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A Voice Command System for Autonomous Robots Guidance

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Abstract - **In this paper, a voice guidance system for autonomous robots is proposed as a project based on microcontroller. The proposed system consists of a microcontroller and a voice recognition processor that can recognize a limited number of voice patterns. The commands of autonomous robots are classified and are organized such that one voice recognition processor can distinguish robot commands under each directory. Thus, the proposed system can distinguish more voice commands than one voice recognition processor can. A voice command system for three autonomous robots is implemented with a microcontroller from Microchip PIC16F876, a voice recognition processor RSC364 from Sensory and a set of radio frequency emitters- receivers. The possibility to increase the number of robots to be controlled is also described.**

I. INTRODUCTION

This new component which is the microcontroller, that integrates within one chip all the necessary elements to design a mother board and used in many different industrial biomedical and robotics applications, is very important and essential in the design of small robots. Many techniques have been developed in order to enhance robot behaviour based on smart sensors and microcontrollers efficiently [1]-[4].

It has been known that the design of a mother board based on microprocessor is not an easy way , it takes time to design the board and cost more money to provide the necessary components. Therefore, the intelligent robots or the intelligent systems implemented by microcontrollers can reduce time of development.

There have been many research projects dealing with robot control, among these projects, there are some projects that build intelligent systems [5][6][9][10]. Since we have read a book like "The Robots of Dawn" from ISAAK ASIMOV published in 1983 by Nightfall Inc., making intelligent robots or intelligent systems became an obsession within the research group. A micromouse in [5] is a computer controlled autonomous mobile robot that can find a predetermined destination when placed in an unknown maze. The micromouse competition has earned high marks on publicity and technology. But the micromouse competition has to be conducted on a maze of unreasonable specification [6]. A vision-guided autonomous vehicle is proposed as an alternative of the micromouse competition in [6]. The track of a vision-guided autonomous vehicle can be easily constructed. Most of components are off-the-shelf products and the level of challenge on software can vary to suit the student. However, since image processing and control of the car are accomplished by a personal computer, a vision-guided autonomous vehicle project is more appropriate in courses related to computer vision, artificial intelligence, and fuzzy logic rather than those related to microcontrollers. In the MIROSOT(Micro - Robot World Cup Soccer Tournament), intelligent autonomous robots compete with each other in the soccer game [10]. The host computer processes vision data and gets the positions of the ball and robots. Each robot receives this position data from the host computer through RF communication. Depending on the sensor data of each robot and the vision data, each robot decides its own behaviour to play the soccer game. MIROSOT is a fast growing new interdisciplinary field where people from different backgrounds such as sensor fusion, intelligent control, robotics, communication, image processing, mechatronics, computer technology, and artificial life are working together for the development of intelligent soccer robots. But the soccer robot system requires a colour vision system that consists of a personal computer, a colour camera, and a colour vision board.

In this paper, a voice command system for autonomous robots is proposed based on the price of design and the use of microcontrollers. Compared with previous projects as in [5][6][10], the cost of the proposed voice command system is much lower. Also, the variation of the proposed voice command system and other applications besides autonomous robots is possible depending on characteristics of the microcontroller and different sensors .

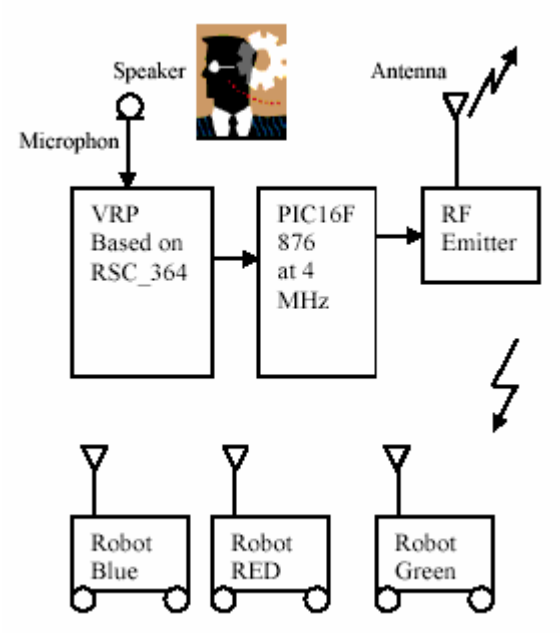

Figure 1. Designed voice command system for autonomous robots.

