Development of the Medical Support Service Robot Using Ergonomic Design

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Abstract: In this study, the concept of autonomous mobility is applied to a medical service robot. The aim of the development of the service robot is for the elderly assisting walking rehabilitation. This study aims that the service robot design parameter is proposed in ergonomic view. The walking assistant path pattern is derived from analyzing the elderly gait analysis. A lever is installed in the AMR in order to measure the pulling force and the leading force of the elderly. A lever mechanism is applied for walking assistant service of the AMR. This lever is designed for measuring the leading force of the elderly. The elderly adjusts the velocity of the robot by applying force to the lever. The action scope and the service mechanism of the robot are developed for considering and analyzing the elderly action patterns. The ergonomic design parameters, that is, dimensions, action scope and working space are determined based on the elderly moving scope. The gait information is acquired by measuring the guide lever force by load cells and working pattern by the electromyography signal.

Keywords: AMR (Autonomous Mobile Robot), service robot, ergonomic design, gait analysis

1. INTRODUCTION

Nowadays the development of the mobile robot for the service field is growing rapidly. The research is progressing in various service fields for example: guide robots for ushering guests to a specific place, a monitoring robot watching a building's surroundings at night, and a cleaning robot cleaning inside of a factory or a large building. Using the SIEMENS navigation system, path generation algorithm was constructed for the cleaning robot and using the cooperative positioning system a cleaning robot system was developed.[1,5] A personal mobile robot was investigated using internet-based control.[2] These studies are based on the special services. For walking rehabilitation, the mobile robot has been applied a sort of services. Especially, the PAM-AID robot was developed for guiding the elderly [11].

Fig. 1 Design conception for the medical service mobile robot

As the elderly are inclined to be cut off the outside, the robot should have more various functions for communicating with other people. As the service robot is used at human space, the robot design should be considered. The industrial robot design is not considered an ergonomic approach because of acting repeatable tasks by this time.

In this study, the medical service mobile robot is proposed for the elderly. Especially, in order to develop the medical support service robot for the elderly, the ergonomic design should be considered because the elderly is not familiar to handling machine. Fig. 1 shows the design concept for developing the medical service mobile robot.
This study aims that the service robot design parameter is proposed in ergonomic view.

2. GAIT ANALYSYS

Gait efficiency has been used for an index how a person can walk without energy losses in medical field [12-13]. Gait efficiency is defined by Work of walking / Consuming of energy. Table 1 shows the gait velocity according to human ages.

Table 1. Gait velocity data

Velocity [km/h]	Ages	
	20	60 ~ 70
3.5	26.22±1.25 (%)	22.15 ± 2.32 (%)
4	27.50 ± 1.54 (%)	24.85 ± 1.66 (%)
4.5	27.18 ± 1.67 (%)	26.31 ± 2.67 (%)

From Table 1, the gait efficiency is increasing statistically according to increasing the gait velocity of same age group. Gait work is determined by the product of walking velocity per time and a person's weight. Energy consuming is usually determined by measuring of breathing amount.

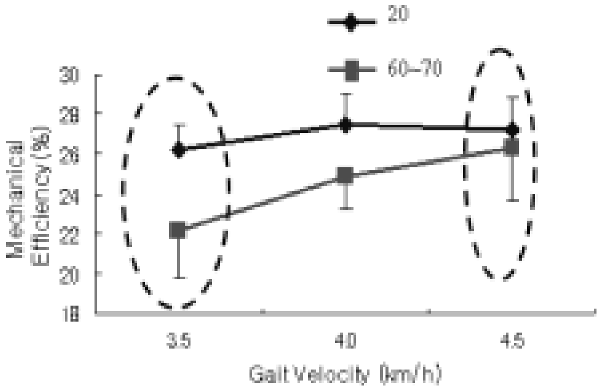


Fig. 2 Mechanical efficiency of the gait velocity for the same age groups

The result in Table 1 can be a factor of the gait efficiency difference which is from the loss of a vertebra rotation and an arm hand-swing as the ages are increased [14]. Also the result in Table 1 can be inferred relating the Picke and et al. study, that is, the gait variance according to the ages is due to the difference from a varying posture and a decreasing balance sensing [15]. Margaria investigated that the muscle efficiency converting the chemical energy from the food oxidation to mechanical energy is about 25% [16]. Donovan & Brooks emphasized that the gait efficiency can be increased about 20.6% ~ 43.0% when a man walks perpendicularly on the other hand about 19.6% ~ 35.2% when a man walks horizontally [17]. Also Fox and et al. proposed that the efficiency can be about 20% ~ 25% when a man exercises in a walking, a running and a cycling but less than 20% when a man exercise in a swimming, a skating, a boating and etc.[18]

