2006 IEEE International Conference on
Systems, Man, and Cybernetics
October 8-11, 2006, Taipei, Taiwan

Application of Neural Network to Identification of Young Females' Body Type

Feng-yuan Zou, Xiao-jun Ding, Shu-jun Zhang, Li-jun Wang, Yong-hong Zhang

***Abstract*— — MTM (Made to Measure) is a new manufacturing trend in which mass-market products (e.g. apparel) are quickly modified one at a time based on customers' needs. It is an effective competing strategy to maximize customers' satisfaction and minimizing inventory costs. To satisfy the need for body type analysis in MTM, an artificial neural network BP algorithm is used to simulate the experience and technology of fashion designers and then a model is established to identify body type. The model, which realizes auto-mapping from body data to specific estimation, has high precision. The result indicates that the model satisfies the need for body analysis in MTM.**

Ⅰ. INTRODUCTION

In the customer centered era, customers are pursuing customized garments and longing for individualized garments which fit for their body form and satisfy their aesthetic need. The developmental trend of garment industry is fashion and customization, and the require for comfort and high quality makes MTM a necessity, which make it possible to apply MTM in garment industry [1]. So far, MTM has been the newest garment producing mode and is the developmental trend of garment manufacture in 21st century.

Body type analysis plays an important role in MTM. It is not only one of the key technologies to realize MTM, but also an important procedure to combine 3D body scanner with digital garment production. Body type analysis means to analyze the data in Anthropometrical Database, then acquire parameters by computing the data based on the statistical theories, finally classify human body characteristics using clustering analysis. It provides advantageous help to the mapping from body form to clothing size and other application of MTM [2].

The traditional method of body type analysis is to judge the body character according to the experience of fashion designers factitiously. While this method is "one-to-one" and time wasteful. So it is disadvantageous to mass customization and long distance MTM.

It is useful to describe body type correctly to designers. Because it provides designers with an abundance of information about the body type, enables designers to transfer feelings to ration judgment and makes the structure more reasonable [3].

But the description of body character involves the relationship between data and specific judgment, which is hard to depict by traditional mathematic methods because of the non-linear relation among parameters and the existence of multi influencing factors. So we adopt artificial network which is the very method to resolve this kind of problems. By checking the model through actual body measurements, the method in this paper can fully satisfy the need of body type analysis in MTM.

The rest of the paper organized as follows: Section 2 describes the general structure of the BP network model; Section 3 explains the data source and classification; then, an empirical analysis is shown in section 4, and finally some concluding remarks are drawn from section 5.

Ⅱ. ARTIFICIAL NEURAL NETWORK

Artificial neural network is suitable for system with handled problem because of uncertainty, inaccuracy, etc, it can shine upon complicated input-output relation [4], [5].The Back Propagation Algorithm (notes by abridging for BP) is a basic method to train artificial neural network, it is already widely used now. BP neural network has been applied to the area of price of the future, control, forecast etc and has made good result. BP network is made up of forward propagate and back propagation two parts, its structure as Fig.1 shows.

Manuscript received March 21, 2006. This paper is supported by Hang Zhou Science Bureau named The Female Body Data's Establish &Application in Hangzhou and the Personnel Department of Zhejiang Province named Research of The Human Body Identification and Character Parameters Based on Neural Network

Feng-yuan Zou is with Faculty of College of Fashion and Art, Zhejiang Sci-Tech University, Hangzhou, 310018, China. zfy166@hotmail.com.

