A Study on Technique of Navigation with Power-Reflected of the Walker in the Indoor Environment

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<Abstract>

Today, the elderly is increasing gradually in the Republic of Korea society and this problem will be more serious in the near future. Therefore, engineering support for aged people is required. We are establishing a new field of healthcare engineering for elderly people and aiming to support for aged people and disabled people using adaptive control and instrument technology.

In this paper, the goal is to implement the shared control of a robot mobility aid for the elderly. As using this type of assistive technology to be useful by its intended user community, it supports elderly people and handicapped people to live independently in their private homes. The interface transforms the force applied by the user into the robot's motion. Devices like buttons, joysticks, and levers already exist for relaying user input; however, they require hand displacement that would loosen or otherwise release the user's hold. Such interfaces make operation very difficult and potentially unsafe. Therefore, we propose a shared control system. It's safe more than joysticks and buttons. The shared control is a means of registering the user's intention through physical interaction. It's an important component in the development of robotic elderly assistant. The concept of shared control describes a system which is two or more independent control systems. We are using that the three component blocks consist of pressure sensor (flexible force sensor), circuit of measurement and transfer function. Experimental trials of this paper have been tested at the indoor environment. The robot is able to know the user intended direction through haptic device were logged along with the robot's force sensor.

Keywords: healthcare engineering, robotic elderly assistant, flexiforce sensor, haptic device, shared control system, transfer function

1. INTRODUCTION

Today, the elderly is increasing gradually in the Republic of Korea society and this problem will be more serious in the near future. According to the survey of the National Statistics Office, around 7.2 percent were seniors above 65 in 2000. With the demographic development continuing, nineteen years after that the number of people above 65 years old will comprise more than two times, in the year 2060 even 28 percent of Korean's population [1]. Similar numbers are reported from other industrial nations all over the world, in the U.S and Japan. It's making a greater demand for devices that extend independent living and promote improved healthcare [2].

Many seniors have mobility impairments that cause a downward trend in their quality of life. Lack of independence more and exercise can have dramatic results. As locomotion is most often the primary form of exercise for the elderly, this segment of the population dominates the users of devices that offer mobility assistance [3]. There's a growing interest in developing intelligent assistive devices for the elderly. The Robotic Walker, is a robotic assistance aid that provides some physical support and navigation function, obstacle avoidance [4]. The Hitomi is a robotic travel aid for the blind in outdoor environments. It provides users with orientation and map-based guidance based on information about obstacles and Landmarks [5]. The Care-O-bot II is a development of a next generation robotic home assistant. It's intended to aid mobility, do household jobs, and provide communication and entertainment functions. It's also a new method for sensor based manipulation using a tilting laser scanner and camera integrated in the head of the robot has been implemented. Additional sensors in the robot hand increase the grasping capabilities [6].

Such robotics has very important issue what are interface way at between robot and the user. Because, the elderly is some with cognitive impairment and also haven't enough of robot's motion control power. Therefore, the design must take into consideration the user's characteristics. The users of mobility aids generally have direct physical interaction with the system for support. But, most of researches have been used joysticks, button and levers so and there weren't to ensure safety.

This paper presents a haptic device and shared control system attached at the assistant robot for the elderly safety. The shared control is a means of registering the user's intention through physical interaction. It's an important component in the development of robotic of assistant robot for the elderly. Generally, the concept of shared control describes two or more independent control systems [7, 8]. We use the three component blocks consisted of pressure sensor (flexible force sensor), circuit of measurement and transfer function.

The actions taken by the elderly operator and those taken by shared control software must resolve through the physical haptic device. That is to say, if the elderly tries to push the haptic device for left, and the control software is either steering to the right, or applying the brakes. These are implemented on a mobile robotic platform. The physical system is depicted in Figure 1.

