# The New Design of an Infrared-Controlled Human–Computer Interface for the Disabled

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***Abstract*— This paper reports on the development of an eyeglass- type infrared (IR)-controlled computer interface for the disabled. This system may serve to assist those who suffer from spinal cord injuries or other handicaps to operate a computer. This system is comprised of three major components: 1) an infrared transmitting module, 2) an infrared receiving/signal-processing module, and 3) a main controller, the Intel-8951 microprocessor. The infrared transmitting module utilizes tongue-touch circuitry which is converted to an infrared beam and a low power laser (<0.1 mW) beam. The infrared receiving/signal-processing module, receives the infrared beam and fine tunes the unstable infrared beam into standard pulses which are used as control signals. The main controller is responsible for detecting the input signals from the infrared receiving/signal-processing module and verifying these signals with the mapping table in its memory. After the signal is verified, it is released to control the keys of the computer keyboard and mouse interface. This design concept was mainly based on the idea that the use of an infrared remote module fastened to the eyeglasses could allow the convenient control of the input motion on the keys of a computer keyboard and mouse which are all modified with infrared receiving/signal-processing modules. The system is designed for individuals with spinal cord injuries and disabled in which the subjects' movement are severely restricted. The infrared transmitting module can be easily mounted on eyeglasses or artificial limbs.**

***Index Terms*— Computer keyboard and mouse interface, disabled, eyeglass-type, infrared-controlled, infrared transmitting module, spinal cord injuries.**

## I. Introduction

PATIENTS with spinal cord injuries (SCI) and persons with disabilities involving paralysis increasingly utilize electronic assistance devices to improve their ability to perform certain essential functions. The functional areas in which the disabled most commonly utilize electronic equipment are: communications, environmental control and powered wheelchairs. A wide range of interfaces between the user and the device are available. The interface may be an enlarged keyboard or a complex system [1], [2], [10], [13] that allows the user to operate or control a function with the aid of a mouthstick, eye movements, an eye imaged input system [4]–[9], [11], [12], [15], [16] electroencephalogram (EEG) signals [14], etc. In many disabilities such as quadriplegia, the mouthstick method has poor accuracy and is uncomfortable. The eye movement and EEG methods provide few available controlled movements, can have slow response time for signal processing and requires substantial motor coordination. However, these instruments all tend to be highly specialized and are generally cost prohibitive. Thus, alternative systems which utilize commercially available electronics to assist in the performance of special tasks such as computer operation and environmental control are sorely needed.

The ability to operate a computer is becoming increasingly more important to the disabled persons and to those with SCI as advances in technology allow more and more functions to be computer controlled. There are many reasons for operating a computer. These include acquiring new knowledge and communicating with the outside world. However, they also include doing work at home, leisure activities, and many other things. This paper reports on the design of an infrared (IR)-controlled [3], [4] human–computer interface for patients who are paralyzed from a cervical cord injury with quadriplegia but retain the ability to rotate the neck and perform shrugging movements.

The infrared-controlled human–computer interface utilizes a small infrared-transmitting module mounted on the user's eyeglasses, and a tongue-touch panel on the input headset was developed and designed for this system. The user utilizes the tip of the tongue to gently touch the panel which is attached to one side of the mouth in order to turn the power switch of the infrared transmitting module on or off. The infrared transmitting module generates an infrared beam and a low power laser beam. The infrared beam is used for selecting the keys from a keyboard, while the laser beam allows the user to see which keys are selected. All the keys of the computer keyboard have been replaced with infrared receiving/signal-processing modules. By aiming the laser beam at the desired number, letter, or function key, the user can select the key. After verification for error, a main controller, the Intel-8951 microprocessor, carries out the signal reception processing and input functions. The microprocessor is also responsible

