

New speech processor and Ultrasonic Sensors Based Embedded system to Improve the Control of a Motorised Wheelchair

Mohamed Fezari¹, Abd-Errahmene Khati¹, karim Hamza²-

University of Annaba, Faculty of Engineering,

Laboratory of Automatic and Signals Annaba

2-University Houari Boumediene Alger, Department of electronics

E-mail: Mohamed.fezari@uwe.ac.uk, akhati@yahoo.fr, hamzakrimo@yahoo.fr

ABSTRACT

Users are able to operate a joystick to control the chair, however many more severely handicapped users need some other means of controlling the wheelchair. The aim of this work is to implement an interesting application using small vocabulary word recognition processor and some sensors on a smart system. The adopted model is based on grouping a microcontroller with a new voice recognition module for isolated word and speaker dependent. The resulting design is used to control a wheelchair for a handicapped individuals(tetraplegic) based on a vocal command. In order to gain in time design, experiments have shown that the best way is to choose a speech recognition kit and to adapt it to the application. The input of the system are a set of eight Arabic words used to control the movement of an electric wheelchair, a vector of information on the context given by a set of sensors and a joystick for security actions; The output is a corresponding command and a set of indicator LED (Light Emitting Diodes).

The system is developed in order to be installed on the wheelchair. Therefore it should be easy to carry, easy to operate and with low power consumption.

Key Words: Speech recognition, embedded systems, ultrasonic sensors, speech processor

1. Introduction

In recent work different techniques were introduced to improve the command of an electric wheelchair such as a computer and speech recognition techniques namely: DTW (Dynamic Time Warping) Crossing Zero and HMM (Hidden Markov Model) [1-2]. With the exponential increase in computing power and shrinkage of size and cost, the RISC (Reduced Instruction Set Computer) component which is microcontroller is finding its way into every aspect of human life. It's used as examples in a wide spectrum of applications such as auto assembly plant, data handling and acquisition systems, waveform generation, stepper motor control, robotic control, and smart sensor systems. Moreover, special components for speech processing have been emerged in the last decade and implemented in various application fields [3]-[5]. This is due to various studies made in the last few years which led to good results in both research and commercial applications. Also thanks to the fact that increasingly faster computers have become accessible for simulation and emulation of the new components to a growing number of users [6]-[8].

This paper proposes a new approach to the problem of the recognition of isolated words, using a speech recognition development kit from 'sensory' and implements it for vocal command of a handicapped

person wheelchair (HPWC) [9]-[12]. The increase in complexity as compared to the traditional approach is negligible, but the system achieves considerable improvement in the matching phase, thus facilitating the final decision. The study is part of a specific application concerning system control by simple vocal commands. It has to be implemented on a portable system and has to be robust to any background noise confronted by the system. The objective of this design is therefore the recognition of isolated words from a limited vocabulary in the presence of stationary background noise. This application is speaker-dependent. It should however, be pointed out that this limit does not depend on the overall approach but only on the method with which the reference patterns were chosen. So by leaving the approach unaltered and choosing the reference patterns appropriately, the application can be made speaker-independent. To enhance the designed system by avoiding obstacles and secure the wheelchair driver, a set of ultrasonic sensors for obstacle detection in addition to a speed engine sensor and a joystick were used [13] and [14]. The application to be integrated in this embedded system is first simulated using MPLAB, then implemented in a RISC architecture microcontroller adapted to a speech recognition development kit 'Easy-VRStamp produced by MikroElectroniKa'. Experimental tests

showed the validity of the new hardware adaptation and Test Results, within the laboratory experience area, are acceptable.

2. General Description of The Designed Embedded System

The designed System as shown in Figure 1 is developed around the following components:

- The VR-Stamp based on RSC4128 special processor, which is the heart of the vocal command system.
- A set of ultrasonic sensors to avoid collisions.
- A joystick to control a vocal misleading command of the wheelchair.
- And an interface card to control power circuits of the electric wheelchair.

