive input switch is developed to meet the user's physical condition and then users can input the commands. Finally, the input command is recognized and executed in the SAID control box. The following will describe these procedures in detail.

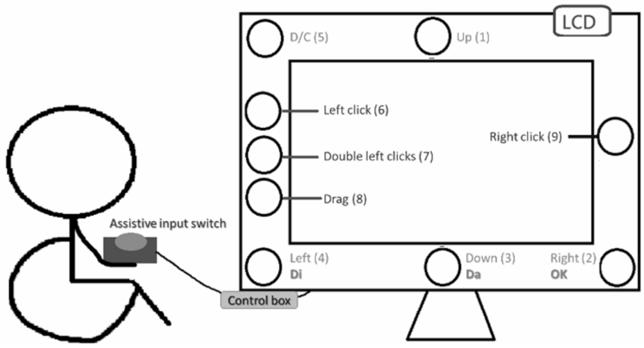


Figure 1. The architecture of SAID

2.1 Design of the Function Indicator Lights

In this study, an SAID system including mouse mode and Morse code keyboard mode is proposed to help severely disabled. SAID control box using a microprocessor (Arduino pro micro) to design the function of mouse and keyboard, and setting the scan cycle is one second. In the mouse mode, there are nine indicator lights that referred to "up", "right", "down", "left" four kinds of direction lights, "left click", "double left clicks", "drag", "right click" four kinds of click function lights, and a direction/click function switch indicator light. In the Morse code keyboard mode, one LCD screen and three indicator lights (numbered 2, 3, and 4) are used to refer to "OK", "Da", and "Di". "Da", and "Di" are referred to long and short tone of Morse code, respectively. "OK" referred to the confirm key.

2.2 Assistive Input Switch

The choice of input accessory will be in accordance with the physical disability condition of each user. In this study, the input accessories connected with SAID is divided into three types of components, including mechanical, sensing, and bio-signal (e.g. eye movement) and described in the following.

2.2.1 Mechanical Switch

The mechanical switch is mainly based on a push-button switch and a micro switch and is characterized in that it is not necessary to additionally provide a power to drive the switch. The mechanical switch is connected by a wire to a 3.5mm mono male connector. When the switch is clicked, it will output a low level, otherwise, it will output a high level. Following the state of the different patients, it can change the type of mechanical switch.

2.2.2 Sensing Switch

This study combines an infrared sensor with an operational amplifier (OPA) comparator to provide a binary output. The OPA reference voltage value sets the reflection distance of the infrared light detected by the sensor. In order to avoid triggering unstable infrared reflection signals multiple times, a circuit that feedbacks the Schmitt trigger, whose reference voltage increases the stability of the special infrared switch, is designed. At the same time, we consider the user's operating habits, we have designed two modes to operate this switch, one is "On state" trigger, and the other is "off state" trigger state.

In addition, this study used the 555 oscillator integrated circuit (IC) to design Morse code (short and long tone) feedback sounds (di and da sound) for severely disabled people to learn Morse code. For the sensor assistive switch, the design of the infrared assistive input switch is taken as an example in this study. In this study, the TCRT5000 infrared sensor was selected. The detection reflection distance is 1mm ~ 8mm and the focal distance is 2.5mm. To make user input more stable, this study adjusted the sensing distance to 1mm, which means that the sensor will only respond when touched.

The circuit design is shown in Figure 2. It consists of an infrared sensor, a buzzer, a sound switch and a reverse switch. The sound switch can be adjusted with or without a beep. The reverse switch is used to change the operation mode of the infrared sensor assistive switch. For example, mode 1 is to cover the sensor to 1 and release it to 0, and mode 2 is to cover the sensor to 0 and release it to 1. The circuit uses SMD-type resistors, capacitors, and ICs to reduce the size (4.8cm *2.7cm) and reduce costs with the TCRT5000 infrared reflection sensor.