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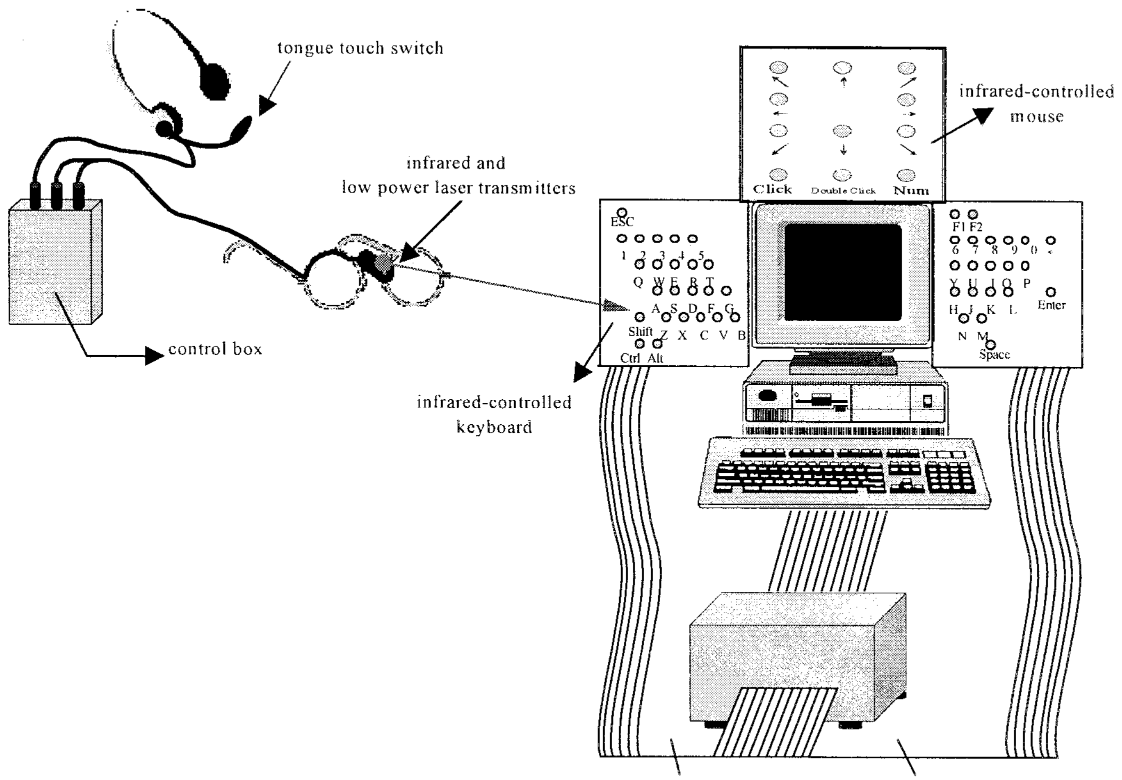


Fig. 1. Configuration of the infrared-controlled human–computer interface.

for controlling the computer keyboard interface and providing feedback to the user that the input motion has been completed.

## II. Materials and Methods

The configuration of the infrared-controlled computer interface is shown in Fig. 1. This system replaces the keys of the original computer keyboard with infrared receivers and mounts an infrared transmitting module onto the eyeglasses of the disabled user. The user employs neck rotation movement to aim the infrared beam at the key of the computer keyboard in order to input data and perform all computer functions. The computer keyboard was divided into three parts: two parts are placed beside the monitor, for numbers, letters and function key input, and the third part is situated upon the monitor for mouse control, which utilized the assistant tool in the control console of Windows98, using keyboard instead of mouse controlling. The mouse-controlled functions include: up, low, left, right, upper-left, upper-right, lower-left, lower-right, single click, and double clicks. The circuit diagram for the infrared-controlled computer keyboard is shown in Fig. 2. This circuit for the infrared-controlled human–computer interface is composed of three major elements: 1) an infrared transmitting module, 2) an infrared receiving/signal-processing module, and 3) a main controller, the Intel-8951 microprocessor. The infrared transmitting module utilizes tongue-touch circuitry to activate an infrared beam and a low-power laser beam. The infrared receiving/signal-processing module, apart from receiving the infrared beam, also processes any unstable component of the infrared beam into standard pulses that are then used as control signals. The main controller is responsible for detecting the input signals, verifying the mapping table in its memory, and releasing correct signals to control the computer keyboard or other electronic interfaces.