These components are controlled by a CMOS-RISC microcontroller from Microchip, a new generation of powerful computation, low-cost, low-power microcontrollers. The system is fed by a battery as a power supply regenerated by an alternator.

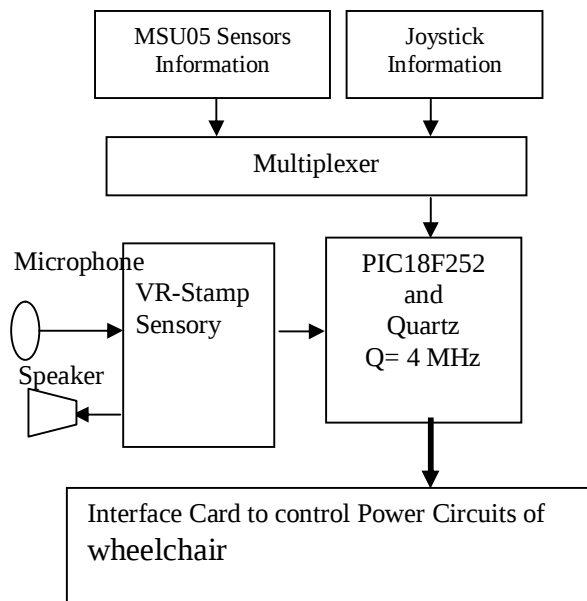


Fig.1. Block diagram of the designed system.

3. Practical Details

The control module is developed around the VD364 and a set of sensors controlled by the PIC18f252. For best performance, the system gives better results in a quiet environment with the speaker's mouth in close proximity to the microphone, approximately 5 to 10 cm.

3.1 VR-Stamp (Voice recognition Stamp)

Voice Recognition Stamp is a new component from Sensory inc. It has more capabilities designed for embedded systems. It was designed for consumer telephony products and cost-sensitive consumer electronic applications such as home electronics, personal security, and personal communication because of its performances:

- Noise-robust Speaker Independent (SI) and Speaker Dependent (SD) recognition.
- Many language models now available for international use.
- High quality, 2.4-7.8 kbps speech synthesis &
- Speaker Verification Word Spot (SVWS) -Noise robust voice biometric security.
- Audio Wakeup from sleep.
- Touch Tone (DTMF) output.

. It includes award-winning RSC-series general-purpose microcontrollers plus a line of easy-to-implement chips which can be pin-configured or controlled by an external host microcontroller.

The RSC family of microcontrollers are low-cost 8-bit designed for use in consumer electronics. All members of the RSC family are fully integrated and include a speech processor, A/D and D/A converters, ROM as program memory, and RAM circuitry on chip. The RSC-4128 also include on chip pre-amplification.

The module VR-Stamp is based on the following components: a special microcontroller RSC4128, a Flash program memory of 4 Mega-byte that holds the main program of word recognition, a reference word storage 24C65 of EEPROM type that holds the parameters of referenced word produced during the training phase, and a parallel interface of 24 lines (divided into 3 8-bit ports) to generate the results of recognition or to introduce commands, and audio communication lines for microphone and speakers. This type of module can perform a full range of speech or audio functions including speech recognition; Speaker verification, speech and music synthesis, and voice record or playback.

3.2 The microcontroller PIC18F252

As an interface between the power circuits of the HPWC and the vocal module VD364, a microcontroller with at least 16 input/output lines and minimum of 4 kilo instructions is needed. Therefore a better choice was the PIC18F252 from Microchip.

Its main characteristics are: Program memory of 32 kilo instructions capacity, data memory of 256 bytes capacity, Random Access memory of 1536 bytes capacity, 3 timers to count internal or external events, 5 channel 10-bit A/D Converter, USART interface adapter, and 3 TTL type ports (A, B, and C) providing 23 digital I/O lines.

The main function of the microcontroller is to get the information from the VR-STAMP and latch a corresponding binary code on B port. It also detects the beginning and end of the word pronounced by

the user. The A port is used to control the power circuits of the HPWC while the C port is used to get information from sensors and joystick.

