A Nursing Robot System for The Elderly and The Disabled

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Abstract

This paper describes a nursing robot system that is called DO-U-MI developed for helping elderly and disabled people. For that purpose, the nursing robot system has a capability to assist elderly and disabled people to move independently in indoor environments such as a nursing home. It also provides a convenient man-machine interface for easy usage and various entertainment services for users. In human friendly man-machine interface, the nursing robot can detect a human face and localize a sound source with cameras and microphones in order to detect the position of the user for the service. Also the user can use various entertainment services such as music, movie, email by the computer that the robot is equipped with. In this paper, the overall system is introduced and the detailed subsystems and functions are presented.

1. Introduction

As society develops, the improvement of the quality of life is becoming an essential task. As the medical care system improves the quality of life, the population of elderly people is growing. On the other hand, the population that supports elderly persons is decreasing. This means that elderly people are becoming lonely in modern society. The situation of physically disabled people is similar to that of elderly people.

Robotics technology is developing dramatically. In this sense, the robot system is an alternative since accuracy for sensors and control system is increasing and computer technology, one of basics in robotics, is rapidly developing.

This paper presents a nursing robot system that was developed for elderly and disabled person's independent life. In this paper, the overall system of the robot will be reviewed and the detailed parts of the system are discussed.

2. Overall System

Fig. 1. Nursing robot in intelligent residence

Figure 1 shows the nursing robot system that has been developed for supporting daily life of the elderly and disabled. The main purpose of the robot is to provide mobile assistance to a person who has difficulty to move in a indoor environment and supports various entertainment services such as playing music, movie, etc.

For the comfort mobile assistance, the robot has an arm supporter that supports the upper body of a user. The user can control the robot with control switches in the arm supporter during the movement. Two motorized wheels that can be controlled by the user or the robot itself make the robot move to any direction or position. The ultrasonic and infrared sensors equipped in the base of the robot can detect obstacles around the robot and enable the robot to avoid obstacles despite operation errors by the user.

The cameras and microphones equipped in the robot help the robot recognize environments. Two color cameras in the robot head can detect and track the human face and make the robot approach the user for services. Two microphones receive sound and localize the sound source. If a person wants to be served by the robot, he can notify the robot by clapping his hands. Then the robot detects the sound and localizes the sound source by microphones. And based on the rough position by sound localization, the robot searches and tracks the human face with cameras and then approaches the person for services.

Another function of the robot is various interfaces for entertainment such as music, movie, email, internet and so on. The contents in the robot are supplied through the LCD monitor and speaker, which can be updated through wireless LAN. For entertainment services, the user simply touches the menu in the LCD monitor.

3. Mechanical Design

One of the main purposes of the robot is mobile assistance for elderly and disabled people. Because of various diseases, most elderly and disabled people have difficulty to move independently. However their daily lives consist of a lot of movement such as going to the hospital, visiting friends, taking a walk, etc. For their independent lives, the assistance of mobility is important. In our system, a mobile assistance system is designed and implemented in order to make the user move without any assistance from other people, such as a nurse.

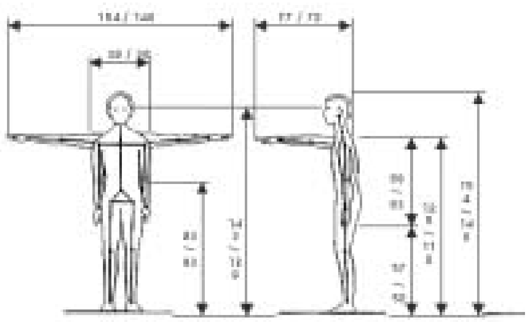

Fig.2. Body size of elderly person

In the design of the robot and the arm supporter as shown in Figure 3, the size of the human body is considered. The average height of elderly people whose age is between 70 and 79 in Korea is about 140~154cm as shown in Figure 2 and the height to the armpit from ground is about 112~125cm. The Figure 3 shows the side view of the robot. Figure 3, the height of the robot, from ground to head, is 120cm and the height from ground to arm supporter is 107cm. In the design of the robot, the height of an elderly person was considered as 145cm. Also the arm supporter, as shown Figure 3, is designed to be flexibly adjusted according to the user's height.