### *A. The Infrared Transmitting Module*

The infrared transmitting module links the computer keyboard and mouse interface with the disabled user. The infrared transmitting module includes three main elements: an infrared transmitter and circuitry, a low-power laser transmitter, and tongue-touch circuitry, as shown in Fig. 2. Its dimensions are $3.0 \times 2.0 \times 1.5$ cm$^3$. It weighs about 8 g and can be easily mounted onto a pair of eyeglasses, as shown in Fig. 3(a).

The system adapts to an infrared receiver with a HC-377M model, therefore, the receiving frequency is 37.9 kHz or higher [17], [18]. The oscillating frequency of the infrared transmitter through the unstable multivibrator circuitry must be designated at 37.9 kHz or higher, as shown in Fig. 2.

The infrared beam, an invisible beam, has a wavelength which ranges from 0.75 $\mu$m to 1000 $\mu$m. The projected angles of the infrared beam are in a positive relation ship to the distance of the projection. Because the beam is invisible, it is difficult to determine whether it is accurately aimed at the infrared receiver's window. In order to solve this problem, a low-power laser is incorporated below the infrared transmitter to aid in positioning the infrared beam. In addition, a tongue-touch switch was included to facilitate coordinated use. This makes it convenient for the disabled user to turn on or turn off the power of the infrared-transmitting module, as shown in Fig. 3(b).

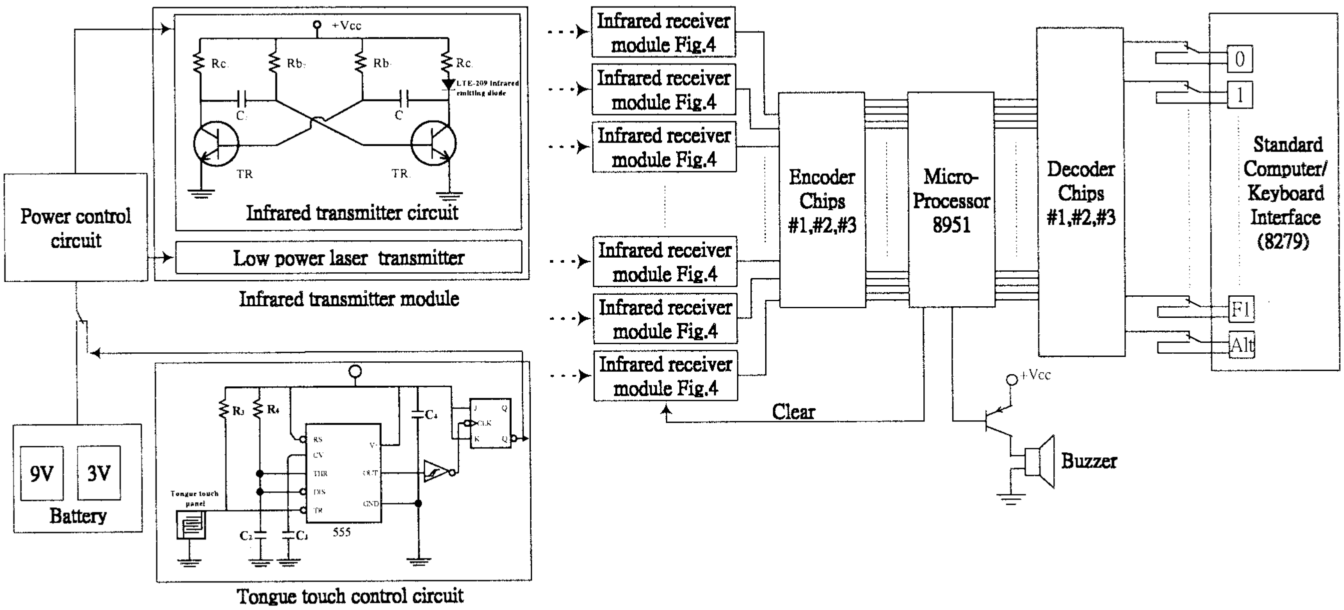


Fig. 2. Circuit diagram of the infrared-controlled computer keyboard system.

