

Using Gray Relational and Artificial Neural Network in Insole Design and Development for Diabetes

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Abstract

The purpose of this research is to design Insole for the diabetic patients. Using the multiplex system analysis, it compares the foot pressure data of 20 testers (Including a Diabetic Patient) plus insole measurement with six different materials and shapes to obtain the best diabetic shoes. In addition to the detailed discussion of the application of various methods in this unit, the questionnaire is also used. Based on these, the biomechanical experiments are used between patients and healthy people to prove the theory of this method's feasibility.

Taking The “Comfort Rating” of diabetics is the research direction. General products of clinically-used foot treatment insoles are used to design a “Grey Relational” assessment model which is based on foot pressure measurement as the precondition. The model used is to find the most relevant insoles and foot shapes as practicing samples for “Artificial Neural Network (ANN)”. Through multiple iteration calculations and automatic grouping of the data input the most suitable patient insole pattern will be found from the samples. Then, the selected pathological insole as well as its design features are to be analyzed and discussed in detail for subsequent research, development and design.

Keywords: Diabetic Insole; Design Feature Foot Pressure Measurement; Grey Relational; Neural Networks

Introduction

According to the report issued by the World Health Organization (WHO) in 2016, the number of patients has tripled from 1980 to 2014, up to 4.22 billion people. In addition, according to the International Diabetes Federation (IDF), the global medical cost of diabetes 2017 was about 0,7 trillion dollars, accounting for 12% of global medical expenditure. It is estimated that it will reach 0,9 trillion dollars in 2040. Boulton [1] believes that diabetic patients account for approximately 50% of all non-traumatic lower extremity amputations, Gordois [2] study shows that diabetic foot ulcers are caused by neuropathy or vascular ischemia. Among them, about 65% of foot ulcers are caused by neuropathy. From these literatures, we know that foot ulcers not only affect the quality of life of patients, but their pathogenesis often leads to a regrettable outcome. The prevention of foot ulcers has become a vital issue today [3].

About 10% of people with diabetes who suffer ulcers during illness are caused by increased pressure in the shoes. Armstrong,

[4], in its study indicates that wearing a specific design of the footwear, the patient's worsened condition can be reduced during the follow-up care. Maciejewski, et al, [5], from the pathological literature, it stresses the importance of wearing a therapeutic shoe to prevent ulcers. Knowing that footwear is the main prevention; the content specifically mentions that the design of the relevant medical footwear is one of important Influencing factors.

All studies indicate that wearing a pair of comfortable insoles is important to prevent diabetic patients from getting worse. The special diabetes insole can reduce the foot pressure to a certain extent and prevent the wear of foot skin. It is also designed to provide good foot support and improve the patient's balancing capability while walking.

To design shoes for diabetic patients, the first thing is to avoid the risk of getting foot ulcers. The rising foot pressure may be caused by improper design of the inner space of the shoe and improper selection of materials. The increase in temperature and humidity may easily lead to ulcer. Therefore, the main goal of designing shoes for diabetic patients are to reduce the pressure on the sole and create a comfortable interior space [6]. Although the CAD system for manufacturing models of shoes has been developed,

two major shortcomings remain which limit the applicability and production of footwear. First, they do not have any follow-up system to organize and support the data of diabetic patients. In other words, there is no database for patients. Secondly, there is no standard measurement system to follow so the risk of ulceration can be reduced. Considering the factors of normal foot care, medical expenses and wearing comfort, this study is proposing an intelligent analysis system to find insole design features for diabetic patients. Based on patient foot pressure data and shoe samples, specific comfort fits are calculated and analyzed so a patient can find a suitable insole and reduce the risk of ulcers.

Research Limit

Based on the study of Chapman [7], it is recommended that the feet of patients with neuropathy need to travel slowly and exercise regularly. It has been known that patients with diabetes can't walk fast, so the angle of heel movement and toe elasticity measurement is not to be discussed in this study. Since, the foot pressure measurement experiment is also based on the fixed-point standing measurement, therefore, the walking test is not to be conducted. In addition to Dynamic pressure measurement, because the sensitivity of the machine measurement gasket has its limitations, the length of the data transmission line has its limitations, and the lengthy experiment time may affect patients' psychological reaction, and the gait measurement and analysis are not available, the correct gait measurement and analysis cannot be acquired, so it is not being used [8].

