Portable communication aid for deaf-blind people

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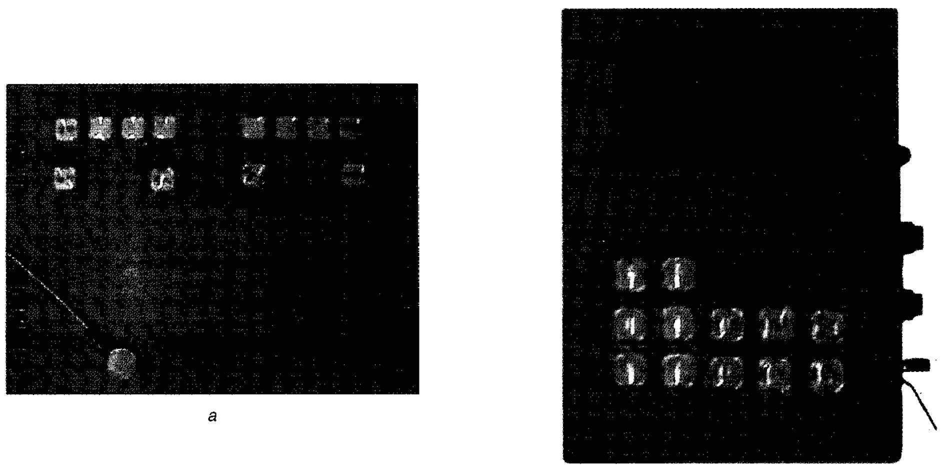
The development of a portable communication aid, which allows deaf-blind people to communicate with others without the help of an assistant, is reviewed. The system comprises two major units: one for deaf-blind people and the other for sighted people. A deaf-blind person can send messages by typing on a Braille terminal and the messages will be converted to Mandarin phonetic symbols, which are then displayed on an LCD display to be read by a sighted partner. Then the sighted partner can send messages back by typing on a simple keyboard and the messages will be displayed on a Braille display to be 'read' by the blind-deaf person. The aid has been designed to be effective, reliable and inexpensive. Some experimental results are reported to demonstrate the applicability of the aid.

As a result of congenital malfunction, diseases or accidents, deaf-blind people are unable to interact with the external world in the same way as non-handicapped people usually do. The tactile channel is the only communication channel available for deaf-blind people. Although deaf-blindness is a low incidence handicap, it presents many intriguing and difficult challenges to rehabilitation engineers.

Deaf persons can depend on vision to understand their environment; therefore, they usually develop gestures and then express themselves to others through sign language or other modes. People who are blind can use their intact sense of hearing to receive environmental cues. As a result, blind persons usually have little difficulty in learning to speak and in communicating with others. However, deaf-blind people function quite differently from people who are either deaf or blind. Due to extreme sensory deprivation, they cannot respond normally to their family members and others. Therefore, some of them function in some ways like mentally retarded people. Thus, developing some kind of communication aid to help them communicate with others and to enable them to lead more productive lives is a very demanding challenge.

The only communication channel available for deaf-blind people is the tactile channel. Therefore, technological assistive devices for deaf-blind people must somehow convert internal stimuli into useful tactile sensations. There are many factors hindering the developments of such assistive devices. Firstly, in many countries in the world, there is only very limited funding to support the development and manufacture of such devices. Second, the deaf-blind population is very low. This represents a limited market and prohibitive costs. Fortunately, there still are a number of commercially available devices. A brief description of some of these devices was presented in Reference 1. For example, the tactician 1600 multi-channel electro tactile communication system,[2] the TACTAIDII,[3] the Fonator system,[4] the Teocher TM system,[5] the Minivib 3,[6] the VOICE-LITE I,[7] the MOWAT sensor,[8] the TELE Braille communication system[9] etc. Langtao and Balachandran built a small, easy-to-use, and low-cost electronic compass for the use of blind or deaf-blind pedestrians.[10] A PC-based telephone communication system designed for deaf-blind people was proposed in Reference 11. Recently, Damper and Evans developed an electronic system to alert a deaf-blind man to the occurrence of a variety of household sounds, such as a doorbell, telephone or a smoke alarm.[12]