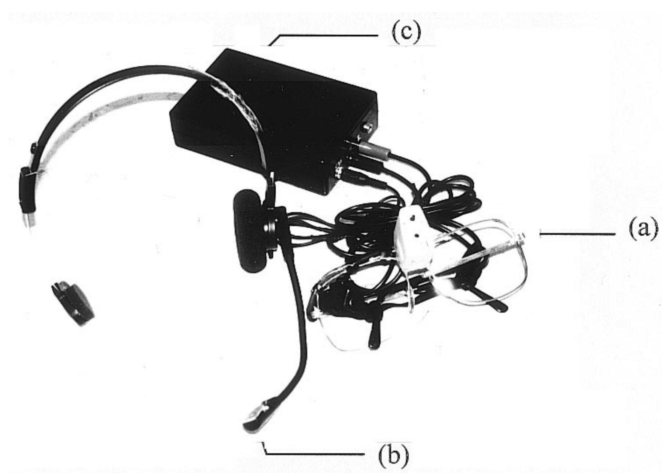


Fig. 3. The schematics of (a) an infrared transmitting module mounted on a eyeglasses is used to generate a infrared beam and a low power laser beam, (b) a tongue-touch switch is played as a power switch, and (c) a control box.

To alleviate refraction of the infrared beam, the viewing angle of the LTE-209 infrared transmitting diode is positioned at $\pm 8°$ [17], [18]. After appropriate filtration, the radius area of its projection within a distance of 50–100 cm, is approximately 0.5 cm. An optic filter is used to regulate the characteristics of the infrared beam closer to a paralleled beam. The transmitting focus of the infrared transmitting diode is about 0.2 cm from that of the low-power laser transmitter. Thus, the target of the low-power laser beam projection is 0.2 cm from the target of the infrared beam projection [19]–[22].

One 9 V and two 1.5 V batteries are used to supply the power needed for all of the devices contained in the control box apart from the infrared transmitter oscillating circuitry, the low-power laser transmitting circuitry, and the tongue-touch circuitry of the circuitry control box. The control box measures $12.5 \times 8 \times 3$ cm$^3$, and weighs roughly 150 g, as shown in Fig. 3(c). This allows the operator to conveniently attach it to the waist or over other body areas.

### B. Infrared Receiving/Signal-Processing Module

The infrared receiving/signal-processing module consists primarily of two parts: an infrared receiver, and the infrared signal processing circuitry. In order to replace all manual input motion, all keys of the computer keyboard were replaced by infrared receivers. A total of 60 infrared receivers are used in this system. A common infrared receiver, HC-377M optic receiver module, $V_{\rm cc} = 5.8$ V, $I_{\rm cc} = {\rm Max.}$ 3 mA with a receiving range: 10 M, $\theta = 45°$, resolution frequency $= 37.9$ kHz, and $\lambda_p = 9400$ mm are employed [17], [18].

In order to utilize the infrared beam to perform control and calculating functions, an infrared receiving/signal-processing interface is designed into this system, as shown in Fig. 4. The unstable signals are received via the infrared receiver and converted into fixed timing, cyclical pulsation (with a cycle of 1 per second) through use of the nonretriggered circuitry. The relationship between the input and output of the HC-377M and the use of nonretriggerable circuit is shown in Fig. 5. As shown in Fig. 5(a), the output of the HC-377M is at a high level (+5 V) when there is no infrared input. After the infrared beam is received by the HC-377M, the output of HC-377M becomes unstable, as shown in Fig. 5(b). The nonretriggerable circuit converts this unstable signal into a standard pulse train, as shown in Fig. 5(d). The duration and duty cycle of the standard pulse depends on the values for R1 and C1, as shown in Fig. 4. The standard pulse is set like a clock and sent to the shift registers (D-type flip-flops), which act as a delayed time counter while the user focuses on the infrared receiver. The LED1 (light-emitting diode) remains lit while the input processing is completed, and at the same time all the infrared receiving/signal-processing modules receive a control signal to clear their shift registers