In order to command autonomous robots by voices as in Figure 1, a voice recognition system has to be designed. There is a lot of research about designing voice recognition systems. Most of the voice recognition systems have been built in workstations, personal computers, or DSP (Digital Signal Processor) chips by developing voice recognition algorithms.
Depending on which algorithm is applied, voice recognition systems of different characteristics can be made.

Therefore, the voice recognition system built in workstations, personal computers, or DSP chips can achieve various characteristics. Also, they can achieve high voice recognition rate under a general environment. However, because techniques about voice recognition built in workstations, personal computers, or DSP chips are complicated and needs more time for development, a voice recognition processor is proposed in this paper. Which is a dedicated processor that can recognize voices and therefore if the voice recognition processor is used, a voice recognition system can be built without knowing any voice recognition algorithms.

The proposed voice recognition system is used as a voice command system for autonomous robots. The effectiveness of the voice input compared with other input devices in robot systems was discussed in [11]-[15]. In order to command the tasks of autonomous robots by voices, the same number of words as tasks have to be recognized. Since one voice recognition processor can only recognize a limited number of voices (words) , the tasks of autonomous robots more than the limited number cannot be distinguished if one voice recognition processor is used alone.

In this paper, a RISC architecture microcontroller is combined with one voice recognition processor for controlling different robots. Given the tasks of autonomous robots, each robot task is classified and is organized such that the number of robot tasks under each directory is not more than the maximum recognition number of one voice recognition processor. Then one voice recognition processor can distinguish robot tasks under each directory.
In section 2, is a presentation on how to build a voice command system that can distinguish a lot of robot tasks by voices. A voice command system for three autonomous robots is presented in section 3. Then, a discussion on the advantages of the proposed voice command system is presented in section 4. The benefits of this design are enumerated in section 5. The results of tests are shown in section 6. Finally, a conclusion and future works are mentioned in section 7.

II. THE PROPOSED VOICE COMMAND SYSTEM

The proposed voice command system consists of a special low power microcontroller and a Voice Recognition Processor (VRP) that can recognize a limited number of voices. Let the maximum number of recognizable voices by this VRP be N >2 , the number of commands to be given to a robot are p > 2, then the maximum number of robots to be controlled by this VRP is n=N/p as shown in figure 2. So the orders can be grouped into sets, each set of order is affected to a selected robot. In this case each robot can be affected different tasks. The VRP 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. The VRP extracts patterns from acoustic signal and store them in its internal memory. During this phase, the operator might be asked to repeat a word many times, specially if the word pronunciation is quite different from time to time.

In the recognition phase, given a voice command, the VRP recognizes the voice command by matching the most similar pattern in its memory unit and then sends the recognition result to the microcontroller.
According to the recognition result, the microcontroller selects a group and provides another memory unit to the VRP. This memory unit contains the voice commands under the selected group and therefore the VRP waits for the next voice command under the selected group. If a voice command is recognized by the VRP, the microcontroller makes a command to a robot to perform the corresponding task and the VRP waits for the following voice command.

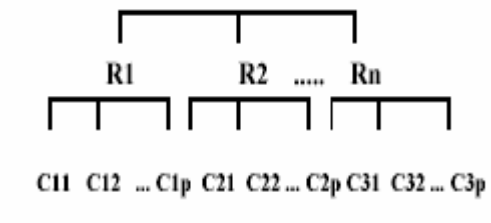

Figure 2. The structure of voice command for n robots.

