A gait recognition system based on BP neural network and plantar pressure

Tengda Shi, Kaifeng Su, Linqian He, Lei Yan*

[1]*School of Technology, Beijing Forestry University, Beijing, China, 100083*

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Abstract

In order to get a faster, more effective and stable control over lower extremity exoskeleton of power assist robot, precise examination on gait information is necessary, thus it is so important to design and establish a gait recognition system with accurate detection. In this paper, a wireless in-shoe wearable plantar pressure acquisition system based on ATmega16 and 8 FSR sensors will be applied to data acquisition for the gaits which consist of standing, walking, jumping and going upstairs. And four volunteers (2 males and 2 females) will be invited in this research to collect the pressure information. The NNT of MATLAB will be applied to establish an 8-12-4 BP neural net model. The input factors come from the eight sensors of plantar pressure system, the output is gait category. Proved by a great deal of experiments, the gait recognition method proposed in this research is quite feasible.

Keywords: gait recognition, BP neural networks, plantar pressure, lower extremity exoskeleton of power assist robot

1 Introduction

1.1 RESEARCH STATUS AND APPLICATION PROSPECTS OF GAIT RECOGNITION SYSTEM

As a developing research field about the technology in recognition of biological characteristics, gait recognition [1] has become the focus of computer fans. How to obtain effective gait information and the accuracy of gait recognition have become the key points and difficulty in recent study.

Bobick [2] has determined human's characteristics of step and extensibility of legs with the aid of structured analysis method in Georgia Tech. The outcome was concluded by some experiments, which involved the problems of shadow and sunlight, because the experiments were finished indoors and outdoors. Kale [3] used the human's side profiles in binarized images as the features of images. Then for each person, they used c-means algorithm to choose a sample in a single gait cycle. In the process of recognition, the FED vector between each frame in a gait sequence and the sample was calculated and recognized by HMM. Lee [4] used seven ovals to represent different body parts in the binarized images of human's side profile. Using four characteristic values including barycenter to represent the height of the body image's barycentre. Meanwhile all 29 characteristic values were used to represent the image of a person's body side. The gait recognition was completed via the method of template matching. In Little and Boyd's [5] method, the gait recognition was achieved with the help of gait sequence images' optical frequency and phase. While Phillips [6] utilized different time-space domain template to accomplish the gait recognition. For Cunado [7], a pendulum module involved thigh and shank was established so that gait characteristics could be detected from the frequency component of the pendulum angel signal.

Gait recognition is a kind of technology that is used for detecting within a certain distance in detecting human's instinct biological characteristics like fingerprint identification and face recognition, some problems related to close contact in physics always exist. In this way, gait recognition can be applied well and has a bright future.

1.2 THE BASIC PRINCIPLES AND CHARACTERISTICS OF ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANN), also called Neural Networks(NN), is a kind of artificial bionic model based on the theory which about synaptic connections in the brain. It is made up of a great deal of neurons [8].

Neuron, the most basic unit in the neural network, plays a quite important role in the network. Different networks are made of different neurons which connects with each other in different ways, which means the structures of neural networks are also various. So they have various functions, too.

ANN has the following outstanding characteristics:

1) it can make the input sample approximate complex non-linear function relation well;

2) it has good fault-tolerant ability and robustness;

3) NN uses the paralleled distributed methodology to manipulate the input sample's information, which makes scientists can finish big-scale arithmetical operation faster.

* ***Corresponding author*** e-mail: mark_yanlei@bjfu.edu.cn

1.3. NEURAL NETWORK MODEL

BP neural network, also called Error Back Propagation Neural Network, is a kind of forward multi-layered neural network. In BP network, signals propagate forwards, while errors propagate backwards. BP network often includes input layer, hidden layer and output layer. Theoretically, it can increase the accuracy and expression ability of the network by adding hidden layers.

According to Kolmogorov Theory, a three-layer BP network can form any mapping from m-dimensions to n-dimensions, which means that just one hidden layer is enough. Such a NN can approximate any continuous function correctly [9] (Figure 1).

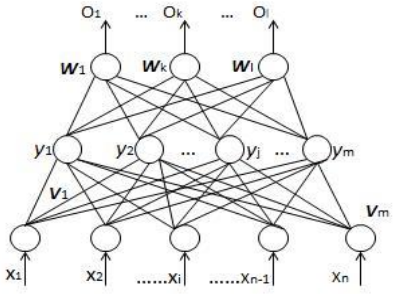

FIGURE 1 A single hidden layer of BP network model

2 BP neural network established for gait recognition

2.1 IN-SHOE WEARABLE PLANTAR PRESSURE ACQUISITION SYSTEM

Due to several outstanding characteristics which include portability, flexibility and great convenience, plantar pressure acquisition system has been one of the most important application techniques in gait recognition and has been extended to other relevant fields, such as medical testing, sport science and robotics research.

