

Feasibility study on walking training biped locomotion surrogate robot

Abstract

This paper discusses the technical feasibility and ethical considerations about walking training of a biped locomotion surrogate robot assisted by a device for reducing the weight load and/or a treadmill, instead of a person with a gait disorder for his safety at the tuning of training period as first ethical condition. For confirming this, some experiments were done using a robot. As the second ethical condition, it was described that the robot was not seen to human. Then, Nebo used here was suitable as a surrogate robot such meanings.

Keywords: locomotion surrogate, treadmill, surrogate robot

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Abbreviations: MAS, message announcement system; VAS, voice announcement system; QAS, question and answer system; SSS, sound sign system; VOS, voice order system; SOS, sound order system.

Introduction

Over the past few years in Japan, the number of senior citizens has increased remarkably, and around 1,650,000 of them have gait disorders. Gait disorder means to become difficult of gait by many kinds of cause. For examples, cerebrovascular disorders and joint trouble are the main causes of gait disorders, which are common ailments among those aged 65 to 74. They may be unrelated to the working Conditions. Many researchers have made progress in having robot surrogates replace humans in many dangerous and dirty endeavors, especially in the fields of aerospace¹ and atomic power,² so as to reduce the need to expose people to risks and also to reduce training costs. However, such robot surrogates have not replaced humans in educational environments. Loco mart like treadmill, wearable power-assistance devices and support robots have been developed for the rehabilitation of people with gait disorders, and load-free treadmills for walking rehabilitation have been executed in a clinical environment.^{3,4} A treadmill is a useful apparatus for gait training and for making evaluations; however, many differences have been reported between walking on a treadmill and walking over the ground. Experimental comparisons of the muscular activity of the leg and of the heart rate have been carried out.⁵ The results suggest care be taken because the training adjustment for treadmills may be dangerous and place an excessive load on patients. There are two loads here: The load of the robot receives from a load imposed by an outside force.⁶ Many machines and tools have been developed for controlling gait, such as ambulation-support machines⁷ and loco motor training tools.⁸ This research applies Feasibility Study (FS) to the problem of Law Governing Engineering and Engineering Ethics and the necessity of robot control and treadmill control in adjustment of surrogate walking training to reduce the risk of overloading patient. The authors reduce this risk by constructing a two-legged surrogate robot of about 1/4 the scale of an average human being in such an adjustment stage.

Assisted-active walking

In this section, the authors present the method and the results on 3 kinds of experiments. One is hand-assisted active walking, the other is active walking without hand-assistance, third is a tread-mill assisted active walking with a load reduce device. The authors have not adopted a passive walking using a slope because it is risky for the surrogate robot to a gait disorder patient.

Hand-assisted active walking

Object of experiments: The load of a person with a gait disorder is evaluated by proxy by quantifying as “light” or “heavy” the motor load on each joint of a surrogate robot imposed by hand-assisted active walking using only an adjustable-load device.

Devices used in the experiments: The Nuevo manufactured by ZMP Co. is used as the two-legged surrogate robot. Nuevo is blue and does not look like a human, even though it is a humanoid robot.

It is normally necessary to use a humanoid robot that is the same size as a human being, and that has the same gait disorder as the patient, to achieve such a technical purpose, that is, evaluating the motor load placed on the joints of a surrogate robot. This paper can be forecast that various ethical problems increase in opposite method of technological engineering ethics. A walking-support apparatus (load device) and a treadmill were manufactures by ourselves, and examined technically easy FS and the ethical problems of using inexpensive ready-made scaled-down robots that do not look human, in order to decrease the development cost and time, and to avoid ethical problems as far as possible.

The authors consider the following conditions for avoiding the mentioned above ethical problem:

- The color is not human-like even if the figure is like a human.
- The face is immature, and is not like human but is not lovely either.
- It is not better than a recent two-legged robot at walking.

The authors consider that the Nuevo is suitable as a surrogate robot for similar second ethical reasons as above.

Experimental methods: The authors compared various degrees of servo compliance by tuning the motor control gain, namely, the amount of increase in motor torque generated by hand-assistance such as backward movement of the foot in a programmed active-gait state (Figure 1). Figure 2 shows comparison of torque of a joint between with assist and without assist. This experiment was conducted after a load-free state was obtained, using our home-built equipment in which the amount of load on the robot's legs can be varied by tightening or slacking a screw.



Figure 1 Hand-assisting.

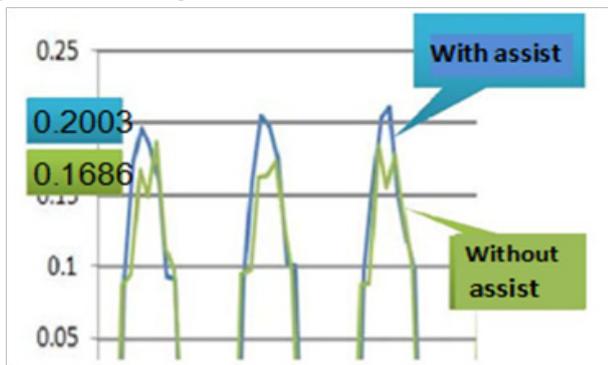


Figure 2 Comparison of torque [N-m] of active walking.

Considerations

- a. That walking is possible in a state where the amount of bending of the joint is decreased in the case of a load-free condition.
- b. That the robot can reduce the load to an extent by implementing load reduction using an external force.
- c. That the next motion can be undertaken early because the load on the robot is reduced in the case of completely load-free condition.
- d. Those elderly persons can reduce the external load so that they do not place too heavy a load upon their knees.

