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A Prototype Design of Wireless Voice-Controlled Power Wheelchair Model with Emergency System

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ABSTRACT

Power wheelchairs are necessary for the elderly and the disabled people in their daily lives. But unfortunately, the inconvenient control of wheelchairs also blocks the users to travel outdoors especially for those have problems with using their hands. Besides, the disabled or the elderly are often need helps when they are alone in dangers. However, the users might not be able to call for help themselves if dangerous accidents happened. Therefore, the proposed voice-control power wheelchair model had been developed not only to control the wheelchair by voice commands as a demonstration prototype but also provided an automatic emergency system to help the users in danger to call for help. The help voice message included a pre-recorded emergency message with real time GPS position information given by the smartphone when any dangerous situation occurred. A prototype model of the proposed system was implemented based on the composition of a self-propelled vehicle, a bluetooth headset and a smartphone to demonstrate the performance of the proposed design. With the help of the proposed system, the convenience and safety of the wheelchair users will be increased whenever they travel outdoors or stay indoors alone.

Key words: Voice-controlled, wi-fi network, bluetooth network, power wheelchair

INTRODUCTION

According to the population structure in Taiwan, the elderly and the disabled people share a considerable proportion. Many of the elderly and the disabled people often rely on wheelchairs in their daily lives. In some cases, the wheelchairs are difficult to control to move freely by them, e.g., those who had problems with using their hands. On the other hand, the emergency button is usually set at a fixed position in the public places. When accident occurs, the wheelchair users are usually difficult to find the emergency buttons or move to the fixed positions to call for helps that will lead to rescue delays and may cause tragedies. Thus, the disabled or the elderly people often need care givers for their daily lives. Therefore, care giving becomes a very heavy burden for the ordinary family (Wu *et al*., 2008). Now-a-days, the security issue is so discussed with the application of wireless network as shown in literature (Baghaei and Hunt, 2004). Therefore, if the power wheelchair can be controlled by voice commands with the help of wireless network, the elderly and the disabled can easily drive the wheelchair by them to any desired place they want. Moreover, when the accidents occur, the proposed emergency system will automatically alarm and call for helps immediately, the safety protection of the users will be increased. Furthermore, the automatic emergency system can automatically dial an emergency phone call for help and send an emergency message composed of the pre-recorded voice message with the real-time GPS location to help the ambulance aid arrive at the right spot where the accident happened. With such designs, the elderly and the disabled people willing to join the crowd and feel safe when they are alone.

Mobile phone features flourish from the traditional communication device to the current smartphone in recent years as well as the wireless transmission technologies continuously progress. The mobile phone technology develops so rapidly because of the varieties of the application programs (APPs). There are three major operating systems for smartphone, such as Android system, iOS and Microsoft system (Wang *et al*., 2006). Among these operating systems,

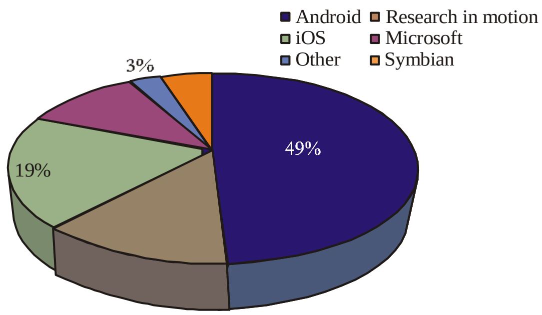

Fig. 1: Mobile operating system market share in 2012

the Android system holds the largest stake of the market share as shown in Fig. 1. Android system provides programmers an open environment where programmers can facilitate their development of programs on it. That is the major reason of the proposed system adopting the Android system in the design of the proposed scheme. On the other hand, voice-controlled wheelchair techniques had been developed in many ways, e.g., using hamming to control the wheelchair (Peixoto *et al*., 2013) using smartphone to connect the control module of the wheelchair, etc. (Al-Rousan and Assaleh, 2011). It seems to have a promising future of using voice-controlled technique to control the wheelchair. The proposed wireless communication techniques include the Wi-Fi wireless communication network, the 3G mobile communication network and the Bluetooth short-range wireless communication network to implement the connection of the smartphone, the power wheelchair and the earphone. Moreover, to make an emergency call (e.g., 911) automatically needs the mobile network to transmit the emergency message from user's smartphone to the emergency aids.

