인간공학적 디자인을 적용한 보행가이드 로봇의 개발

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Development of the Gait Assistant Mobile Robot using Ergonomics Design

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ABSTRACT

In this study, the concept of autonomous mobility is applied to a gait support mobile robot. The aim of the development of the service robot is to assist the elderly with gait rehabilitation. This study proposes an ergonomic service robot design parameter. The gait assistant path pattern is derived from analysis of the elderly gait. A lever is installed in the AMR in order to measure both the pulling force and the leading force of the elderly. The path generation of the mobile robot is developed through consideration and analysis of elderly gait patterns. The ergonomic design parameters (dimensions, action scope and working space) are determined based on moving scope of the elderly. The gait assistant mobile robot was offered the elderly guide service and internet service based on the ergonomic design parameters.

Key Words : Service Robot (서비스로봇), Gait Analysis (보행 분석), Ergonomic Design (인간공학적 디자인), ARV (Autonomous Mobile Robot)

1. INTRODUCTION

Recently, robot research has increasingly moved from the industrial workspace to the human workspace. Service robot research has been focused on the application of robots as assistants to humans. In particular, robots with wheeled-mobile platforms have merit when applied to the human workspace because of its simple movement. This body of research is progressing in various service fields. Examples of this development include guide robots used to usher guests to specific places, monitoring robots that provide surveillance of building surroundings at night, and cleaning robots in factories or large buildings. The SIEMENS navigation system, constructed by Ryo and Shigeo was used to develop a cleaning robot system [15]. In another study, a personal mobile robot was investigated by Kukhyun and et al. using internet-based controls. These studies are based on special services [7].

As the service robot is used in human workspaces, the ergonomic design of the robot should be considered. Dohyung proposed an analysis method for the three-dimensional isocomfort workspace using robot kinematics [1]. Philippe and Etienne developed a service mobile robot for rehabilitation using continuity of cooperation between human and machine [12]. The PAM-AID (Personal Adaptive Mobility AID for the frail visually impaired) robot was developed by Gerard and Kenneth as a mobility aid for people who are both frail and visually impaired [5].

Also researchers have been finding a solution for sharing workspace between robots and human through the analysis of biomechanical data. Steven and et al. are investigated a fire service based on the biomechanical analyses of paramedics [16]. Olanrewaju and Christine investigated the postures adopted when using a two-wheeled cylinder trolley based on the biomechanical data analysis [11]. The design parameter of the gait support mobile robot can be determined by the medical data analysis.

In this study, the authors propose the use of the gait assistant service mobile robot for the elderly. In particular, an ergonomic design should be considered in order to develop the service robot for the elderly who may not be familiar with handling such machines. As the elderly are often isolated from mainstream society, the robot should incorporate various functions to assist the elderly in communicating with other people. Additionally, as the service robot is used in human spaces, the robot must be designed with this in mind.

2. ANALYSIS OF THE ELDERLY

The loss or degradation of sensory input and its effect on mobility is one of the most serious inconveniences faced by the elderly. An accompanying effect for the elderly is the reduction and difficulty of communication with others. This section described analysis of medical data on gait (mobility) and communication.

2.1 Gait analysis

In the medical field, gait efficiency is used as an index of how a person can walk without energy loss. Hamill and Knutzen have suggested that gait efficiency may be defined as the "work of walking/consuming of energy" [6]. Table 1 shows gait velocity according to age. As can be seen in Table 1, the gait efficiency increases statistically according to increases in the gait velocity of the same age group. Gait work is determined by calculating the product of walking velocity per time and a person's weight. Energy consumption is usually determined by measuring of the amount of breathing on walking. The results, as shown in Table 1, can be seen to be a factor of the gait efficiency difference which is caused by the loss of vertebra rotation and arm hand-swing as the individual ages.

Table 1 Gait Velocity data

Velocity	Gait efficiency	
	20 ages	60~70 ages
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 (%)

As well, it can be inferred (as proposed in the Pickle, et al. study) that the gait variance according to age is due to differences resulting from varying postures and decreasing sense of balance with advancing age [13]. Margaria found that muscle efficiency in converting chemical energy from food oxidation to mechanical energy is about 25% [9].

