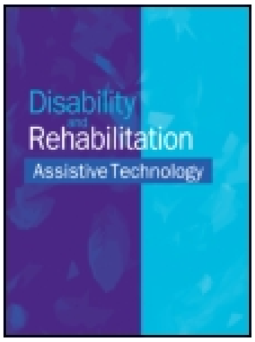

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DEVICES AND PRODUCTS

A novel home appliance control system for people with disabilities

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Abstract

Purpose. This research proposed an eyeglass-type infrared-based home appliance control system for spinal cord injured (SCI) with tetraplegia.

Method. This system is composed of four major components: A headset, an infrared transmitting module, an infrared receiving/signal-processing module, and a main controller, the Intel-8951 microprocessor. This design concept was based on the use of an infrared remote module fastened to the eyeglasses that could allow the convenient control of the input motion on the keys of a remote controller of a home appliance which are all modified with infrared receiving/signal-processing modules. For system evaluation, 12 subjects (4 male, 8 female, 26 – 47 years old were recruited. Six persons without disabilities were in the control group and 6 with SCI with tetraplegia formed the experimental group.

Results. The average accuracy of the control group and the experimental group are 88.8 ± 10.6% and 85.9 ± 14.3%, respectively. The average time cost of the control group and the experimental group are 57.2 ± 8.1 sec and 66.6 ± 12.3 sec, 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 not significant ($p > 0.05$).

Conclusions. Using the novel home appliance control system not only provided the advantages of convenience, accuracy and sanitation for people with disabilities but it also helped them to live more independently.

Keywords: *Infrared, home appliances control system, spinal cord injured (SCI), tetraplegia*

Introduction

Individuals with tetraplegia increasingly utilize electronic assistance devices to improve their ability to perform home appliance control functions. The functional areas in which people with multiple disabilities most commonly utilize electronic equipment are communications and environmental control. A wide range of communication interfaces between the user and the device are available. The interface may be an enlarged, scanning keyboard or a complex system [1,2,10,13] that allows the individual with tetraplegia 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 tetraplegia, 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 home appliances operation and environmental control are sorely needed.

The ability to operate home appliances is becoming increasingly important to the person with tetraplegia. There are many reasons for operating a home appliance controller. It includes acquiring

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knowledge of social activities. This paper reports on the design of an infrared-based [3,4] home appliance control system for patients with tetraplegia.

This study was aimed at: (i) developing an infrared-based home appliance control system for people who are paralyzed (with tetraplegia) from cervical cord injury but retain the ability to rotate the neck and perform shrugging movements, and (ii) assessing this system with a group of people with the aforementioned disabilities and a group of people without disabilities in terms of operation accuracy and time cost.

Materials and methods

The configuration of the infrared-based home appliances control system is shown in Figure 1. This system replaces the keys of the home appliances 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 keys of the home appliances in order to perfom all functions.

The circuit diagram of infrared-based home appliances control system is shown in Figure 2. This circuit diagram for the infrared-based home appliances control system is composed of four major elements: A headset, an infrared transmitting module, an infrared receiving/signal-processing module, and a main controller, the Intel-8951 microprocessor.

The headset has a tongue-touch panel and a wireless earphone. The infrared transmitting module utilizes the tongue-touch panel via tongue-touch circuitry in the control box 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 home appliances or other electronic interfaces.

The headset

The wireless earphone of the infrared-based home appliances control system has been incorporated into a headset worn by the user. In addition,

