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A MOBILE OMNIDIRECTIONAL WHEELCHAIR: ITS IMPLEMENTATION AND EXPERIMENTAL EVALUATION

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In recent years, more and more convenient facilities and equipments have been developed in order to satisfy the requirements of elderly people and disabled people. Among them, wheelchair is a common one which is widely used and can provide the user with many benefits, such as maintaining mobility, continuing or broadening community and social activities, conserving strength and energy, and enhancing quality of life. The wheelchair body must be compact enough to go through narrow doorways. The wheelchair must be wide enough to prevent the patient from falling on the floor. A large footprint is therefore desirable for stability and safety, while wheelchairs must conform to dimensional constraints. In this paper, we present the implementation and evaluation of an omnidirectional wheelchair, which has a small size and can move easily in narrow spaces. In order to evaluate the implemented wheelchair, we carried out some experiments and discussed some implementation and application issues. The experimental results show that the implemented wheelchair in general works properly.

Keywords: Mobile Robos, Omnidirectional Wheelchair

1 Introduction

Robots are being steadily introduced into modern everyday life and are expected to play a key role in the near future. Typically, the robots are deployed in situations where it is too dangerous, expensive, tedious, and complex for humans to operate.

One of the main features of world population in the 20th century is the increment of elderly people. According to WHO (World Health Organization) by 2025, the increase of population over aged 60 is predicted to reach 23% in North America, 17% in East Asia, 12% in Latin

America and 10% in South Asia. There are over 600 million disabled persons in the world constituting nearly 10% of the global population.

With the accelerating development of aged tendency of population and rapid growth in the number of the disabled caused by diseases or injuries, the wheelchair with good performance for the aged and disabled is attracting more and more attention from the society. There are many research works on wheelchairs including wheelchair for recovery, climbing stairs, and multifunction [1]. Therefore, it is necessary to design wheelchairs with features such as easy-walking, convenient-use, and small-radius-swerving because the wheelchair is often used in a relatively narrow and small room.

The wheelchair body must be compact enough to go through narrow doorways. The wheelchair must be wide enough to prevent the patient from falling on the floor. A large footprint is therefore desirable for stability and safety, while wheelchairs must conform to dimensional constraints. Also the footprint must be compact since a large footprint does not allow the vehicle to move in a closely confined place. Stability and maneuverability are therefore conflicting requirements.

In recent years, more and more convenient facilities and equipments have been developed in order to satisfy the requirements of elderly people and disabled people. Among them, wheelchair is a common one which is used widely. A wheelchair can provide the user with many benefits, such as maintaining mobility, continuing or broadening community and social activities, conserving strength and energy, and enhancing quality of life.

In this paper, we present the design and implementation of an omnidirectional wheelchair system, which has a small size and is compact to move in the narrow spaces.

The structure of this paper is as follows. In Section 2, we introduce the related work. In Section 3, we present the proposed omnidirectional wheelchair system. In Section 4, we discuss experimental results and application issues. Finally, conclusions and future work are given in Section 5.

2 Related Work

Most of the work, for mobile robots has be done for improving the quality of life of disabled people. One of important research area is robotic wheelchairs. The persons having physical impairment often find it difficult to navigate the wheelchair themselves. The reduced physical function associated with the age or disability make independent living more difficult. Many research works have been undertaken to reduce the problem of navigation faced by the physically and mentally challenged people and also older age persons. One of the suggestive measures are the development of a Brain Control Interface (BCI), that assist an impaired person to control the wheelchair using his own brain signal. The research proposes a high-frequency SSVEP-based asynchronous BCI in order to control the navigation of a mobile object on the screen through a scenario and to reach its final destination [2]. This could help impaired people to navigate a robotic wheelchair. The BCIs are systems that allow to translate in real time the electrical activity of the brain in commands to control devices, provide communication and control for people with devastating neuromuscular disorders, such as the Amyotrophic Lateral Sclerosis (ALS), brainstem stroke, cerebral palsy, and spinal cord injury [3].

One of the key issue in designing wheelchairs is to reduce the caregiver load. Some of the research works deal with developing prototypes of robotic wheelchairs that helps the caregiver by lifting function or which can move with a caregiver side by side [4, 5]. The lifting function equipment facilitates easy and safe transfer from/to a bed and a toilet stool by virtue of the opposite allocation of wheels from that for a usual wheelchair. The use of lifting function and the folding of frames makes it more useful in indoor environments. Robotic wheelchair based on observations of people using integrated sensors can move with a caregiver side by side. This is achieved by a visual-laser tracking technique, where a laser range sensor and an omnidirectional camera are integrated to observe the caregiver.

