Detecting Slip Perturbation during Walking from Accelerometer and Information

Akifumi Suzuki[1] , Wenwei Yu[1]

[1]*Graduate School of Medical System Engineering Department, Chiba University, Chiba, Japan*
a_suzuki@graduate.chiba-u.jp

Abstract

This research aims at the development and verification of a system that can not only recognize swing and stance phases for walking-assist but also quickly detect the occurrence of slip perturbation during walking from accelerometers and fitted on foot. A back-propagation based artificial neural network (ANN) model was employed to build pattern recognition unit that can deal with the individual variation and time-varying characteristics. Results showed that the occurrence could be detected from triple axes accelerometer information within 50 milliseconds, which could be considered as short enough for walking assist systems to response to the perturbation.

1. Introduction

It is very difficult for most walking-impaired people to cope with the perturbation such as slip, obstacles and uneven ground etc. during walking. Assist systems for the real-world environment walking, should be able to appropriately deal with the perturbation. However, most walking assist systems reported, including robotics systems [1] and those using Functional Electrical Stimulation (FES) [2] couldn't deal with the perturbation.

This research aims at the development and verification of a system that can not only recognize swing and stance phases for walking-assist but also quickly detect the occurrence of slip perturbation during walking from accelerometers and Gyro sensors fitted on foot. The identification was realized by an Artificial-Neural-Network based pattern recognition system.

2. Method

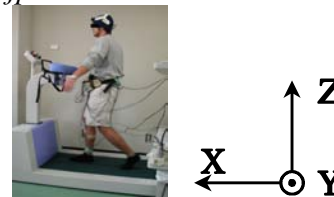### 2.1. Measurement of perturbation occurrence during walking

Fig1. Measuring system

Three 3-Axis accelerometers+gyro sensors (GYROCUBE/3A, O-navi) were fitted on ankle (Fig. 1). A/D cards (DAQ3024, NI) were used to collect all the sensor data, at a 1.6 kHz sampling rate. Perturbation to gait was generated by a split-belt (PW-21, HITACHI), for which the speed of each belt could be independently and accurately controlled from 0-3km/hr., within 270ms (200ms for PC split-belt machine communication and 70ms for speed change), which could be treated as a constant delay to control signal. The real speed was monitored using a rotary-encoder (RP-721 ONOSOKKI). A slip perturbation could be generated by slowing down one side at the moment of heel-strike. 1 male subject with no previous history of musculoskeletal or neurological disease, participated in the experiments.

2.2. Discrimination of the perturbation occurrence from normal walking

Responses to perturbation is varying with individuals and time, therefore information processing should be able to adapt to the changes. Also because, in future, the detection of the perturbation is expected to perform in an on-line manner, a back-propagation based Artificial-Neural-Network was employed.

An input vector of the ANN includes information from the accelerometers fitted on foot, concretely, current readings of 3 axes of accelerometers and their predecessors the readings of 12.5, 25.0, 37.5, 50.0 and 62.5[ms] before, respectively. It was expected that the predecessors could provide the sequential information about the walking phases. Therefore, the neuron number of input layer was 18. The neuron

number of hidden layer was 20, and that of output layer was 3.

The learning dataset contains the sensor recordings for 9 normal walking steps and 1 perturbed walking step. The test dataset for evaluation contains the sensor recordings for 50 normal walking steps and 10 perturbed walking steps.

2.3. Artificial-Neural-Network minimization

It is clear that, in order to realize a portable walking assist system, the ANN based recognition unit should be compact enough. For this reason it is very important to choose optimal size of networks for a particular task. Since, there is no theoretical approach for deciding ANN structures in the discipline, in this study we employed a practical approach based on an idea that, the connections contributing less to a generalization process should be pruned.

Concretely, when a learned network met a mis-recognized test sample, the mis-recognized test sample will be added to the learning data set to adjust the existed network. After the learning curve turned to steady again, the changes of input-middle layer weights would be calculated and the connections with smaller weight change values would be pruned. Then the error rate would be calculated again.

3. Results and Discussion

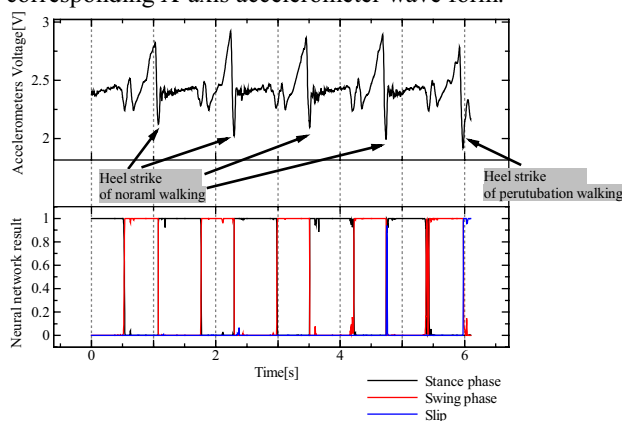Fig. 2 shows the recognition results and its corresponding X-axis accelerometer wave form.

Fig2. X-axis data and NN recognition result

Table 1. Judgment by ANN

States of walking	Success rate (18inputs)	Success rate (15inputs)	Success rate (11 inputs)
Stance phase	50/50	50/50	50/50
Swing phase	48/50	47/50	50/50
Slip	10/10	10/10	10/10

The first column of Tab. 1 shows the recognition results of 18-inputs ANN. The correct rate is high enough, which means it is sufficient for the system to detect slip perturbation and walking phases.

The mis-recognized test sample then was used to adjust the weight of the neuron network. The weight change of each input neuron was calculated by summing up the weight change of the connections between the input neuron and all middle layer neurons.

The input neurons with smaller weight changes were considered to prune. In this case, the number of neurons with a weight change value lower than 10 was 3, and lower than 12 was 7. Then the ANN will learn from scratch again, but with a pruned ANN structure. Table 2 shows the error rates tested by test samples. As shown Tab. 2, the minimized ANN over performed the initial ANN.

Table 2. Average of output error by network learn ten times flowed data unlearned (5 normal walking steps and 1 perturbed walking step data).

	18 inputs	15 inputs	11 inputs
Error rate	0.02468	0.02398	0.02181

4. Conclusion

In this study, a back-propagation based artificial neural network (ANN) model was employed to build pattern recognition unit that can recognize the walking phases and slip perturbed steps.

ANN minimization could contribute to not only the computation efficiency, but also the improvement of success rates.

In the future, the approach should be verified by dataset from different normal subjects and walking function impaired people.

5.Acknowledgements

6. References

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