The Sixteenth International Symposium on Artificial Life and Robotics 2011 (AROB 16th '11),
B-Con Plaza, Beppu,Oita, Japan, January 27-29, 2011

Crutch Gait Pattern for Robotic Orthosis by the Feature Extraction

I.H. Jang, J.Y. Jung, D.Y. Lee, D.W. Lee, H.G. Lee, H.S. Park*

Korea Institute of Industrial Technology, Republic of Korea
(Tel : 82-31-8040-6292; Fax : 82-31-8040-6370)
hsubpark@kitech.re.kr

Abstract: In this paper, we present the method to generate crutch gait pattern for robotic orthosis to walk using motor. In first we define the features to characterize gait pattern and extract features from the normal gait pattern, which is experimental encoder data of hip and knee being taken from motion capture device. We also present the selected features containing physical meaning in gait pattern enable us to vary speed, step size and foot clearance easily. Finally, we make crutch gait patterns using these features and apply them to our exoskeleton robot ROBIN-P1 to verify our method.

Keywords: Exoskeleton, Robotic Orthosis, Gait Pattern, Feature Extraction**.**

I. INTRODUCTION

The exoskeleton type of wearable robots can be divided into power suits for enhancement of a healthy person's activities and rehabilitation robots for support of a physically challenged person.

Of two categories, rehabilitation robots are noted more and more recently as the Aging Society is going on quickly. Robotic orthosis draws special attention recently because the application of rehabilitation robot is extended to a development of rehabilitation robot assisting gait for spinal cord injury patients and their clinic.

In view of control aspects, the movement of wearable robot should be synchronized with a user for safety and natural movement. Therefore we assumed and defined role sharing as follows.

Assumption 1: user has to play a role in the awareness of environment and the decision of movements.
Assumption 2: robot has to control its motion according to user intention.
Assumption 3: user has to play a role in shifting their weight and balancing for robot movements.

Suzuki et al. [1] have applied HAL-3 for paraplegia patients to walk again. This paper describes how to detect user intention by robot for solving the problem concerning assumption 2. For the gait pattern, they use the one extracted from a healthy person's walking. However it can be applied only to a hemiplegia patient and the gait parameters such as walking speed and step size cannot be changed in real time, once it has been determined. ReWalk[2] is a robot for Spinal Cord Injury(SCI) patients but there is no paper or patents describing their control technology. However the analysis of the various video clips on internet showed that ReWalk has several gait patterns depending patient's condition but it also seems not to change its walking speed and step size once the gait pattern is selected. I.H. Jang et al. [3] also have made wearable robotic orthosis ROBIN-P1 for assisting gait of SCI patients. ROBIN-P1 also memorize reference gait pattern in the form of lookup table and use the corresponding gait pattern to control motors according to user intention.

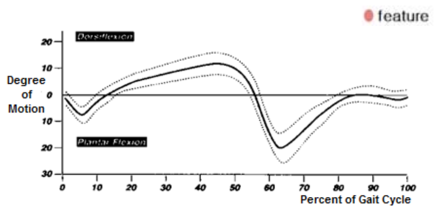
It is not proper for those kinds of methods shown in the case of HAL, ReWalk, ROBIN-P1 to be used in dynamic environments of day life. Therefore this paper describes how to generate gait pattern from the several features and shows that we can change the gait pattern online with the several features.

The rest of this paper is structured as follows. Section II defines features from normal gait pattern and describes the algorithm to generate gait pattern for our exoskeleton robot platform ROBIN-P1. Experimental results are provided in Section III, and finally, Section VI concludes the paper and suggests future research.

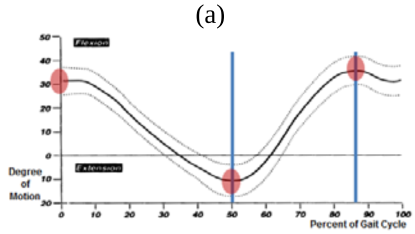
II.DESCRIPTIN OF THE ALGORITHM FOR GENERATING GAIT PATTERN

1. Definition of the feature for gait pattern

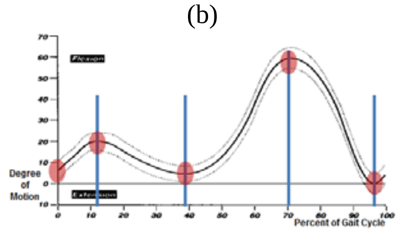
Previous works for gait pattern say that normal people has a gait pattern like Fig.1. The (a) (b) and (c) represent the range of Ankle, Hip and Knee motion respectively. We can find several peaks and both end points from the gait patterns. Meanwhile, if we can know those points, we may be able to recover whole gait pattern by connecting those points with spline method. Therefore we can select those points as the features for gait pattern.