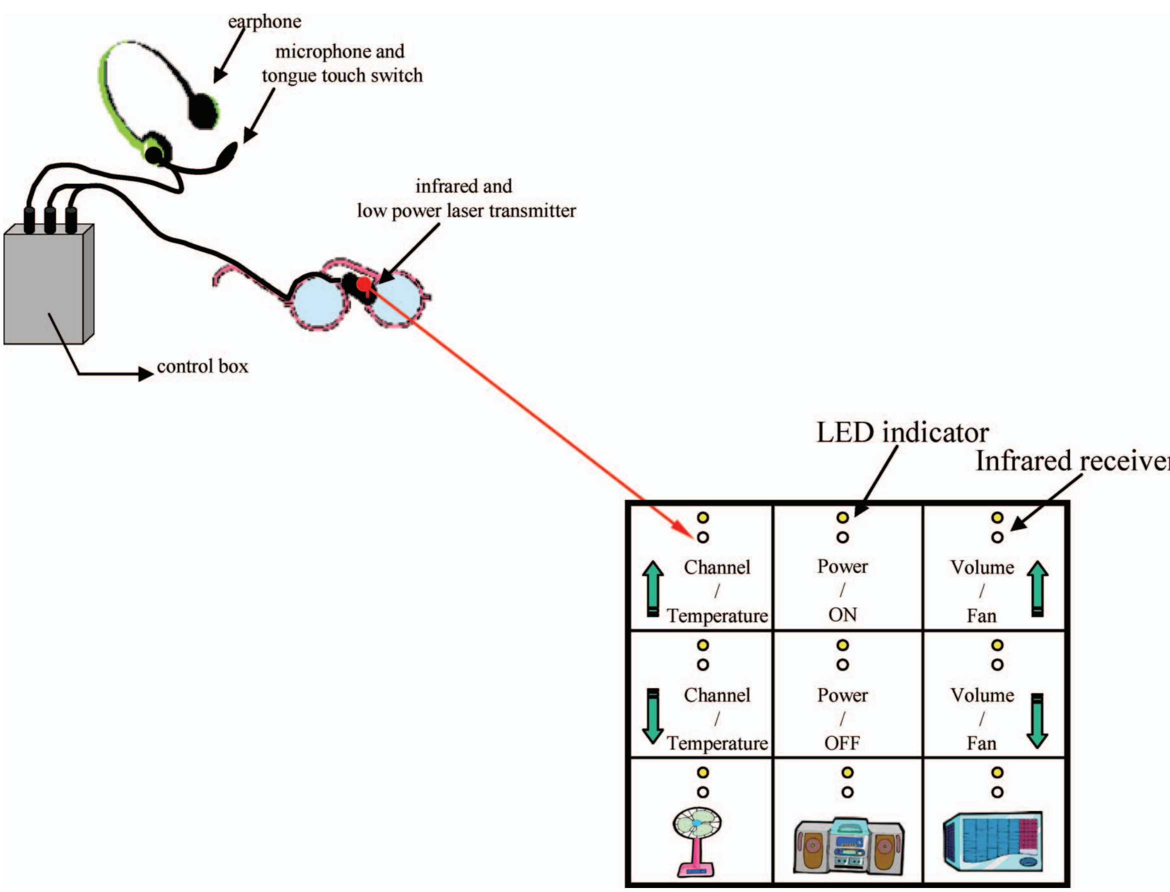

Figure 1. The configuration of the infrared-based home appliance control system.

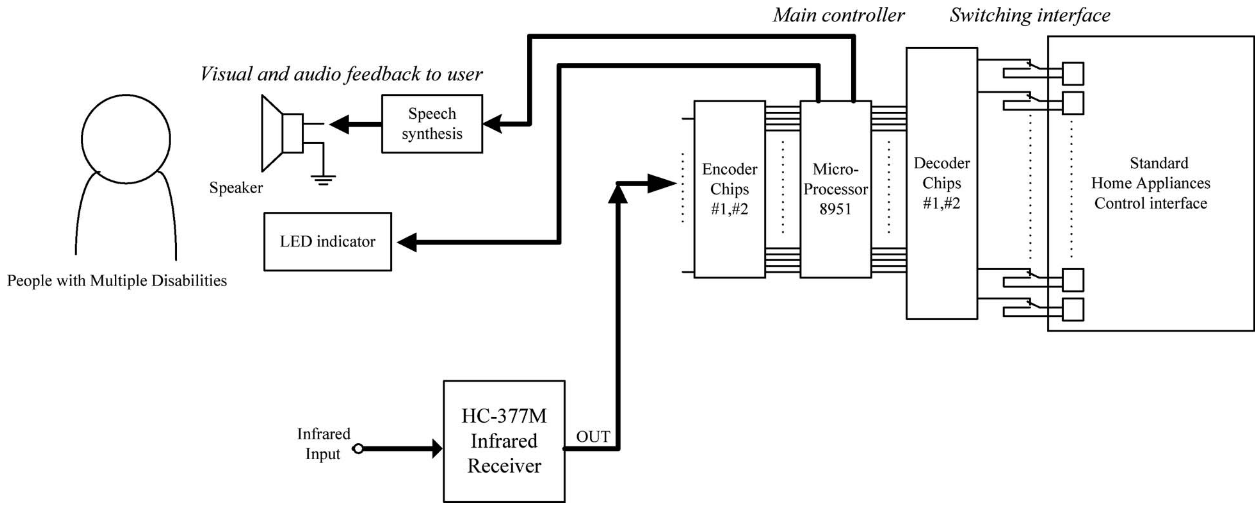

Figure 2. The circuit diagram of the infrared-based home appliance control system.

a tongue-touch panel 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.

