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Development of Active Walker by using Hart Walker

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Abstract: More than one million people have difficulty in walking only in Japan. Many kinds of walker have been developing so far for gait training though, they are used by grasping the front and/or the back part of them in order to hold trunk. It makes forward tilting or backward tilting of the upper half of the body and comes to difficult to keep right posture for walking. Moreover there are few examples of an active walker which is used if people have no muscular force for walking.

In order to solve these issues, we have been developing the active walker by using the Hart Walker (HW) which consists of double upright knee ankle foot orthosis and 4-weeled carriage with a stem located in the center of the carriage. Since waist part of the orthesis is attached to the top of the stem, there is no risk for falling, it is possible to keep the right posture, and both hands becomes completely be free. McKibben artificial muscles are attached to HW in order to control walking motion as an active walker. By walking experiment using child-size doll with the same kind of joints human has, it is confirmed that human-like gait is realized by the active walker developed.

Keywords: Active walker, Gait disorder, Hart walker, McKibben artificial muscle

1. INTRODUCTION

Only in Japan, more than one million people are gait disorder. Many kinds of walker have been developing so far for gait training and/also supporting walking though, they are used by grasping the front or the back part of them in order to hold trunk. It makes forward tilting or backward tilting of the upper half body and comes to difficult to keep right posture for walking. Moreover there are few examples of an active walker which is used if people have no muscular force for walking.

In order to solve these issues, we have been developing the active walker by using the Hart Walker: HW (Fig.1) which consists of double upright knee ankle foot orthosis and 4-weeled carriage with a stem located in the center of the carriage. Since waist part of the orthesis is attached to the top of the stem, there is no risk for falling, it is possible to keep the right posture, and both hands becomes completely be free. By applying the McKibben artificial muscle to the Hart Walker, people can walk by health-people-like gait even if people have no muscular force at all.

In this paper, we introduce the active walker. To realize health-people-like gait by the active walker, we analyze it and acquire the ideal gait pattern for the active walker. Since it is very difficult to use people for experiment in this stage, we apply a doll with the same kind of joints human has and weight. Feedback control method is applied to implement health-people-like gait and we find that our method is feasible and very flexible in weight and height change.

2. STRUCTURE OF THE ACTIVE WALKER

2.1 Hart walker

Hart walker shown in Fig.1 was developed in 1981 at England for mainly applying to infantile paralysis. 4000 children are using all over the world and more than 120 ones in Japan. It consists of knee-ankle-foot orthosis and carriage. User's hands become free and user can keep right posture. Load to the leg is controllable by modifying the position of connecting point between the stem and knee-ankle-foot orthosis. Moreover it is very easy to adjust the length of frames to the body as shown in Fig.2.