Fig. 1 The elderly assistance mobile robot with a haptic device and Touch Screen

To function as an assistant robot, the platform has been equipped with two handlebars, as shown in Figure 1. Both handlebars are mounted in a fixed position relative to the robot's frame, to provide physical support and stability. There are equipped with two force sensors each, enabling the robot to measure forces asserted by the user. Additionally, the robot features a visual touch screen display panel that informs the user about the system's desired motion direction.

2. SHARED CONTROL INTERFACE

The user's intent is able to control the motion direction of the assistant robot that is possible by shared control interface system. The controller gives the user as much control as possible, therefore it ensures user safety by adjusting the control authority based on the demonstrated performance of the user. There's the architecture of the system concept in Fig. 2.

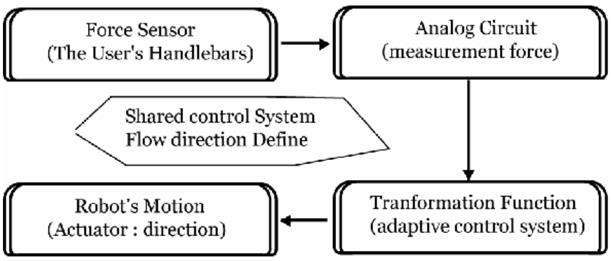


Fig. 2 Architecture of system control for the assistant Robot

Due to their simple structure conventional walking aids easy to use even by inexperienced people. Therefore, the assistant robot walking aid control system is based on a dynamic model of a conventional walking aid system. The forces applied to the walking aid handles of the assistant robot are measured by sensors inside the handles of the walking supporters.

3. HAPTIC DEVICE DESIGNED

The haptic interface consists of force sensors that were embedded into the handlebar structure of the assistant robot. The FlexiForce sensor is an ultra-thin, flexible printed circuit. The force sensors are constructed of two layers of substrate film. On each layer, a conductive material is applied, followed by a layer of pressure-sensitive ink. Adhesive is then used to laminate the two layers of substrate together to form the force sensor. The *FlexiForce* single element force sensor acts as a force sensing resistor in an electrical circuit. When the force sensor is unloaded, its resistance is very high. When a force is applied to the sensor, this resistance decreases. The resistance can be read by connecting a multi-meter to the outer two pins, then applying a force to the sensing area. In the image below, the plot shows both the Force vs. resistance and Force vs. conductance (1/R). Note that the conductance curve is linear, and therefore useful in calibration.(Fig 3)

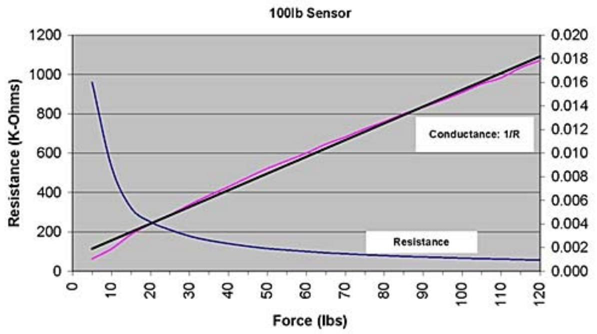


Fig. 3 Force sensor performance analysis result

While there are several methods of measuring of the user force, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. The most widely used gauge is the bonded metallic strain gauge.

$$GF = \frac{\Delta R / R}{\Delta L / L} = \frac{\Delta R / R}{\varepsilon} \tag{1}$$

where GF is the gauge factor(GF) and ε is strain, L is length and R is resistance. A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor. Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain). The sensitivity of the bridge to strain can be doubled by making both gauges active in a half-bridge configuration.

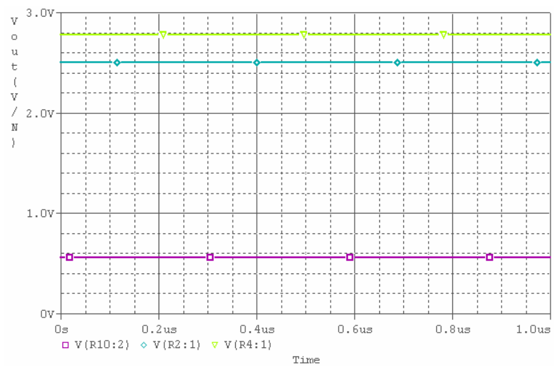
$$\frac{V_o}{V_{in}} = -\frac{GF * \varepsilon}{2} \tag{2}$$

Where V_o is an output voltage and V_{in} is an input voltage. Eq. (2), yield an output voltage that is linear and approximately double the output of the quarter-bridge circuit.