The work reported in this article was initiated by a request from a young deaf-blind girl for a system to help her to communicate with others, especially her father. She



a

b

Fig. 1 Two-unit communication aid for deaf-blind persons: (*a*) the 'Braille unit'; (*b*) the 'normal unit'

is truly deaf-blind. Fortunately, she learned how to read Braille codes and how to use finger-spelling language from the sheltered care facility where she stays. She uses finger-spelling language to communicate with the staff in the facility. When she goes back home the only person she likes to stay with is her mother because her mother knows finger-spelling language, but not her father. Understandably, they all feel very frustrated. In addition, since most non-handicapped people cannot sign, the little girl always needs an assistant as a translator to help her to communicate with others. This motivated us to design a low-cost portable two-unit communication aid designed for face-to-face and wireless communication between her and a sighted partner.

Two-unit communication aid

The prototype is a two-unit system designed for face-to-face and wireless communication between a deaf-blind person and a sighed partner. It is battery operated and portable. The deaf-blind partner would use a 'Braille unit' (shown in Fig. 1(*a*)) with a Braille style keyboard and a three-cell (tactile) display. The sighted partner would use a 'normal unit' (shown in Fig. 1(*b*)) with a liquid crystal display (LCD). The system can be generalised to be used as a communication aid between two deaf-blind people. Communication between two deaf-blind people would involve two Braille units or the sharing of one Braille unit. The block diagram of the communication aid is shown in Fig. 2.

Normal unit

The normal unit operated by a sighted person contains the following five modules.

(*i*) *Simplified keyboard:* The simplified keyboard layout is shown in Fig. 3(*a*). There are 12 keys in the keyboard: six keys corresponding to the six dots in a six-digit Braille cell, one 'CLEAR (CL)' key for correcting a typing mistake, one 'SEND (SD)' key for sending a complete message to the Braille unit, one 'NEXT (NX)' key for entering next character, one 'Calling/Confirmation (CC)' key for either calling out or switching off the buzzer, one 'CHANG (CH)' key for either wireless communication or face-to-face communication, and one 'ENTER (EN)' key for indicating that a six-dot Braille code has been keyed in. Port1 of an Intel 8952 is used to sense which key is pressed.

(*ii*) *LCD display:* We adopted a DG12864 liquid crystal display (LCD) for displaying the corresponding messages. The LCD can display totally 128 characters of size 8*8. The whole screen is partitioned into two parts: the left part for displaying the message being keyed in and the right part for displaying the received message. Port0 (P00~P07) of an Intel 8952 is used to produce the corresponding Mandarin phonetic symbols. Pins P23 and P24 of the Intel 8952 are connected to Pins CS1 and CS2 of the DG12864 LCD, respectively. When the output of the Pin P23 (P24) is at a high-voltage level (+5V) the left (right) portion of the LCD is chosen to display the message and vice versa.

(*iii*) *Buzzer:* The buzzer is used to alert the non-handicapped person when a deaf-blind person is trying to call him or her. The buzzer will produce two different buzzing sounds corresponding to a low-frequency sound and a high-frequency sound, respectively. While a low-frequency buzzing sound indicates an incoming call asked for by a deaf-blind person, a high-frequency buzzing sound indicates an emergency call. Note that the buzzer will continue buzzing until the 'Calling/ Confirmation' key is pressed.

(*iv*) *Communication:* There are two operating modes in the communication module: one for wireless communication and the other for face-to-face communication. For wireless communication, a transmitter and a receiver are required for each unit. There is a large number of simple AM or FM transmitters and receivers available on the consumer market. To minimise time to production of the prototype, we decided to choose commercially available transmitters and receivers. While some transmit encoded data, others simply send an on/off signal. After a thorough evaluation, we finally decided to choose a transmitter (receiver) which can transmit (receive) 4-bit encoded data. The reasons are as follows. We partition a six-dot Braille cell into the left side and the right side. Each side contains three dots, therefore, three bits are required. In addition to the three bits corresponding to the information of which the dot is set or cleared, another bit is required to indicate which side (left or right) is being transmitted. While digit 1 of the first one bit indicates that the 3-bit data of the left side of a Braille code is being transmitted, digit 0 indicates that the 3-bit data of the right side of a Braille code is being transmitted. Digits 1 and 0 alternately change to inform the receiver to correctly combine corresponding information. While the HT-12E (transmitter) and the HT-12D (receiver) are used for wireless communication, a twisted telephone line is used to connect the normal unit and the Braille unit. For face-to-face communication, the contents of the corresponding Braille codes will be stored in the buffer (SBUF) of the Intel 8952 first and then serially transmitted to the Braille unit via the telephone line.