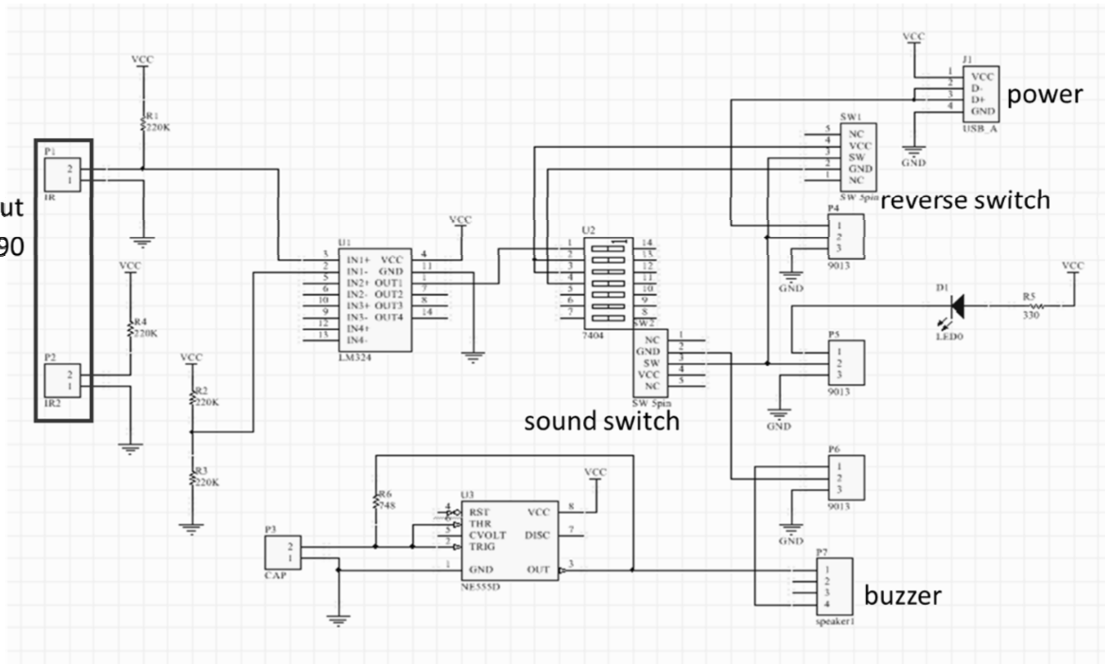
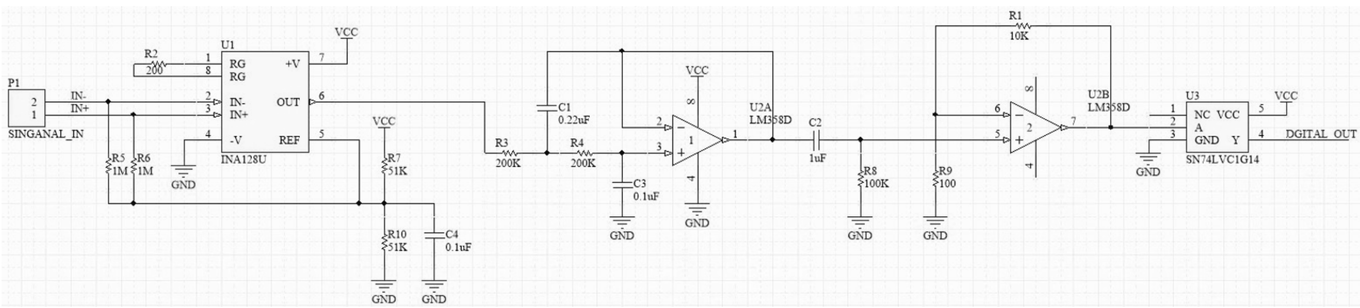