Another important issue for the design of wheelchair is the collision detection mechanism. The omnidirectional wheelchairs with collaborative controls ensures better safety against collisions. Such wheelchairs possess high level of ability when moving over a step, through a gap or over a slope [6, 7]. To achieve omnidirectional motion, vehicles are generally equipped with an omniwheel consisting of a large number of free rollers or a spherical ball wheel. The development of such omniwheels attempts to replace the conventional wheel-type mechanism.

There are also other works which deal with vision design of robotic wheelchairs by equipping the wheelchair with camera for monitoring wheelchair movement and obstacle detection and pupil with gaze sensing [8, 9]. Prototype for robotic wheelchairs have been suggested in various research works, which are exclusively controlled by eye and are used by different users, while proving robust against vibration, illumination change, and user movement [10, 11].

To enable older person to communicate with other people the assisting devices have been developed. They can improve the quality of life for the elderly and disabled people by using robotic wheelchairs. The head gesture recognition is performed by means of real time face detection and tracking techniques. They developed a useful human-robot interface for RoboChair [12].

3 Proposed Omnidirectional Wheelchair System

In this section, we will describe the design and the implementation of the proposed wheelchair system.

In Fig. 1, we show a conventional wheelchair. In the case of kitchen space, the wheelchair can not move on the left or on the right sides. In order to move on right side as shown in Fig. 2, the wheelchair should make 5 movements. This is only one example of using the wheelchair, but when the wheelchair is used in indoor environment is difficult to make movements because of the small spaces.

In order to deal with these problems, we propose an omnidirectional wheelchair as shown in Fig. 3. The image of the implemented omnidirectional wheelchair is shown in Fig. 4.

3.1 Kinematics

For the control of the wheelchair are needed the omniwheel speed, wheelchair movement speed and direction.

Let us consider the movement of the wheelchair in 2 dimensional space. In Fig. 5, we show the onmiwheel model. In this figure, there are 3 onmiwheels which are placed 120 degree with each other. The omniwheels are moving in clockwise direction as shown in the figure. We consider the speed for each omniwheel M1, M2 and M3, respectively.

As shown in Fig. 5, the axis of the wheelchair are x and y and the speed is $v = (\dot{x}, \dot{y})$ and

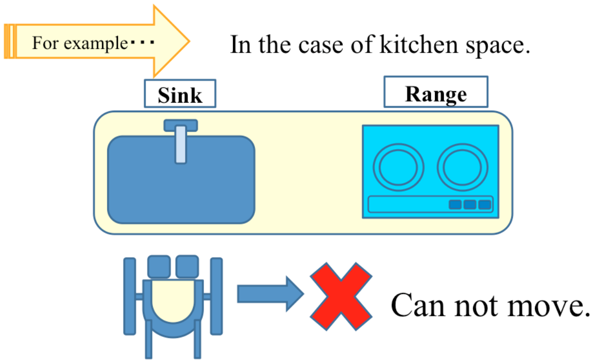

Fig. 1. Conventional wheelchair.

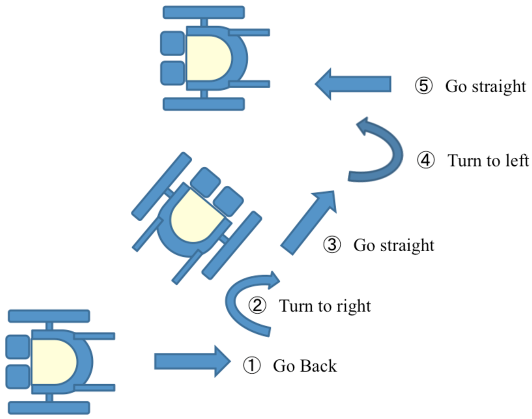

Fig. 2. Moving of conventional wheelchair.

the rotating speed is $\dot{\theta}$. In this case, the moving speed of the wheelchair can be expressed by Eq. (1).

$$V = (\dot{x}, \dot{y}, \dot{\theta}) \tag{1}$$

Based on the Eq. (1), the speed of each omniwheel can be decided. By considering the control value of the motor speed ratio of each omniwheel as linear and synthesising the vector speed of 3 omniwheels, we can get Eq. (2) by using Reverse Kinematics, where (d) is the distance between the center and the omniwheels. Then, from the rotating speed of each omniwheel based on Forward Kinematics, we get the wheelchair moving speed. If we calculate the inverse matrix of Eq. (2), we get Eq. (3). Thus, when the wheelchair moves in all directions (omnidirectional movement), the speed for each motor (theoretically) is calculated as shown in Table 1.