Xiao-jun Ding is with Graduate Student of College of Fashion and Art, Zhejiang Sci-Tech University, Hangzhou, 310018, China. dingxj_tina@hotmail.com

Shu-jun Zhang is with Graduate Student of College of Fashion and Art, Zhejiang Sci-Tech University, Hangzhou, 310018, China. Zhangshujun313@126.com

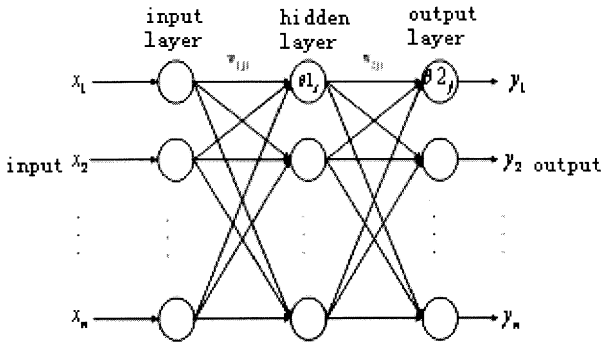

Figure.1 Structure of BP network

There is one layer or more layers besides the inputting node in the network, the same layer nodes do not have any coupling. That means the network with deviation and at least one S type imply layer adding one linear output layer can approach any rational function[6],[7].

III. PREDICITION MODEL OF HUMAN BODY ANALYSIS DEVELOPMENT

A. Analysis on Body Characteristic Parts

According to garment pattern design and the experience of fashion designers, there are more than 80 geometric characteristic sizes [8],[9]. Among them the following four parts, bust shape, side shape, hips shape and abdomen shape can reflect the most of the information about the body form, and are also the most important geometric characters of human body model [10],[11].

The breast is the main factor influencing bust shape. Its size, shape and height directly affect breast dart design of the front piece.

The side part can reflect information which the front part and back part can not reflect. For example, vertical section body form curve can clearly reflect whether the body is prominent bust, bend back or not. Bust and back will influence the length of front centerline and back length, and then result in the changes of patterns.

The hip part is an important part in the research on the fitting of the lower part. The angle from back waist to back hips is a parameter to design back rise. It can reflect the raise shape of hips, the fuller the hips, the larger the angle, and the thinner the hips, the smaller the angle.

The abdomen part influences the waist dart. It is shown that the abdomen shape plays a more important part in the body form. It is easy to accumulate fat for abdomen, which will cause the change of the front of the lower part [12].

Summing up, we get the parameters depicting women's body form as Tab.1shows. And this demonstrates the multi-dimension of human body.

Tab.1 Parameters and Description of the Parts

	Parameters	Description
Bust	under bust slope angle, front neck to breast angle, side neck to breast/ breast to waist, bust to bust /bust front, bust width/bust thickness, bust full	flat(R1) standard(R2) full(R3)
Side	back bend index, the angle from shoulder blade to back neck, the angle from shoulder blade to back waist, Under bust slope angle, Front neck to breast angle	back bend(C1) standard(C2) bust prominent (C3)
Hip	The angle from back waist to back hips, hips full, hips thickness/hips length	flat (T1) standard(T2) full (T3)
Abdomen	the angle of abdomen prominence, waist full, abdomen full, waist length	standard(F1) prominent (F2)

B. Body Type Identification Method Based on BP Algorithm

Because garments enterprises haven't analyzed the target's body form, they always produce "safe" garments, which results that customers can not buy garments fitting their body form. Fully analysis on body form enables people to acquire more information when they are tailoring and transfer sensibility recognition to logos evaluation. This rationalizes the formulation of data.

Therefore, if we can simulate and reconstruct the fashion designers' experience and arrange the proportion of every body form by computer, the designers' burden will be lessened. As the neural network is able to simulate the function of human brain cells, has strong memory and study capacity and can fully approximate the complicated non-linear relation, artificial neural network BP algorithm is adopted to learn and simulate designers' non-linear experience. In this way, we can determine the system category to be developed and garment production using the results of body form analysis.

In this thesis four sub-neural networks are constituted on the basis of bust shape, side shape, hips shape and abdomen shape and their optimized network structures are acquired. These sub-networks are then re-combined via a linking process forming a combined network, which has the ability to solve the entire problem.

To explain how to design a neural network, we take the classification of bust shape as an example.