The diabetic patients whose lesions are not developed are selected in this study. Based on the Wagner classification, one patient with minor symptoms can be defined as grade 0 and is the best candidate to be tested. Those people with grade above 0 may not be tested because they may already have ulcers. The adoption of this method has the following reasons: the needs of patient's care; the cost of pathological footwear; and most importantly, the concept of "prevention is better than cure" [9].

Diabetic patients often use their own subjective feeling to decide if the insoles are comfortable. From the concept of "Human Factors Engineering" it may be adequate. But from scientific viewpoints this kind of medical treatment is not enough for patients. The poor blood circulation of limbs caused by diabetes which affects the sensitivities of skin cannot be used to judge the fitness although the shoes may be felt comfortable by patients. Therefore, a comfortable and correct insole requires an objective and scientific way to correct all problems. This is another reason why questionnaire about comfort answered by patients should be avoided. Measurement seems to be the solution.

Methods

In this study, the Grey Relational evaluation model was de-

signed based on the "Comfort of Diabetic Patients" to find out the most relevant insole style in the foot and insole samples. As the most suitable insole option, this result will be used as a follow-up. The training of the Artificial Neural Network (ANN) is evidenced. The research process is described as (Figure 1).

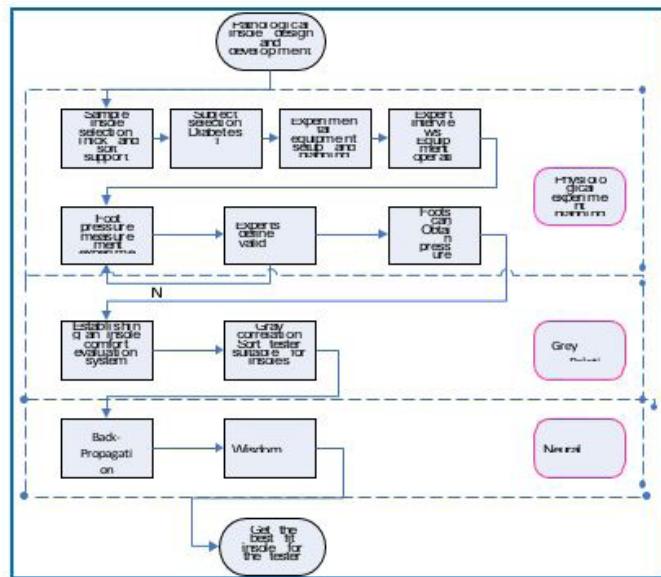


Figure 1: Pathological insole design research process.

Experimental Design: Neural Network Learning Parameter Design

In order to verify the learning of "Back-Propagation Neural Network", the Matlab program simulation is performed for the recognition and grouping problem of 2D graphics according to the inverse transfer learning algorithm of "the Gradient Steepest Descent Method". First prepared a set of five different original patterns (Figure 2), converted to grayscale patterns (Cat, Squirrel, Rabbit, Chicken, Bird) through Mat lab calculations, and used these samples as a network reference. For the sample, each pattern is defined by the grayscale value of the 12×12 matrix, and the original grayscale pattern is shown in (Figure 3). The grayscale value is a real value between 0 and 1, when the grayscale value is 0, it is defined as white; the grayscale value is 1, it is defined as black. In order to facilitate the calculation of network learning, we also adjust each pattern to a 144×1 -line vector pattern.



Figure 2: Original learning sample pattern

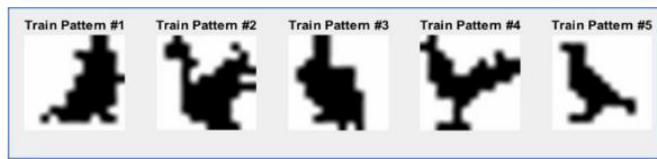


Figure 3: Original learning sample grayscale pattern.