The nursing robot system consists of many components such as batteries, motors, and a computer and it also supports the human body. So the frame of the nursing robot must have enough strength to support its components and a human body. In our system, the main frame of the robot is made of aluminum profile that is light and strong. The aluminum profile is a kind of aluminum stick, which has long and thin groove. It is easy to assemble the profile with just screws.

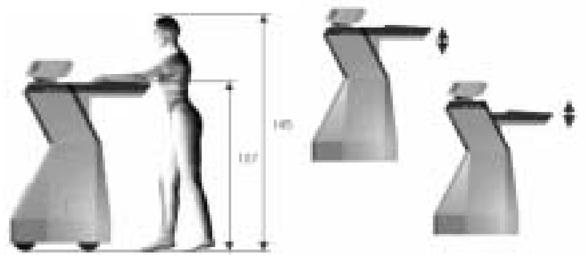

Fig.3. Frame of the robot

4. Overall System Architecture

Figure 4 shows the overall architecture of the nursing robot. The main computer, PentinumIII-866MHz, controls the overall system. The LCD monitor with a touch screen shows the information from the computer and receives commands from the user through the touch screen. The wireless LAN, embedded in main computer, communicates with other computers through the Internet at a speed of 10Mbps.

The robot has two motored-wheels in the base for movement. The wheels of the robot can be controlled by a human or the robot itself. When the robot assists a human, the wheels are controlled by a human. In other case the wheels are controlled by the main computer in the robot.

The power of motor is supplied by the batteries that are embedded in the robot. For safe operation, the robot has ultrasonic and infrared sensors. The ultrasonic sensor can detect long-distance obstacles and the infrared sensor can detect very close obstacles. The robot has 13 ultrasonic sensors and 13 infrared sensors for detecting obstacles.

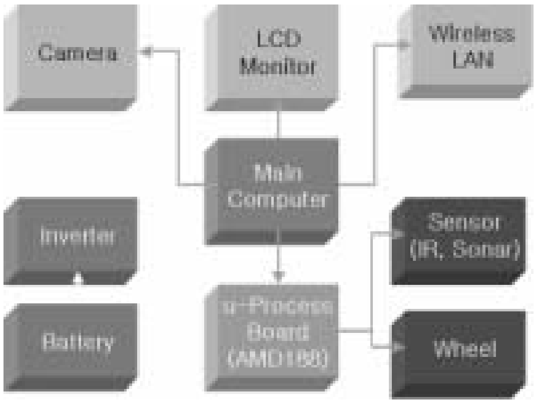

Fig.4. Block diagram of the robot

The low level control of the wheels is performed by a u-process module. Also to control the wheels of the robot safely, the u-process module controls the ultrasonic and the infrared sensors that detect obstacles around the robot. The high level control of the movement is performed by the main computer. Thus the main computer must send commands to the u-process module for controlling the robot through a serial port.

The battery module that consists of batteries and inverter provides electric power to all components of the robot. The capacity of the battery is 24V-100Ah and the main computer consumes about 5A. Thus the main computer in the robot works about 20 hours if the robot does not move.

The two cameras that are mounted on a pan-tilt module capture images to recognize environments and detects the human face. The cameras are connected to image grabbers in the main computer and images are captured. One of the two cameras has a narrow view angle and the other has a wide view angle for large detection range.

5. Man-Machine Interface

For convenient interaction between the robot and a human, intelligent man-machine interfaces are required. As mentioned above, various sensors, such as cameras, microphones and a touch screen equipped in nursing robot system are able to help convenient interaction between the robot and a human. For the convenient interface, the nursing robot can detect human faces and localize the sound with cameras and microphones, which helps the robot provide services for the users.

5.1. Face Detection

Two zoomed cameras controlled by the main computer through RS-232C protocol are installed on the top of the robot. Because the cameras are mounted on the top of the pen-tilt system as the robot eye, the cameras can scan large views for detecting objects. By using these cameras the robot can detect and track the user’s face to determine the position of the user and to interact with the user.