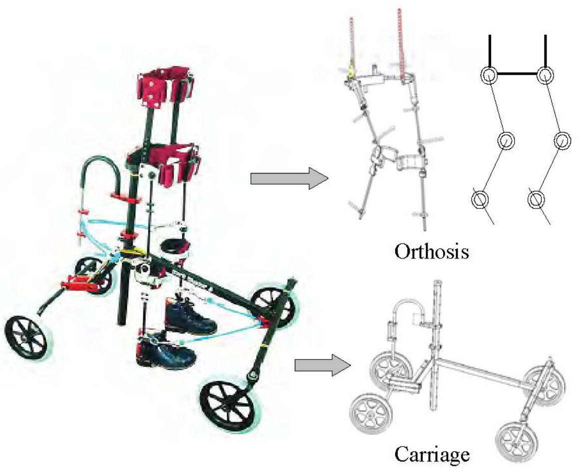

Fig.1 Hart Walker

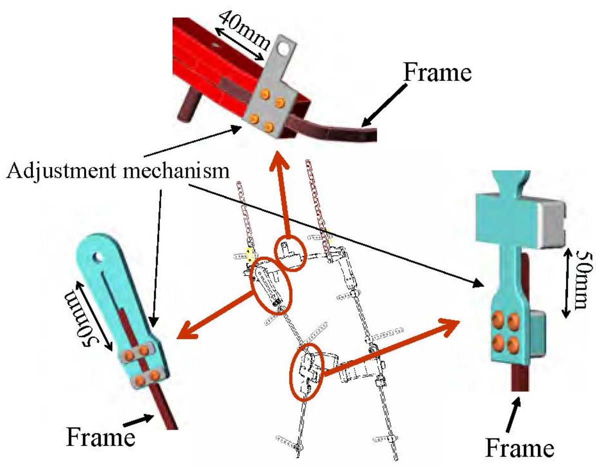

Fig.2 Size adjustment mechanism

In order to measure angles for hip and knee joint, we utilize potentiometers described inn Fig.3.

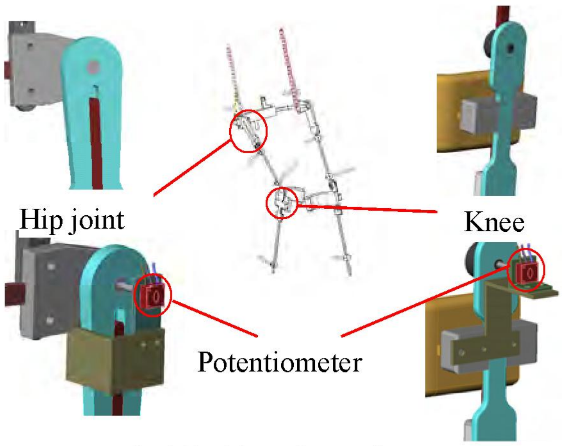

Fig.3 Position of potentiometer

2.2 McKibben artificial muscle

The McKibben-type actuator consists of an internal bladder surrounded by a braided mesh shell (with flexible yet non-extensible threads) that is attached at either end to fittings. As shown in Fig. 4, when the internal bladder is pressurized, the highly pressurized air pushes against its inner surface and against the external shell, tending to increase its volume. Due to the non-extensibility of the threads in the braided mesh shell, the actuator shortens according to its volume increase and/or produces a load if it is coupled to a mechanical load. About 35% contraction can be expected with no load, and more than 20% for a load of 20 kg.

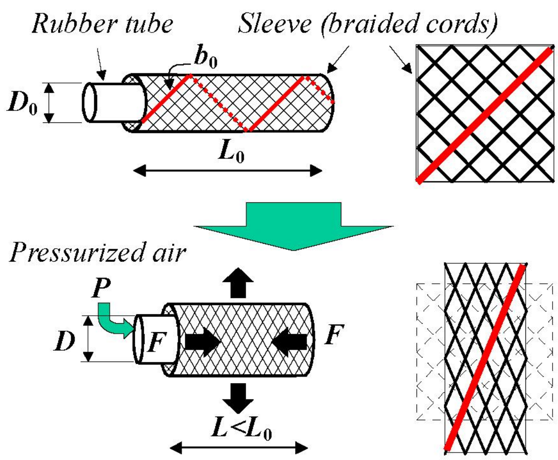

Fig.4 McKibben artificial muscle

Table 1 Number and length of McKibben artificial muscle

	A	B	C	D
number	2	1	1	1
Length(mm)	280	300	330	200

2.3 Actuator layout

Referring to muscle of human used for walking shown in Fig.5, actuator layout for the active walker is decided as shown in Fig.6. Table 1 describes number of actuator and length.