Figure 2. The sensor circuit of the infrared ray

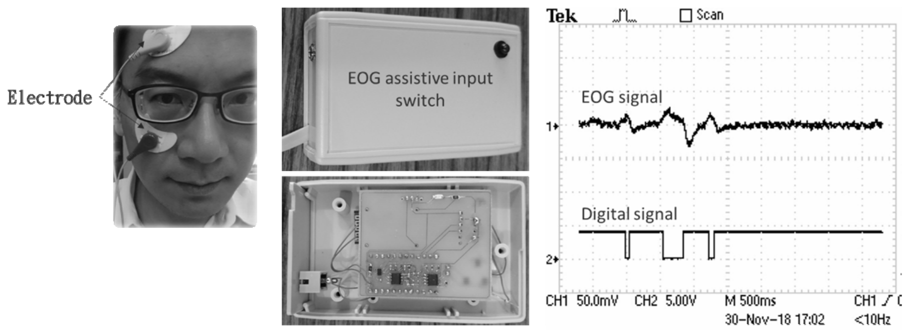
2.2.3 Bio-signal Switch

In the bio-signal type switch, this study designed an EOG assistive input switch. EOG is one of the many ways to measure eye movement. It mainly measures the potential difference between the angle of rotation of the eye and the surrounding muscles. The measured voltage data is about 50 to 3500 μV, the frequency is DC-100 Hz, the eyeball rotation range is about plus or minus 30 degrees, and is proportional to the EOG voltage, so we can judge the direction and angle of the eyeball according to the eyes rotation. The EOG circuit detects the differential signal of the eye movement by the INA128 instrumentation amplifier, and amplifies it by 251 times, then filters the noise by the 0.5Hz~30Hz band pass filter, and then amplifies 100 times by the inverse amplifier. Finally, the EOG analog signal is converted to a digital motion signal by the single Schmitt-trigger inverter (SN74LVC1G14), such as Figure 3(a).

The EOG assistive input switch needs to put the surface electrode around the eyes to get the EOG signal. Everyone's signal strength is different. Therefore, the position of the surface electrode needs to make a little adjustment when the user uses the EOG assistive input switch. In Figure 3(b), the electrode patches are attached to the top and bottom of the eye. The user can generate EOG signals by moving the eyeball up and down. The EOG signal is converted into a digital signal by a 10bits A/D converter of Arduino pro micro, which can be used as a switching signal.



(a) The detection circuit of EOG



(b) EOG signal converts to a digital signal test

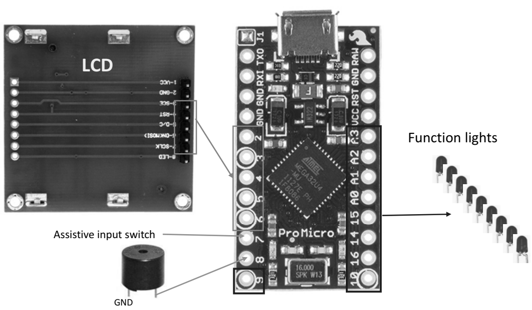
Figure 3. EOG assistive input switch

2.3 The Circuit and Function Design of SAID Control Box

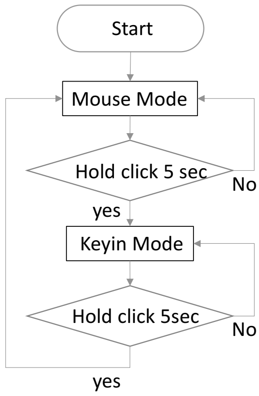
The SAID control box consists of a microprocessor (Arduino pro micro), an LCD screen, 9 Function lights, an input switch, and a buzzer, such as Figure 4. This system only needs an input switch to operate. SAID has a mouse and keyboard function, which can be switched between the two by the user self. The mouse function including 4 directions and 5 keystroke functions commands. The keyboard including 3 selecting lights and it is applied to input the commands by using Morse code encode. Scanning is the most common indirect selection method in which the selection set is presented by a display and is sequentially scanned by a cursor or light on the device. The user selecting the desired choice by pressing a switch when it is indicated by the display.