Fig. 2 shows the comparisons of age group with the mechanical efficiency versus gait velocity. Especially, 20's age is higher working efficiency than 60's and 70's age all velocity range. In cases of 60's and 70's age have tendency of increasing the walking efficiency from 2.7% to 4.2% as the walking velocity of 60's and 70's age is increased from 3.5km/h to 4.5km/h. In other words, the mechanical efficiency is more improved at the high speed than low speed in same ages. In other words, the gait efficiency is more improved at the high speed than low speed in same ages.

The AMR path navigation algorithm is developed for the gait rehabilitation assistant by gait exercise until 20's gait velocity likely in this study.

3. ROBOT DESIGN

The AMR design objectives are as following:

1. The path pattern should be suitable for the elderly.
2. The lever mechanism should be applied for measuring walking states.
3. The wireless internet should be applied for communicating with supporter.

In order to generate a path algorithm for the elderly, a path tracking algorithm is developed based on the analysis of the walking pattern of the elderly.

In this section, the medical service robot design procedure is described based on an ergonomic design approach.

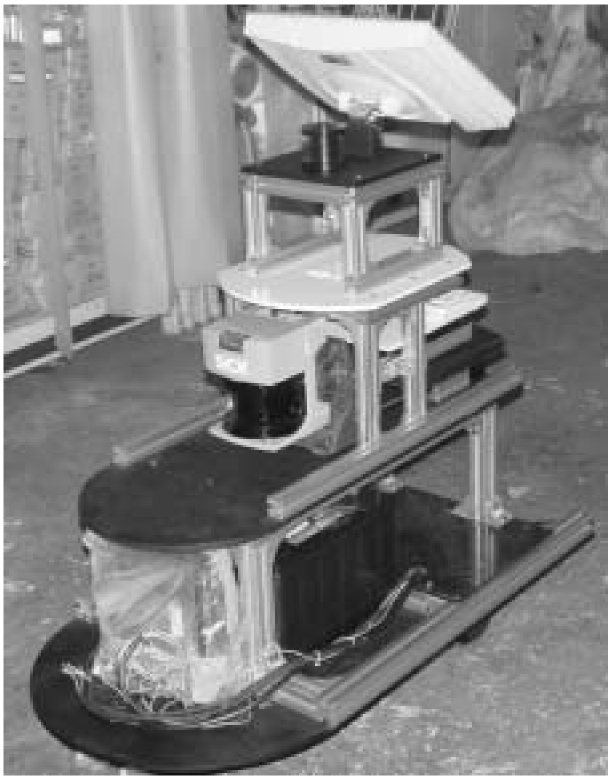


Fig. 3 Installation motor feature in the medical service mobile robot

3.1 Mobile robot design

The AMR is composed of a laser range finder for path recognition, two driving wheels, and a lever as shown in Fig. 3. The driving motor and wheel sets are located on both sides and two caster wheels are located at the front and rear of the AMR. The maximum speed of the wheel is 1.8m/sec. It is powered by a DC source which exerts an output of 24 volts with a two hour capacity at a continuous maximum speed.

Fig. 4 shows the hardware structure of the AMR and the internal signal flowchart for controlling the AMR. The Multi-Motion Controller (MMC) transfers the rotating angle signal of each wheel to the main controller, and transfers the control algorithm output to the motor's driver through a voltage signal.