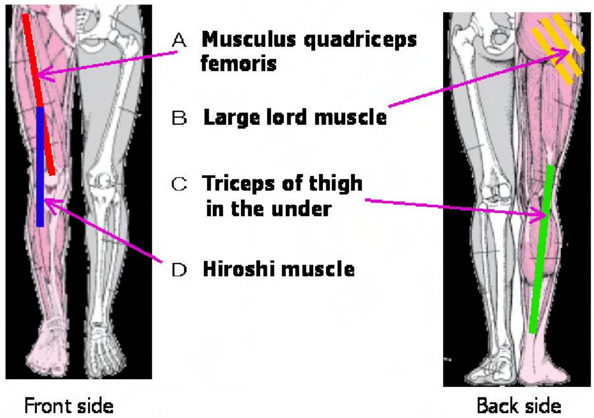

Fig.5 Layout of human muscle

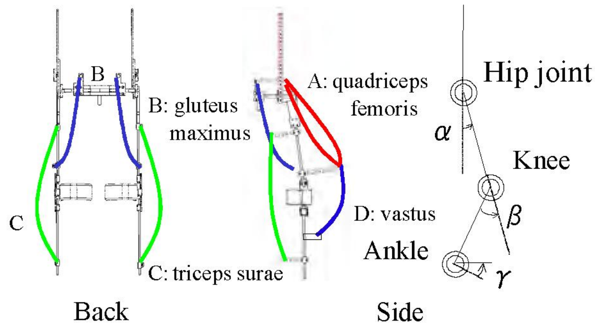

Fig.6 Actuator layout

2.4 Standing up mechanism

In case of HW, after attaching orthosis to user, helper has to lift him/her to mount to the stem. It is hard load for helper. To solve this issue, we develop standing up mechanism by using linear motor as described in Fig.7. Then orthosis can be attached to user when he/she is in a sitting position and he/she can stand up automatically.

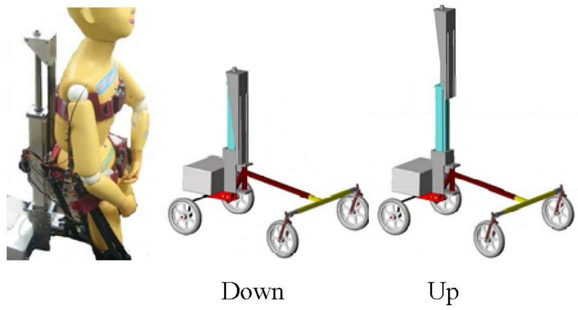

Fig.7 Standing up mechanism

2.4 System configuration

System configuration is shown in Fig.8. The active walker consists of PC, A/D, linear motor, its driver, compressor, potentiometers for measuring hip and knee joint angle, and electropneumatic regulator.