In order to verify the learning effect of the Back-Propagation Neural Network, under the noise data, the R2010b version of the Artificial Neural Network Toolbox (ANNT) is used, and the built-in Trained (Gradient Descent Backpropagation with Adaptive Learning Rate) The learning algorithm is used for learning verification. The network architecture, as shown in (Figure 4),

$$N = \frac{1}{2}(N_{in} + N_{out}) \quad (1)$$

(2) N is suggested neurons, N_{in} is the neurons in the input layer, N_{out} is the number of neurons in the output layer.

In this example, we use the formula (2) to calculate the number of neurons in the Back-Propagation Neural Network, which is $N = \sqrt{(144 \times 5)} N=27$, and the number of hidden layer neurons is set to 27. The neural network related learning parameters are set as follows: Training parameter (Table 1).

Training Epochs(Epochs)	1000
Neurons	27
Noise	20
Performance Goal(Goal)	0
Learning Rate(Lr)	0.01
Momentum Constant(Mc)	0.9
Minimum Performance Gradient	1.00e-10
Training Pattern Extend(Test)	100

Table 1: Neural network related learning parameter.

Design Element: Pathological insole comfort design insole design, most of them use image capturing equipment to obtain the three-dimensional contour data of the foot, and then make partial modifications according to the individual's physiological condition by professional technicians or doctors. According to the modern point of view, the above design pattern is more subjective and subjective, that is, experience. As a benchmark for the evaluation of design decisions, the law is biased. A pair of comfortable diabetes insoles need to have the following features and needs:

(1). wearing fit and even distribution pressure. (2). Decompression and soothing for local pain (3). adjust the stability of the body to static posture and movement. (4). The pressure can be balanced (5) insole material and angle adjustment to achieve the shock absorption effect. (6). The medical expenses required are lower and safer than other treatments. (7). Can alleviate sore problems.

contains an input layer, a hidden layer and an output layer. The number of neurons included in the input layer and the output layer is determined according to the input and output pairs of the learning, regarding the number of hidden layer neurons, that the formula (1) and formula (2) can be used to determine.

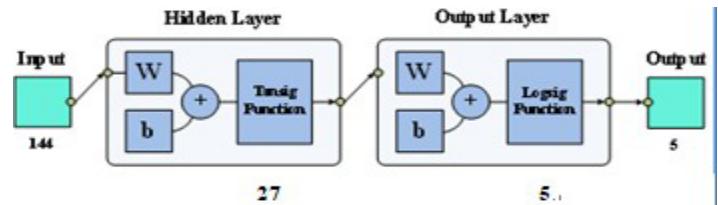


Figure 4: Network architecture diagram (verification).

$$N = \sqrt{N_{in} \times N_{out}} \quad (2)$$

Research Method Execution

In view of the above-mentioned medical insole design requirements, the physiological foot pressure is used as the basis for measurement, and an objective comfort evaluation model is established to replace the traditional expert rule to calculate the insole comfort. To explore the comfort correlation between the patient's foot and the "insole"

This study addresses the needs of the research topic and divides method execution into the following three steps.

Biomechanical Experiment Planning

The biomechanical experiment aims to explore the type of insole used by the tester's foot, which can achieve the pressure of a certain dispersion and reduction in a certain block, and use it as a case for the subsequent evaluation of the comfort of gray theory.

Physiological Experiment Variables and Design Planning

This experiment mainly analyses the comfort evaluation of the tester's foot pressure, in order to find the insole form suitable for the tester. The total number of experimental samples is 20, including one primary diabetic patient, the experimental object is male over 20 years old, and the weight is not limited. The sample number is from A-U (including R patients with diabetes). The experimental materials are commercially available male full-pad insoles, totalling 6 models, with the main function of reducing the foot pressure, which can be tailored according to the foot type of self-cutting, increase the wearing comfort, and avoid the pain position to be hurt again, it is classified as thick, thin, soft, hard, and supported by the upper and lower arches. In order to assort the limitations and accuracy of the foot pressure test pad, the size is the suitable for those who wear the (American) specifications 7 to 11, The sample characteristics are as follows (Table 2) (Table 3).