3.3. Ultrasonic Sensors Modules

In order to avoid and maintain a safe distance from obstacles, a set of ultrasonic sensors modules is installed around the wheelchair; the microcontroller selects a module and reads the information from the sensor in order to get more knowledge on the environment. The set of ultrasonic sensors are based on Ultrasonic Sensors Modules (MSU05). The MSU05 is a module based on a microcontroller, an ultrasonic transmitter and an ultrasonic receiver sensor of 40 KHz type MURATA. The module is activated by a brief pulse; it sends a signal with frequency 40 KHz pulses. The pulses reach an obstacle and then come back. The module computes the travel time of the pulses; it then generates a pulse with a width proportional to the distance from the obstacle, figure 2 illustrates one ultrasonic Sensor module with LCD and LED's controlled by a mid range PIC Microcontroller. Three modules are placed in front of the wheelchair in such a way, that the area between 2-3 m in front of the vehicle is covered, upper front and lower objects can be detected. And two other modules are placed in left and right side respectively in order to control the left and right turn of the wheelchair. If there is any obstacle that leads to a lock situation in a left or right turn then system predicts this case and avoids taking an action in these cases.

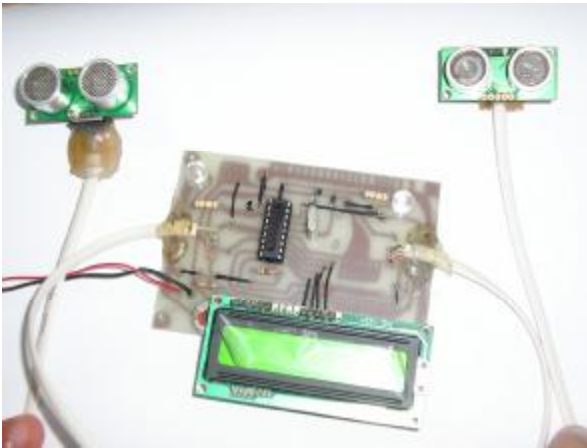


Fig.2. Overview of designed Ultrasonic Sensor Module with LCD and to LED's Indicators

3.4 Joystick

In order to avoid any disagreement in the vocal control of the wheelchair, the user can in emergency case use the joystick to stop or to correct the action, thus the joystick has higher priority.

4. Speech Recognition Module

The development of the application needs to follow some steps:
First the user creates the vocabulary words using any voice record software, however we recommend the use of windows media play.
The recorded words should be compressed using quick synthesiser 4 (QS4) from sensory and built, the qs4 will produce an adapted file 'qs4/HPWC_voice.h' to be included in the C program of the application.
Some libraries from FluentChip software of Sensory have to be included also namely techlib.h.
The main program is developed in C language on RSC4 mikroC Compiler. And then the produced Hex file is programmed on the VR-Stamp. As shown if the following figures 3.a 3.b and 3.c.