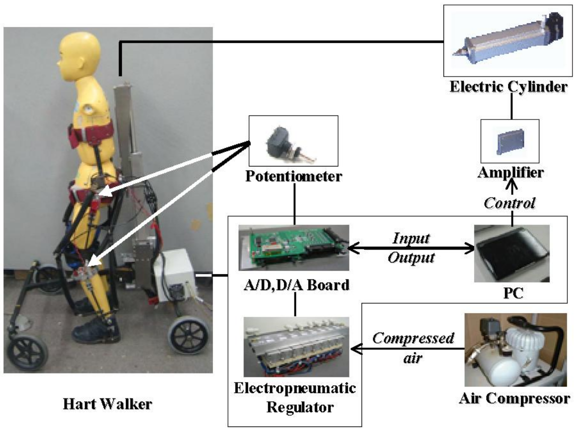

Fig.8 System configuration

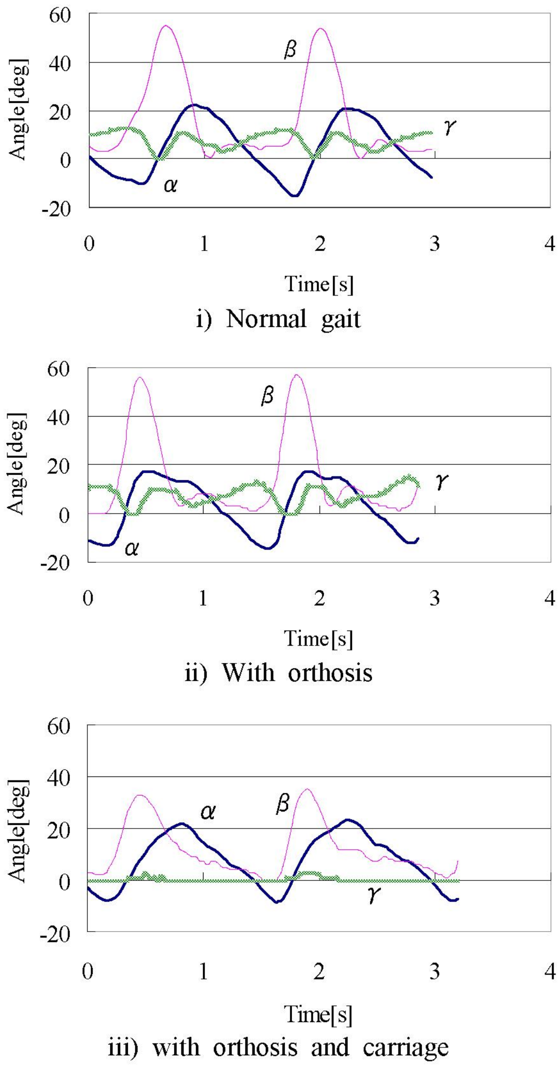

Fig.9 Human gait measured

3. ANALYSIS OF HUMAN GAIT

In order to realize health-people-like gait by the active walker, in the first place, human gait must be investigated. 3D precise measurement instrument which has 0.1mm measurement error called "OPTOTRAK Certus" is used for measuring hip joint angle α, knee joint one β and ankle joint one γ. For analyzing the effect of using orthosis(HW), 3 conditions are examined; i) normal gait, ii) with orthosis, and iii) with orthosis and carriage.

Fig.9 shows results from one subject. Fig.10 depicts maximum angle for i), ii) and iii) in terms of each 6 subject. Because of increase of the bodily restraint, we find that maximum angles become small in the order of i), ii), and iii).

Fig.11 shows phase differences for i), ii) and iii) in terms of each 6 subject. Although there is some differences between i), ii) and iii), and also each subject, we can say that bodily restraint gives less effect on phase compare to amplitude. We then decide to use 0.3 rad as phase differences.

For safety, it is necessary to use carriage and therefore gait pattern of iii) is employed for the active walker.

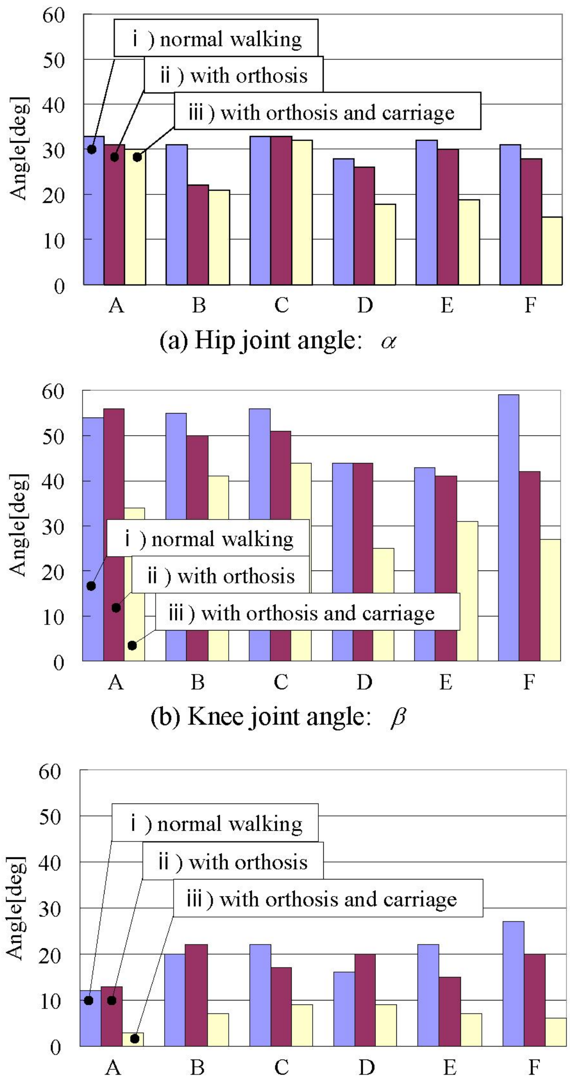

Fig.10 Max. joint angle for 6 subjects (A to F)