1) Input and Output: Based on the analysis on human body form character and fully considering the need of garment pattern design, we can use the parameters which in Tab.1 as the input of the neural network, they are: the under bust slope angle, the angle from front neck to bust, side neck

to bust/bust to waist, bust to bust /bust front, bust width/bust thickness, bust full. 10 experts are asked to give semantic description of the body form and their judgments "flat", "standard" and "full" (the "description" in Tab.1) are regarded as output vectors.

2) Ascertain the collection of training samples: The performance of the neural network is closely related to the training samples, so it is very important to select appropriate number and reliable samples. In this experiment, we choose 350 young women age from 18 to 35, average height 160.55cm, average weight 50.5kg and average age 23. Equipment: [TC] 2 3D body scanner made in American, the revised altimeter and weight scale and so on.

First, the 350 young women's bodies are scanned by 3D body scanner. Then, 10 experts score the parts. The data of the 350 individuals' bodies are made as input and the corresponding description as output, so the training sample collection is got. Finally, 300 of them are regarded as training samples and 50 as testing samples.

Because sigmoid function is affected by saturation phenomenon, the data are normalized in [-1 ,1].

The normalization formula is

$$x_i' = 2 * \frac{x_i - \min\{x_i\}}{\max\{x_i\} - \min\{x_i\}} - 1 \qquad (1)$$

(x_i: the original data of index variables.

max $\{x_i\}$: the maximum of the same index data.

min $\{x_i\}$: the minimum of the same index data.)

In the process of training, there are 3 categories of output in every training sample, which are 1, 2, 3. Accordingly, their goal outputs are [+1,-1,-1], [-1,+1,-1], [-1,-1,+1]. And we make the category corresponding to the maximal output as the category for classifying.

IV. EXPERIMENT

A. Model Parameter

The network structure as Fig.1 is adopted; and because the two parameters "under bust slope angle" and "front neck to breast angle" of the bust part are the same as the two in the side part, so the number of input-layer nodes is 16 and the number of output-layer nodes is 11.

By testing every parameter, we know when Learning ration (Lr) =0.05, the maximal iterative steps (epochs) =100000, goal precision(goal)=le-2, experiment times(r)=20, the error index get to its optimization. Therefore, the neural network model structure of bust shape is 6:10:3. This network structure refers to there are 6 input parameters, and there are 10 hidden nerve cells and 3 output nodes on the first layer.

B. Experimental Research on the Other Parts

Similar to the identification of the bust shape, we test the other parts, including the side part, the hips part and the abdomen part.

Accordingly, to the side part, we adopt back bend index, the angle from shoulder blade to back neck, the angle from shoulder blade to back waist, the angle from breast to under bust and the angle from front neck to breast as input vectors. And 3 classes are got according to the experts' judgments, which are "back bend", "standard" and "bust prominent". And we normalized the input and output parameters in [-1, 1].We adopt 3 output nodes, and get their goal outputs [+1,-1,-1], [-1,+1,-1], [-1,-1,+1].

To the hips shape, we make the angle from back waist to back hips, hips width/hips thickness, hips full as input vectors. And according to the experts' judgments 3 classes are got, which are "flat", "standard" and "full". And we normalized the input and output parameters in [-1, 1].We adopt 3 output nodes, and get their goal outputs [+1,-1,-1], [-1,+1,-1], [-1,-1,+1].

To the abdomen shape, we regard the angle of back abdomen prominence, waist full, abdomen full, and waist length as input vectors. And according to the experts' judgments we get 2 classes, they are "standard" and "abdomen prominence". And we normalized the input and output parameters in [-1, 1]. We adopt 1 output node, and get their goal outputs {+1,-1}.

According to the above method to ascertain network, there are 350 samples every single part. 300 of them are made as training samples and 50 of them as testing samples. After repeated tests, we select the neural network models whose structures fit the producing in clothing factories most, and the models have been applied to garment producing and the result shows the model works well. The optimized structures see Tab.2. The three numbers in the network structure separately stands for the number of input layer nodes, hidden layer nodes and output layer nodes.