For the face detection module in the nursing robot system, we have modified the method that was developed by Henry Rowley *et al.*[4]. In their algorithm, the whole image is scanned to detect human faces using trained neural network. It can detect human faces reliably under a wide range of lighting conditions and various face sizes. However, it takes too much computational time. Here, for fast computation, we use a multi-size template matching to find faces instead of a trained neural network.

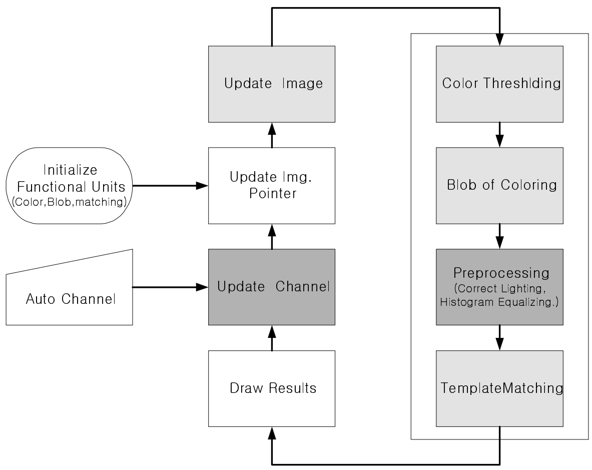

Fig.5. Flow-chart for face detection

The size of face changes according to the distance of the face from the camera. If we wish to detect the face with template matching, we need a lot of templates that

Fig.6. Face detection result

have various sizes according to distance and template matching using a lot of templates is a time-consuming process. To reduce the number of templates we use two cameras that are zoomed differently.
In our algorithm, the candidates of face regions are selected by human skin color model at first. Then each candidate is matched with multi-size template in the image from narrow zoomed camera. If the face detection fails, a face is searched in the wide zoomed camera with the same template. It is continued until it finds a face. This algorithm can detect a face in real-time by reducing the number of templates.

5.2. Sound Localization

For the human friendly interface, the nursing robot has two microphones that can catch sound around the robot. As humans can detect the direction of the sound source with two ears, the robot can determine the direction of the sound source using two microphones as human ears. Localizing the sound source helps the robot detect the position of the user. In the nursing robot system, the direction of the sound source can be found by the phase difference of the sounds from two microphones.

As shown in Figure 8, the sounds captured from different positions have similar shapes and time-delayed phase. If we can find the distance *l* from delayed time in Figure 7 we can determine the direction of the sound source.

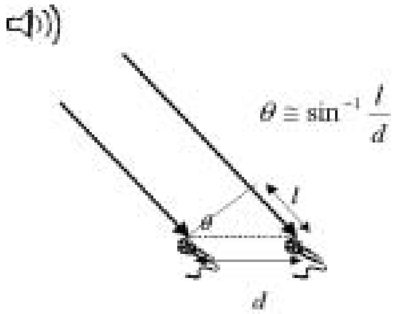

Fig.7. Sound localization

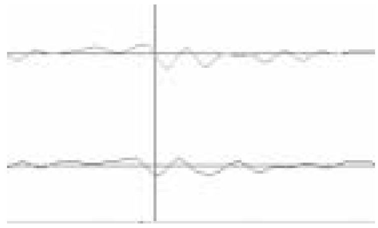

Fig.8. Left and right signal captured by microphones

Figure 9 shows the experimental setup. In Figure 9, the sound source is located 100cm from the center of two microphones. The location of the sound source is changed by 10° continuously and the sounds are captured by microphones in 44.1kHz sampling frequency, 8bit resolution. The distance between the two microphones is 22cm, which is similar to the distance between two human ears.

Figure 10 is the experimental results. In Figure 10, the axis x represents the real angles of the sound sources and the axis y represents the evaluated angles by the sampled data. In experiments, the average error is 3.412° and the standard deviation is 3.511°.