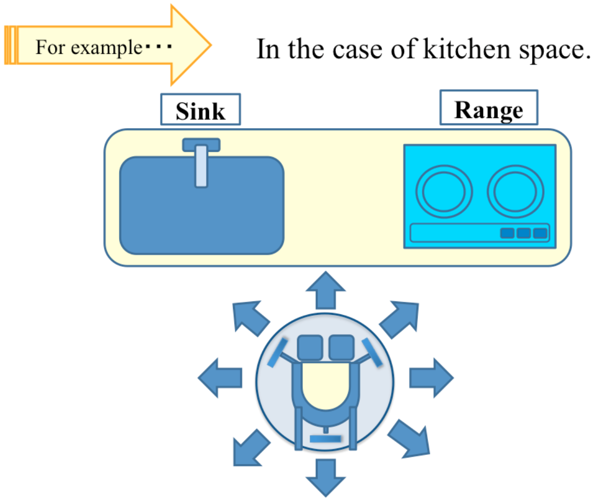

Fig. 3. Design of omnidirectional wheelchair.

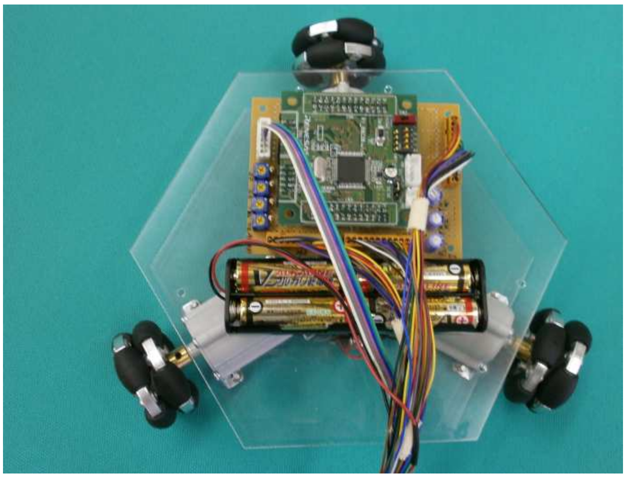

Fig. 4. Image of proposed omnidirectional wheelchair.

$$\begin{vmatrix} M_1 \\ M_2 \\ M_3 \end{vmatrix} = \begin{vmatrix} 1 & 0 & d \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & d \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & d \end{vmatrix} \begin{vmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{vmatrix} \tag{2}$$

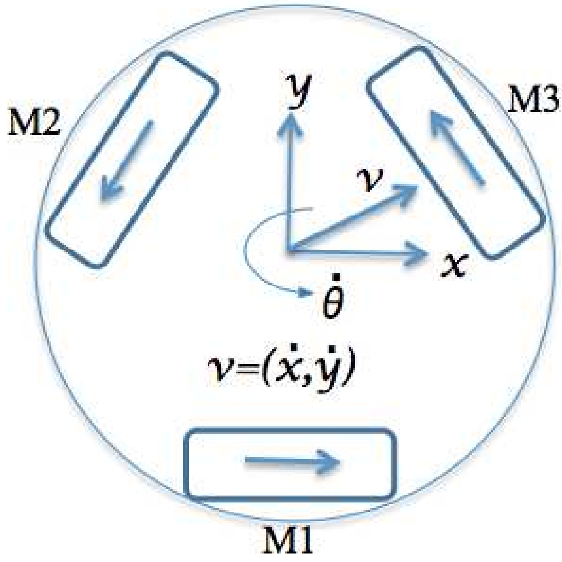

Fig. 5. Model of omniwheel.

$$\begin{vmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{vmatrix} = \begin{vmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{3d} & \frac{1}{3d} & \frac{1}{3d} \end{vmatrix} \begin{vmatrix} M_1 \\ M_2 \\ M_3 \end{vmatrix} \quad (3)$$

Table 1. Motor speed ratio.

Direction (Degrees)	Motor Speed Ratio		
	Motor1	Motor2	Motor3
0	0.00	-0.87	0.87
30	0.50	-1.00	0.50
60	0.87	-0.87	0.00
90	1.00	-0.50	-0.50
120	0.87	0.00	-0.87
150	0.50	0.50	-1.00
180	0.00	0.87	-0.87
210	-0.50	-1.00	-0.50
240	-0.87	0.87	0.00
270	-1.00	0.50	0.50
300	-0.87	0.00	0.87
330	-0.50	-0.50	1.00
360	0.00	-0.87	0.87

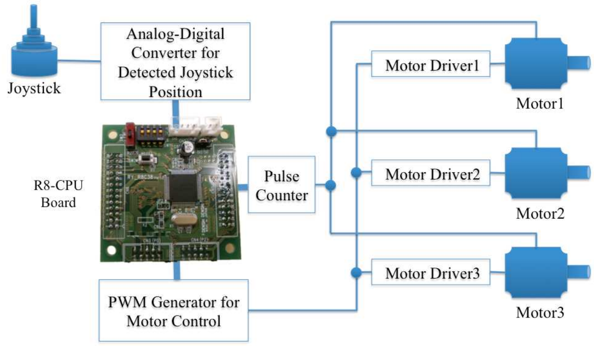

Fig. 6. Control system for omnidirectional wheelchair.