Now a days the mobile phone market is shared by many different operating systems including Android, iOS, Microsoft, Symbian, etc. The Android system shares the biggest market among these operating systems of smartphone. Figure 1 shows the pie chart of the market share for the smartphone operating systems in 2012. In which android system occupied almost half of the entire market. It was obviously to conclude that the Android, iOS and Microsoft operating systems are the three major operating systems for smartphone in the world (Chiu, 2010). The Microsoft operating system was first released by Microsoft Co. in October 11th, 2010 for Windows-based smartphone whose mobile interface called "Metro" and iOS is developed by Apple Co. as the operating system for iPhones, iPods and iPads. These two operating systems are not so convenient to learn compared with Android system due to providing the open environment for simulation of Android system. Therefore, android system had been adopted in the proposed control scheme to play the role as an ergonomics mobile interface. Some applications were thus developed based on the smartphone of Android system such as location, monitoring and so on (Yan, 2001; Grigoras and Riordan, 2007; Shu *et al*., 2009; Cai *et al*., 2012). Furthermore, voice-controlled wheelchair techniques had been successfully fulfilled in many aspects, e.g., using hamming sound to control the wheelchair (Peixoto *et al*., 2013) using smartphone to connect the control module of the wheelchair, etc. (Al-Rousan and Assaleh, 2011). The proposed system adopts the most popular mobile communication system android, to setup all the application programs and it combines both voice controlled system with automatically emergency system within the smartphone. Furthermore, the WiFi, Mobile communication 3G and Bluetooth system are integrated into the proposed system. Thus, the proposed system becomes feasible and implemented. The smartphone adopted in the proposed scheme must equip with the Bluetooth module, the Wi-Fi module and the gyroscope (or accelerator) to make the fulfillment of the overall system feasible. The main purpose of this study is to implement a prototype of such design and validate its feasibility.

MATERIALS AND METHODS

The proposed system had three major parts, a power wheelchair model, a Bluetooth earphone and a smartphone of Android system. A power wheelchair model was composed of a self-propelled vehicle, a WiFi wireless communication module and Lego module to simulate the real power wheelchair which was controlled by the smartphone of Android system. The introductions of hardware and software of the proposed system are listed as follows.

Hardware: The downsized prototype of the power wheelchair model was composed of the following components.

Self-propelled vehicle: The BASIC Stamp2 was the microprocessor adopted in the self-propelled vehicle as shown in Fig. 2. The programs of BASIC Stamp2 module can be stored in the EEPROM inside the module to prevent the programs from missing when power off. The assembly program of BASIC Stamp2 module can be rewritten which is a very useful feature in program development process for designing the prototype of new ideas.

Many different electronic components mounted on the circuit board called the Board Of Education (BOE) and USB (BOE large circuit board) as is shown in Fig. 3. There are the BASIC Stamp2 and the Parallax Stepper motor as shown in Fig. 4a-b and the Wi-Fi chip as shown in Fig. 5, respectively. With the help of such circuit board, many extended functions seemed feasible in the developing stage.

The Parallax Stepper motor was the motor used to drive the vehicle which received the control commands from control chip and then translated them into impulse intervals to control the motor. Figure 4b shows the outcomes of rotating speed (r sec^{-1}) verse impulse interval (ms) which was acquired by the experiments.

WIFLY RN-131C is a wireless network card based on the 802.11b standard to transmit and receive data in WiFi system as shown in Fig. 5. With the help of WIFLY RN-131C, the smartphone and the control chip can be connected by using wireless Ad hoc network structure.

Figure 6 shows the final implementation of the self-propelled vehicle. The vehicle was composed of one BASIC Stamp2, one BOE board, two Parallax Stepper motors and one Wi-Fi chip as mentioned.