Insole number	Image file	Description
Insole No.1 Thin plat type (20HV)		Thin soft insole: rubber Surface, latex material Bottom layer, comfortable to wear, it is too thin and easy to fray,
Insole No.2 Thick plate type (36HV)		Thick and Medium hardness insole: rubber Surface, latex material Bottom layer. Thicker can change the contact surface with the foot shape,
Insole No.3 Thickened under the arch (48HV)		12.5mm lower Half moon type of the arch supports the soft insole and provides a hidden arch support. leather Surface, foam Bottom layer
Insole No.4 Thickened on the arch (28HV)		13.5mm upper half moon type of the arch support, directly attached to the foot, can provide support for the arch, Elastic woven fabric& rubber Surface Polyurethane Bottom layer,
Insole No.5 Thickened under the arch (36HV)		Semi-rigid insole: The material is made of rubber and polyethylene, and the midsole provides a hard PE arch support with a thickness of 12.5 mm..
Insole No.6 Special thickening under the arch (42HV)		Semi-rigid insole: The material is made of rubber and polyethylene, and the midsole provides a hard PE arch support of 17 mm thickness.

Table 2: Comparison table of Sample insole features.

The experimental site is located in Taiwan Taichung Shoes and Sports Leisure Technology R&D Center (Shoe Technology Centre). The foot mechanics experimental equipment of this study is Tek-Scan contact pressure measurement pad. The hardness measurement data is measured by the Shore C Hardness of six times. Using the German GEMMETER measurement.

Insole number	Foot thickness (mm)	Arch thickness (mm)	Heel thickness (mm)
InsoleNo1	5.2	5.2	5.2
InsoleNo2	9.5	14	14.5
InsoleNo3	6.5	12.5	14.5
InsoleNo4	6	13.5	11.5
InsoleNo5	5	12.5	11.5

InsoleNo6	5	17	11,5
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Table 3: Sample insole partition thickness.

Experimental assumptions

According to the literature, when the plantar contact area changes, the foot pressure will reflect different data, so this experiment assumes that different styles of insole style will affect the distribution of interface pressure, and the insole style is closer to the foot type, the total pressure and peak value will also decrease, and the contact area will increase. Praet [10] believes that the height of the arch is linear with the pressure of the foot, while the thickness of the insole increases and the peak pressure of the heel also decreases. According to the theory, the thickness of the insole No. 2 selected in this experiment is increased, the No. 3 insole has a thickened arch function, and the No. 5 insole particularly strengthens the insole arch and heel thickness and hardness.

Most scholars have proposed The influence of the foot pressure parameters also includes the area of contact. When the plantar contact area changes, the foot pressure will reflect different data. All experiments are carried out using a full-touch insole. It has a considerable effect on reducing foot pressure. Therefore, this experiment uses the full-foot touch insole, and the half-type insole is not used. The literature also proposed that the peak pressure of the general foot should fall in the palm area and near the heel. The diabetic patients are more obvious. This experiment also sets the same research hypothesis, so that the follow-up results can be used as a verification and discussion [11].

Experimental Limitations

The number of full-pressure test is more than 4 times, but in the end, only the complete 4 of the image files are adopted, and the average value is calculated (the shoe technique expert has precluded the foot pressure type with large defect). The measurement of the experiment only uses the right foot. Due to research constraints, and most of the customary are right feet, that is the subject of discussion. Although this effect has lost effectiveness, the strict requirements and consistency of the measurement posture can make up for its lack.

Experimental Procedure

The experiment consists in measuring the pressure distribution of the tester's static stepping on different styles of insoles, obtain five pressure parameter data: Pressure Peak (PP), Pressure-Time Integral Value (PTI), contact area, Power Peak (PF), Power-Time Integral Value Data (FTI), total Measured more than 4 times. The measurement method adopts a one-way static measurement,

and the insole is fixedly placed in a pre-planned position for the tester to measure in the bare foot state, in order to express in a clear and simple manner, the experiment is performed by computer image type. (Figure 5a,b).

