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Wheelchair User Support System Using Humanoid Robots
- System Concept and Experiments on Pushing Wheelchair -

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Abstract: This paper discusses wheelchair support system using humanoid robots as an example of human support using humanoid robots. In this proposal system, humanoid robots provide both of mobility and manipulation supports for the wheelchair users. Then we show the experimental results on pushing a wheelchair using a real humanoid robot HRP-2, because it is essential for humanoid robots to perform this task for creating this proposal system.

Keywords: Humanoid Robots, Human Support System, Wheelchair, Pushing Manipulation, User Interface

1. Introduction

Since the kinematical structure of humanoid robots is similar to that of humans, humanoid robots are expected to work instead of humans in the same environment. Previously, the researches of humanoid robot have mainly focused on the hardware design and bipedal locomotion. In recent years, as the technologies of humanoid robots have progressed, some applications of humanoid robots are being investigated. As the outstanding attempt, Ministry of Economy, Trade and Industry of Japan has promoted the Humanoid Robotics Project (HRP)[1] since 1998 Japanese fiscal year (JFY) for five years. In this project, some applications of humanoid robots – operating industrial vehicles[2], maintenance tasks of industrial plants[3], cooperative works by a human and a humanoid robot[4], and so on – have been developed.

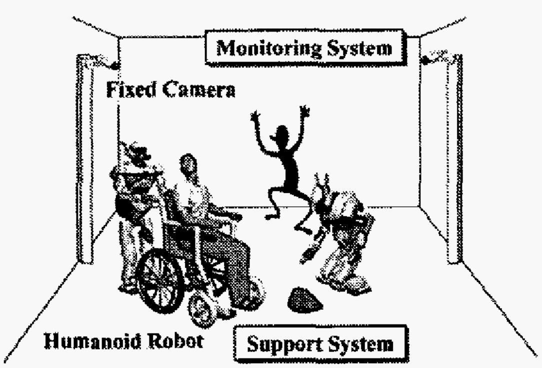


Fig. 1. Integrated system of monitoring and support system.

By the way, we see a lot of problems where "safety" and "security" are threatened in modern society. It is the highest priority issue to create safe, secure and reliable (SSR) society. For the purpose of creating SSR society, we have proposed an integrated system of monitoring and support system[5-6]. The monitoring system finds the sign of problem quickly in the environment by watching wide area in detail using many fixed or moving cameras. The support system prevents the danger from occurring or copes with the occurring danger rapidly, thus reducing damage to the minimum; in the present project, humanoid robots are used as supporting devices. This is because humanoid robots can move in our environment and use some tools and machines as humans do. In this way, this integrated system can offer safe environment to us, and we feel security and comfort in the environment. Our project aims at conceptual design of such monitoring and support system and making a prototype of the system(Fig. 1).

It is important for us to focus on everyone including elderly people and handicapped persons, for creating SSR society. Especially, elderly people and handicapped persons require the life support. Taking these points into account, we focus on the wheelchair users. In this paper, we propose the wheelchair user support system using humanoid robots as concrete application of humanoid robots. The remarkable characteristic of this proposal system is to provide the total support of mobility and manipulation for wheelchair users. Since humanoid robots

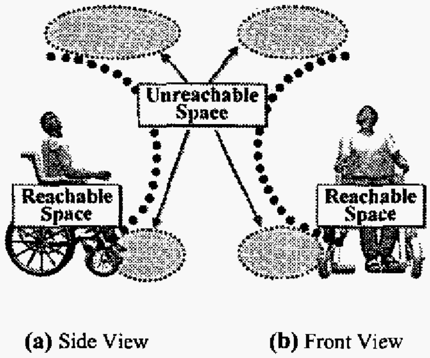


Fig. 2. Reachable space of the wheelchair users.

have two arms and two legs, humanoid robots can perform this total support.

The rest of this paper is organized as follows; Section 2 describes the surroundings of wheelchair users. Section 3 clarifies the architecture of wheelchair user support system using humanoid robots. Finally, we show the experimental results on pushing a wheelchair using a real humanoid robot in section 4.

2. Surroundings of Wheelchair User

In proportion for the rapid aging of the population, the number of wheelchair[7-8] users is getting increased. Thus it is important to create the environment in which they get around safely, securely, and actively in a wheelchair. To that end, we need to improve the infrastructures, solve the lack of care-giver and make the care service complete.