3.2 Control System of the Proposed Omnidirectional Wheelchair

For the control of the proposed omnidirectional wheelchair, we considered R8C38 CPU board from Renesas Electronics Corporation. This CPU board has a small size and high speed processing time. The core of the CPU has a maximum frequency of 20 MHz. It is equipped with a flash memory, which is easy to rewrite. The R8C38 board has the following features:

- 8bit multi functions timer: 2,
- 16bit output competition timer: 5,
- Real time clock timer: 1,
- UART/clock synchronization type serial interface: 3 channels,
- 10bit A/D converter: 20 channels,
- 8bit D/A converter: 2 circuits,
- Voltage detected circuit,
- Number of output and input port: 75,
- External interrupt input: 9.

In Fig. 6 is shown the control system for the proposed omnidirectional wheelchair. The direction movement of the wheelchair is decided by the Joystick. The Analog-Digital Converter changes the analog value to a digital value needed for R8C38 board. The R8C38 board based on the Eq. (2) calculates the motors control value. Based on this value, the Pulse Width Modulation (PWM) generator generates an appropriate value for the control of each motor. The number of rotation of each motor is detected by Pulse Counter and is sent to the R8C38 board in order to make a correct feedback control.

4 Experimental Results and Discussion

In order to evaluate the implemented omnidirectional wheelchair, we carried out some experiments. The experimental results are shown in Fig. 7 and Fig. 8, respectively.

We set up the omnidirectional wheelchair to move in different directions: 0 degree, 60 degree, 120 degree, 180 degree, 240 degree, and 300 degree. For every 1 meter movement, we considered the theoretical and experimental values. In Fig. 7, we carried out the experiments 10 times. The experimental results show that the difference distance between theoretical

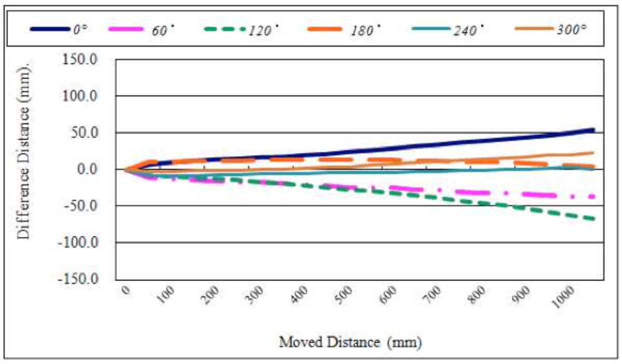

Fig. 7. Difference distance of experimental and theoretical values.

Fig. 8. Snapshots of moving omnidirectional wheelchair.

and actual values is increased with the increase of the distance. However, the values are reasonable.

In Fig. 8, we present some snapshots when the omnidirectional wheelchair was moving. We found that in general the wheelchair was moving properly. However, when there is a human control error, the wheelchair may collide with surroundings. For this reason, in the future work we want to implement a system to detect the environment by using a map recognition method. Thus, the wheelchair can avoid the collision with other objects.

Now the movement of wheelchair is done by joystick. We want to make the control of the wheelchair more convenient for disabled persons. For this reason, we want to implement an automatic control.

There are many applications of wheelchairs for supporting aged and disabled persons. However, we want to apply our omnidirectional wheelchair for sports such as tennis and badminton. Also, the application of the proposed wheelchair for transport in plants and factories will be considered.

5 Conclusions and Future Work

In this paper, we presented the implementation of an omnidirectional wheelchair, which has a small size and can move easily in narrow spaces. We introduced some of the previous works and discussed the related problems and issues. Then, we presented in details the kinematics and the control system for the proposed omnidirectional wheelchair. Finally, in order to evaluate the proposed system we carried out some experiments and discussed some implementation and application issues. The experimental results show that the implemented wheelchair in general moves properly.

In the future work, we want to implement a system to detect the environment by using a map recognition method in order that the wheelchair avoids the collision with other objects. Also, we want the implement an automatic control.

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