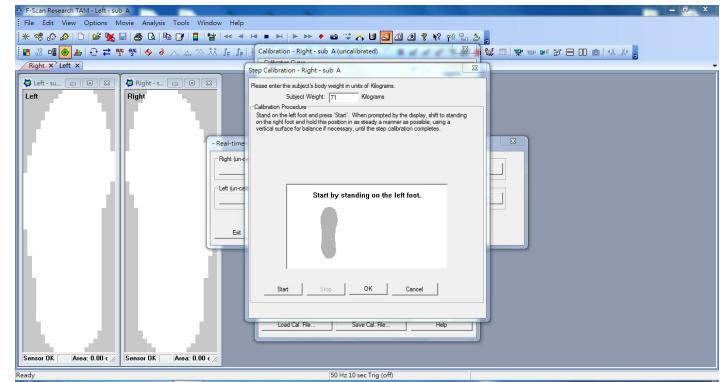


Figure 5a: Measurement start and correction.

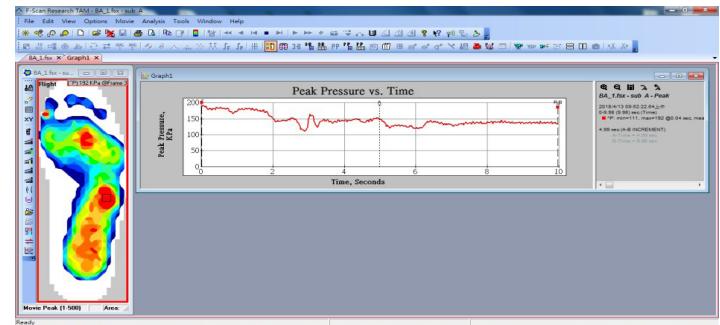


Figure 5b: Foot pressure peak PP curve.

The various foot pressure measurements and min and max data are in the (right window) and the graph is in the (middle window) foot pressure map (left window) as follows. The pressure type of each foot type and the insole, through the expert experience, the pressure pattern of 4 times or more is selected, the bare-foot measurement of the S-tester is taken as an example to deduct the bad pressure pattern. After only four of the pressure samples (Figure 6) were adopted as the follow-up data. Finally, through the internal automatic calculation function and Fots can software to obtain the pressure parameters are used for subsequent comfort evaluation calculations, the optimal insole selected for comfort evaluation can be converted into matrix form for the "optimal insole grouping" of this study.

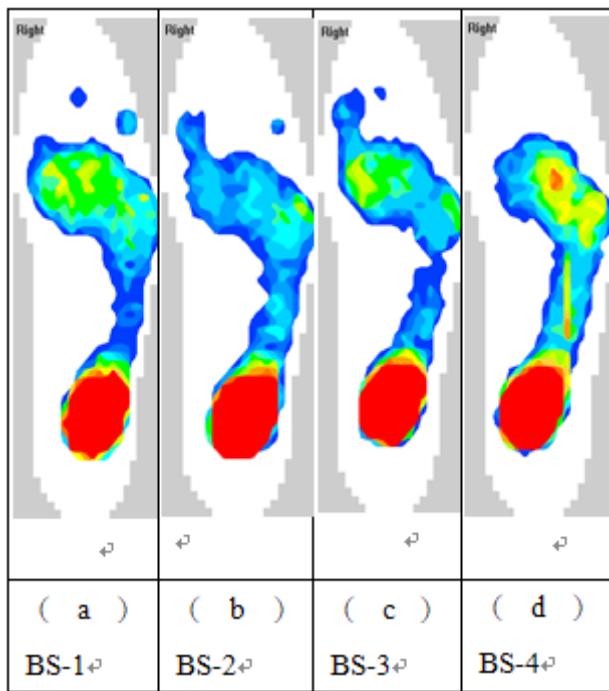


Figure 6: Sifted foot pressure sample (s tester).

Comfort Evaluation: Application of Grey Relation Theory

Using human foot pressure data to explore unclear comfort information, this method is in keeping with the concept of Grey theory, “external information is clear, but internal information is not clear” and “for uncertainty, multivariate input, scatter data Do effective processing”. This means that in the absence of information, this study will use gray correlation to derive the essence of the system and get the best answer [12].