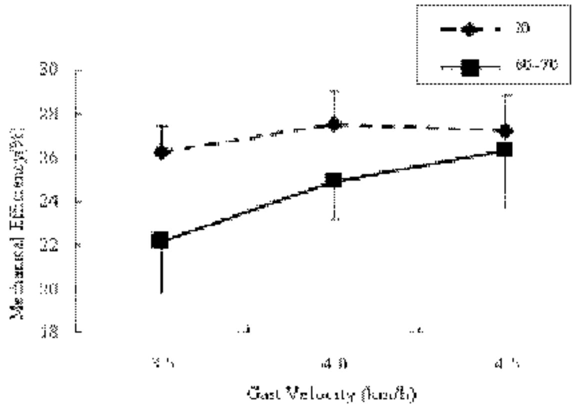

Fig. 1 Mechanical efficiency of the gait velocity for the same age groups

Donovan and Brooks emphasized that gait efficiency can be increased about 20.6% ~ 43.0% when a person walks perpendicularly; on the other hand, gait efficiency can only be improved by about 19.6% ~ 35.2% when a person walks horizontally [2]. In another study, Fox and et al. proposed that the efficiency will be about 20% ~ 25% when a person exercises by walking, running and cycling but less than 20% when a person exercises by swimming, skating, boating and other such activities [4]. Fig. 1 shows age group comparisons in mechanical efficiency versus gait velocity.

In particular, individuals in their 20s show higher working efficiency than those in their 60s and 70s through all the velocity ranges. In cases of individuals in their 60s and 70s, gait efficiency tends to increase from 2.7% to 4.2% as gait velocity is increased from 3.5km/h to 4.5km/h. In other words, gait efficiency improves more at higher speeds than at lower speeds in the same age groups.

Consequently, the mobile robot velocity can be an ergonomic design parameter as the gait efficiency of the elderly is improved by controlling the robot velocity.

2.2 Web-communication

Flint, et al. suggested that the elderly workspace is very small and the opportunity of communicating with others is decreased by a decline in physical or mental abilities [3]. The elderly workspace, however, could be extended by use of internet services electronic commerce services, tele-home care services, national administration network services, internet banking service and other such services.

Recently, internet services which allow easy access for the elderly have been studied. Fig. 2 shows the response results found in a study of frequency of

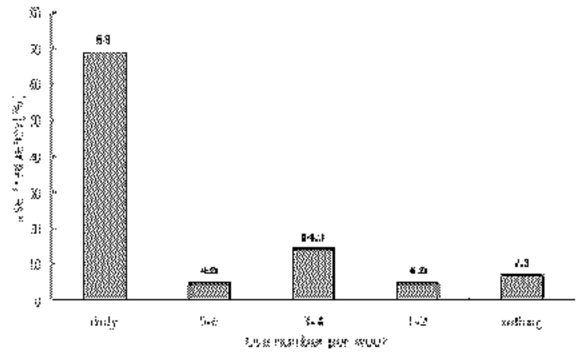

Fig. 2 Internet use frequency per week for the elderly

internet use by the elderly (Jae-Hue and et al.) [8]. Fig. 2 shows that more than 70 % of the elderly accessed internet daily or 5~6 times per week. Even though the elderly often have performance difficulties, such as weak eyesight, slower understanding, hand shaking, and poor memory, they desire to access the internet. Table 2 shows the response results of the elderly for the improved lifestyle through use of internet communication.

3. HARDWARE DESIGN

The design objectives of the gait support mobile robot are as follows:

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.

As the social sympathy is aroused though off-line friendship among the elderly after communicating the internet, the elderly can be overcome the isolation for outside. Consequently, this paper focused that the welfare life and mental health of the elderly may be improved by the mobile robot with the internet communication which is aroused sympathy among the elderly and is feeling as a membership for the social.

Table 2 Improved life styles for the elderly through use of internet communication

Life style	Response rate (%)
Improvement friendship in On/Off Line	44.6
Applying information in Web-communication to own life	39.3
Raising confidence for adapting modern life	16.1

In order to generate a path algorithm for the elderly, a path tracking algorithm was developed, based on analysis of the elderly gait.