III . VOICE COMMAND FOR AUTONOMOUS ROBOTS

A voice command system and three autonomous robots that receive voice commands are implemented. The voice commands of robots are selected from French words used to control a vehicle ("Rouge", "Bleu", "Vert"', "Avant", "Arrière", "Gauche", "Droite", and "Stop") and their meanings are listed as in Table 1,

Table 1. The meaning of voice command vocabulary.

1	Rouge	Choose the first robot, red colour
2	Bleu	Choose the second robot, blue colour
3	Vert	Choose the third robot, green colour
4	Avant	Go forward, action on M1
5	Arrière	Change direction back, action on M1
6	Droite	Turn right, action on M2
7	Gauche	Turn left, action on M2
8	Stop	Stop the movement, stops M1 and M2

in which voice commands for each robot are the same. However, voice commands for the three robots may be different from each other as mentioned early.

A. Voice command system description

The voice command system as in Figure 6 consists of a voice recognition processor RSC-364 [16], a microcontroller from Microchip the PIC16F876 [17], a radio frequency emitter module, and a microphone . The RSC-364 is a speaker-dependent isolate-word recognition processor that can recognize up to 15 words in stand-alone mode , up to 60 words or phrases can be recognized in slave mode, the response time is less than 200ms to a given voice input. 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 Converter, D/A converter, ROM as program memory, and RAM circuitry on chip. The RSC-364 also include on chip pre-amplification The module VD364 is based on: a special microcontroller RSC364, a program memory AT27C512 of EPROM type that holds the main program of word recognition, a reference word storage 24C65 of EEPROM type, and a parallel interface of 16 lines to generate the results of recognition.

To train and to recognize 15 words, an external 8K–byte EEPROM (Electrical Erasable Programmable Read Only Memory) needs to be connected to the RSC-364. No software programming of the RSC-364 is needed. The Microchip PIC16F876 is an 8 bit microcontroller designed to handle high-speed calculations and fast input/output operations. Since a PIC16F876 includes a five channel 10bit A/D converter, a serial port, Three 8 bit high-speed I/O, and two PWM (pulse-width-modulated) modules, this microcontroller can be used to design a simple controller. Typical applications using the PIC16F876 include data acquisition system, robot motion control and domestic appliance control. To transmit orders to different robots, a Radio frequency (RF) is used. Based on the characteristics and price, an emitter FM 433.92 MHz with transmission speed 5 kbs (kilo bit second) referenced "TXM-433-5 RF emitter" [18] was chosen In the implemented voice system, the PIC16F876 plays an important role as an interface between the VD364 and RF transmitter and sending commands to three autonomous robots.

B. Training

In order to train a voice in the manual mode of the VD-364, a push button is used to initialise the training mode, the system asks the user to enter the voice, which should be entered into the RSC-364 through a microphone connected to the RSC-364. During training, the VRP stores patterns of each word in its memory.

Voice commands "Rouge", "Bleu", and "Vert" are used to select the first robot, the second one, and the third one, respectively. ("Rouge", "Bleu", and "Vert" are the words representing the three main colours in a colour TV). Since voice commands of each robot are stored in different memory areas, different voice commands may be trained depending on each robot.

C. Recognition

In the recognition, when the voice input through the microphone is detected, the VD-364 tries to find the most similar voice pattern to this input and sends a byte representing the recognition result to the PIC16f876. This byte is sent to the PIC16F876 through a TTL buffer 74LS245. Depending on this byte, the PIC16F876 sends an appropriate frame of 12 bits as in figure 3, where the four first bits represent the address of the robot chosen A3-A0 and the remaining bits represent the command to be executed by that robot C7-C0. This format allows the control up to 16 robots with 256 commands . Finally the frame is modulated and transmitted by the RF emitter.

A 3	A 2	A 1	A 0	C 7	C 6	C 5	C 4	C 3	C 2	C 1	C 0

Figure 3. The frame format.