In-shoe plantar pressure acquisition system, which is able to measure plantar forces and detect gait-phases of human at the same time, has become an attractive alternative for ground mounted force platform. Researchers in this field can make more products by using it [10].

Many researchers have proposed many different numbers of force sensors to recognize the gait phase. For instance, a research group used four force sensors to identify the gait phases with a classification algorithm and has obtained good results [11], Faivre employed eight sensors in the in-shoe plantar pressure system according to the literature [12], and flexible force sensor(Tekscan Inc., USA) and FSR sensor(Interlink Electronics, USA) has been commonly used.

As we illustrated in the Figure 2, the heel, metatarsals and hallux are the main regions to sustain people's weight [13]. Thus, we designed to place four force sensors configured at the Heel, Meta 2nd, Meta 1st and Hallux for each foot to obtain plantar pressure and detect gait phase. These sensors were packaged in two pairs of insole and the insole was adhered to a pair of shoes, as shown in Figures 3 and 4.

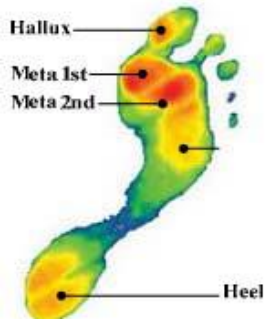

FIGURE 2 Plantar pressure distribution [14]

FIGURE3 The package of sensors in the shoes

FIGURE4 The position of sensors in insole

2.2 DATA ACQUISITION AND PROCESSING

In order to get more universal and accurate data of plantar pressure, we invited four volunteers: two females and two males to conduct the data acquisition of this experiment. The brief information of these four volunteers is shown in Table 1.

TABLE 1 General information of volunteers

Gender	Age	Height	Weight	Feet size
Female	23	167cm	55kg	39cm
Female	22	160cm	48kg	37cm
Male	20	174cm	60ke	41cm
Male	22	167cm	65kg	40cm

A network can have a plurality of output variables, in this study, there are four output variables, because of the input of numeric variables, the output is also corresponding to numerical quantity. Actually, network's output is only 0 to 1 or -1 to 1, so the desired output must

need to be normalized.

Normalization is a method of data processing by means of the network input and output limits in the [0,1] or [-1,1]. Normalization process is performed in order to avoid absolute error components that the large value is large and the small one is small, the network will just adjust the weight value of the total error, as a result, the output component that has a small share of the total error will have larger relative error. In this paper, the output of all the types of gait is normalized, thus [1,0,0,0] was chosen to represent 'standing'; [0,1,0,0] represented 'walking'; [0,0,1,0] for 'jumping' and [0,0,0,1] for 'going upstairs'.

2.3 ESTABLISH GAIT RECOGNITION SYSTEM BASED ON BP NEURAL NETWORK MODEL

The purpose of this research is to achieve information of human gait which gathered based on plantar pressure system and then use MATLAB software to simulate the BP algorithm to find the suitable BP network model to distinguish the type of gait. A total of eight input characteristic value and four output type value. After a large number of experiments, according to preparation of the train-dataset, test-dataset and design of the BP network' structure, the following three-tier network model constructed by MATLAB R2012a's BP neural network toolbox [15], a good gait recognition system was obtained in this research:

1) eight input-layer neurons;

2) output-layer nodes in the hidden layer was set to twelve according to the number of training samples and the dimension of the input and output layer nodes;

3) the dimension of the output layer equals the types of gait, four; the construction principle of the output layer is: different types of output in the corresponding position is 1 and the rest position is 0, for example, [1,0,0,0] represented 'standing', [0,1,0,0] represented 'walking', [0,0,1,1] for 'jumping' and [0,0,0,1] for 'going upstairs'.

4) logsig is selected as the network error transfer function from the input layer to the hidden layer and logsig from hidden layer to the output layer.

5) we chose Powell-Beale connection gradient BP training function 'trainlm' as the learning function;

6) The learning numbers of the network is set to 3000, the learning rate is set to 0.0005 and training objectives set to 0.004. We used an 800x8 dataset which contained 200 data from 'standing', 200 data from 'walking', 200 data from 'jumping' and 200 data from 'going upstairs' to train the network. A 400x8 data that comprised 100 data from 'standing', 100 data from 'walking', 100 data from 'jumping' and 100 data from 'going upstairs', with the accuracy of the test results and the square error value we can judge whether the types of gait can be classified.