(a)



(b)



(c)

Fig.1. (a) Ankle Range of Motion (b) Hip range of motion and (c) Knee range of motion

2. Algorithm for generating gait pattern

In order to get the crutch gait pattern of normal people, we have designed encoder system that is the exoskeleton type of dummy robot having encoders at hip and knee joint replacing DC motor of ROBIN-P1. The encoder system has same constraint as our platform ROBIN-P1.

ROBIN-P1 actually has DC motors at hip and knee joints and each joint has full range of motion as shown in Table 1.

Table 1. The range of motion at each joint for the ROBIN-P1

Joint	Range (degree)
Hip	-10 ~ 125
Knee	0 ~ 115
Ankle	Fixed

In order to generate a gait pattern for ROBIN-P1, we have edit normal people's gait pattern being acquired using this encoder system. In previous case, we have to renew the whole gait pattern and restore that in a lookup table whenever the gait speed or step size changes. Therefore, ROBIN-P1 cannot change its gait pattern by online manner and then it is very difficult for robot to adapt itself in dynamic environment of day life. In order to solve this problem, we have developed new algorithm to generate gait pattern and this new algorithm use the features which is defined at previous chapter.

Our new algorithm consists of totally 6 steps as follows:

Step1: sample one period of gait pattern, heel strike to heel strike, from the encoder data on Fig.2.

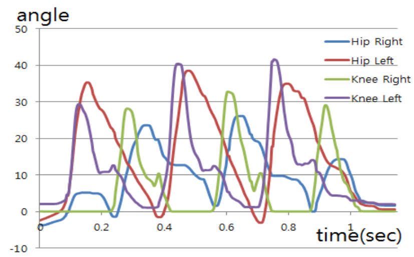


Fig.2. The raw data being acquired from the encoder system in the case of healthy person

Step2: Make the time-axis of sampled gait pattern to normalize with the range of 0 to 100.

Step3: Select peaks, both end points and points being changed rapidly on a gait pattern as the features.

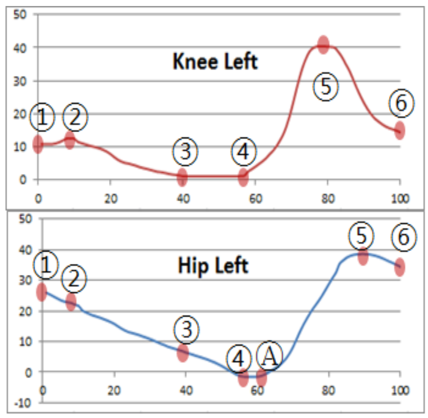


Fig.3. Feature extraction from hip and knee encoder data

Step4: Repeat step1~3 and make an average of each feature point over the sets of feature point.

Step5: Connect each averaged feature point by using spline method and prune graph out of joint movement range as shown in Fig.4

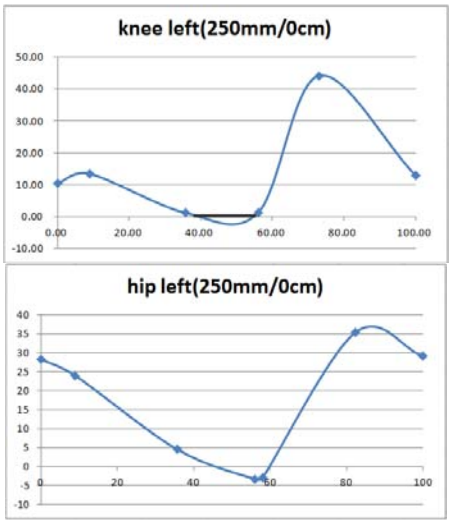


Fig.4. Gait pattern made by connection of feature points through cubic spline and correction

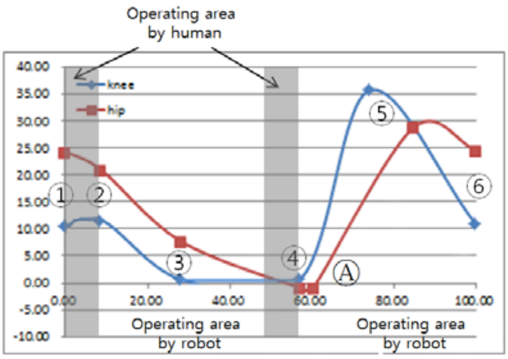


Fig.5. The gait pattern can be divided two parts: operating area by human and that by robot.