IV. AUTONOMOUS ROBOTS

As in Figure 4, the structures of the mechanical hardware and the computer board of autonomous robots in this paper are similar to those in [5] and [10]. However, since the autonomous robots in this paper need to perform simpler tasks than those in [5] and [10] do, these autonomous robots can more easily be constructed. The computer board of each autonomous robot consists of a PIC16F84 , with 1 K-instruction EEPROM (Electrically Programmable Read Only Memory) [17], two H bridges drivers using BD134 and BD133 transistors for DC motors, a RF receiver module from RADIOMETRIX which is referenced "SILRX-433 RF receiver" a receiver FM 433.92 MHz with the same transmission speed as the emitter (5 KBs), this receiver is used in the remote controller of consumer electronic products [18], and a four bit micro-switch to fix the

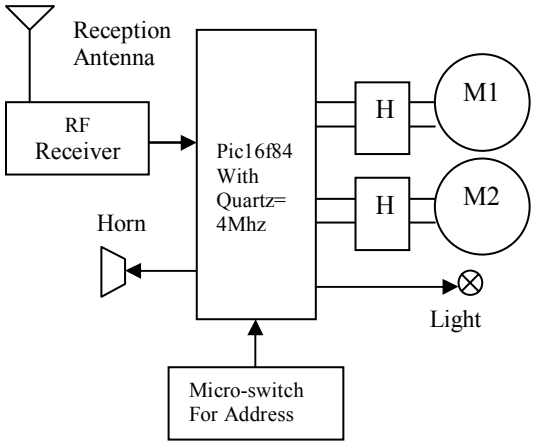

Figure 4. Autonomous robot block diagram

address of each robot.
Each autonomous robot performs the corresponding task to a received command as in Table 1. Commands and their corresponding tasks in autonomous robots may be changed in order to enhance or change the application.

V. BENEFITS OF THE DESIGNED SYSTEM

In section 3, a voice command system is designed and is constructed to make commands to three autonomous robots. This voice command system can be applied to other systems as well as Autonomous robots. The followings are the advantages of the proposed system:
1) The proposed system, to command and control an autonomous robot by human voices, is totally based on microcontrollers as shown in figure 5.
2) Compared with previous projects that build intelligent systems as in [5][7][10], the cost of the proposed voice command system is much lower.
3) An autonomous robot controlled by human voices is one of the projects that can be assigned to a heterogynous research group and therefore require the cooperation of each member. Depending on the research field of group members, this autonomous robot can be divided into several modules and each module can be assigned to one individual researcher.

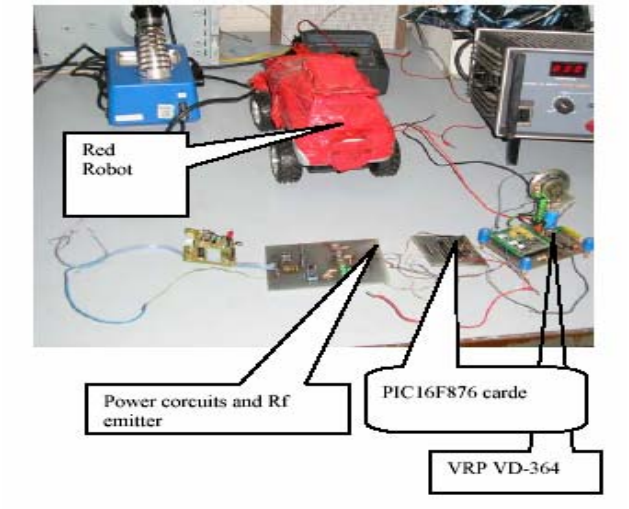

Figure 5. Overview of the voice command system.

For example, one person designs a voice command system and the other person an autonomous robot, while a third person may work on behaviour of several robots.