Wheelchair users need care in the following situations for moving around:

- irregular terrain
- step
- ditch
- ramp
- stair

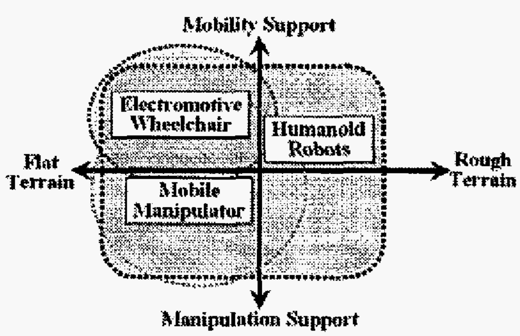


Fig. 3. Support areas for the wheelchair users.

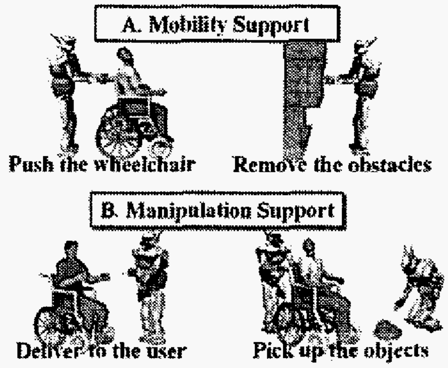


Fig. 4. Example of wheelchair user support by humanoid robots.

In addition to this mobility support, they need manipulation support. This is because their arms cannot reach for wide space(Fig. 2). According to the Japanese people anthropometric data in their 20s – 50s by the Research Institute of Human Engineering for Quality Life, male reaches 1650-1720[mm] height and female reaches 1570-1620[mm] height averagely, when they are sitting on 400[mm] sitting position. Hence, we propose the wheelchair user total support of mobility and manipulation using humanoid robots.

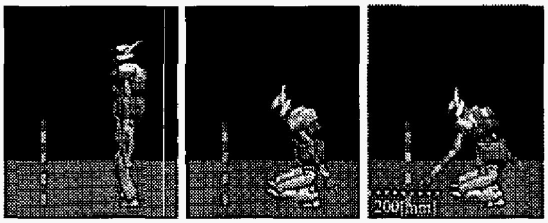
3. System Concept

An electromotive wheelchair is one of the solutions for lack of care-giver. Though there have been many researches on electromotive wheelchairs and intelligent wheelchairs, for instance [9], most of them provide only mobility support(Fig. 3). Besides, in response to diversification of values among the people, several alternatives for users are required. Thus we propose the system that humanoid robots support people in wheelchair with cooperating fixed or moving cameras. Humanoid robots have many degrees of freedom, so they provide mobility and manipulation support using their redundancy(Fig. 4). In addition, humanoid robots get the information about wide area in detail from many fixed or moving cameras, they take account of the environment.

In the human support system for creating SSR society, it is important for humanoid robots to consider the users and the environment. This system, therefore, covers the following points by using fixed or moving cameras, in addition to the situations discussed in section 2.

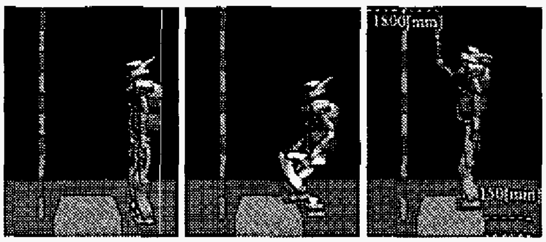
- Control of robots' hand vibration caused robot motion
- Control of wheelchair vibration in irregular terrain or step
- An obstacle avoidance operation in our environment
- Notice and warning about robot motion
- Motion planning in consideration for psychology

This system provides suitable service for users by software upgrade and they communicate with humanoid



(a) 0[sec] (b) 9[sec] (c) 25[sec]

Fig. 5. Simulation results on reaching for low position.



(a) 0[sec] (b) 7[sec] (c) 20[sec]

Fig. 6. Simulation results on reaching for high point.

robots. Besides, as care-giver is not a person, they are cared without feeling any constraint.

3.1 Support Contents

In this proposal system, wheelchair users receive mobility and manipulation support. The concrete support contents are as follows:

A. Mobility Support
- A-1) To push or back the wheelchair.
- A-2) To support for the user on bump.
- A-3) To secure the course.
- A-4) To walk along the user.
- A-5) To open the door.