In this section, the gait support mobile robot design procedure is described, based on an ergonomic design approach.

3.1 Mobile robot design

The mobile robot 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 that exerts an output of 24 volts with a two-hour capacity at a continuous maximum speed.

Miller and Wagner found, in their study, that the number of sensors for path generation may be reduced, so that sensor inputs are more effective with the AMR controller [10]. 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 the Miller and Wagner study, a laser range finder (LRF) was applied both for easy recognition of the path pattern and for reducing sensor noises. Fig. 4 shows the signal block diagram between the main controller and the LRF controller. The LRF has a measurement scope of 80meters, a resolution of 0.5 degrees, a response time of 53 milliseconds and voltage of 24 volts. The LRF signal originates from laser fanning motion. Serial communication was used for reception and transmission between the main controller and the LRF controller.

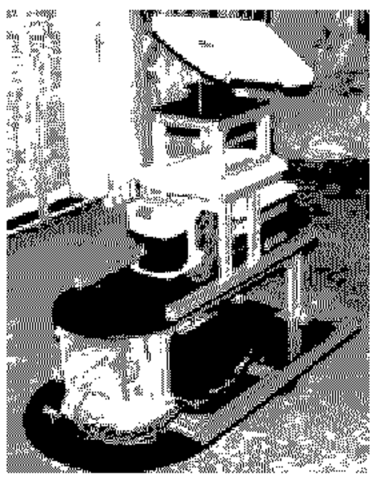

Fig. 3 Installation parts in the gait assistant service mobile robot

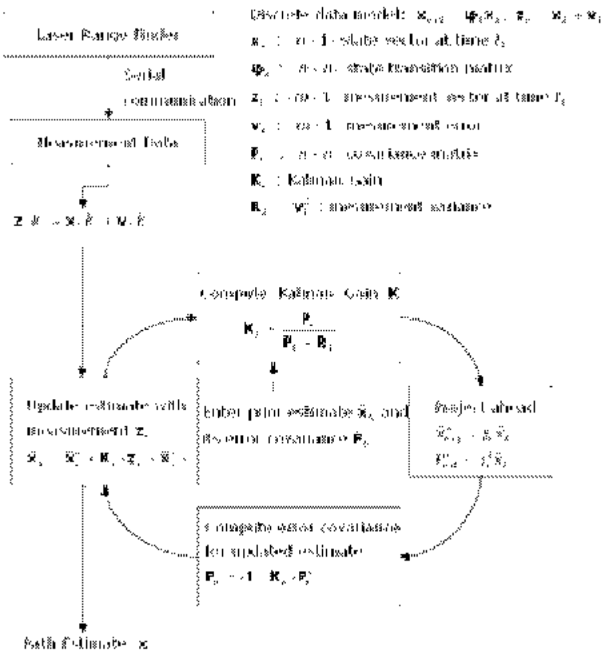

Fig. 4 Laser range finder signal block diagram

3.2 Human interaction mechanism design

In this study, a grip lever mechanism was added to the gait assistant service robot with reference to the commercial gait support mechanism. A grip mechanism was proposed to replace the conventional gait support cart and to acquire the medical data for gait rehabilitation from the gait support mobile robot in this study. This lever senses the gripping force of a user. A load cell, which can output up to 1000 N, is used for sensing the force

If the user holds the grip and follows the gait support 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. 7 shows the AMR control signal flow using the grip mechanism.

4. SOFTWARE PROGRAMMING

The programming of the gait assistant service mobile robot is composed of the algorithms which support gait velocity for the elderly and communication with supporters through wireless internet. In this section, the path algorithm for the gait support mobile robot and programs of the internet communication are described.

In this paper, the path generation algorithm for guiding the elderly is set up as following;

1. Turning pattern should be smooth, not turning at the original place.
2. Only forward motion is permitted because the elderly user is behind the robot.

The path generation algorithm for guiding the elderly is based on the kinematics of the AMR. The gait assistant path is set up as a reference path. After the real AMR recognizes the deviated path from the reference path by sensing, an algorithm is applied for tracking this reference path. In order to obtain simple kinematics modeling, The assumption is used that no slip conditions exist between the wheels of the AMR and the ground. The AMR kinematics is controlled through steering which is derived from the velocity difference between the two driving wheels.