4) Several interesting competitions of voice-controlled autonomous robots will be possible. In the competition, autonomous robots will perform various tasks by human voice commands. Each team may use its own voice commands different from those of other teams. One example of the competitions is a robot soccer tournament by human voice commands.
This is different from a robot soccer tournament by vision as in [10]. Another example is to get the robot out of a maze under an unstructured environment by human voice commands. How to compose voice commands of voice-controlled autonomous robots may change the competition result. Items such as tournament score, the time to complete task, the accuracy, and the originality will be used to evaluate voice-controlled autonomous robots in a competition.
5) While previous intelligent systems as in [5][6][9][10] are under a full automatic control, voice-controlled autonomous robots are under a supervisory control. Therefore, it can be used to solve some problems in the supervisory control. One of problems in supervisory control is due to the time delay [19]. The time delay mainly caused by the recognition time of voices and the time of reception of an RF signal then reaction of the robot, the effect of time delays in controlling autonomous robots can be observed.
6) Other systems besides autonomous robots can be combined with the proposed voice command system. For example, a voice-controlled remote switch can be built by using this voice command system, an infrared transmitter/receiver pair, and some relays. A voice-controlled remote controller of consumer electronic products can also be built by using this voice command system and an infrared transmitter/receiver pair if the codes of the remote controller in consumer electronic products are known, example the RC5 code for Philips products [20].
7) Another voice command system will be possible to construct by other VRP besides RSC-364 [22]-[25]. It will compare the characteristics of each voice command system such as the speaker-dependency, the number of voice recognition, the recognition rate, and the recognition time. Also, the complexity of a voice command system will vary depending on which voice recognition processor is used.

VI. TESTS OF THE VOICE COMMAND SYSTEM

The developed system has been tested within the laboratory of L.A.S.A, there were two different conditions to be tested: The distance of the microphone from the speaker, and the rate of recognition in stationary noise and non-stationary noise (NSN). The system, first, had been tested in the laboratory and outside in order to detect the environment effect on the recognition rate. After testing the recognition for each word 25 times in

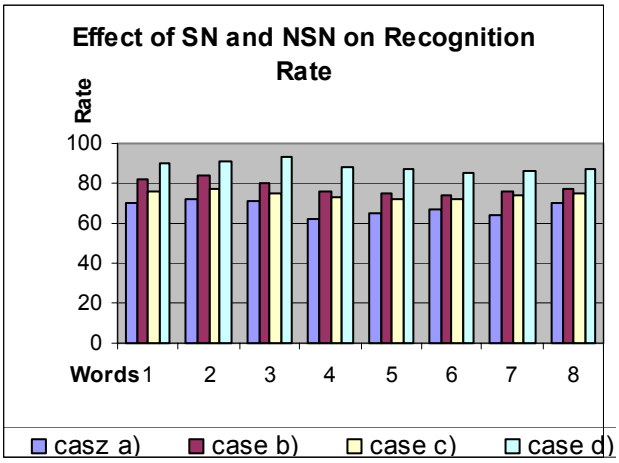

Figure 6. The effect of SN or NSN in and out the laboratory.

the following conditions: a) outside the Laboratory (LASA) with NSN, b) outside the LASA with stationary noise (SN), c) inside the LASA with NSN, and d) inside the LASA with SN. The results are shown in figure 6 where the numbers in abscess axe corresponds to the order of voice command word as they appear in Table1.

VII. CONCLUSION

A voice command system for autonomous robots is proposed and is implemented based on microcontrollers. Since the proposed system consists of a VRP, a microcontroller, and other low-cost components namely RF transmitters, the hardware design can easily be carried out. The results of the tests shows that a better recognition rate can be achieved inside the laboratory and specially if the phonemes of the selected word for voice command are quite different. However, a good position of the microphone and additional filtering may enhance the recognition rate. In order to recognize voice commands more than the maximum recognition number of one voice recognition processor, all voice commands can be grouped and organized such that the VRP always tries to find the most similar voice pattern from one memory unit. The number of the voice commands in one memory unit is not more than the maximum recognition number of one voice recognition processor. Several interesting applications of the proposed system different from previous ones are possible. The variation of the proposed voice command system to fit other applications besides autonomous robots is under study. Future work is also in adding some sensors on the robots in order to avoid obstacles and integrate reinforcement learning algorithms.

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