B. Manipulation Support
- B-1) To perform manipulation task on low and high place.
- B-2) To deliver the object to the user.

To create the mobility support, we focus attention on the realization of maneuvering a wheelchair using humanoid robots. In this paper, we show the experiments on pushing a wheelchair using a real humanoid robot in next section.

On the other hand, to create the manipulation support, it is important for us to look at the situations that we reach for low or high point in our daily life. As an example of these situations, we performed a computer simulation of reaching out a humanoid robot hand for 200[mm] and 1800[mm] above the ground by using simulation software

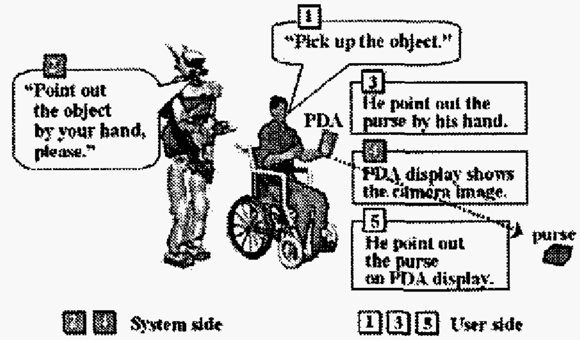


Fig. 7. User interface.

OpenHRP[10-13]. As a model of humanoid robots, we used the physical parameters of HRP-2[14]. This robot is the final version of humanoid robotics platform of the Humanoid Robotics Project(HRP), and it is 1539[mm] in height, 621[mm] in width, 58[kg] in weight, 30 degrees of freedom(DOF) includes 2 DOF for waist, contains computers and butteries in its body. The snapshots of the simulation are shown in Fig. 5 and Fig. 6. A humanoid robot successfully reaches out its hand for desired 200[mm] and 1800[mm] above the ground. From Fig. 6, it is ascertained that humanoid robots can use steps for the purpose of reaching out for higher position, as humans do. In order to reach out for low point, it is one of the ways for humanoid robots to drop on their knees. Future works includes the development of the control method to drop on their knees stably.

3.2 User Interface

In this system, wheelchair users can use personal digital assistance and voice command as user interface. Fig. 7 shows an example of situation that a user instructs a humanoid robot on the manipulation target.

In addition, humanoid robots perform the nonverbal communication such as bow and sign language as humans do; this is merit on supporting everyone including elderly people and handicapped persons.

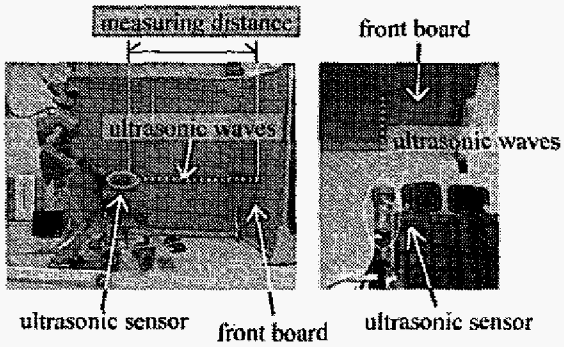
4. Experiments on Pushing Wheelchair

In the wheelchair user support system using humanoid robots, it is a basic task for humanoid robots to push wheelchairs safely and reliably. In this section, we show the experiments on pushing a wheelchair using a real humanoid robot HRP-2.

4.1 Conditions

Experimental conditions are shown in Fig. 8. For measuring the wheelchair displacement, we use a ultrasonic sensor. This sensor's range is from 400[mm] to 3000[mm], its sampling period is 10[ms] and its resolution is approximately 1[mm].

In addition, to compare a humanoid robot and a human, we perform the experiments that three persons push a



(a) Side View **(b)** Upper View

Fig. 8. Experimental conditions.

wheelchair under the same conditions. All of them are in their 20s.

4.2 Control method

Fig. 9 shows overview of the controller used in the experiment. We assume that the dynamically balanced walking pattern based on the linear inverted pendulum mode[15-16] is given as a series of the target joint trajectories and the target Zero-Moment Point(ZMP)[17] trajectory. In order to push a wheelchair on the straight, we make a modification on target hand joint trajectories. We also use the stabilizing controller[18] to compensate the error caused in the position of the ZMP as well as the inclination of the body.