Based on the kinematics model, a controller is designed to track to the reference path through user command when the AMR is diverted by an obstacle. The desired output is for the deviated AMR to follow the reference AMR's velocity and orientation. Fig. 5 shows the path generation algorithm in this paper.

Richard and Shankar show that the AMR has controllability when showing the reference tracking

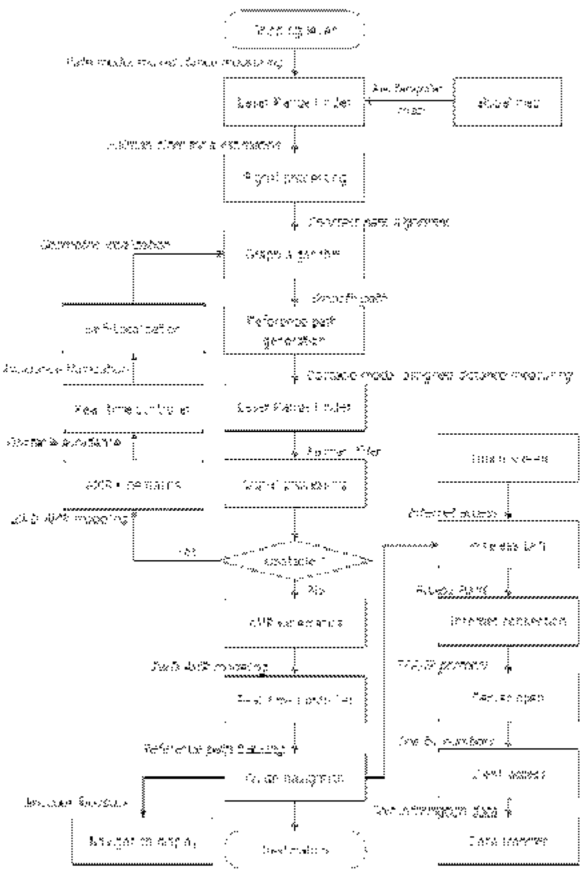

Fig. 5 Gait Support mobile robot path generation algorithm

model or chained system, although the kinematic model of an AMR has nonholonomic constraint which specifies the tangent direction along any feasible path for the robot and a bound on the curvature of the path [14]. For guiding elderly, therefore, the reference path pattern should be smooth not moving backward or zigzagging because the mobile robot and the elderly should move together. The path generation controller, based on the kinematic model of an AMR, is considered not only a controllability of the mobile robot posture but also a smooth path pattern and the robot velocity control algorithm for the gait assistant based on the elderly gait analysis.

Using an access point device, wireless internet communication is applied to the AMR with TCP/IP protocol. The TCP/IP protocol program is employed through Windows Socket programming. The type of communication adapted in this study is of one by others. The AMR plays the role of server and the others contact the robot as clients. A client can access both the data and the control in the AMR. Fig. 6 shows the signal flow wireless internet communication. Using the mobile device, clients connect through a Personal Digital Assistant (PDA) in this study. The mobile network program uses the Windows CE Socket program. The PDA is used for checking brief gait information, such as elderly walking velocity and location information in large indoor constructions.

4. ERGONOMIC ANALYSIS

Based on analysis of elderly gait and internet communication, the gait assistant service mobile robot was designed, using an ergonomic approach, for elderly gait rehabilitation.