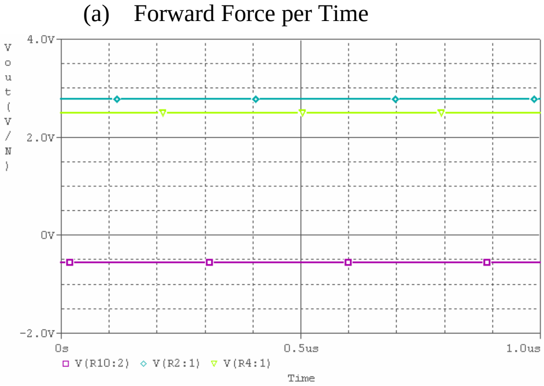
The other analog circuit is a low power instrumentation amplifier. Its versatile 3-op amp design and small size make it ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain. For example, Frequency is a 70KHz at G equal 100.

$$V_{out} = (\frac{2R}{R_g} + 1)(V_1 - V_2) \tag{3}$$

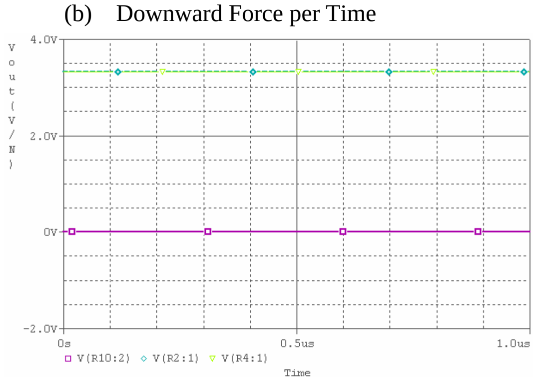
where R is a feedback resistant and R_g is a gain control resistant. The system input/output voltage is individual (V_1-V_2) and V_{out} . As result of experiments, the assistant robot presents Fig. 4 through field trials.



(a) Forward Force per Time



(b) Downward Force per Time



(c) Equal Force per Time

Fig. 4 the user force experimental result. [V_{out} (purple), V_1(green), V_2(blue)]

Fig. 4 shows typical results of the assistant robot driven by an elderly user. First, Fig. 4 (a) shows the case with the elderly presses forward-force. This result is a 6.75Kg (15lb at Fig 3) pressure that converter from the elderly force to-voltage with Eqs. (2) ~ (3). Its result sign is positive. And Fig 4 (b) shows that the elderly control the assistant robot's direction into downward-force with the handlebars. At this moment, the pressure is 6.75Kg. The result value is negative. The other case shows that the elderly moves in accordance with the assistant robot's motion. So the elderly doesn't operate handlebars then Fig. 4 (c) shows an output voltage that is zero.

4. TRANSFER FUNCTION

The assistant robot needs in order to motion control such Fig. (5) that is a transfer function.

Fig. 5 Concept of TF(Transfer Function)

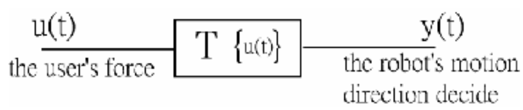


Fig. 5 shows an input u(t) has five states. These are LF(Left-Forward), RF(Right-Forward), LD(Left-Downward), RD(Right-Downward) and NF(Non-Force) and output y(t) decides two motor direction. We will design the effective and safety TF. There are many examples of physical processes which require feedback control systems capable of functioning at a number of different process operating points. Generally, there are four style for the design way. (1) gain scheduling (2) model reference adaptive control (3) self-tuning regulators (4) dual control. [12]