Comfort Evaluation Mode Establishment

In order to achieve the goal, this study uses the Matlab program to perform the comfort evaluation calculation. The method is to analyse the pressure parameter data of the mechanical experiment by statistical average method, the pressure parameters are presented in a matrix, and Normalize the processing, select the large value and the small value of each pressure parameter to define a new reference sequence. After completing the above steps, calculate the distance of the original sequence. And new reference

sequence and set the recognition coefficient $\zeta 0.5$. Further, the Gray relation coefficient is calculated, and the relation degree is determined. The calculation process is as follows (Figure 7).

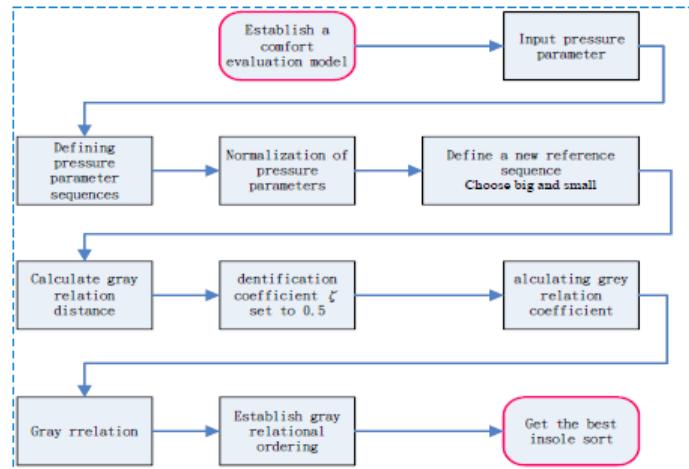


Figure 7: Grey relation calculation flow chart for comfort evaluation.

Comfort Evaluation Calculation

By the association of variables and parameters as the basis for calculating the degree of Grey relation, the steps are divided into six major items, including a. defining the pressure parameter sequence, b. normalizing the pressure parameters, c. defining a new reference sequence, d. calculating the gray relation distance, e. Calculate gray relation coefficient, f. Calculate gray relation degree and sequence.

Comfort Evaluation Test Certificate

From the table (Table 4,5), the Gray relation calculated according to the six insoles and the optimal insole sorting the No. 2 insoles that are best for the feet of most experimenters., because the initial screening of the sample insole is Experts recommend classification according to the difference between thick, thin, soft, hard and support positions. Mainly to verify the different functions of each sample insole, did not expect this experimental result, in order to more accurately find a suitable insole difference for each tester, this study will move the No. 2 insole, remaining five The insole is again subjected to gray relation analysis and calculation, obtain the optimal insole sorting of the tester's second experiment, and also to find the insole suitable for diabetic patients, and to analyse the final result (Table 6,7).

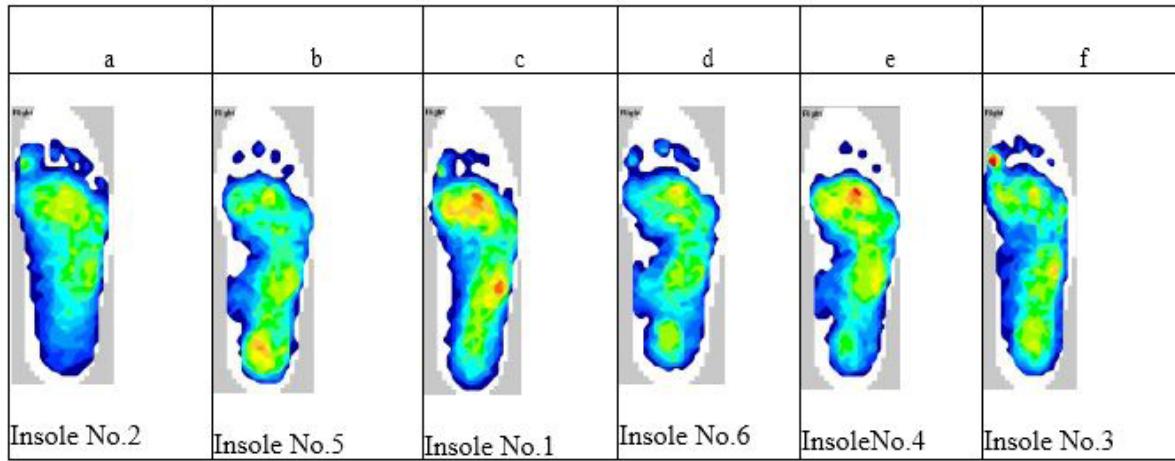


Table 4: Grey relation sequence of A Testers (six insoles).