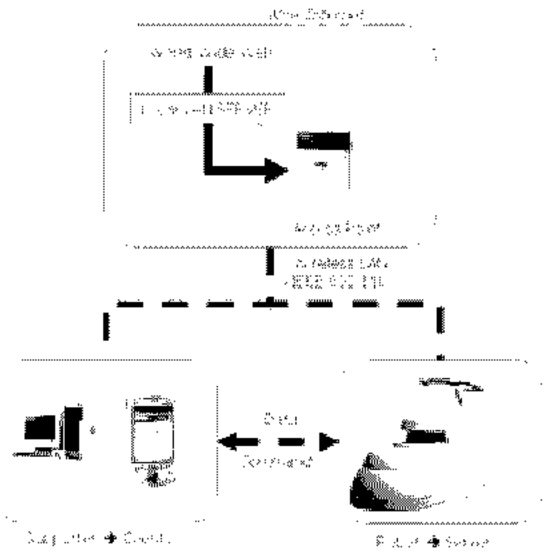

Fig. 6 Signal flow of the wireless internet communication

The mobile robot with one LRF and two wheel-driven motors has functions which include a grip mechanism for controlling gait velocity, a small seat and wireless internet for communicating health monitoring information on the elderly user. Fig. 7 shows the path navigation results for guiding the elderly.

The path pattern was smooth when the AMR met an obstacle. The AMR's path algorithm was constructed from the path tracking algorithm with the optimal controller and the path recognition algorithm by a LRF. The self-localization of the AMR is constructed in the scope of scanning by the path recognition algorithm using a LRF scanning method.

Table 3 contains the average data which shows the required action force on the grip mechanism, determined through a series of experiments. The results in Table 3 show the validation the use of the grip mechanism for balancing between the driving velocities of the gait assistant service mobile robot.

Fig. 8 shows the wireless internet communication program in the gait support mobile robot. The AMR can transmit such data as AMR velocity, the load cell output and the navigation images through the wireless internet. Using a web-camera, image information provides navigation information to the clients. In this way, the client, as a supporter, can have remote access to the elderly gait information.

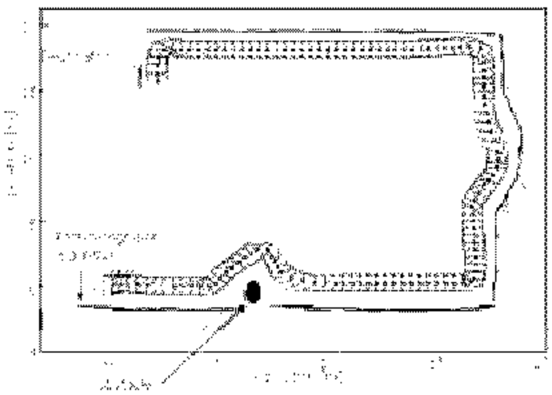

Fig. 7 Destination arrival result by path recognition using laser range finder

Table 3 Grip force data result

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

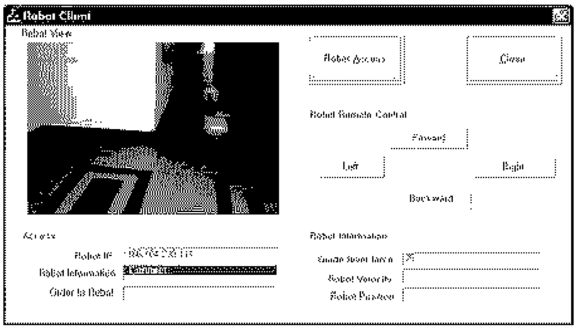

Fig. 8 Communication program by the wireless Internet in the gait support service mobile robot

5. CONCLUSION

The gait support mobile robot is developed for the elderly using ergonomic design parameters in this study. The action scope and the service mechanism of the robot are developed for consideration and analysis of the elderly action patterns. Also, the robot action program is determined by the elderly gait information. The gait information is acquired by measuring the guide lever force by load cells and communicated the supporters using wireless internet.

The conclusions of this study are as follows:

1. As the goal of the development of the gait assistant mobile robot was to support the elderly, elderly gait patterns were investigated. Consequently, it was determined that higher speeds are more desirable for the gait efficiency of the elderly.

2. Wireless internet communication software and touch screen device for accessing internet easily were examined as ergonomic design parameters from investigating of data for the elderly internet use.

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

4. A lever mechanism was applied to the gait assistant as a human interaction mechanism; that is, the velocity of the gait assistant service mobile robot was controlled by the force sensor in the lever mechanism.

5. The path generation of the mobile robot was determined by the elderly gait pattern which does not have backward movement, smooth turn and zigzag path patterns.

6. With the use of wireless internet software, the gait assistant service mobile robot transferred the data of the elderly gait and images of the navigation.

후 기

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