The mouse action flowchart such as Figure 5(a), the scanning mouse action divide into two statuses (Figure 5(b)), status m1 is polling the moving direction of the mouse waiting for click, when LED5 is clicked than switch the status to status m2 and status m2 is polling the keystroke functions of the mouse. Operation the scanning mouse, the user only needs to judge the position of the indicator light and press the input button to perform the corresponding mouse action. The users also can control the mouse to key in the text by using the built-in keypad.

The keyboard action flowchart such as Figure 6(a), the scanning keyboard action divide into two statuses (Figure 6(b)). When there is no input yet, namely the status k1, the light only switches between "Di" and "Da", After input, the status will switch to status k2, the light will be polling between "Di", "Da", and "OK" in order. Operation the scanning keyboard, the user only needs to judge the position of the indicator light and press the input button to select the short/long tone of the Morse code (Figure 7). The selected tone will be displayed on the LCD screen. When the user types the wrong tone, he/she can press and hold the input button for 0.5 seconds, then the system will beep and delete the tone. Once you have chosen to complete the character composition of Morse code, you will need to select the confirm key via input button to send it out to recognize. Then the system will recognize Morse code through the Universal Morse Code Table and convert it to readable characters. Press and hold the input button for 3 seconds and the system will change the operating mode.

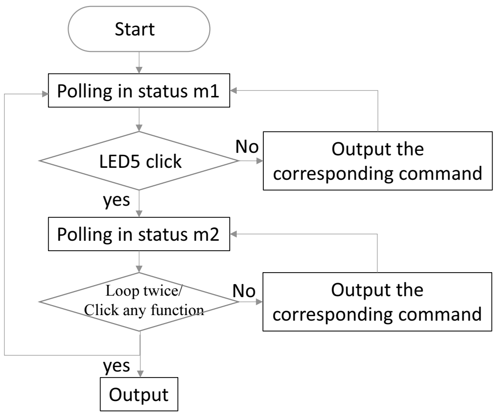


(a) The circuit

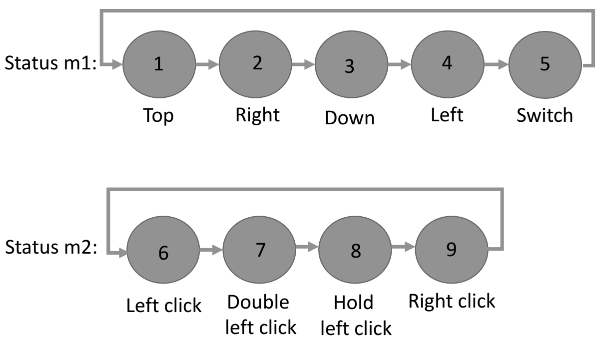


(b) The operation mode for SAID control box

Figure 4.

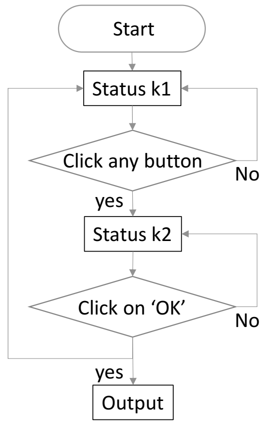


(a) The operation flowchart

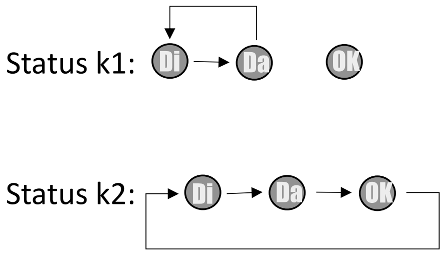


(b) The moving sequence of each status for the mouse mode

Figure 5.



(a) The operation flowchart



(b) The moving sequence of each status for the keyboard mode

Figure 6.