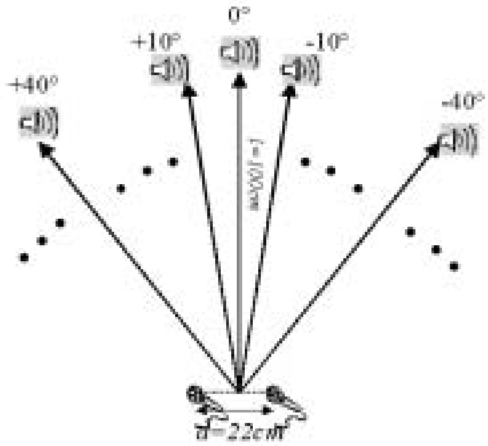

Fig.9. Experimental setup for sound localization

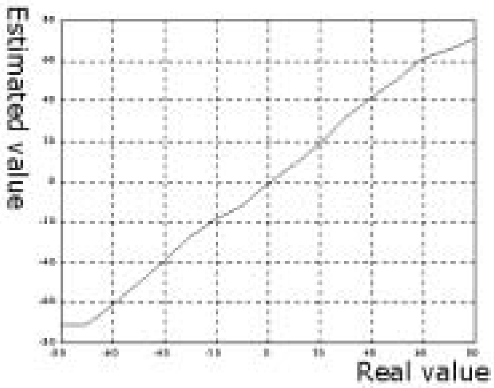

Fig.10. Experimental result

5.3. Entertainments

Fig.11. Menu of entertainment services

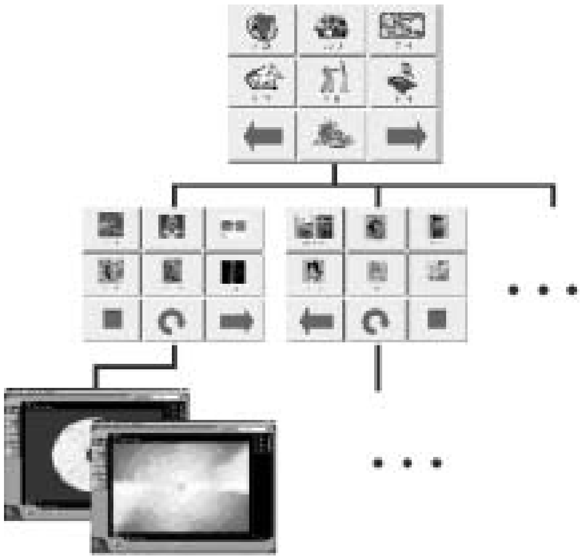

Fig.12. Hierarchical structure of menu

The main program for managing entertainment services is controlled by a user through the touch screen in front of the robot. Figure 11 shows a management program that consists of large icons for giving easy recognition and manipulation. In Figure 11 each menu has an hierarchical structure. If a user selects the icon in the menu then the submenu is displayed in the next image. For example, if one selects the music icon, then the list of albums is displayed in next image.

Another service supported by the robot is to read email for the elderly using a voice synthesizer since it is very hard for elderly people to read small characters on a monitor.

6. Summary and Conclusions

This paper described a nursing robot system for the elderly and the disabled. The robot has functions to assist elderly and disabled people to live independently and provide various entertaining services.

All parts of the system are implemented but some parts, such as the subsystem, face detection, sound localization etc., are not yet integrated. In the next development phase, the integration will be completed. Additionally auto navigation is considered for a more intelligent robot.

References

[1] R. D. Schraft, C, Schaeffer, T. May, “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.

[2] W. K. Song, H. Y. Lee, J. S. Kim, Y. S. Yoon, Z. Bien. A. N. Expert, A Book He Wrote, His Publisher, 1989. “KARES: Intelligent rehabilitation robotics system for the disabled and the elderly," *Proc. of the 20th Annual International Conference EMBS*, vol. 5, pp. 2682-22685, 1998.

[3] 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.

[4] H. A. Rowley, S. Baluja, T. Kanade, “Neural Network-Based Face Detection," *IEEE trans. on Pattern Analysis and Machine Intelligent*, vol. 20, no. 1, pp. 23-38, 1998.