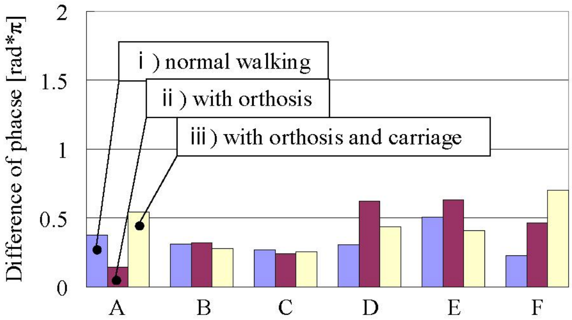

Fig.11 Phase between α and β for 6 subjects

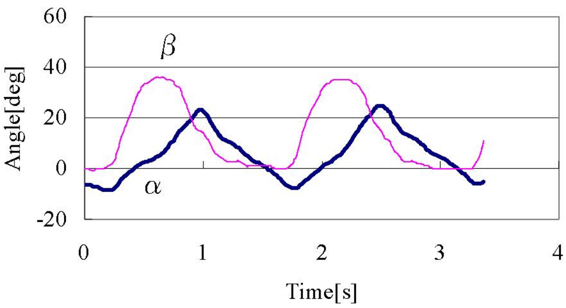

Fig.12 Target gait pattern for the active walker

4. WALKING BY THE ACTIVE WALKER

4.1 Target gait pattern

As the target gait pattern for the active walker, polynomial approximation was applied to curved lines for α and β in Fig.9 iii) in the first place. However, we could not realize human-like gait, we tried many method though. The reason might be the following. Human can control each angle with dexterity and in this case, load changes dynamically especially when sole of the foot is on the floor or not. We then decide to focus on the amplitude and phase and try to obtain gait pattern by trial and error method. Fig.12 describes the target gait pattern we acquired.

By using it, the doll can walk very naturally. However, gait itself was unstable in various situation, i.e. not flexible in floor condition, weight change, and height change. Feedback control is applied as shown in next section.

4.2 Gait control

For controlling α, actuator A and B in Fig. 6 is utilized. For β, C and D. Control block diagram is shown in Fig.13. Variables in this figure describes as follows;

P_{FF}: target gait pattern (Fig.11)