Smartphone: The specifications of the smartphone of Android system adopted in the proposed system are listed as:

- Model: HTC One X
- CPU: 1.5GHz, quad-core

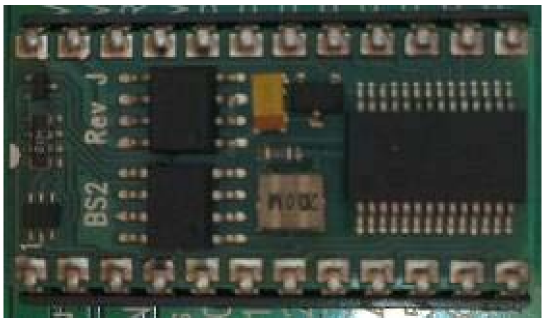

Fig. 2: BASIC Stamp2

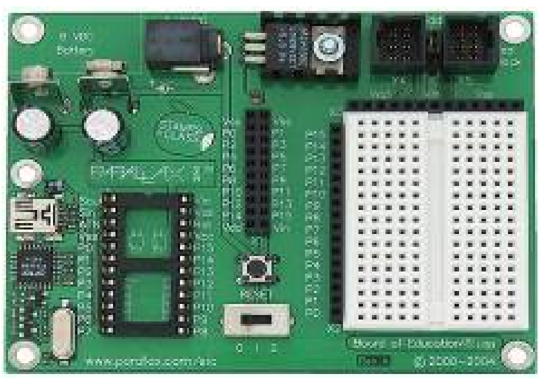

Fig. 3: BOE circuit board

- Operating system-F Android 4.0 with HTC Sense 4+
- Bluetooth technology-FV 4.0
- Wi-Fi: FIEEE 802.11 a/b/g/n

Bluetooth earphone: The requirements of the Bluetooth earphone used in the proposed system are described as:

- Bluetooth technology: FV 2.0
- Transmission range: FAbout 10 m

Lego model: To simulate the power wheelchair of the proposed scheme, logo blocks were used to compose the prototype of the power wheelchair model. The prototype of the power wheelchair model was implemented as shown in Fig. 7. It was composed of a self-propelled vehicle and the combination of Lego module.

Software: The software application programs used to implement the proposed system are listed as:

- Android Simulator: Bluestacks
- Software development tools: Eclipse
- Android development version: V 2.1

With the help of the above software application programs and hardware, the functions mentioned in the previous section thus were fulfilled successfully.

Methodology: Android is developed by Google. Comparing with other operating system's android system is an open operating system with many open-sources on the Google official website to provide facilities for the development of application programs. Besides android system holds the largest share of the operating system market of smartphone. Hence, the proposed system adopts the Android operating system as the development environment. The given figure is the block diagram of overall system, in which, the voice mode is divided into two parts for normal operation (the right branch) and dangerous situation (the left branch) as shown in Fig. 8.

The wireless self-propelled vehicle was given to simulate the power wheelchair in the proposed scheme. The Bluetooth

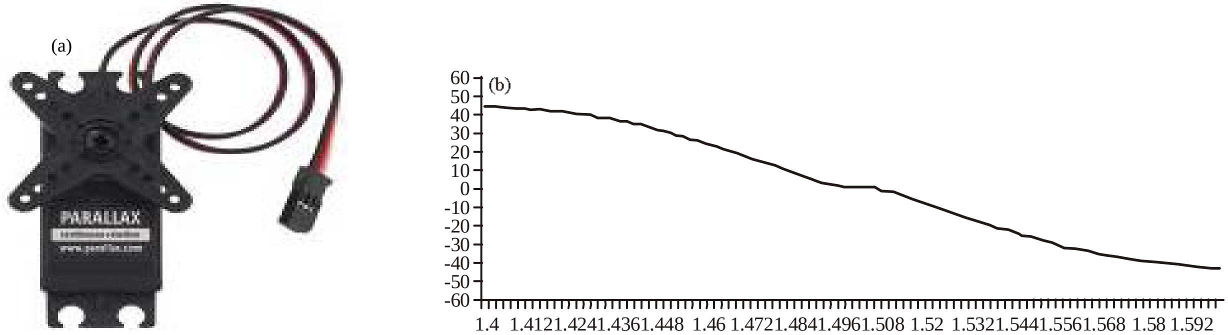

Fig. 4(a-b): Parallax Stepper motor, (a) Photo of stepper motor and (b) Speed (r/s) v.s. pulse interval