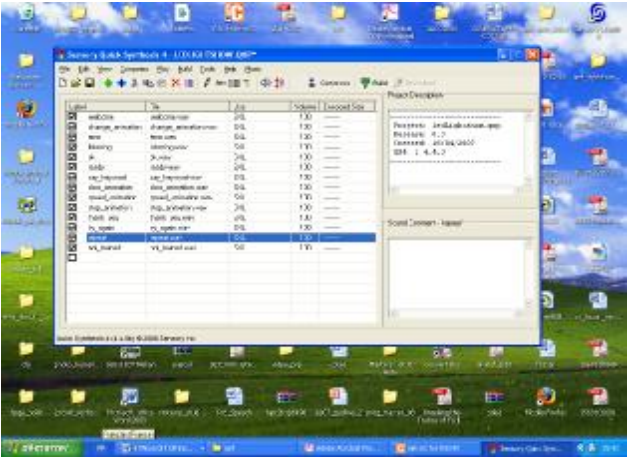


Fig. 3.a QS4 for vocabulary compression

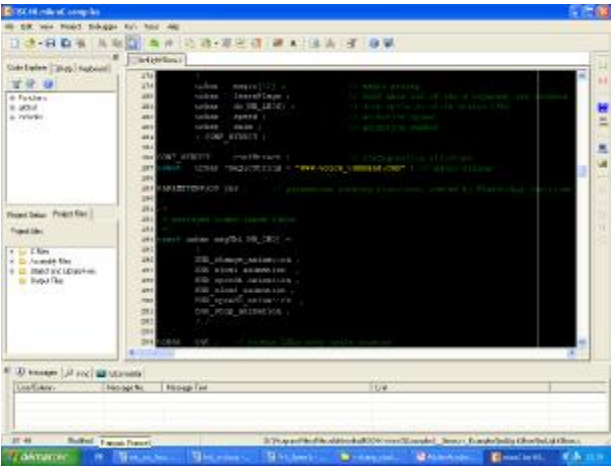


Fig. 3.b Main windows of RSC4 mikroC Development tool.



Fig. 3.c : Easy-VR-Stamp tester and programmer

4. Description of the Application and Operation

The application is based on the development of a vocal command for HPWC, by means of simple vocal messages. It therefore involves the recognition of isolated words from a limited vocabulary. The HPWC specifications are eight commands that are necessary to control the wheelchair: switching on and off the engine, forward movement, backward movement, stop engine, turn left, turn right, speed up the engine and speed it down. The vocabulary chosen to control the system contains a total of eight words. The number of words in the vocabulary was kept to a minimum both to make the application simpler and to make it easier for the user to use. However, this number can be increased if any improvement is necessary such as adding words to control a horn or lights installed on the HPWC. The selected eight Arabic words are from a vocabulary which is used in vocal control of an AGV and where the phonemes are quite different from a word to another.

These words are:

- "Muharek": To switch the engine on or off, if it is on then it will be off and if it is off then it will be on.
- "Amam": To keep the movement upward.
- "Wara": To move backward, which means a turn of 180 degree.
- "Kif": To stop the movement.
- "Yamine": To make a right turn 90 degree.
- "Yassar": To make a left turn 90 degree.
- "Sarian" : To increase the speed of engine by a step.
- "Batian" : To reduce the speed of engine by a step.

In order to run a wheelchair safely and comfortably by vocal commands, a set of sensors were added to detect obstacles and avoid misleading [14] and [15]. The developed system 'WS', the set of ultrasonic sensor modules, the microphone and the joystick will be installed as shown in Figure 4.

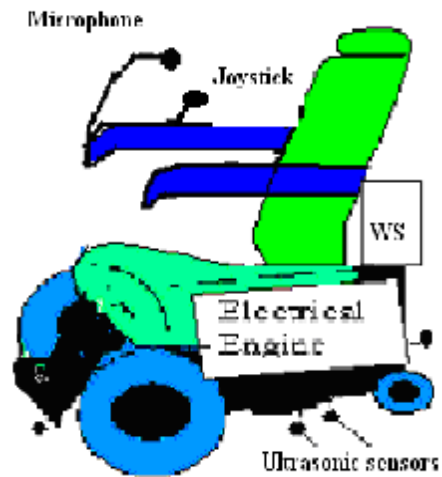


Fig.4. Handicapped Person Wheelchair (HPWC).

External noise affects the system since it is by nature in movement within the wheelchair. In designing the application, account was taken to reduce the affecting noise on the system at various movements. To do so, the external noise was recorded and spectral analysis was performed to study how to limit its effects in the recognition phase. However this is just done within the experience area.

The vocal command system works in two phases: The training phase and the recognition phase or verification phase. In the training phase, the operator will be asked to pronounce 'say' command words one by one. During this phase, the operator might be asked to repeat a word many times, especially if the word pronunciation is quite different from time to time. Once the 8 words have been used for training the system, the operator can start the second phase. The recognition phase represents the use of the system. In this phase, the system will be in a waiting state, whenever a word is detected.