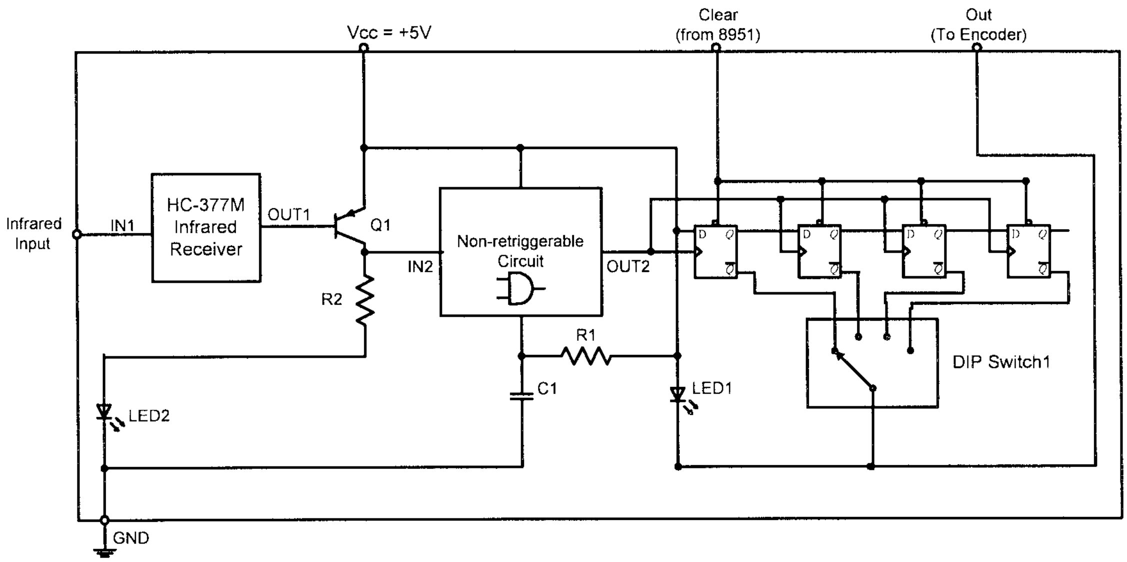


Fig. 4. Circuit diagram of the infrared receiving/signal processing module, the HC-377M is responsible for receiving infrared beam, the nonretriggerable circuit is used to convert the unstable infrared beam into a standard cycling pules, and the shift registers play as a counter to count the delayed time for user need to aim at the desired key.

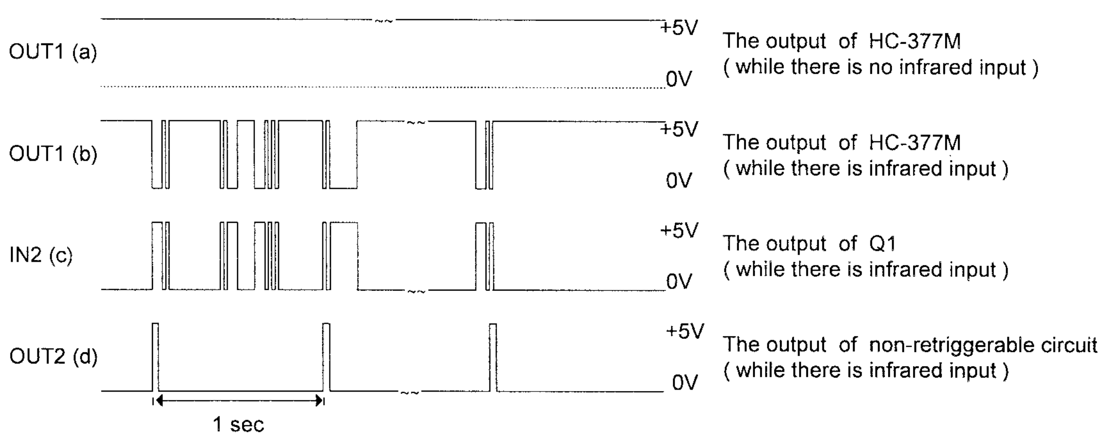


Fig. 5. Input and output signals at the infrared receiving/signal-processing module: (a) the output of the HC-377M while there is no infrared input, (b) the output of the HC-377M while there is an infrared input, (c) the output of Q1 while there is an infrared input, and (d) the output of the nonretriggerable circuit while there is an infrared input.

from Port2 of the Intel-8951. This can be set according to the user's preference for aiming the infrared receiver key for 1, 2, 3 or 4 seconds of uninterrupted or continuous aiming before it is recognized and input. Otherwise, no input will be processed. This design in response to the infrared receivers of the infrared-controlled computer keyboard, is configured using a two-matrix alignment method. The margins between any two keys are all set at 1 cm. Thus, when the user operates the system, the infrared transmitting module will not inadvertently select a nontargeted key. Therefore, to incorporate this function into the design, the user must aim at the target key by maintaining the beam continuously on the target for one second or more as per the designated activation time. The timing of the focus can be designated through the user's control of the infrared transmitting module sensitivity by adjusting the dual-in-line package (DIP) switch on the infrared receiving/signal-processing module.