(*v*) *Microprocessor control:* The Intel 8952 microprocessor is the main controller of the system. It is a 40-pin chip that is available in shops at an affordable price (e.g. NT$160). A table-verifying method is deployed via Port0 to dispatch signals to produce Mandarin phonetic symbols on the LCD display. The Intel 8952's Port1 is used to sense which function key is pressed. Port2 dispatches all control signals which are required by surrounding circuits. The main function of Port3 is to transmit/receive signals to/from the Braille unit via the RF transmits/ receiver or telephone line.

(*vi*) *Auxiliary portion:* There are a 'POWER' key, a 'RESET' key, a green LED, and a red LED in the auxiliary portion. The 'POWER' key is used to switch on the battery power supply. The 'RESET' key is used to

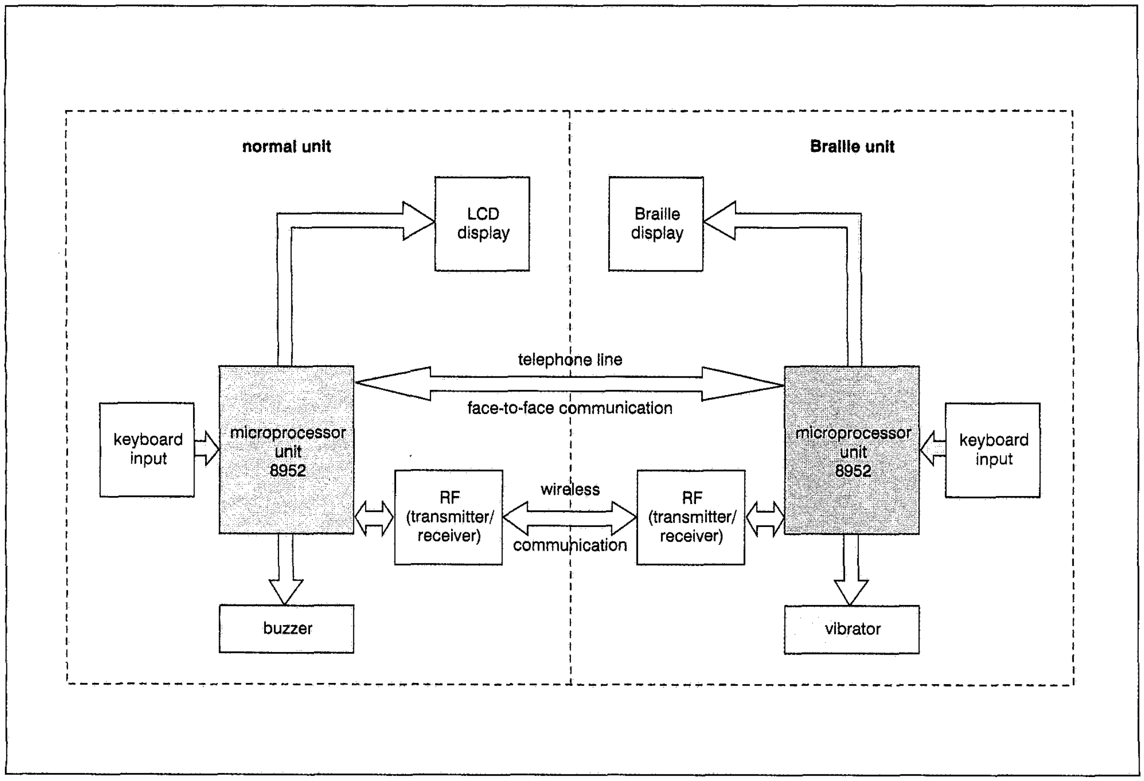


Fig. 2 Block diagram of the communication aid for deaf-blind persons

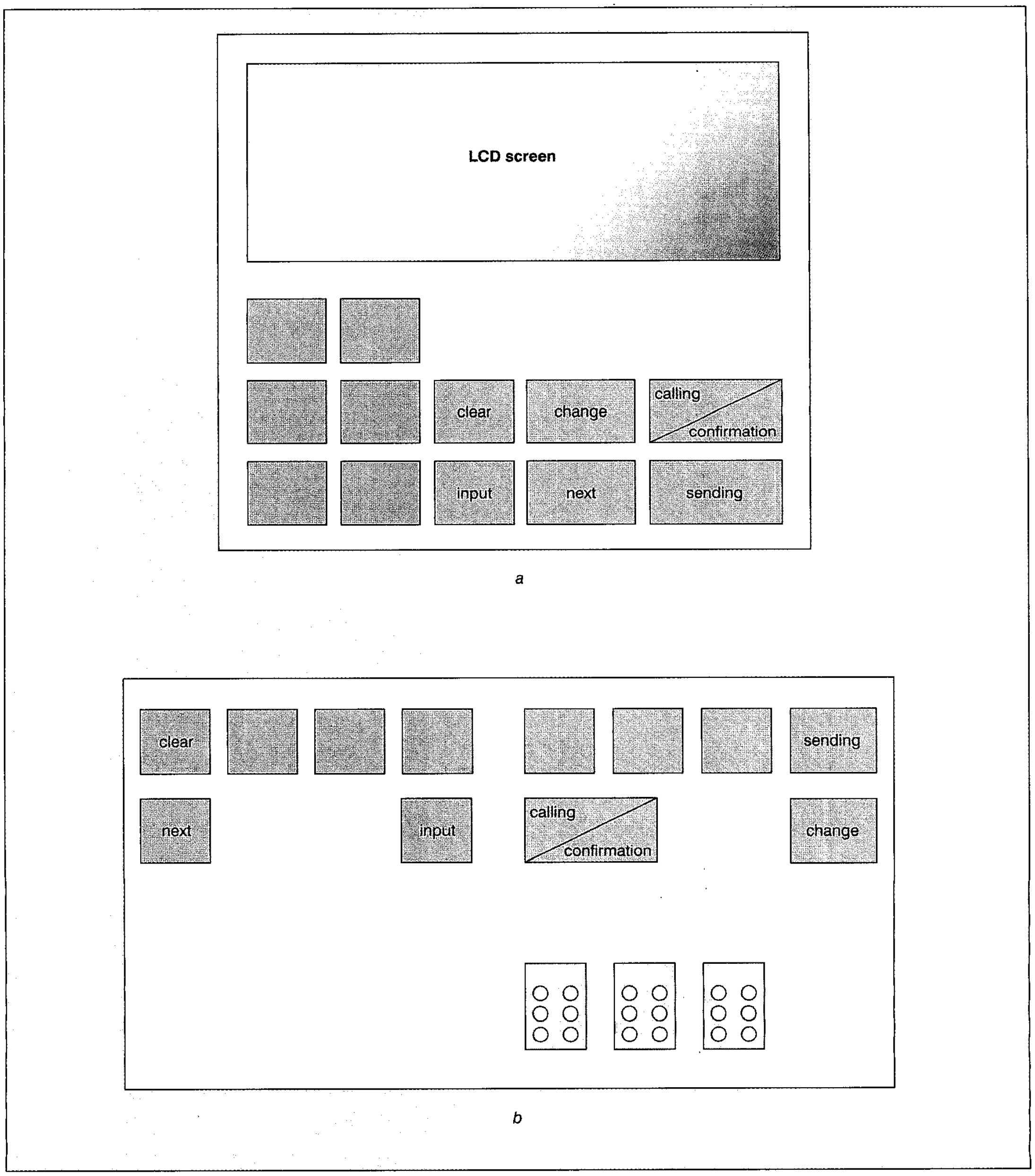


Fig. 3 Layouts of the keyboards: (*a*) the simplified keyboard layout; (*b*) the Braille terminal layout

reset the whole system. While the green LED indicates the power is on, the red LED indicates the wireless communication mode is adopted.