The acquisition step will be activated, and then the parameters of that word are extracted and compared to those of reference words. If there is any matching between a reference word and the user word, the likelihood rate is high, and then the appropriate command will be generated. However, the command taken should not put the user in dangerous position. The system might take a proper decision for example 'stopping the wheelchair or reduce the speed' to avoid collisions of the HPWC (Figure 5). The joystick is used to avoid any misleading in vocal command, hence this input device has higher priority than sensors or voice command.

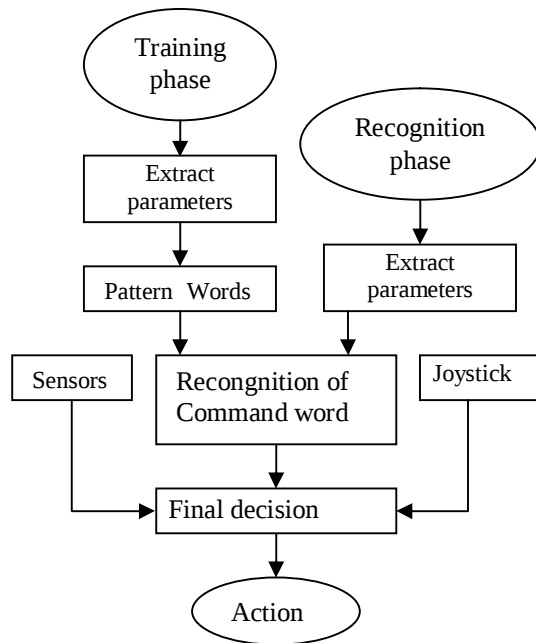


Fig.5. System phases flowchart.

5. Results of The Simulation

The PIC 18F252 program was simulated by MPLAB which is a Windows-based Integrated Development Environment (IDE) for the Microchip Technology Incorporated PIC micro microcontroller families, under windows XP as operating system. For a mono speaker, in the training phase, the speaker repeats two times each word to construct the database of referenced words. In the recognition phase, the application gets the word to be processed, treats it, then takes a decision if the word belongs to the eight command-words (referenced words) or not.

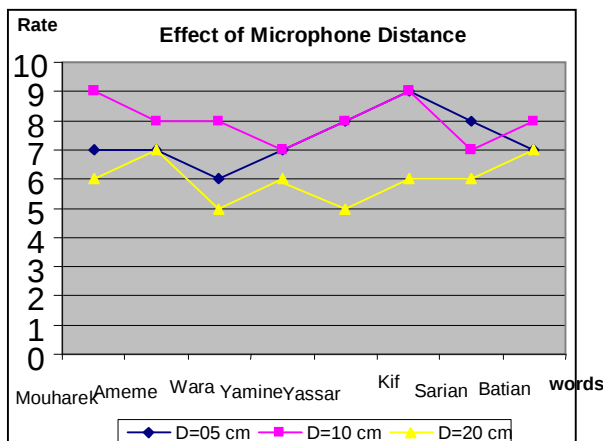


Fig.6. the effects of microphone distance on the designed module.

If so, then the corresponding bit on the port B of the PIC18F252 is set to one. Otherwise a bit on port A is set to one, lighting a red LED, which means, 'the word is not recognized'. Many tests on the developed vocal command, were done and the results are shown in Figure 6.

6. Conclusion

In this paper, a hardware design of a special portable vocal command system for a handicapped person wheelchair is presented. The bulky and complex designs have, however, been overcome by exploring new speech recognition kit. Interfacing this special vocal microprocessor to the wheelchair was controlled by the PIC18F252. Thus the program memory capacity is improved in order to design more complex controls, and no need to an AD and DA Converters, since they are already integrated within the VR-Stamp. The application might be used to enhance AGV in robotics or other type of vocal command system. However, in order to increase the recognition rate, the training and recognition phase should be done in the same area of tests, which means that stationary noise has no effect on the recognition rate. In addition, the sensors types can be improved to play a secondary role in sharing the control of the HPWC. More software work for this module are in development stage such as speech synthesis and speaker identification.