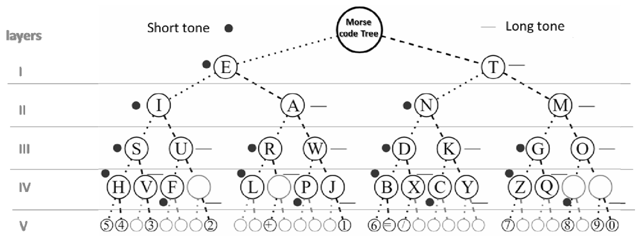
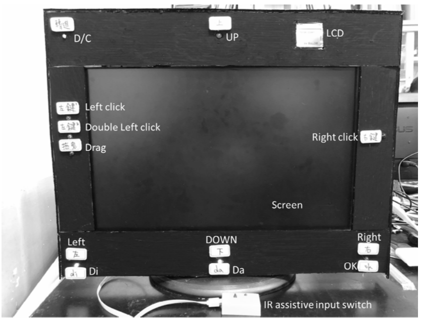


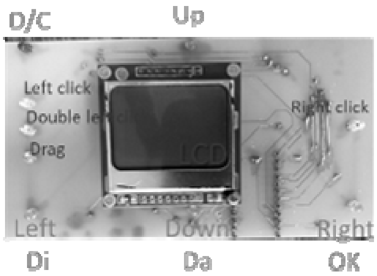
Figure 7. The Morse code combination the left side or the right side represents the short or long tone in each node

3 Experimental Results and Discussions

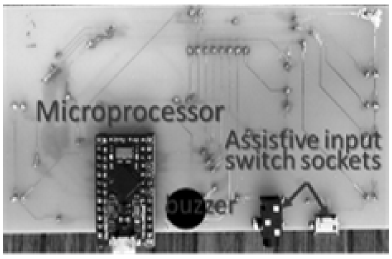
The proposed SAID system had been implemented and shown in Figure 8. The SAID system consists of an assistive input switch (Figure 8(a)), a scanning control circuit (Figure 8(b) and 8(c)), and the indicator lights display (Figure 8(a)). The indicator lights display is around the screen, and then users can directly operate SAID by the residual light of looking at the screen and tracking the position of the light. The performance of proposed SAID system is evaluated in the following.



(a) SAID system



(b) The front panel of control box circuit

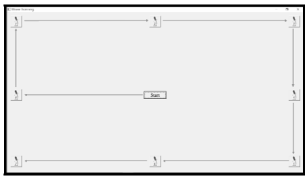


(c) The back panel of control box circuit

Figure 8. The implemented assistive input device

3.1 The Experimental Results of Mouse Function of SAID

In order to train a user, he/she is familiar to move the cursor or mouse with the scanning mouse, a mouse training software puts nine icons on the screen in which the arrangement (as shown in Figure 9). In this experiment, the screen is a 19-inch standard ratio LCD monitor, the resolution is 1280*1024 (in pixels). The user is then asked to trace sequentially the eight identified (Figure 9(a)) paths and to click each of the indicated buttons on the screen. The software shows the total time intervals to finish the designated buttons (Figure 9(b)), so the user knows if he/she has improved his or her performance. In this study, there were five normal participants (4 males, 1 female) who performed the scanning mouse performance test. They were all beginners and tested five times per person. In the experiment, the user uses the IR assistive input switch to test. Mouse test results show as Table 1. The total average time of complete the test was 97.36 seconds, and the standard deviation was 5.95 seconds.



(a) before

(b) finished training

Figure 9. The screen of training of mouse mode for

Table 1. The input rates (seconds) of the mouse operation test for each subjects

Testing times	The no of subjects				
	1	2	3	4	5
1	105	110	109	123	103
2	96	92	95	101	98
3	99	108	89	93	85
4	89	104	87	108	92
5	83	93	84	104	84
Average	94.4	101.4	92.8	105.8	92.4

3.2 The Experimental Results of Keyboard Function of SAID

When SAID in the keyboard mode, the user can input Morse code to type, such as Figure 10. Five participants were asked to use the Morse code to type the sentence “This is an apple.” This sentence total of 17 characters including blank characters and punctuation, there are all 52 Morse codes, case-insensitive, and record the test time. Typing test results were shown as Table 2. The total average time of complete the test was 91.56 seconds, and the standard deviation was 3.63 seconds.