Fig. 5: Wi-Fi chip

Fig. 6: Outlook of self-propelled vehicle

Fig. 7: Prototype of power wheelchair

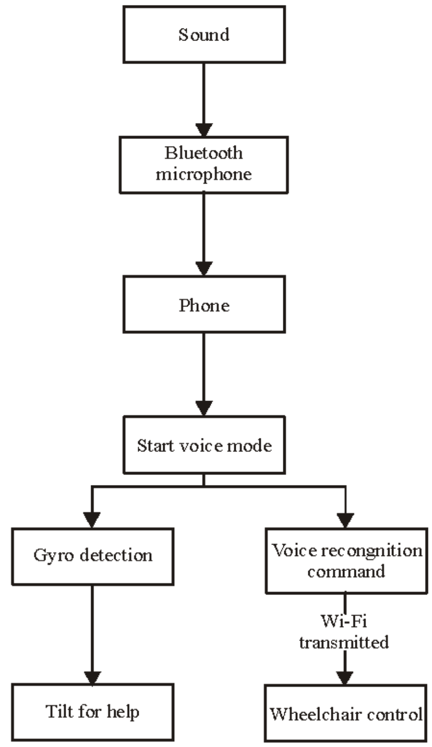

Fig. 8: Block diagram of overall system

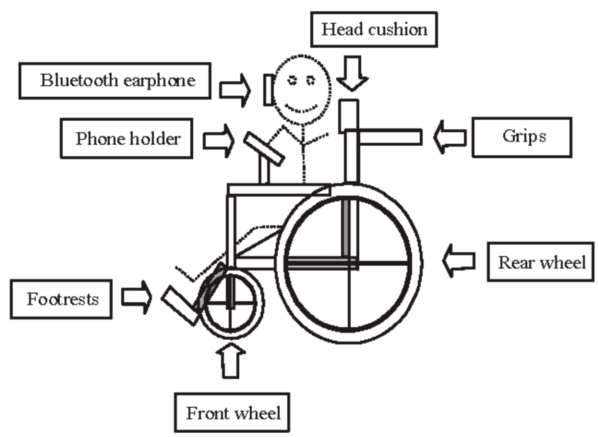

Fig. 9: Schematic diagram of the proposed system

network was also given to communicate the Bluetooth earphone and the smartphone (Gonzalez-Castano *et al*., 2005) and the Wi-Fi Ad hoc network connected the control board of the self-propelled vehicle and smartphone directly. In such mode, the active range of the proposed system will not be constrained by the coverage of Access Points (APs) because of their deployment (Erasala and Yen, 2002). The user can move freely with the help of wireless communication e.g., WiFi, Bluetooth techniques and so on (Galvan-Tejada *et al*., 2012; Challoo *et al*., 2012; Bakhsh *et al*., 2011; Ibrahim and Ibrahim, 2010). The schematic diagram of the proposed system is shown in Fig. 9.