4.3 Results

In this experiment, a humanoid robot pushes a wheelchair by 14 steps in 10 seconds. The snapshots of the experiment on pushing a wheelchair using a humanoid robot HRP-2 are shown in Fig. 10. It is ascertained that a humanoid robot pushes a wheelchair steadily in both double and single support.

Fig. 11 shows ZMP trajectory in x-direction when a humanoid robot pushes a wheelchair. Fig. 12 and Fig. 13 show respectively the wheelchair displacement and velocity in x-direction when a humanoid robot or one of the three persons pushed it. From Fig. 12, by comparing the case where a humanoid robot pushed a wheelchair to the case where a person pushed a wheelchair, we see the difference in phase 2. That is, the wheelchair velocity shows the more variation in the case where a humanoid robot pushed a wheelchair. From Fig. 13, it is ascertained that wheelchair velocity periodically vibrates. We should note similarities between the cycles of Fig. 11 and Fig. 13(a). It seems, therefore, that robot vibration causes wheelchair velocity variation. As a future research topic, we will refine the wheelchair vibration when a humanoid robot pushes it, and evaluate on user's psychological aspect when their wheelchair is pushed.

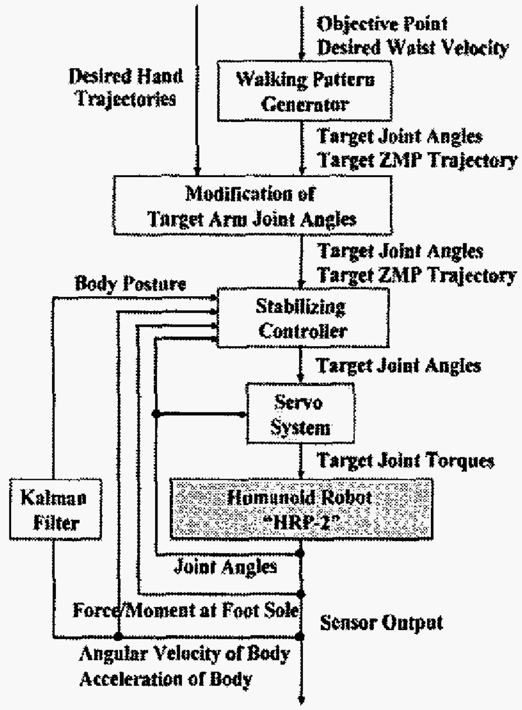


Fig. 9. Overview of the controller.

5. Conclusions

This paper discussed the architecture of wheelchair user support system using humanoid robots for creating safe, secure, and reliable society. This system provides the total support of mobility and manipulation for wheelchair users, because humanoid robots have similar structure to humans.

Then we showed the successful experimental results on pushing a wheelchair using a real humanoid robot HRP-2. This is because it is essential for humanoid robots to perform this task for creating this proposal system.

In the future works, we will develop the control method of robots' hand vibration caused robot motion and consider user's psychological aspect in robot motion planning.

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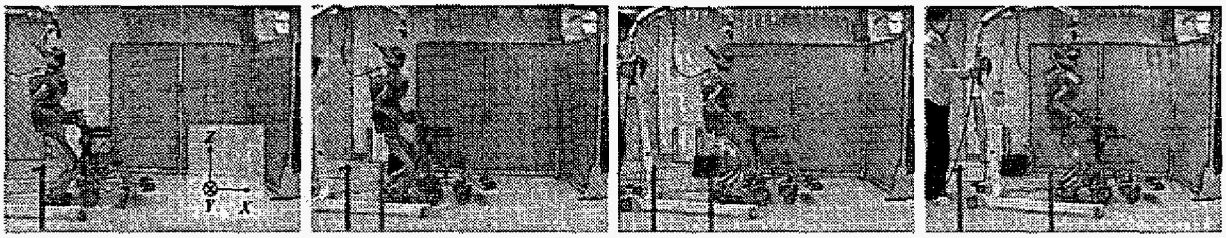
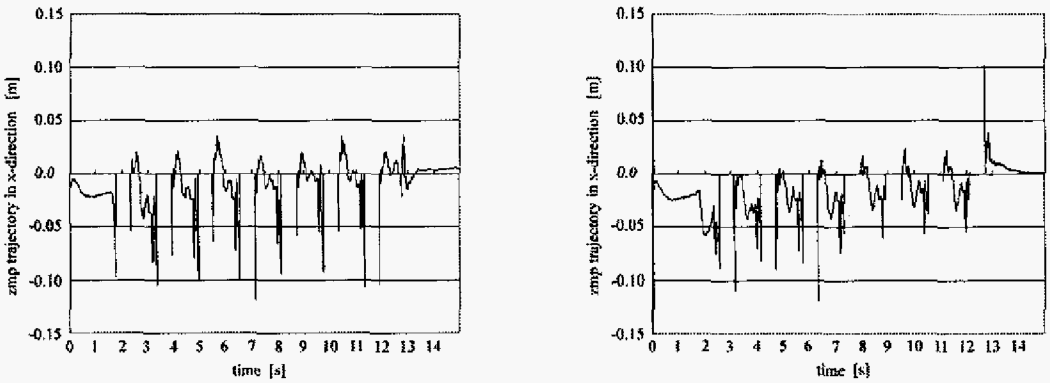