Treadmill-assisted active walking with a load-reducing device

There are many studies about treadmill-assisted walking, for example, a weight support treadmill by center gravity control has been developed for human patient by Furusho et al.⁹ This section

shows objects of experiments and devices used in the experiments on simple treadmill-assisted active walking with a load reduction device for testing of the surrogate robot.

Object of experiments: These experiments evaluate the load on a patient is evaluated by proxy as the load imposed on each joint by the treadmill in assisted active walking with the device for reducing the robot load. Table 1 shows the list of major specifications of a treadmill for surrogate walking training tuning.

Table 1 Shows the list of major specifications of a treadmill for surrogate walking training tuning

Name of device	Tread mill
Width	370mm
Depth	260mm
Height	95mm
Width of Belt	210mm
Length of Belt	670mm
Power	12vBattery
Max Value of Variable Resistance	42Ω
Range of Speed	50mm/s~145mm/s
Material	Aluminum, Iron, Rubber, Plastic

Experimental methods: These experiments evaluate the torque of each joint motor is evaluated by measuring the current in the motor, and the load for passive walking is evaluated from these motor current readings.

The present study plotted, both the rotation speed of the treadmill and the load were gradually changed and the current in each joint motor. The authors identified regions where the joint load current was within a prescribed range.

Results of experiments: Figure 3 shows the change in torque in the ankle and knee joints when the control gain is adjusted using the treadmill.

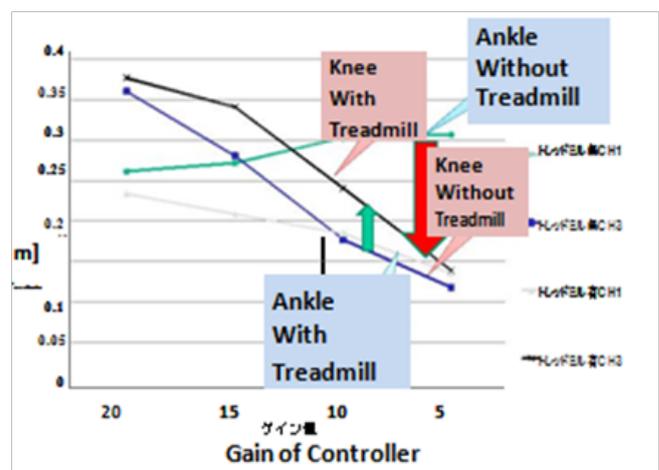


Figure 3 Relation between torque and control gain for each joint motor during treadmill training.

- a. Generally speaking, a hard servo increases the motor torque because the control gain is large-although no large change is seen in this Figure 3. (Here, a hard servo means that the operator feels the servo hard because displacement/force is smaller.
- b. The knee torque decreases when the control gain is reduced so that the servo becomes soft (Here, displacement/force is larger). However, there is a tendency for the ankle torque to increase because the robot leg is extended, the leading foot is dragged, and the leading foot catches on the floor.

Considerations

- a. It is expected that the motor torque (the energy for walking) will decrease if the robot is controlled by a hard servo in the fixed-leg phase (walking that requires effort), the ankle torque will be decreased in the subsequent phase if it is controlled by a soft servo

- in the moving-leg phase (walking in which force is weakened, and its knee torque is lowered.
- b. It is expected that human- like walking can be achieved by using gain scheduling control that synchronizes the walking phase (repeated fixed leg and moving leg).

Future plans

Figure 2 shows the limitations of this work and details concerning the surrogate robot and the training apparatus, as well as the directions for future achievement are shown in Table 2. There is a room for improvement because the number of degrees of freedom arrangement of the leg of the surrogate robot used in this research is considerably different from that of a human. It might be difficult for the surrogate robot like this to express abnormal long time fixed pain etc. by the artificial face expression.^{10,11}

Table 2 Future development policy for robot and devices

Future development policy			
	Future requirement	This study	Achievement method
Robot	Human-like walking	Constant gain	Variable gain (gain Scheduling according to state)
	Human-like driving method	Motor control	Artificial muscle
Device for training	Automatic speed tuning of treadmill	Constant speed	Detection of walking speed by sensors
	Independent load tuning of each joint	Overall load tuning	Device for load tuning of each joint

Discussion and considerations

The three robot principles of Asimov are famous as a basis for robot design, and the concept is mainly based on defending human life and not harming it. The authors considered also the following requirements for surrogate training robots, including the reasons for choosing the Nuevo as a surrogate:

- a. The walking training of a genuine patient must not test for until the safety can confirm though an enough condition cannot be set yet here.
- b. ‘The pain that sees the robot suffer like human is not given to spectators’, summarizing, ‘the robot is not seen to human’ though it is likely to reverse as shown later according to purpose.

It is expected that the result of this research will be useful in the promotion of surrogate robot development (although there is a room for more discussion as to whether a humanoid robot would be more suitable) for the adjustment of rehabilitation training apparatus. There are more interesting themes in this area, that is, the message announcement system (MAS), voice announcement system (VAS), question and answer system (QAS)¹² and the sound sign system (SSS) by the surrogate robot, the voice order system (VOS) and the sound order system (SOS)¹³ by the human or robot instructor, etc.. Moreover, any text announcement, order and sign using the concept of the possession phenomena like ITACO from PC display to the robot display,¹⁴ and/or monitoring of any sign by artificial face expression

(pain etc.^{10,11}) for remote control of treadmill robot¹⁵ by instructors will be future interesting themes.

Conclusion

First, this paper presents hand assisted active walking and treadmill assisted active walking with a load reducing device using simple non-human like robot Nuevo as walking training surrogate robot with consideration and future plan. Moreover, this paper discusses and considerations about requirements for surrogate training robots referring to three principles for robot design of Asimov, and more interesting themes in the future.

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Conflict of interest

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