Braille unit

The Braille unit consists of five modules: a Braille terminal module, a Braille (tactile) display module, a vibrator module, a communication module and a microprocessor control module.

(*i*) *Braille terminal:* The Braille terminal layout is shown in Fig. 3(*b*)). As in the simplified keyboard of the normal unit, there is a total of 12 keys in the terminal: six keys corresponding to the six dots in a Braille code and six function keys.

(*ii*) *Braille display:* As mentioned in the first section, the deaf-blind girl has been educated to be able to read Braille codes and understand finger-spelling language. In

Mandarin, there are in total 21 consonants, 16 vowels, and 22 diphthongs, shown in Fig. 4. In addition, each Mandarin character is associated with one of five different tones. As expected, each character requires at most three cells corresponding to a consonant, a vowel or a diphthong, and a tone, respectively. Therefore, the minimum requirement for the Braille (tactile) display is three cells. As a trade-off between the complexity of the system and the efficiency, we decided to adopt three six-dot Braille cells.

(*iii*) *Vibrator module:* The vibrator module is used to alert the deaf-blind person when someone is trying to talk to him or her. Whenever a sighted partner from a long distance tries to communicate with the deaf-blind partner, a signal is transmitted to the Braille unit and the vibrator will produce vibrations to alert the user to start a conversation. The standard means of producing a vibrating output in devices for the deaf and deaf-blind is to drive a small electric motor with an eccentric, out-of-balance weight on its shaft. A 5V DC motor of 13 mm diameter was selected. There are two different rhythmical patterns of vibrations. While the first rhythmical pattern indicates a conversation is requested by a sighted partner, the second rhythmical pattern indicates an emergency alarm (e.g. a fire alarm etc.) which alerts the deaf-blind person to be very careful of the changes of the environment.

(*iv*) *Communication:* As in the normal unit, there are two operating modes in the communication module: one for wireless communication and the other for face-to-face communication. Details of the communication module have been given in the corresponding subsection for the normal unit.

(*v*) *Microprocessor control:* The Intel 8952's Port1 is used to sense which function key is pressed. Six pins of Port0 (P00 P05), Port2 (P20 P25), and Port3 (P30 P35) are used for three Braille cells, respectively. At the same time, Port3 is also used to transmit/receive data via the RF module or telephone line.

(*vi*) *Auxiliary portion:* There are a 'POWER' key, a 'RESET' key, a green LED, and a red LED in the auxiliary portion. The 'POWER' key is used to switch on the battery power supply. Details of the auxiliary portion have been given in the corresponding subsection for the normal unit.

Operating procedures

In the prototype, there are two operating modes: sighted-to-disabled mode and disabled-to-sighted mode.

Sighted-to-disabled mode

In this mode, a sighted person tries to communicate with a deaf-blind person. The operating procedure involves the following steps:

1 The sighted partner first presses the 'POWER' key and then checks whether the green LED is on. The green LED was included in the unit to facilitate system testing.
2 For wireless communication, the sighted partner should press the 'CHANG' key to power the RF modules and check whether the red LED is on. Otherwise, it means we select the face-to-face communication via the telephone line.
3 Press the 'Calling/Confirmation' key (a four-bit '0000' message is then transmitted to the Braille unit) and wait for the buzzing sound.
4 When the Braille unit receives the calling message, the vibrator will produce a rhythmical pattern of vibrations for the deaf-blind person to notice. The deaf-blind person will then press the 'calling/confirmation' key for the attention of the sighted partner (the buzzer will buzz for a while until the sighted person presses the 'Calling/Confirmation' key again) that he or she is ready to continue a conversation.
5 The sighted partner may then key in the Braille codes of the message to be transmitted. The corresponding Mandarin phonetic symbols will be displayed on the LCD display so that the sighted person can check whether there is any typing mistake. Whenever a mistake occurs, the sighted person can press the 'CLEAR' key and then key in the right Braille codes. Note that the 'NEXT' key should be pressed whenever a complete six-dot Braille code is keyed in (a consonant, a vowel, a diphthong or a tone). Then the 'ENTER' key should be pressed, when the user finishes the codes for a complete Mandarin character. After all Braille codes have been keyed in, the 'SEND' key should be pressed to transmit those Braille codes to the Braille unit.
6 The Braille codes are transmitted via the RF modules or telephone line. Then these Braille codes will be displayed on the three-cell Braille (tactile) display so that the deaf-blind partner can read the message. After the deaf-blind partner reads the message, the 'calling/confirmation' key should be pressed to inform the sighted partner. At the same time all Mandarin phonetic symbols disappear from the LCD display, the sighted person may wait for the response from the deaf-blind person or continue keying a new message.