3 The training and simulation results of BP neural network model

After the BP neural network's hidden layers, the number of neurons, the input and output layers are all determined, it is virtually certain that the network model can be simulated by programming in MATLAB R2012a(as shown in Figure 5)

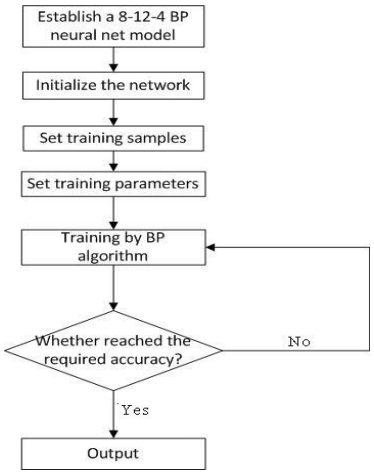

FIGURE 5 System architectures of based on BP Neural Networks of the gait recognition system

The final classification model based on BP neural network was done by the algorithm designed by this research through neural network toolbox of MATLAB. And result of final gait recognition was shown in Figure 6.

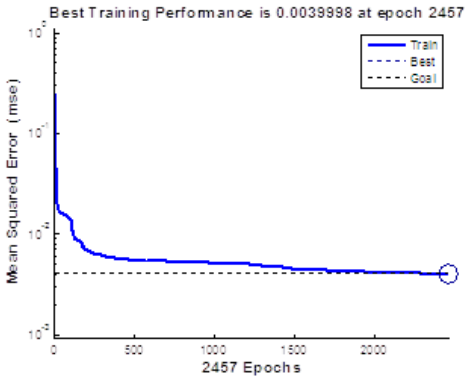

FIGURE 6 The results of training MSE

From the experimental result of the final gait recognition shown in Table 2, it can be concluded that we obtain a better gait recognition system which is based on BP neural network and plantar pressure. The accuracy of the gait recognition is more than 90% except for 'going upstairs' because of its complication among other three gaits.

TABLE 2 The result of final gait recognition

Gaits	True number of gaits	Classified number of gaits	Accuracy of the gait recognition
Standing	100	99	99%
Walking	100	90	90%
Jumping	100	91	91%
Going upstairs	100	85	85%

4 Discussions and conclusions

From the results of the final experiment, we obtain a high recognition rata as shown in the Table2. Consequently, using in-shoe wearable plantar pressure acquisition system to collect gait information is a good method for recognizing the types of gait with the function of classification of BP neural network. It can provide much more accurate gait information of human for the lower extremity exoskeleton of power assist robot, making the robot provide better services to help the human body.

Although we get a high recognition rate from the results of the final experiment, this is just a preliminary study, there are still many issues that need further study, such as finding a better algorithm to improve the recognition accuracy of 'going up-stairs', studying more complicate gait and so on. Thereby, there are lots of works to do to improve the accuracy rate of gain recognition.

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Authors

Tengda Shi, born in June, 1993, Beijing Forestry University, Beijing, P.R. China

Current position, grades: a senior student (BSc) in Electrical Engineering at Beijing Forestry University, China.
Scientific interests: image processing, pattern recognition, computer simulation.
Publications: more than 3 papers.
Experience: teaching experience of 2 years, 3 scientific research projects.

Kaifeng Su, born in October, 1992, Beijing Forestry University, Beijing, P.R. China

Current position, grades: A senior student (BSc) in Electrical Engineering at Beijing Forestry University, China.
Scientific interests: pattern recognition.
Publications: more than 1 paper.
Experience: teaching experience of 2 years, 3 scientific research projects.

Linqian He, born in April, 1995, Beijing Forestry University, Beijing, P.R. China

Current position, grades: A sophomore student (Bsc) in Electrical Engineering at Beijing Forestry University, China.
Scientific interests: pattern recognition.
Experience: teaching experience of 1 years, 3 scientific research projects.

Lei Yan, born in June, 1979, Beijing Forestry University, Beijing, P.R. China

Current position, grades: Associate Professor of School of Technology, Beijing Forestry University, China.
University studies: M.Sc. at Jilin University in China. PhD at Kyungpook National University in Korea.
Scientific interests: development of automatic control systems, image processing, pattern recognition.
Publications: more than 40 papers.