θ^{cmd}: target joint angle

$\dot{\theta}^{cmd}$: target joint angular velocity

K_p: feedback gain: 0.02

K_v: feedback gain: 0.001

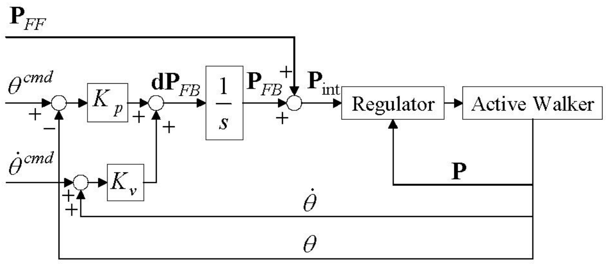

Fig.13 Block diagram for feedback control

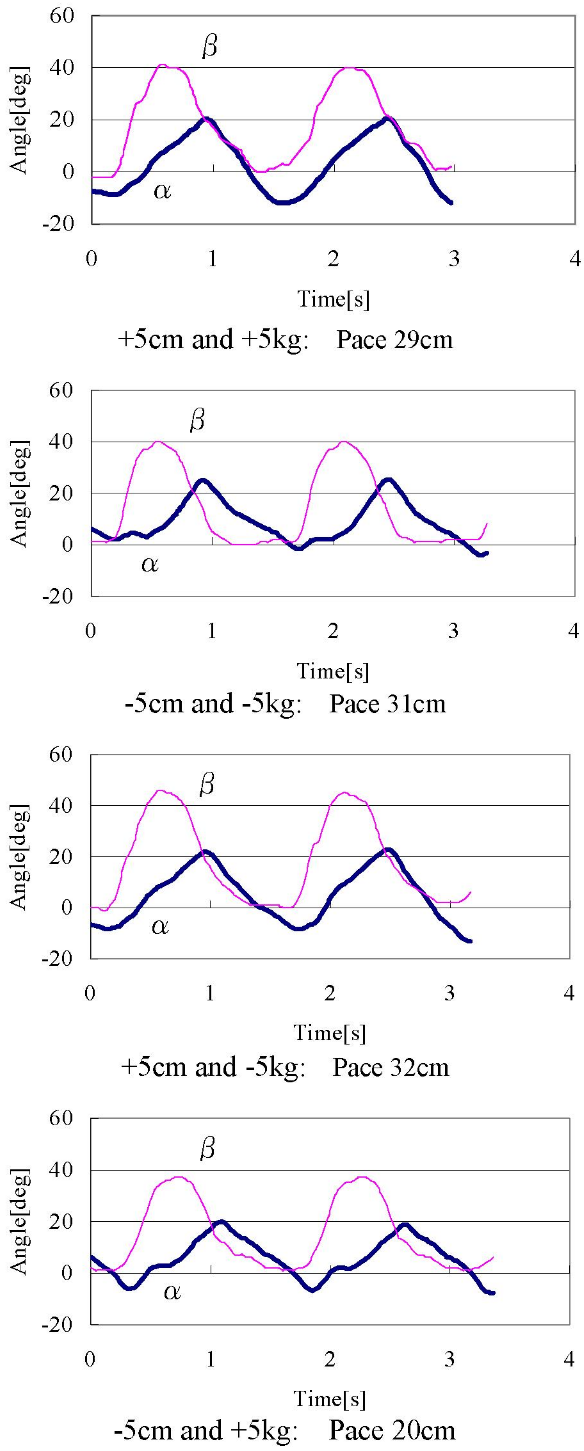

Fig.14 Gait patterns obtained by the active walker

4.3 Realization of walking by using a doll

Using a child-size doll (130cm height, 26kg weight) with the same kind of joints human has, walking experiment is undertaken. As mentioned in Fig. 2, HW has function to change the length easily. In case of 130cm height, we can change height in the range of +5cm to -5cm. Following by height change, weight should change in the range of +5kg to -5kg. Since we want to show how adaptive the active walker is in terms of height and weight change depending on user, we investigate experiments as follows.

There are many combinations in the range of +5cm to -5cm and +5kg to -5kg. The most extreme cases are 4 ones; +5cm and +5kg, -5cm and -5kg, +5cm and -5kg and -5cm and +5kg. Fig.14 shows the results. We find that amplitude and phase are realized in each case. And it is quite difficult to recognize from these figures thought, gait realized was very natural. We apply the same experiment on the carpet and results are almost the same.

We can conclude the active walker we have developed can realize human-like gait with size and weight adaptation.

5. CONCLUSION

Although only in Japan, more than one million people has problem in gait, there are few developments of an active walker which is possible to use if people have no muscular force for walking. In this study, the active walker has been developing. The active walker consists of McKibben artificial muscle and the Hart Walker: HW which consists of double upright knee ankle foot orthosis and 4-weeled carriage with a stem located in the center of the carriage.

We in the first place, analyze human gait in order to obtain ideal gait pattern for the active walker. Because of dynamical change in load for walking, it turns out that human gait pattern is not ideal for the active walker. We then focus on amplitude and phase of hip and knee angle, we produce the target gait pattern for the active walker. By using feedback control method, human-like gait is realized with size and weight adaptation.

We are currently trying to move to the clinical investigation. We hope the active walker would be used for many handicapped people in future.