The infrared transmitting module

The infrared transmitting module links the home appliance control system with the disabled user. The infrared transmitting module includes two main elements: An infrared transmitter and circuitry, and a low-power laser transmitter, as shown in Figure 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.

The system adapts to an infrared receiver with an HC-377 M 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.

The infrared beam, an invisible beam, has a wavelength which ranges from 4000 – 7500 Å. The projected angles of the infrared beam are in a positive relationship 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.

To alleviate refraction of the infrared beam, the viewing angle of the LTE-209 infrared transmitting diode is positioned at $\pm 8^\circ$ [17,18]. After appropriate filtration, the radius area of its projection, within a distance of 50 – 100 cm, is approximately 0.5 cm. An optical 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.

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. This allows the operator to conveniently attach it to the waist or over other body areas.

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 home appliances were replaced by infrared receivers. A total of 20 infrared receivers are used in this system. A common infrared receiver, HC-377 M optic receiver module, Vcc = 5.8 V, Icc = Max. 3 mA with a receiving range: 10 M, $\theta = 45^\circ$, resolution frequency = 37.9 KHz, and λp = 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. 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 from Port 2 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 sec of

Figure 3. The components of the novel home appliance control system.

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-based home appliances is configured using a two-matrix alignment method. The margins between any two keys are all set at 2 cm. Thus, when the user operates the system, the infrared transmitting module will not inadvertently select a non-targeted 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 1 sec 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 home appliances 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 home appliances' own schematics, and for ease of installation.

The main controller, Intel-8951, microprocessor

The Intel-8951 microprocessor is the main controller of the system. The Intel-8951's Port 1 and Port 3 utilize decoders to intersect the remote input signals transmitted via the infrared receiving/signal-processing module, and store the input data in its input buffer (&Buf). The Intel-8951 does not send any control signal to the home appliance's interface until the enter key is selected. A table-verifying method is deployed via Port 0 to dispatch signals commensurate to control input motion of the home appliances. At the same time, Port 2 dispatches all control signals which are required by the surrounding circuits, including LED, and speech synthesis as a visual and audio feedback, respectively, to the operator for confirming that his input motion has been completed.

Table I. The test results of the novel home appliance control system.

	Control group (6 normal subjects)	Experimental group (6 SCI subjects with quadriplegia)	p
Average accuracy (%)	88.8 ± 10.6	85.9 ± 14.3	$p > 0.05$
Average time cost (sec)	57.2 ± 8.1	66.6 ± 12.3	$p > 0.05$

System evaluation

For system evaluation, 12 subjects, (4 male, 8 female, 26–47 years old) who had operated other home appliances controllers were selected and gave their informed consent in this study. Six persons without disabilities whose neck movements were constrained below a fixed and stationary position were assigned as the control group, and six persons with SCI with tetraplegia formed the experimental group.

All of the subjects were given 20 min instruction and training for operation prior to using this new infrared-based home appliance interface. Then, they were given 12 sets of input commands with a total of 15 input motions.

Results

The infrared-based, home appliance software and hardware installation have been completed, and this equipment is shown in Figure 3, including a headset, an infrared transmitting module, and an infrared receiving/signal-processing module, and a main controller, the Intel-8951 microprocessor. The people with multiple disabilities need only to put on the new developed eyeglass-type infrared transmitting module in order to accomplish the objective of operating the home appliances.

The clinical test results were shown in Table I and Figure 4. The average accuracy of the control group and the experimental group are $88.8 \pm 10.6\%$ and $85.9 \pm 14.3\%$, respectively. The average time cost of the control group and the experimental group are 57.2 ± 8.1 sec and 66.6 ± 12.3 sec, 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 were not significant ($p > 0.05$).

After the clinical assessment, some suggestions were collected by clinicians. The components (earphone and eyeglasses) of this novel infrared system now are assembled by market products, and are not customized products. The participants suggested a preference for an ergonomic and user-friendly customized product.