In the design of the main structure of the computer keyboard, due to the restricted or stiff neck movement of the users, we added certain special function to the main structure with a design and production concept in order avoid the need to alter the keyboard's own schematics, and for ease of installation. An ordinary computer keyboard can be plugged into the system for immediate use. The infrared-receiving keyboard includes the basic 60 keys on a common modern computer keyboards.

### C. The Main Controller, Intel 8951, Microprocessor

The Intel-8951 microprocessor is the main controller of the system. The Intel-8951's Port1 and Port3 utilize decoders to intersect the remote input signals transmitted via the infrared receiving/signal-processing module. A table-verifying method is deployed via Port0 to dispatch signals commensurate to control input motion of the computer keyboard. At the same

Fig. 6. Schematic of the infrared-controlled computer interface used by a SCI subject with quadriplegia.

TABLE I
TEST RESULTS OF THE INFRARED-CONTROLLED HUMAN–COMPUTER INTERFACE

| | Control group (3 normal subjects) | Experimental group (3 SCI subjects with quadriplegia) | p |
|---|---|---|---|
| average accuracy (%) | 97.4 ± 5.3 | 94.6 ± 7.6 | p>0.05 |
| average time cost (min) | 3.6 ± 1.5 | 4.9 ± 2.0 | p>0.05 |

time, Port2 dispatches all control signals which are required by the surrounding circuits, including LED1 and buzzer control as a visual and audio feedback, respectively, to the operator for confirming that his input motion has been completed.

## III. RESULTS

The infrared-controlled, computer keyboard software and hardware installation have been completed, and this equipment is shown in Fig. 6, including an infrared transmitting module, and an infrared receiving/signal-processing module, and a main controller, the Intel-8951 microprocessor. The infrared transmitting module and the tongue-touch switch are shown in Fig. 3(a) and (b), respectively. The disabled user needs only to put on the new developed eyeglass-type infrared transmitting module in order to accomplish the objective of operating the computer and communicating a message through the World Wide Web (WWW).

For system evaluation, six subjects (all men, 26–39 years old, three are normal subjects and three are SCI with quadriplegia) who had operated computer were selected and gave their informed consent in this study. The three normal subjects whose neck movements are constrained below a fixed and stationary position were assigned as the control group. The other three SCI subjects with quadriplegia were assigned as the experimental group. All of the subjects were given 10 min instruction and training for operation prior to using this new developed infrared-controlled human–computer system. Then, give them a short article with 97 letters (includes space key, see Appendix A). The test results were shown in Table I and Fig. 7. The average accuracy of the control group and the experimental group are 97.4±5.3% and 94.6±7.6%, respectively. The average time cost of the control group and the experimental group are 3.6±1.5 min and 4.9±2.0 min, respectively. An independent $t$-test revealed that the differences in the average accuracy and the average time cost of the control group and the experimental group are no significant $(p > 0.05)$.

## IV. DISCUSSIONS AND CONCLUSIONS

The increasing number of various accidental injuries over the years has resulted in a dramatic increase in the disabled population. Although there are many devices which can supplement the loss of function in patients suffering from spinal cord injuries, there are substantial differences in their convenience and accuracy. Most devices intended to serve as computer keyboard supplements for the disabled utilize