Bitmap design to model the two dimensional plane where the chair is being used indoor in order to facilitate the navigation [15]. These works should improve the application in the next future.

References

- [1] Mohamed FEZARI and Mounir Bousbia-Salah, "Speech and Sensors in Guiding an Electric Wheelchair", AVT Journal(Automatic Control and Computer Sciences Journal), SpringerLink Publication, Vol . 41 no. 1, pp.39-43, Mai 2007.
- [2] Mohamed Fezari, M. Boughazi, M.S. Boumaza and M. Bousbia-Salah, " Embedded Control System based on sensors and Speech for a 'SMART' Electric Wheelchair", in abstract of JSS'07 Journées des signaux et sytemes 14&15 Nov. 2007, Guelma, pp.29, 2007.
- [3] Microchip manual, PIC18F252 Application notes, Microcontrollers, Microchip Technology Inc., 2003. Available at : www.microchip.com
- [4] R. A. Cooper, D. K. Jones, S. Fitzgerald, M. L. Boninger, and S. J. Albright, "Analysis of position and isometric joysticks for powered wheelchair driving", *IEEE Transactions on Biomedical Engineering*, Vol 47, no. 7, pp. 902–910, 2000.
- [5] H.R. singh, A. Mobin, S. Kumar, S. Chauhan, "Design and Development of Voice/Joystick Operated Micro-Controller based Intelligent Motorized Wheelchair", in Proc. TENCON'99, 1999, pp.1573-1576.
- [6] M. Mazo, F. Rodriguez, J. Lazaro, J. and Al., "Wheelchair for physically disabled people with voice, ultrasonic and infrared sensor control", *Autonomous Robots*, vol. 2, pp. 203–224, 1995.

- [7] V. Ramasubramanian and Amitav Das, "Text-dependent speaker recognition: A survey and state of the art", IEEE International Conference on Acoustic Speech, and Signal Processing 2006, France.
- [8] J. Huang, N. Ohnishi, N. Sugie, "Sound localization in reverberant environment based on the model of the precedence effect", *IEEE trans. on Instrumentation and Measurement*, vol. 46, no. 4, pp. 842-846, 1997.
- [9] C. A. McLaurin and P. Axelson, "Wheelchair standards: an overview", *Journal of Rehabilitation Research and Development (Clinical Supplement)*, vol. 27, no. 2, pp. 100-103, 1990.
- [10] J-W Min, K. Lee, S-C Lim, D-s Kim, " Human-Friendly Interfaces of Wheelchair Robotic System for Handicapped Persons", in Proc. Of the 2002 IEEE/RJS Intl Conf. on Intelligent Robots and Systems EPFL, Switzerland, pp.1505-1510, 2002.
- [11] R. D. Schraft, C. Schaeffer, "Care-O-bot: The concept of a system for assisting elderly or disabled persons in home environments", *Proc. of the 24th Annual Conference IECON98*, vol. 4, pp. 2476-2481, 1998.
- [12] Sensory Data sheet for RSC-4128, *Sensory Inc.*, 2005.
Available at : www.sensory.com
- [13] S. L. Oviatt, P.R. Cohen, "Multimodal interfaces that process what comes naturally", *Communication of the ACM*, Vol. 43, no. 3, pp. 45-53, 2000.
- [14] S. Porta, H.R. Singh, A. Mobn and S.S. Agrawai, "Design and Development of Voce-Cum-Auto Steered Robotic Wheelchair Incorporating Reactive Fuzzy Scheme for Anti-Collision and auto Routing", *Proc. IEEE HRI 2000*.
- [15] R. C. Simpson, D. Poirot, F. Baxter, "The Hephaestus smart wheelchair system", *IEEE Trans. on Neural Systems and Rehabilitation Engineering*, vol. 10, no. 2, pp.118-122, 2002.