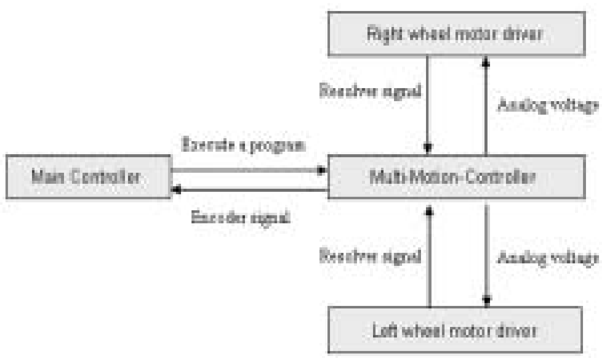


Fig. 4 Hardware block diagram of the controller

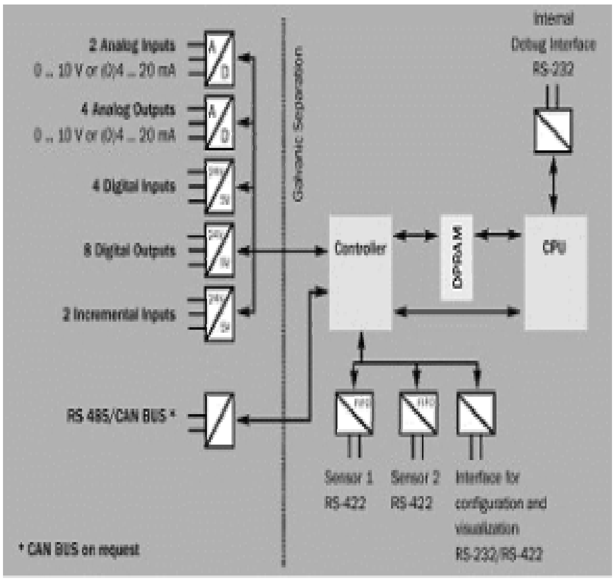


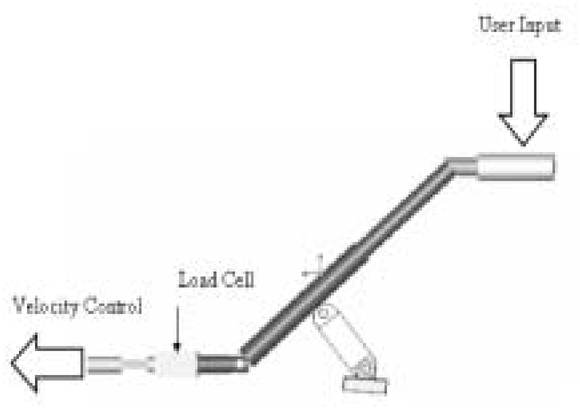
Fig. 5 Laser range finder signal block diagram

The number of sensors for path generation may be reduced, so that sensor inputs are more effective with the AMR controller. As the sensor inputs become larger, they require more accompanying filters or a larger quantity of managing data. Consequently, a higher level of control is needed or there would be increased difficulty in driving at high speeds. In this study, a laser range finder (LRF) was applied for recognizing the path pattern easily and reducing sensor noises. The LRF has a measurement scope with 80[m], a resolution with 0.5 degree, a response time with 53[msec] and voltage with 24[v]. The LRF signal is from the laser fanning motion. Serial communication was used for receiving and transmitting between the main controller and the LRF controller. Fig. 5 shows the signal block diagram between the main controller and the LRF controller.

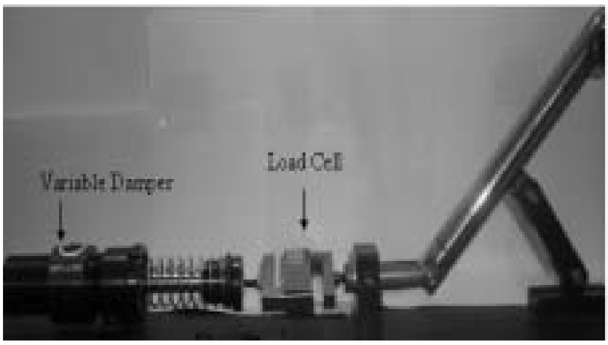
3.2 Human interaction mechanism design

In this study, a grip lever mechanism was designed referring the commercial gait support mechanism for applying the medical service mobile robot.

Fig. 6 Commercial gait support cart



(a) Grip mechanism design



(b) Grip mechanism

Fig. 7 Grip mechanism applied to the medical service mobile robot

Fig. 6 shows the commercial gait support cart with braking and a seat. This cart has the functions which are controlling the cart in grip and sitting in the way of walking. A grip mechanism was proposed for replacing the conventional gait support cart and acquiring the medical data for the gait rehabilitation from the medical service mobile robot in this study. This lever senses the gripping force of a user. A load cell is used for sensing a force and it can output up to 1000 N.