Tab.2 The Network Structure of Separate Part

	Network structure	Success rate in training sample (%)	Success rate in testing sample (%)
Bust	6:10:3	97.6%	92.0%
Side	5:6:3	97.9%	85.7%
Hip	3:6:3	98.7%	92.0%
Abdomen	4:5:2	98.2%	91.9%

From Tab.2 we know that the average precisions of training sample and testing sample of the four parts are above 85%. The precision of bust shape, hip and abdomen is over 90%, which indicates fine prediction. Former researches have demonstrated that to make the network learn more knowledge, it needs as more training samples as possible for

common precision models, but it's enough for actual application if the error is within 10%. The following two aspects cause the lower precision of the side shape. First, the 3D body scanner often makes mistakes when looking for the neck back, and the side shape is reflected by Neck to Waist-Front and Neck to Waist-Back, these cause the input samples incorrect relatively. Second, the training samples are not adequate. So in further researches, we should improve the measuring method and BP neural network to reduce the error.

C. *Body Type Identification Method based on BP Algorithm*

As mentioned above, four sub network models to four local parts have been established. But if we identify them separately, the result isn't very intuitionistic and doesn't fit for the emergent response mechanism, either. So in this chapter, the four sub networks are combined and a neural network system forms which can comprehensively reflect body type identification. So enterprises can find out the body type which has the largest coverage and have guidance for production.

There are 350 samples in this experiment and they are also divided into two groups, 300 of them as training samples and 50 as testing samples. We adopt one hidden layer because one hidden layer is enough to give birth to satisfying results for usual nonlinear mapping [13].

First, we make the sizes of 16 characteristic parts as input parameters (see Tab.1). Then the non-linear mapping relation between them is studied.

Secondly, the outputs of the four sub networks are connected, thus, a 10D vector is acquired. Every three dimensions stand for the judgment of a part. For example, we suppose a body form whose bust shape is standard, side shape standard, hips shape full and abdomen standard, the goal output vector is [-1,1,-1,-1,1,-1,-1,-1,1,-1]. Similarly, to certain part's category, the category corresponding to the maximal output is made as the category for classifying, and finally the four outputs are colligated as the final result.

Thirdly, the testing samples and the output of neural network are compared. By repeated tests, we find that when lr=0.05, epochs=10^5, goal=le-2, r=20, the error index get to its optimization. Therefore, the neural network model structure of bust shape is 16:20:12. The results see Tab.3.

Tab.3 The BP Network Structure of Human Body Identification

Network Structure	16:20:12
Size of testing samples	50
Number of training sample	300
Square error sum	0.006
Success rate in training sample (%)	89.5%
Success rate in testing sample (%)	82.6%

From Tab.3 we know that the number of error sub items in comprehensive nerve cell network is more than the summation of the number of error of the four sub networks. This is because the performance of comprehensive nerve cell network is worse than that of sub networks. But the difference is small. Because the error sub items belong to different persons, it's reasonable that the error number is big relatively. So to get better results and for convenient, we usually transfer a network model of multi output to several models of one output.

In this paper, a new product size mark is put forward: "size + body form factor + part character factor". For example, "160/84A+R2C3T3F2" means the apparel of this label is fit for customers whose whole body is relatively slim, bust shape standard, back shape bend, hips relatively full and abdomen relatively protuberant.

Obviously, the revised garment mark shows the figure type more clearly, which fully describes the need of body form. Firstly, compartmentalization of systems enables enterprises to make clear how to develop new products, e.g. enterprises can develop the categories which have great market potential and less competition.

Secondly, compartmentalization of systems provides customers criterion for purchasing apparel. Customers will have more choices, they can choose garments whose size, body type are fit for their body. Vice versa, garments of certain size are fit for corresponding individuals whose height and body form match it. This method not only saves customers' fitting time, but also convenient for internet shopping.

V. CONCLUSIONS AND FUTURE WORKS

A. *Conclusions*

1) The research in this paper demonstrates the feasibility of artificial neural network applied to body type classification and prediction. Four sub neural networks are established aimed at bust shape, side shape, hips shape and abdomen shape. The experiment results demonstrate the models are precise (see Tab.1). The models have been applied to garment producing and the result shows the models have a good effect on the garment producing.