(a) 0[sec]: Double support **(b)** 5[sec]: Single support **(c)** 8[sec]: Double support **(d)** 13[sec]: Double support

Fig. 10. Experimental results on pushing a wheelchair using a real humanoid robot HRP-2.



(a) ZMP trajectory of left foot **(b)** ZMP trajectory of right foot

Fig. 11. ZMP trajectory in x-direction when a humanoid robot pushes a wheelchair.

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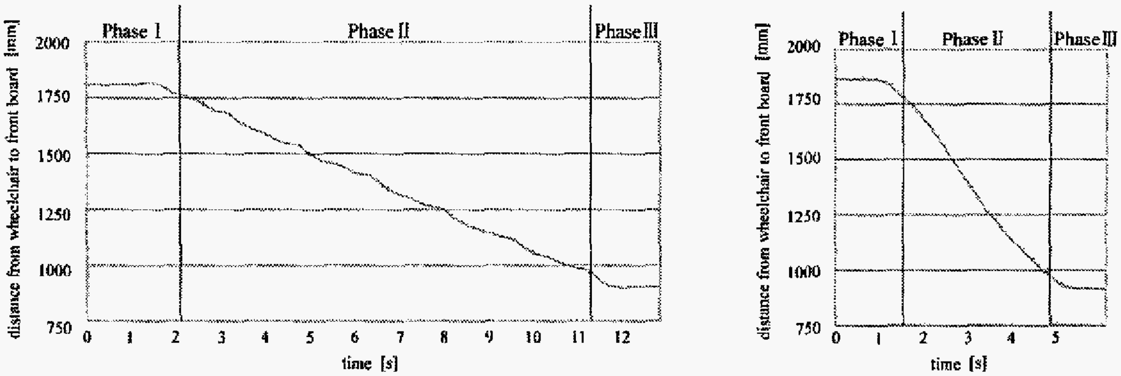
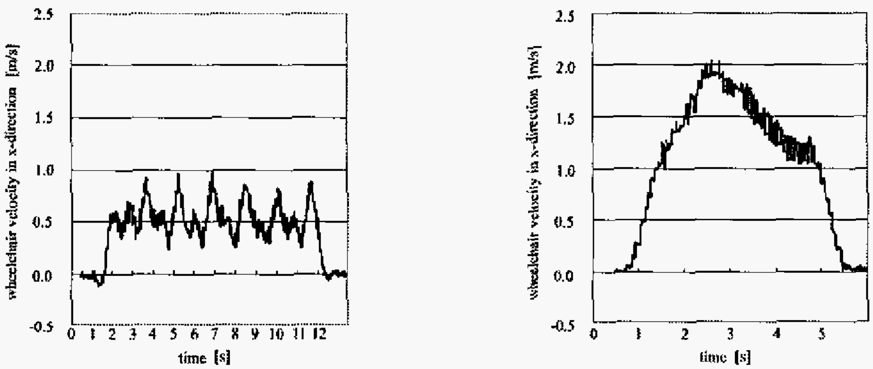


(a) The case where a humanoid robot pushed a wheelchair

(b) The case where a person pushed a wheelchair (He is 1600[mm] in height and 64[kg] in weight.)

Fig. 12. Wheelchair displacement when a wheelchair is pushed on the straight.



(a) The case where a humanoid robot pushed a wheelchair

(b) The case where a person pushed a wheelchair (He is 1600[mm] in height and 64[kg] in weight.)

Fig. 13. Wheelchair velocity when a wheelchair is pushed on the straight.

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