Disabled-to-sighted mode

In this mode, a deaf-blind person tries to communicate with a sighted person. The corresponding operating procedure involves the following steps:

1 Press the 'POWER' key and check whether the vibrator produces a special rhythmical vibration.
2 The 'CHANG' key is used for selecting the wireless communication mode or the face-to-face communication mode via the RF modules and telephone line.

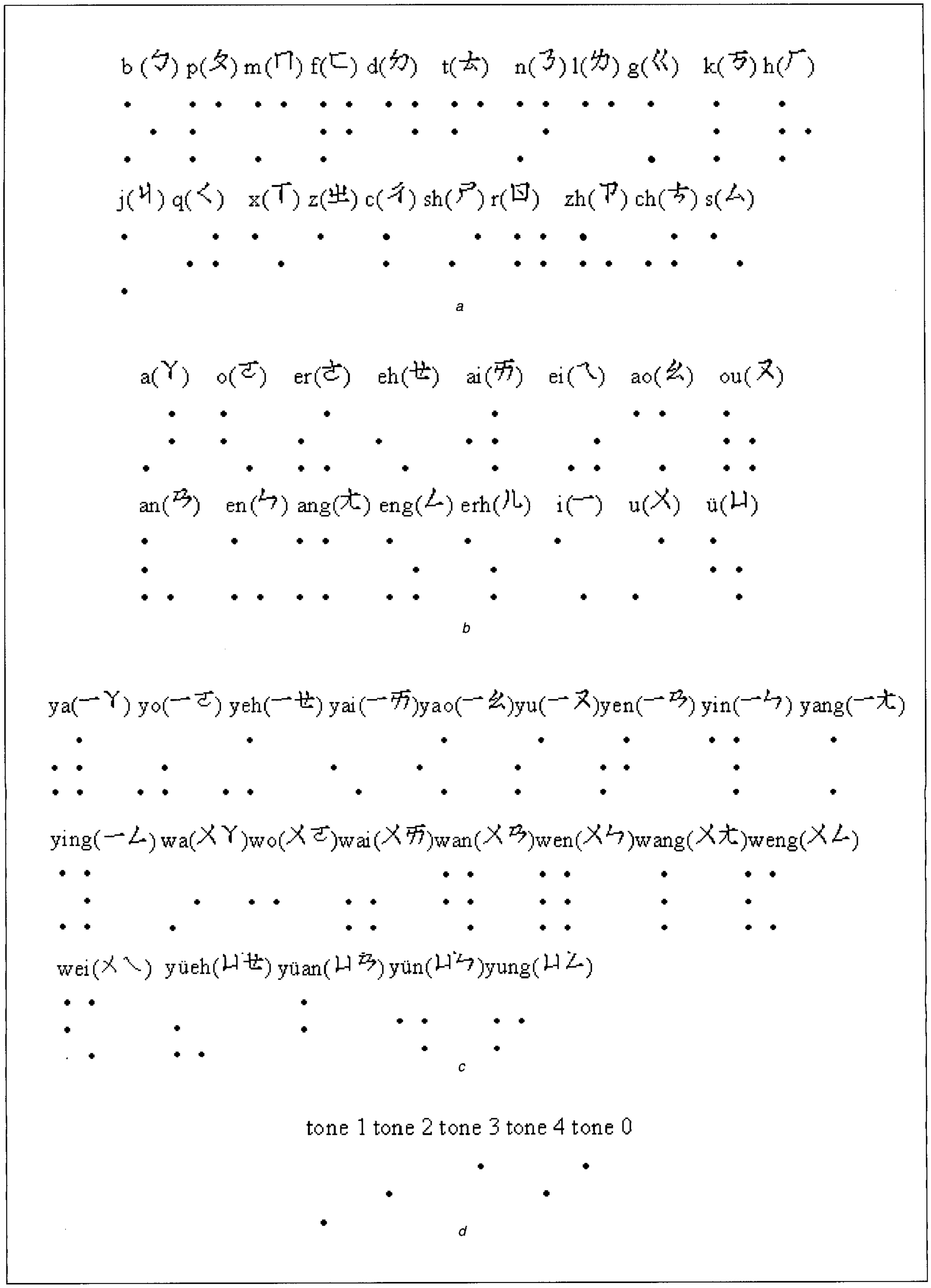


Fig. 4 Mandarin phonetic symbols and their corresponding Braille codes: (*a*) 21 consonants; (*b*) 16 vowels; (*c*) 22 diphthongs; and (*d*) 5 tones

However, the selection of which communication mode is usually made by the sighted partner.

3 Press the 'calling/confirmation' button and wait for the vibration signal.
4 When the normal unit receives the calling message, the sighted person will press the 'calling/confirmation' key for the attention of the deaf-blind partner (the vibrator will vibrate for a while until the 'calling/confirmation' key is pressed again) that he or she is ready to continue a conversation.
5 The deaf-blind person may then key in the Braille codes of the message to be transmitted. Note that these Braille codes will be displayed on the three-cell Braille (tactile) display so that the deaf-blind person can check whether there is a typing error. Whenever a typing error exists, the user can press the 'CLEAR' key to clear the Braille codes and re-enter them. The key 'NEXT' should be pressed whenever a complete six-dot Braille code is keyed in. Since the Braille (tactile) display can only show one Mandarin character at a time, the user must press the 'ENTER' key for showing the next character. After all Braille codes have been keyed in, the 'SEND' key should be pressed to transmit the message to the normal unit.
6 When the Braille codes are transmitted via the RF modules or telephone line, the three six-dot Braille cells are then all set to notice the user the message were transmitted. The Braille codes will be converted into corresponding Mandarin phonetic symbols and displayed on the LCD display. After the sighted partner reads the message, the 'Calling/Confirmation' key should be pressed to inform the deaf-blind partner. When all dots are cleared, the deaf-blind person may wait for the response from the sighted person or continue keying new messages.