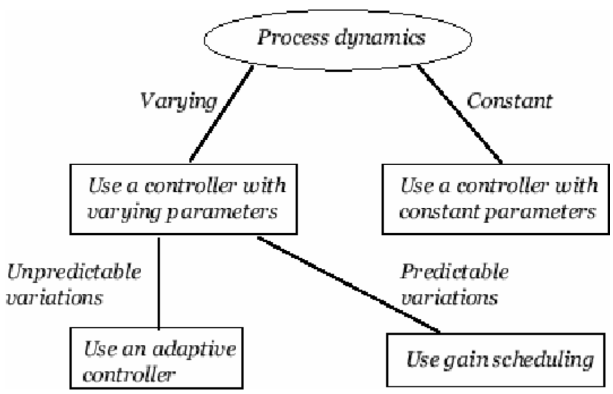


Fig. 6 Transfer Function design select condition

We have the variables for force sensor state. these are to predict with four states. Therefore our design model is using a gain scheduling. Gain scheduling based on measurements of operating conditions of the process is often a good way to compensate for variations in process parameters or known nonlinearities of the process. It is controversial whether a system with gain scheduling should be considered an adaptive system or not, because the parameters are changed in an open-loop or preprogrammed fashion. We designed a transfer function that represent in Fig. 7. Each variable was defined at Table 1 and blocks function descript at Table 2.

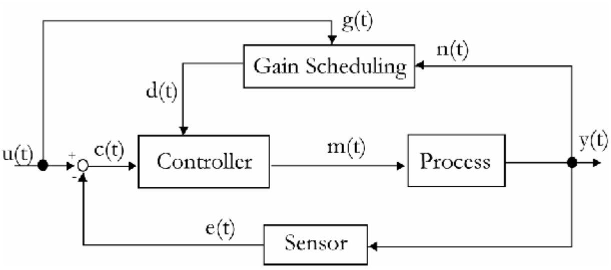


Fig. 7 Close-loop system with gain scheduling for TF

Table 1 Define of variables for TF

Variable	Description
u (t)	Input Signal (command signal)
c (t)	Controller Input [c(t) = u(t) + e(t)]
e (t)	Feedback signal through Sensor
g (t)	g (t) = u (t)
d (t)	Controller parameters
m (t)	Control Signal of process
n (t)	n (t) = y (t) that is feedback signal or zero
y (t)	Output signal (Robot's motion control)

Table 2 The desirable blocks function for TF

Block name	Description
Process	Two axis motion part
Sensor	Encoder or Velocity measurement sensor or direct feedback
Gain scheduling	Comparison and Calculation circuit

We design the transfer function for the control of the assistant robot's two wheels. Then we analyze characteristic of the dc motor. It derives transfer function.

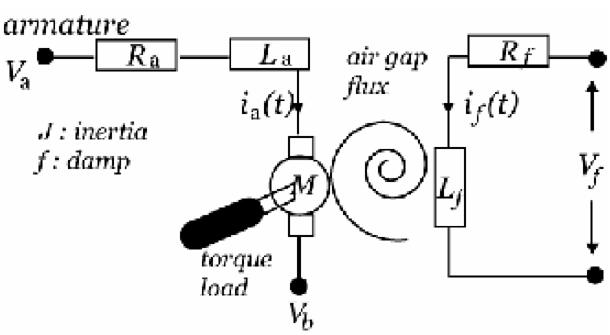


Fig. 8 DC motor modeling for mathematical analysis

The dc motor's air gap flux increase in proportion of field magnet.

$$\phi = K_f i_f \tag{4}$$

K_f is the parameter value that is constant and i_f is a field current. Therefore the dc motor generates torque T_m. It is equal to multiply of armature energy and field magnet energy.

$$T_m = K_1 K_f i_f(t) i_a(t) \tag{5}$$

T_m is total torque at the dc motor. Either $i_a(t)$ or $i_f(t)$ should be a constant in order to analyze with the linear system. So the field current is a constant that Eq. (5) change into laplace transform.