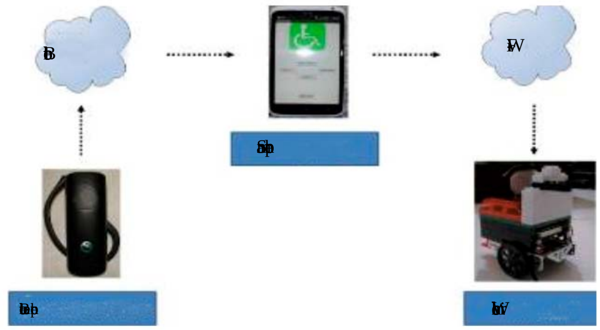

Fig. 10: Voice-controlled process

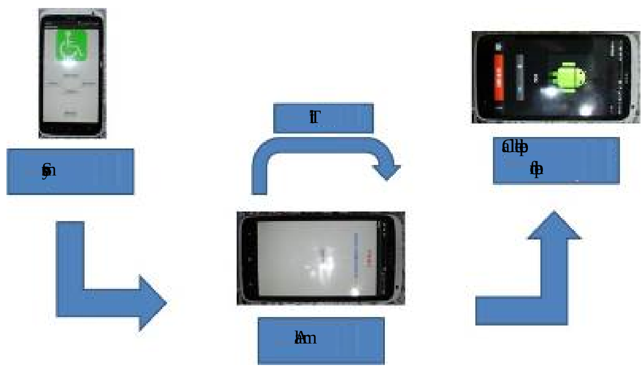

Fig. 11: Schematic diagram of emergency system process

The users can set the smartphone on the phone holder mounted on the power wheelchair and control the wheelchair by sending the control signal to the Wi-Fi chip module mounted on the control board of the vehicle via Wi-Fi wireless communication network. The Bluetooth earphone was also provided to connect the smartphones and control the power wheelchair by voice commands. Therefore, the voice recognition was very important in the proposed scheme. On the other hand, if the smartphone detected the posture of the power wheelchair excessive some critical tilt value, then smartphone would activate the emergency system to send out the emergency alarm automatically to call the near help if any. Moreover, if the rescue didn't appear in a period of time e.g., 30 sec to push the release button on the display of the smartphone, then the emergency system would automatically dial the emergency call (e.g., 911) for help to rescue the wheelchair user. The emergency call was composed of the pre-recorded voice message with real-time GPS location to help the ambulance aid arrive at the right spot in time. The schematic diagram of voice-controlled process is shown in Fig. 10.

The emergency system process is shown in Fig. 11. When the gyro (or accelerator) inside the smartphone detected a tilt over the predefined critical angled, the proposed emergency system would activate and operate the emergency system process as mentioned previously. There was a release button on the screen of the smartphone to cancel the emergency process and go back to normal mode if someone pushed the button, otherwise, the emergency alarm would keep beeping. If the release button was not pushed in time then the emergency system would start to make an emergency call for help (e.g., 911). The pre-recorded voice message with real time GPS position information would be provided in the call to help emergency aid arrive at the right spot as soon as possible.

RESULTS

Figure 12 shows the picture of smartphone connecting to the prototype of the power wheelchair. The smartphone screen displayed the voice command interface as shown in Fig. 13. In this case, the Bluetooth earphone was connected to the smartphone. When voice command was received by the smartphone and converted to control signal, the converted signal then was transmitted to the control module mounted on the power wheelchair by Wi-Fi Ad hoc network to control the power wheelchair moving in four directions, forward, backward, left, or right as demands.

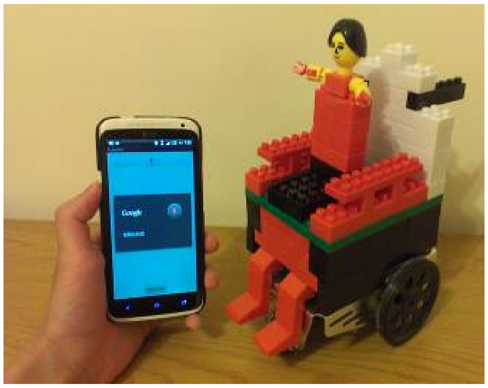

Fig. 12: Experimental hardware solid entities of the prototype

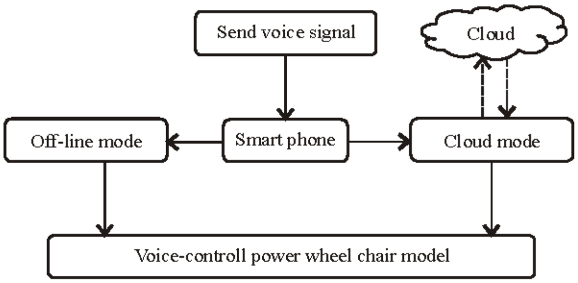

Fig. 13: Block diagram of the overall voice recognition system

Voice recognition system: The voice recognition of the proposed system was divided into two categories, one was the cloud mode and another was the off-line mode. In the cloud mode, the user sent voice commands to smartphone by Bluetooth earphone and then the voice signals would be transmitted via Internet to Google speech servers for voice recognition. On the other hand, the off-line mode, the user sent voice commands to smartphone and then the voice signals would be translated into instructions directly to control the power wheelchair by the smartphone. In either case, the noise was always a major problem. It had to be dealt with carefully, especially, the noise from the environment. (Linting *et al*., 2013). In cloud mode, the Google speech servers sent the recognized signals back to smartphone and then the smartphone transmitted those signals to the control board as instructions to control the power wheelchair. On the other hand, the smartphone recognized the voice signal directly by the recognition program built inside the smartphone in the off-line mode. Figure 13 shows the block diagram of the overall voice recognition system.

