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Original Research Article

Control of speed and direction of electric wheelchair using seat pressure mapping☆

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ABSTRACT

An electric wheelchair controlled through seat pressure mapping was developed to accomplish hands-free operation. The seat pressure mapping resulting from a change in posture was measured using a pressure sensor array seated on the wheelchair in real time. The movements of the upper body were discriminated using template matching. The speed and direction can be controlled based on the similarities between the measured pressure distribution and five templates of neutral, forward, backward, left, and right movements. The developed interface was built into a commercial electric wheelchair. As the results of an experiment show, the proposed wheelchair can be controlled in any direction and velocity.

1. Introduction

Wheelchairs are important vehicles for elderly and disabled people who have difficulty walking. By using a wheelchair, they can expand their range of daily activities, which can improve their quality of life and help them achieve independence. Along with an aging society and social advancements for people with disabilities, the demand for wheelchairs is increasing. In addition, because the degree of disability of wheelchair users varies from person to person, the need for wheelchairs is becoming more complicated and diversified.

There are two types of wheelchairs available: manual and electric. A joystick or steering wheel is mainly used as the operation interface of electrical wheelchairs. However, these are not suitable for all users owing to a paralysis of the upper limb function and a decrease in complicated movement ability of the wrist with age. Thus, it is desirable to develop a hands-free interface to control an electric wheelchair.

As a control method for electric wheelchairs without using the hands, methods for detecting tongue motion with a magnetic sensor [1], or hand, head, or shoulder motions with an acceleration sensor have been proposed [2–4]. Moreover, methods using a biological signal such as an

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electromyogram [5] or an electroencephalogram [6] have been proposed. Emotive EPOC sensor was deployed to detect facial expressions and head movements of users [7]. In these interfaces, the user needs to wear equipment on the body, which is a burden. Although methods using eye gazing have been attempted, because it is necessary to set a camera in the front of the user, it has hindered the user's visibility [8–10]. Speech-based control of an intelligent wheelchair was also investigated [11]. For comprehensive review of smart wheelchair, see [12].

Several researchers have investigated the pressure distribution when sitting on a wheelchair to evaluate the comfortableness of the seat cushions or to prevent pressure ulcers [13–20]. Furthermore, the interfaces for an electric wheelchair using a pressure signal on the head or back have been investigated, but it is necessary to keep the body in tight contact during operation [21–23]. Ideally, as an interface for operating an electric wheelchair, it is less burdensome to the user, and can be input intuitively.

In a previous study, we investigated an electric wheelchair controlled using seat pressure mapping [24]. Eight directional movements were distinguished through changes in posture. However, the direction was limited to a certain angle and the speed was constant. In this study, we aimed at improving the operability by arbitrarily controlling the speed and direction. To accomplish this aim, the parameters were empirically optimized to provide an exact and safe control of wheelchair.

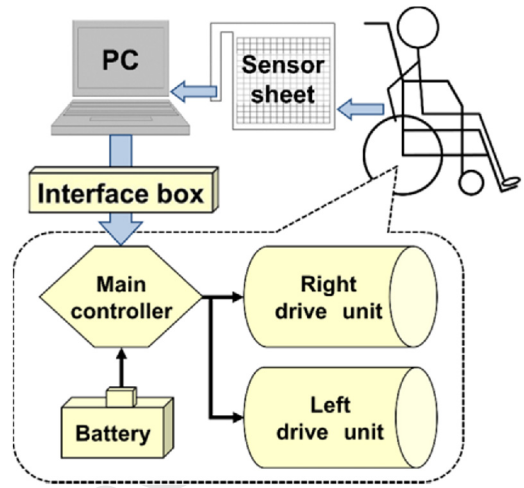

Fig. 1 – Block diagram of electric wheelchair control interface using seat pressure mapping.

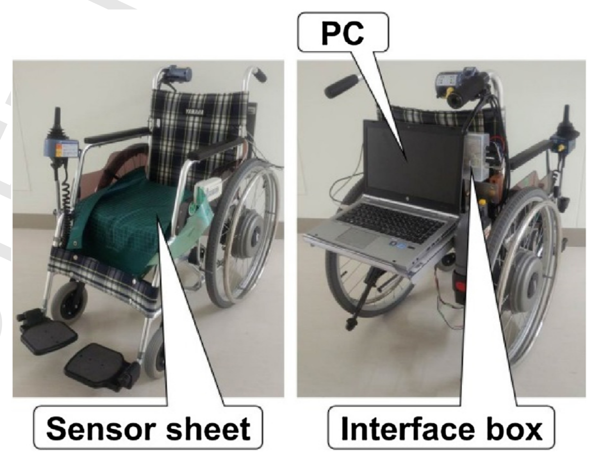

Fig. 2 – Inprementation of control interface for electric wheelchair.

2. Materials and methods

2.1. Subjects

Five healthy subjects in their 20 s participated in the experiments. An average height and mean weight are 170.6 ± 4.4 cm and 59.6 ± 7.3 kg, respectively. The study was approved by the Ethics Committee of the Faculty of Engineering, Niigata University, and written informed consent was obtained from each participant prior to the experiments.

2.2. Wheelchair control system

2.2.1. System configuration

A block diagram of the control interface for the electric wheelchair is shown in Fig. 1. The proposed electric wheelchair was implemented using a control interface based on a pressure sensor sheet, and the seat pressure mapping was measured using this sheet (CONFORMat, NITTA Co.). The features of the body motion were extracted from the seat pressure mapping. The features were transferred to the control signal. An interface box that controls the left and right driving motors was built into the electric wheelchair.

2.2.2. Electric wheelchair and control interface

In this research, we used a commercially available electric wheelchair (JW1-22B, YAMAHA Co.), as shown in Fig. 2. The size of the wheelchair seat is 400 mm × 400 mm, and the radius of the wheel is 290 mm. The control system consists of a joystick, a main controller unit, left and right drive units, and a power supply. The electrical power is supplied from the battery attached to the electric wheelchair. The driving system is composed of two pairs of motors, an encoder, an electromagnetic brake, and a printed circuit board for the motor controller, which rotates the two wheels.

In existing electric wheelchairs, the main controller supplies voltage suitable for the left and right drive units to drive the two motors upon receiving a command signal. When the joystick is tilted vertically, the wheelchair moves forward or backward. When the joystick is tilted horizontally, the wheelchair rotates left or right. When the joystick is tilted obliquely, the wheelchair turns left or right. The operating speed varies in proportion to the tilt angle.

The interface box consists of a DA converter (12-bit 2ch MCPM 4922E/P, Microchip) and a microcomputer (Arduino UNO). The wheelchair can be operated using either a joystick or through seat pressure distribution, which can be selected using a switch. According to the identification results, the interface box outputs two types of command voltages for the left and right motors to the main controller. The command

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