$$T_m = (K_1 K_f I_f) I_a(s) = K_m I_a(s) \tag{6}$$

The armature's input voltage is equal to the Eq. (7)

$$V_a = (R_a + L_a s) I_a(s) + V_b(s) \tag{7}$$

$V_b(s)$ is a feedback voltage. It increase in proportion of the dc motor velocity. $V_b(s)$ can be represented feedback constant K_b and the dc motor's velocity $w(s)$. [$V_b(s) = K_b w(s)$] then $I_a(s)$ is equal to Eq. (8)

$$I_a = \frac{V_a(s) - K_b W(s)}{(R_a + L_a s)} \tag{8}$$

$$T_L = Js^2\theta(s) + fs\theta(s) = T_m(s) - T_d(s) \tag{9}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{k_m}{s[(R_a + L_a s)(Js + f) + K_b K_m} \tag{10}$$

T_L is a load torque and T_d is external interference. Here, T_d is too small, so it is zero.

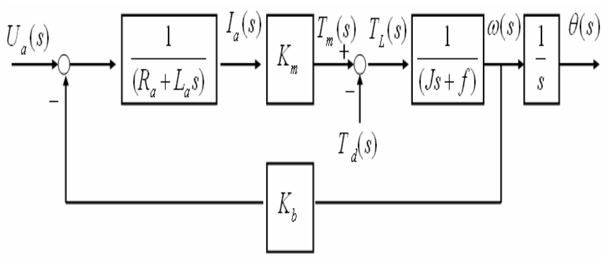


Fig. 9 The dc motor modeling with Armature control

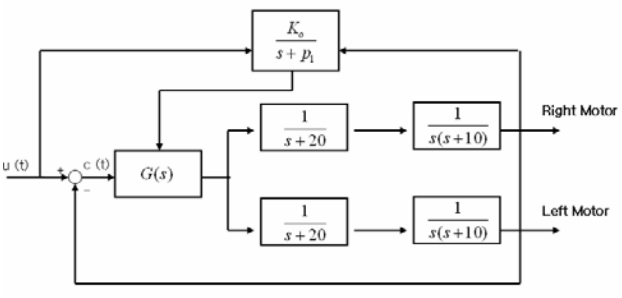
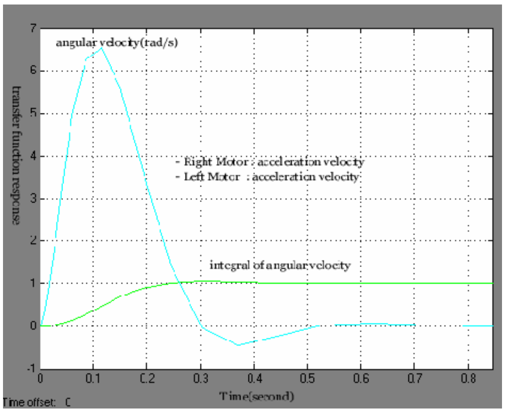


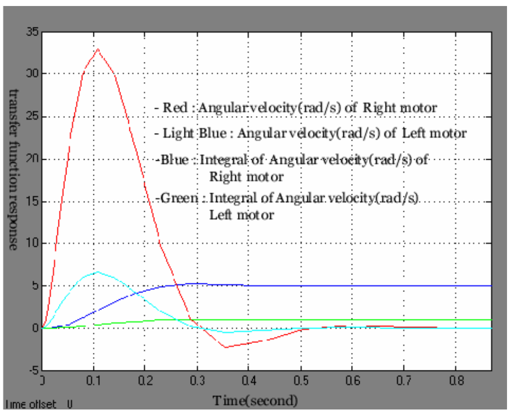
Fig. 10 Two wheels modeling for the assistant robot