If the 3G or Wi-Fi wireless communication network was available, the recognition system would use the cloud mode first to recognize voice command by Google servers via Internet. Otherwise, the system adopted the off-line mode to recognize the voice command by smartphone directly. The voice commands were transformed into control signals by either way to control the power wheelchair model.

Table 1: Successful rate of voice recognition in cloud mode and off-line mode

Voice command	Success rate (%)	Average success rate (%)
Cloud mode		92.8
GO	98	
Back	97	
Turn left	86	
Turn right	84	
Stop	99	
Off-line mode		90.2
GO	93	
Back	98	
Turn left	83	
Turn right	83	
Stop	94	

Table 2: dB values in distance of 0 and 1 m

Test/Distance	0 m	1 m
1	58.00	49.00
2	61.00	47.00
3	61.00	49.00
4	64.00	48.00
5	64.00	53.00
6	62.00	53.00
7	58.00	48.00
8	62.00	48.00
9	62.00	49.00
10	65.00	48.00
Average dB	61.70	49.20
Standard deviation	2.35	2.09
Minimum dB to activate	59.00	68.00

Table 1 show the success rate of cloud recognition mode and off-line recognition mode, respectively. Table 1 shows success rates of the cloud recognition mode that voice commands were recognized among 84-99% in different voice commands with the average of 92.8%. On the other hand, the success rates of the off-line recognition mode were recognized among 83-98% with the average of 90.2% as shown in Table 1. Each voice command was tested for 100 times in the experiments. According to the results of Table 1, the cloud mode had better performance than off-line mode in voice recognition. However, the distance between voice source and microphone influences the result of recognition a lot. In the proposed system, the minimum value to activate the power wheelchair was 59 dB at distance = 0 m (directly received from the earphone) and the minimum voice strength I_0 was 10^{-12} w m^{-2}. The voice strengths were obtained by using the dB equation as follows:

$$dB = 10 \log I/I_0$$

Moreover, the minimum noise strength must be larger than 68 dB at distance = 1 m to activate the system in experiment. The normal voice strength of different distances (0 and 1 m) was measured and the experimental results were shown in Table 2. As a result, the noise strength must go larger as the distance extended to activate the system.

Voice controlled of power wheelchair: The voice commands included "go" (moving forward), "back" (moving backward), "turn left" (turning left), "turn right" (turning right) and "stop"

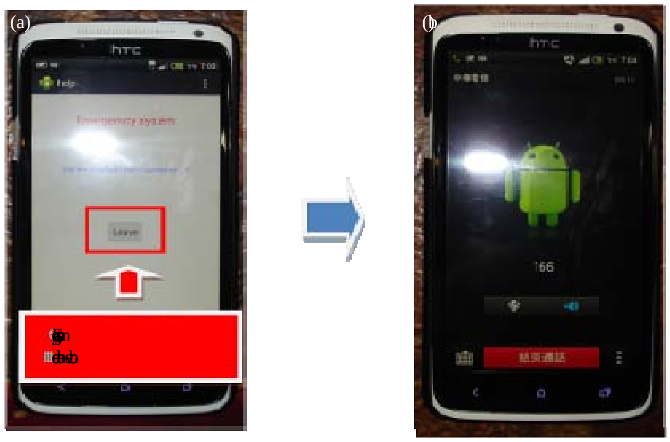

Fig. 14(a-b): (a) Emergency mode screen and (b) Call for help screen

Table 3: Successful rate of recognition without and with auxiliary database system in cloud mode

Voice command	Successful rate (%)	Average successful rate (%)
Without auxiliary database system		77.4
GO	94	
Back	91	
Turn left	57	
Turn right	68	
Stop	77	
With auxiliary database system		92.8
GO	98	
Back	97	
Turn left	86	
Turn right	84	
Stop	99	

Table 4: Successful rate of recognition without and with auxiliary database system in off-line mode

Voice command	Successful rate (%)	Average successful rate (%)
Without auxiliary database system		65.8
GO	77	
Back	88	
Turn left	42	
Turn right	45	
Stop	77	
With auxiliary database system		90.2
GO	93	
Back	98	
Turn left	83	
Turn right	83	
Stop	94	

(stop). The maximal distance between the smartphone and the power wheelchair was 30 m to remain connection in the experiments. This limitation of working range was far enough for the elderly and the disabled with their power wheel chairs. Moreover, some recognitions failed due to the different pronunciations, thus, the proposed system created a database auxiliary system of voice instructions inside the smartphone to improve the successful rate of voice recognition. The auxiliary database system automatically categorized the input voice command into the most similar one. The experimental results of such design are illustrated in the Table 3-4.