Experimental results

Usually, the evaluation criteria for assessing an assistive device are whether a disabled person chooses to use it and if he or she can do so with a low level of frustration, low error rate, and high efficiency. Without any doubt, the advantages of using the device must be greater than the disadvantages encountered. After we presented the prototype to the deaf-blind girl and her assistant, they agreed that the prototype is a very important communication aid for the deaf-blind girl even if its communication capability is limited. In addition, an advantage of the prototype is that the training of the system needed to learn the communication methodology can be done in a short session.

For further system evaluation, three pairs of conversation partners were asked to test the prototype. They were asked to complete the following dialogue:

Person one: *How are you?* (corresponding to three Mandarin characters)
Person two: *I am fine* (corresponding to another three Mandarin characters)

The test results were shown in Table 1. It took 1·7 minutes on average to complete the dialogue.

Conclusions

The objective of the system in this article was to demonstrate the use of low-cost microprocessors as an aid for communicating with deaf-blind people in Taiwan. Due to dual sensory deprivation, deaf-blind people have difficulties in interacting with the external world, so they usually need the help of an assistant. The use of the prototype allows them to have a more normal life and be more autonomous. As a result, the system is conducive to the user's social, emotional and cognitive development. The total component cost of the prototype is about NT$4000, affordable for most families that have deaf-blind members. In the future we would like to improve the efficiency of the system by adding more Braille cells in the tactile display and other functions.

Acknowledgment

The authors would like to thank the 'Service center for the visual impaired student of Tamkang University' for providing them with Braille displays and many valuable suggestions for developing the prototype.

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