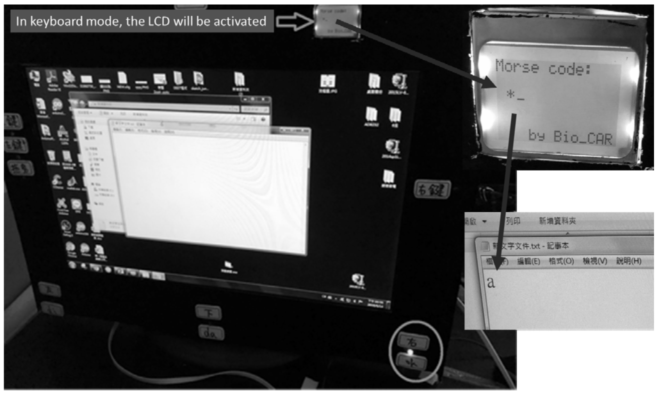


Figure 10. The results of keyboard mode of SAID for typing text

Table 2. The input rates (seconds) of the keyboard operation test for each subjects

Testing times	The no of subjects				
	1	2	3	4	5
1	117	125	119	108	98
2	87	92	86	86	89
3	88	96	84	88	93
4	84	89	91	80	96
5	73	80	82	71	89
Average	89.8	96.4	92.4	86.6	92.6

3.3 The Experimental Results of Case Study

This study observes a case of cerebral palsy testing a portable SAID as shown in Figure 11, and performs a performance test analysis according to the mouse and typing test method described above. Patients with cerebral palsy often have too much tension due to physical limitations, so they are not ideal in terms of arbitrary limb control. Therefore, this case uses the chin for input. After 5 minutes of practice, 5 tests of the mouse and keyboard are performed. In the part of the mouse test, the subject took an average of 108.2 seconds, with an average of per option of is13.53 seconds. In the typing test part, the subject took the average time of 162.7 seconds, and the average time of per character was 9.57 seconds.

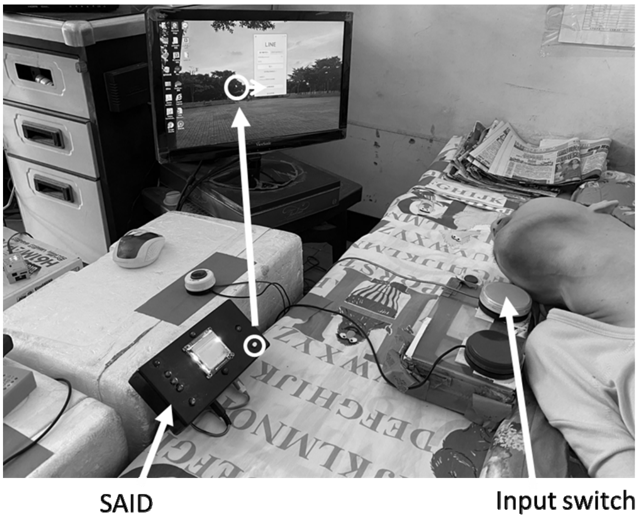


Figure 11. A severely disabled was operatint the mouse by the proposed SAID

4 Conclusions

In this study, an SAID system had been successful developed to help severe disability in daily live. Using the developed alternative keyboard and mouse function, the users can easily use the applications such as LINE, WeChat, Skype, etc. in computers by using USB interface or in mobiles by using OTG lines. Therefore, the proposed SAID system can help users to communicate with others. Besides, using the appliance control software [24], the users can control home appliances by themselves without relying on others. The proposed SAID system can customize the polling time and then the input speech of the scan assistive input system can meet the conditions of severe disability. The experimental results showed that the input speed of the SAID can meet the needs of users with severe disability. Hence, the proposed SAID would be useful in practical applications and then can help users with severe disability in daily life.

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