Fig. 7 shows the grip mechanism in the medical service mobile robot. If the user holds the grip and follows the medical service mobile robot, the robot should move at a restricted velocity and turning speed. This permits the use to move smoothly at a comfortable pace. In other words if an excessive pushing force is sensed, the AMR drives faster and if an excessive pulling force is sensed, the AMR reduces velocity. Fig. 8 shows the AMR control signal flow using the grip mechanism.

Using an access point device, the wireless internet communication is applied to the AMR with TCP/IP protocol. TCP/IP protocol program is used by windows socket programming. The communication which has the type of one by others is adapted in this study. The AMR plays role to be a server and the others contact the robot as a client. A client can access the data and the control in the AMR. Also using the mobile device, the Personal Digital Assistant (PDA) is applied in this study as a client connecting.

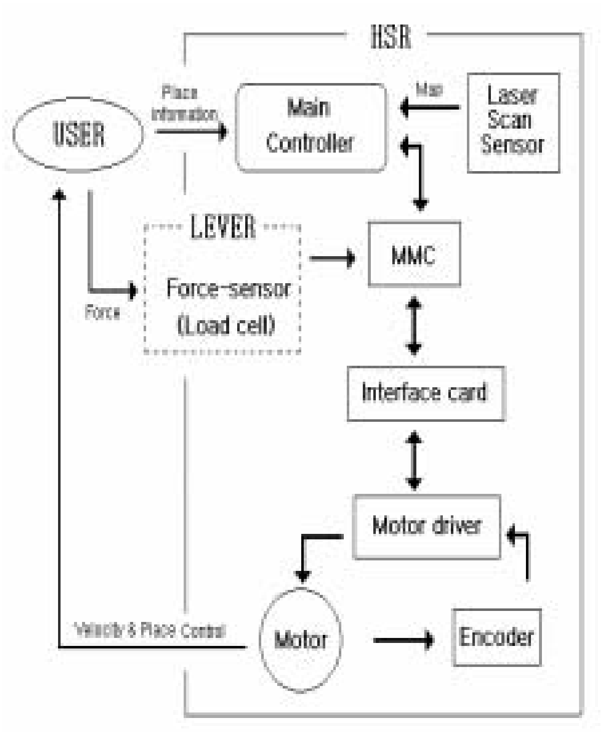


Fig. 8 Control signal flow of the grip mechanism in the medical service mobile robot

Fig. 9 shows the network connection flow of applying wireless communication. The mobile network program is used by the WINDOW CE Socket program. The PDA is used for checking the brief walking information, which is the elderly walking velocity and location information in large construction indoor.

Fig. 9 Wireless communication application in the service mobile robot

Fig. 10 Ergonomic design of the medical service mobile robot

4. ERGONOMIC ANALYSIS

Fig. 10 shows the ergonomic design result in this study. Based on the ergonomic design, the medical service mobile robot was designed for the elderly gait rehabilitation. The mobile robot with one LRF and two wheel-driven motors has the functions which are the grip mechanism for controlling gait velocity, small seat and a wireless internet for communicating the elderly health monitoring. Table 2 is the average data which shows the required action force on the grip mechanism through many experiments.

Table 2 grip force data

	Force [N]		Velocity [m/sec]
	Pulling	Leading	
Elderly	12	400	1.26
Youths	80	150	3.34

Fig. 11 Communication program by the wireless Internet in the medical service mobile robot

The results in Table 2 show the validation of the grip mechanism for balancing between the driving velocity of the medical service mobile robot.

Fig. 11 shows the wireless internet communication program in the medical service mobile robot. The AMR can transmit the data which is the AMR velocity, the load cell output and the navigation image through the wireless internet. Fig. 11 shows the program result of the internet communication. Using web-camera, the image information gives the navigation information to the clients. Therefore, the clients as a supporter can be accessed remotely to the elderly walking information.

5. CONCLUSIONS

The medical service robot is developed for the elderly by the ergonomic design parameters in this study. The action scope and the service mechanism of the robot are developed for considering and analyzing the elderly action patterns. Also the robot action program is determined by the elderly moving information. The moving information is acquired by measuring the guide lever force by load cells and working pattern by the electromyograph signal. The conclusions of this study are as follows:

1. As the service robot developing aim to support the elderly action, the elderly moving patterns were investigated.

2. The ergonomic design parameters, that is, dimensions, action scope and working space are determined based on the elderly moving scope.

3. In view of software, the robot action program is determined by the elderly moving information.

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