2) In this paper, a new product size mark was put forward: "size + body form factor + part character factor". The revised garment mark can show the body form more clearly and fully describes the need of body form.

3) As long as we find out the factors influencing figure characteristic and enough samples to be learned by the network, we can make accurate and applied evaluation on body type, and optimize the index. This is significant to garment enterprises because it provides them with basis to arrange producing garment size reasonably.

This paper provides powerful data support to the mapping between body form and garment size and solves one of the key technologies to realize MTM. The body type analysis algorithm in this paper satisfies the need of body type analysis; it will promote the realization of MTM in our country.

B. Future Works

To improve the arithmetic speed and the veracity, the neural network model in the system need to be improved on. First, we need to improve the measuring methods to reduce error. Second, more samples are need to make the model have more extensive applications. Third, we can combine genetic algorithm with neural network, or study on the parameter setting further.

VI. ACKNOWLEDGEMENTS

The paper is supported by Hang Zhou Science Bureau named The Female Body Data's Establish &Application in Hangzhou, and also supported by the Personnel Department of Zhejiang Province named Research of The Human Body Identification and Character Parameters Based on Neural Network. The authors would like to thank the 10 experts for their contributions to this project.

REFERENCES

[1] Michael T.Fralix.(2001). From Mass Production To Mass Customization. Journal of Textiles and Apparel, Technology and Management, 2, Pp.1-13.

[2] Karla Simmons, Cynthia.L. (2004).Female Figure Identification Technique (FFIT) For Apparel. Part I: Describing Female Shapes. Journal of Textiles and Apparel, Technology and Management, 4, Pp.1-16.

[3] WANG Hua-e. Research on body form parameters of women's trunk. Beijing Textile Journal.2005, 26(5):Pp.59-61.

[4] Alfuhaid A S. Cascaded Artificial Neural Network For Short-Term Load Forecasting[J]. Ieee Trans On Power Systems, Volum:2, Issue:111997,Pp.1524.

[5] Kim Kwang-Ho, Youn Hyoung-sun,Et Al. Short-Term Load Forecasting For Special Days In Anomaly Load Conditions Using Neural Networks An Fuzzy Inference Method[J].Ieee Trans On Power Systems,Volume:15,Issue:2,2000.

[6] Lu Jian-Chang, Niu Dong-Xiao, Jia Zheng-Yuan. A Study Of Short-Term Load Forecasting Based On Arima-Ann, Proceedings of The Third International Conference On Machine Learning And Cybernetics,Volume:5,Issue:7,August,2004,Pp.3183-3187.

[7] Park D C, Ei-Sharkawi M A, Marks R J Li Et AL. Electric Load Forecasting Using An Artificial Neural Network[J]. Ieee Transactions On Power Systems, Volume: 6, Issue: 2, 1991.Pp.442-449.

[8] Self.(2000,March). The best workout for you body type. Self.22 (3), Pp.65.

[9] Tsang, B., Chan,C.K.&Taylor,G.(2000). Kin anthropometry: Study of the physique of disciplined personnel. International Journal of Clothing Science and Technology, 12(2).

[10] LePechoux,B.(1998,September).Standard sizing and fit testing applied to women's hosiery. Unpublished Doctoral A1 requirement paper, North Carolina State University, College of Textiles.

[11] Tamburrino,N.(1992,April).Apparel sizing issues-Part1. Bobbin. 33(8), Pp.44-46.

[12] ZHANG Zu-fang,DAI Wei. Study on Characteristic Parameters on Female Torso Shape. 2004 Shanghai International Fashion Culture Festival. Pp.180-181,189.

[13] LyerMS. Rhinehart RR(1999). A Method to Determine the Required Number of Neural-Network Training Repetitions. IEEE TR Neural Networks, 10,Pp.427-432.