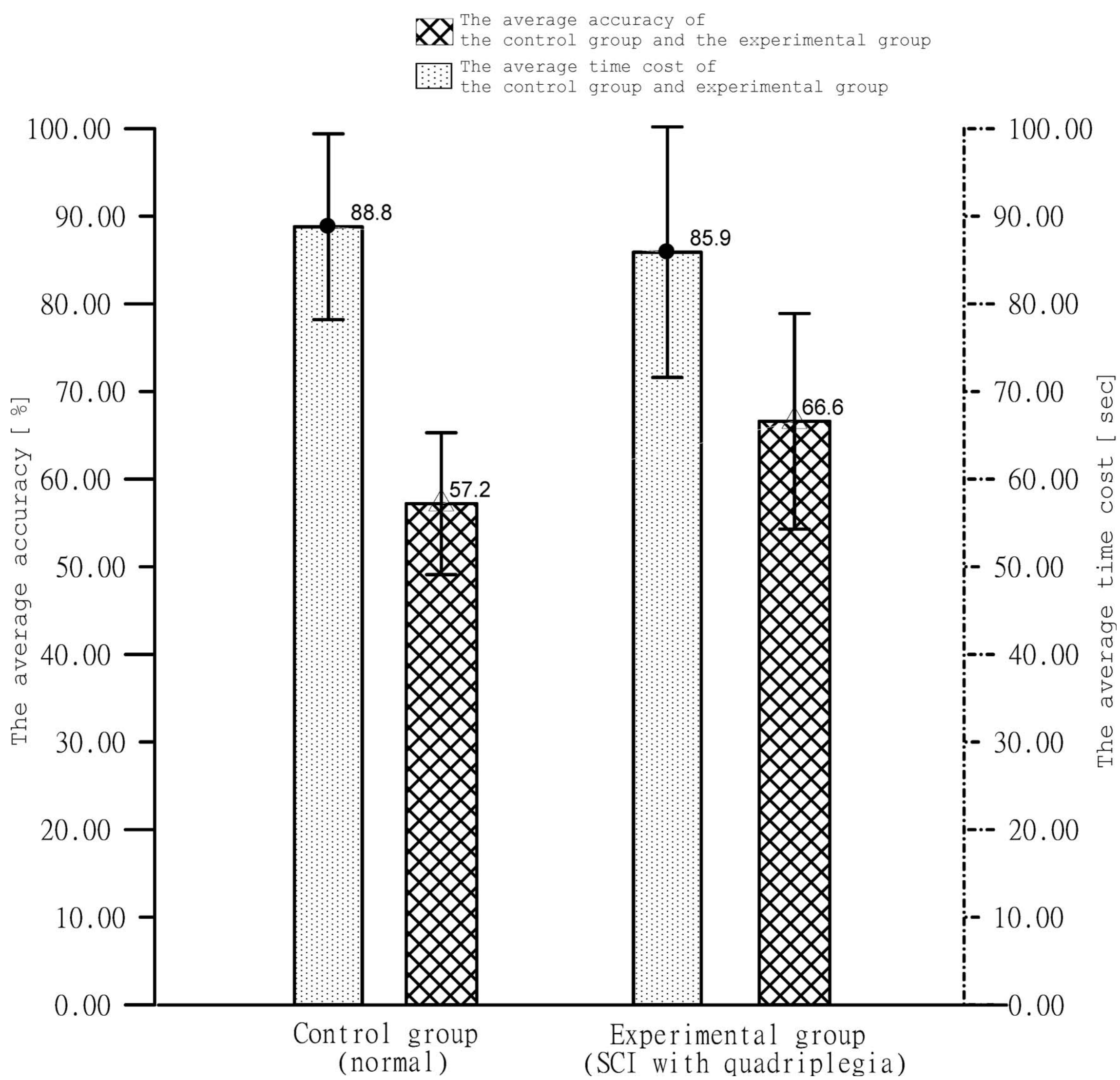

Figure 4. The test results of the control group and the experimental group of the novel home appliance control system.

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 with language disorder, there are substantial differences in their convenience and accuracy. Most devices intended to serve as home appliance supplements for the disabled utilize 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 home appliances, 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 command. 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 technology, we hope disabled people 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 home appliances. It has several user-friendly features, such as allowing the user to check if his input motion is correct and providing an LED indication and speech synthesis 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 spinal cord injuries.

This novel home appliance interface utilizes current circuit technology to effectively accomplish the control of home appliances. In the future, this control interface could potentially be introduced into many controls of the environment such as electric wheelchair control, personal computer control, etc.

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