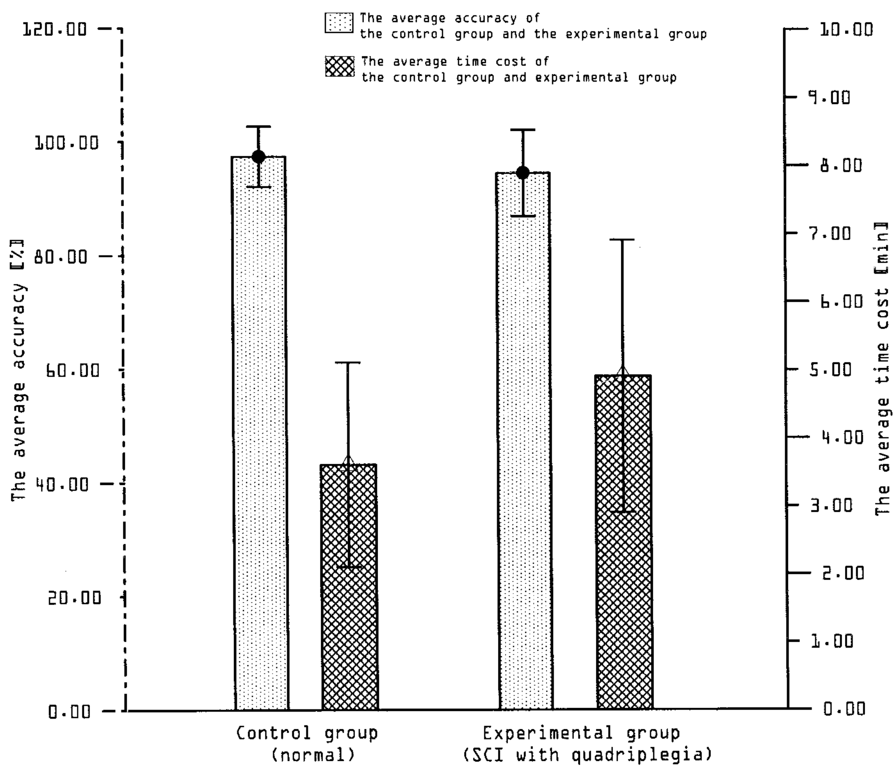


Fig. 7. Test results of the control group and the experimental group of the newly developed infrared-controlled human–computer interface.

mouthstick, eyeball movements, or eyeball-imaging methods to complete the input motion [4], [5], [9], [11], [15], [16]. Although many of these systems provide reasonable function and allow successful input through the computer keyboard, they frequently lack good sanitation or convenience because they are orally activated. Eyeball movement and eyeball-imaging based systems rely on high-level imaging analysis, provide questionable accuracy, and need a longer operating time to input a number or a letter. In addition, these systems have the disadvantage of expensive instrument costs and may require extended operational training.

In today's era of leaps in electronics and computer technologies, we hope the disabled will not become technological orphans in this era. We hope to utilize the least amount of circuitry design with highly accurate control systems to provide devices for the disabled to overcome the inconveniences in their daily lives. The system presented in this paper allows the disabled person to avoid the need to use uncomfortable input methods such as clutching a mouthstick. The system utilizes the remaining neck rotating function, directly applying an infrared transmitting module to control the computer keyboard and mouse. It has several user-friendly features, such as allowing the user to check if his input motion is correct and providing a LED indication and buzzer as visual and audio feedback to the user when input motion is completed. Thus, this system has the definite advantages of convenience, accuracy, and sanitation over the mouthstick-based system. In addition, an eyeglass-type control method is especially suitable for those who suffer from quadriplegia due to spinal cord injuries. Disabled users can also mount the infrared transmitting module on a prosthesis, on protective gear, or on a power wheelchair to achieve the objective of administering control.

This infrared-controlled human–computer interface utilizes current circuit technology to effectively accomplish the control of a computer keyboard system. In the future, this interface could potentially be introduced into many control systems at home including powered wheelchairs, telephones, and electronics.

The cost of all parts of the infrared-controlled human–computer interface is approximately $450 U.S. This cost could be used to estimate the production costs of this device. In comparison, an IR modular eye movement monitor produced by Universal Initram Corporation [12], [23] costs about $12 175 U.S. Also, the response time of the new infrared-controlled human–computer interface is shorter than other systems, and the response time could be set from 1 to 4 s adjustable.

## APPENDIX

The short article is the following.

This is a test, for evaluation of the new developed infrared-controlled human–computer interface.

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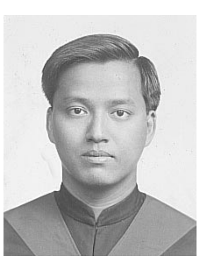

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