$$G(s) = \frac{K(s+11)^2}{(s+24)^2} \tag{11}$$

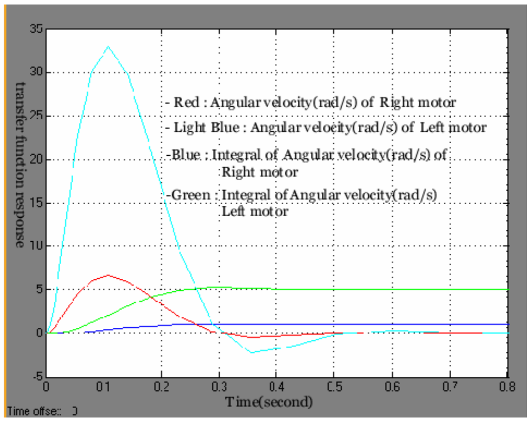
The motion response of the assistant robot system can be seen in Fig. 11. For each states of input, we tested with its condition. The input u(t) has five states. These are LF(Left-Forward), RF(Right-Forward),LD(Left-Downward),RD(Right-Downward) and NF(Non-Force). Output y(t) decides two motor direction.



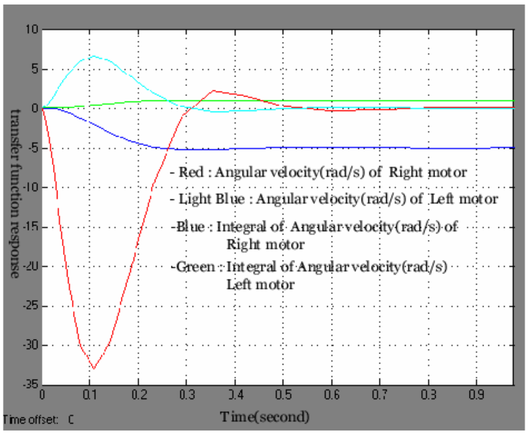
(a) NF(Non-Force) State Result



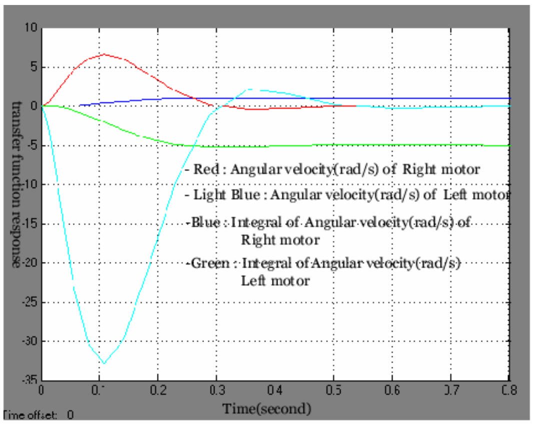
(b) RF(Right-Forward State Result



(c) LF(Left-Forward) state Result



(d) RD(Right-Downward) state Result



(e) LD(Light-Downward) state Result

Fig. 11 The dc motor response as the user force

Fig. 11 shows that the system has response velocity with 5.1 percent overshoot, 0.2sec rising time, and 0.38sec setting time. The output velocity has all same result in Fig. 11 (a), as the elderly don't force to the shared control. If the elderly forces for left to move to the right, the motor of the right hand side of the system accelerates more than it of the left in Fig. 11 (b). On the contrary, Fig.11 (c) shows the result that the elderly force for right. Fig. 11 (d) represents the result forced as the elderly want to move for back-left. The phase was reversed with 180 degree against (a), (b) and (c). Fig. 11 (e) shows the result for back-right. This experiments have been seen the effective and safe control status through using the shared control system. The shared control system helps for the elderly to effectively control the assistant robot. Our system is easy to operate more than devices such as buttons, joysticks, and levers. Because, our system require some hand displacement.

5. CONCLUSIONS

In this paper we presented to implement the shared control so that robot aids the elderly movement. The shared control system recognizes the user intent through the haptic device after analyzing the transfer function, it operate the motion of the assistant robot. This system provides the safe user interface that can be utilized with the assistant robot for the elderly.

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