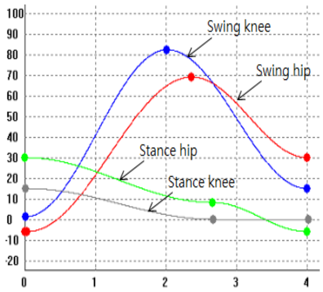


Fig.6. The DC motor input data at hip and knee joint for a stance and a swing phase respectively.

From the assumption being described at introduction, one period of gait pattern has to be divided into two parts for controlling DC motor: Fig. 5 shows these two parts that are *operating area by human* and *operating area by robot*. The operating area by human indicates the area that users shift their weight and balance themselves for next step. The operating area by robot indicates the area that all motors at joints are actually operated. The first operating area by robot in Fig.5 means the phase of stance for gait and the second operating area by robot means the phase of swing for gait. One leg is always at stance phase whenever the other is at swing phase, so the robot motions on these two phases occur at the same time for the different two legs alternately. Therefore we can capture these two phases of operating are by robot from a period of gait pattern and make them overlap as shown in Fig.6.

Step6: Finally, Correct the gait pattern for use them as DC motor input values. In other words, we need to adjust the starting point of the stance and the end point of the swing at hip and knee joint respectively for recurring use.

III. EXPERIMENTAL RESULTS

The gait pattern was generated from only 8 features if we count both end points as one because both end points are same on Fig.5. And then the speed can be varied according to the desired time value being converted from the normalized time value.

Fig.6 represents that it takes 4seconds in a swing/stance phase time while the step size is fixed at 250mm. We have experimented with our exoskeleton platform ROBIN-P1 varying its swing/stance time from 2seconds to 5seconds. We also changed the step size by varying the *step size in angle domain* that is defined as the difference between the starting angle of *swing hip* and the starting angle of *stance hip* on Fig.6. However there are more things we have to take into account because the peak angle values at hip and knee on swing phase may also have some correlation with the step size. In our experiments, ROBIN-P1 did not show natural gait pattern when we varied the *step size in angle domain* beyond 5 degree.

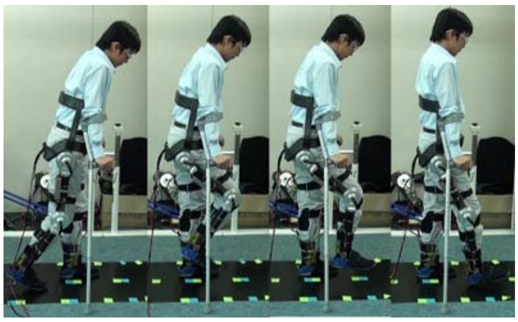


Fig.7. Results of experiment assisting gait using ROBIN-P1 with a gait pattern which is generated through feature extraction.

VI. CONCLUSION

We defined the feature in a gait pattern and described our algorithm to regenerate gait pattern using several features in Section II. Our experimental results in Section III also showed that it is possible for the ROBIN-P1 to walk not by lookup table type of control data but by a gait pattern being generated from several features in real time. This means that it is possible to change the gait parameters (speed, step size) in online manner. However, we find it necessary to analyze the correlation the features and the step size in order not to lose natural of original reference gait pattern. What gait pattern do we select as a reference gait pattern? These are for our future work.

REFERENCES

[1] Suzuki K, Kawamura Y, Hayashi T, et al. (2005), Intention-based walking support for paraplegia patient. IEEE International Conf. on Systems, Man and Cybernetics; 2005: 2707–2713.
[2] [Online] Available: http://www.argomedtec.com/
[3] I.H. Jang et al.(2010), Development of the rehabilitation robot assisting gait for spinal cord injury patients (in Korean). J. Institute of Control, Robotics and System 16(9): 860-865