It is obvious that the successful rate of voice recognition had been improved with applying the auxiliary database system in ether off-line mode or cloud mode.

In the experiment of emergency system, when the gyro (or accelerator) detected the value of X, Y axis being larger than 60° (or any predesigned value), the emergency system process would automatic activate and the smartphone start to beep for help. If a helping hand arrived in time, then the release button ("leave" as shown in Fig. 14a) had been pushed to exclude the emergency situation. Otherwise, if the accident occurred more than 10 sec (or any predefined period) and there was no rescue appeared, then the emergency system would automatically dial the emergency call for help as shown in Fig. 14b. The emergency call was composed of a pre-recorded voice help message with GPS location information provided by the smartphone. The dialing number could be arbitrary preset such as 911, 166 or any other number. Then the policemen or the ambulance personnel could arrive at the right spot where the accident happened as soon as possible.

The application programs developed based on Android system are popular than those with other mobile operating systems for smartphones. Therefore, android system was used as the platform in the proposed system to make the proposed system can be applied in a wider range.

DISCUSSION

The proposed voice-controlled power wheelchair system provides not only to control the power wheelchair by voice commands but also to implement the emergency system while accidents occurred. During the development of the voice-controlled system, language is the most concerned due to its diversity (Peixoto *et al*., 2013) (Al-Rousan and Assaleh, 2011). The reference voice commands are decided to be pre-recorded by the users. Therefore, the input voice commands make the power wheelchair be only controlled by the results of the comparison with the specified references unless the memory of the control board is refreshed for recognition (Chiu, 2010; Linting *et al*., 2013). On the other hand, the traditional wheelchair user usually needs someone to accompany with for the safety reason. But the implementation of emergency system makes the wheelchair users are willing to travel outdoors and feel safety while they are alone. Moreover, the power wheelchair is more stable than the traditional wheelchair because of the help of motors. Furthermore, the emergency system is equipped with automatically dialing/connecting function to call for help itself if necessary. After combining of GPS information and pre-recorded voice message, the emergency call can report the latitude and longitude position of the user in English to the emergency unit and the message of help in any language which pre-recorded in the memory (Erasala and Yen, 2002; Galvan-Tejada *et al*., 2012; Wu *et al*., 2008). The emergency call also can be sent via the mobile system or the wireless communication system to any arbitrary emergency telephone number or website that are pre-assigned in the system (Cai *et al*., 2012; Grigoras and Riordan, 2007; Shu *et al*., 2009).

CONCLUSION

The proposed wireless voice-controlled power wheelchair model with automatic emergency system was developed based on Android system to provide a safer environment for the elderly and the disabled people. The hardware of the proposed system included a Bluetooth earphone, a smartphone and a self-propelled vehicle to implement the prototype of the proposed system. With the help of the proposed systems, the work of the care givers might be less. Furthermore, the elderly and the disabled people may travel outdoors much safer than before as well as stay indoors alone. The proposed systems had successfully developed a prototype of a voice-controlled power wheelchair model which can be easily control by smartphone based on Android system. Besides, an auxiliary database system had also developed to improve the successful rate of voice recognition. On the other hand, an emergency system was also developed to help the user in dangerous situations. A beeper would be trigged when accidents happened and the automatic telephone call would also be completed with voice message with location information if no rescue was around. With the help of such designs, the quality of life for the wheelchair users can be improved. Moreover, the stress of those care givers could be also reduced. In addition, the emergency system was independent from the wheelchair, thus, the emergency system can be used in many other occasions such as mountain climbing, hiking, bicycling and so on. The wheelchair users just need to bring their smartphones with them and load the emergency application program in the smartphones then the emergency system will help the users if any dangerous situation happens.

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