	Insole No.1	Insole No.2	Insole No.3	Insole No.4	Insole No.5	Insole No.6	Fit Insole
A tester	0.815173	0.943334	0.770541	0.803337	0.839296	0.809525	2
B tester	0.744014	0.974009	0.755242	0.603723	0.763376	0.542909	2
C tester	0.747783	0.901872	0.701708	0.748046	0.686388	0.756456	2
D tester	0.671959	0.960707	0.795055	0.727984	0.654611	0.699062	2
E tester	0.524422	0.899278	0.68817	0.699428	0.739524	0.678928	2
F tester	0.611056	0.89952	0.689213	0.681308	0.68019	0.831363	2
G tester	0.669197	0.982906	0.910551	0.757839	0.874971	0.77478	2
H tester	0.584233	0.961564	0.829249	0.694132	0.613606	0.646163	2
I tester	0.568563	0.868096	0.807502	0.917348	0.71679	0.714341	4
J tester	0.60391	0.889226	0.768586	0.639841	0.643236	0.711983	2
K tester	0.656198	0.87938	0.989274	0.839595	0.731824	0.75246	3
L tester	0.59647	0.922816	0.78841	0.770352	0.676498	0.783171	2
M tester	0.767716	0.807825	0.782753	0.704695	0.732568	0.864776	6
N tester	0.559733	0.863501	0.839777	0.648558	0.737679	0.707761	2
O tester	0.587535	0.792212	0.790059	0.906465	0.671046	0.717292	4
P tester	0.671351	0.993336	0.815081	0.758816	0.662169	0.710241	2
Q tester	0.679166	0.733247	0.821136	0.86385	0.685511	0.684502	4
R tester	0.810604	0.943334	0.749122	0.776918	0.794452	0.758923	2
S tester	0.630442	0.840333	0.94365	0.780798	0.72011	0.722467	3
T tester	0.575222	0.814684	0.805749	0.721291	0.655179	0.624268	2

Table 5: 20 testers calculate Gray relation and optimal insole sorting (six insoles).

The bottom line of the data is Gray-relation data. The red data is the most suitable order for diabetics. The blue data is the second best position in the six insoles.

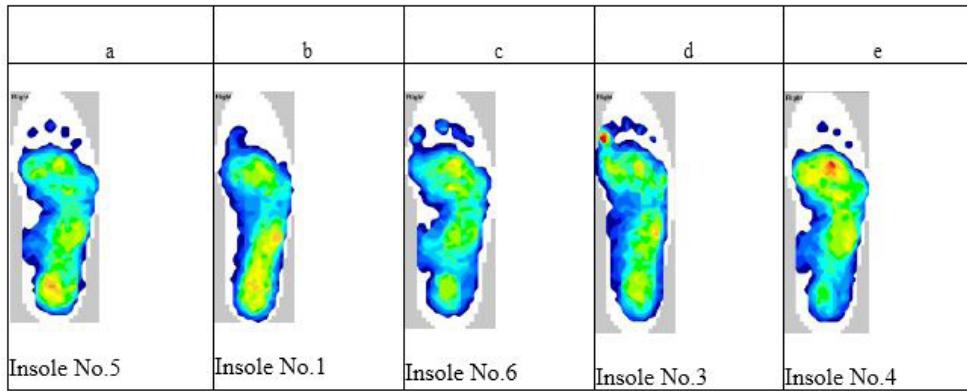


Table 6: Grey relation sequence of A Testers (five insoles).

	Insole No.1	Insole No.3	Insole No.4	Insole No.5	Insole No.6	Fit Insole
A tester	0.830811	0.814813	0.813773	<u>0.866137</u>	0.817291	5
B tester	0.859176	<u>0.903541</u>	0.754529	0.833078	0.598971	3
C tester	0.744758	0.787211	<u>0.791734</u>	0.682921	0.758246	4
D tester	0.650377	<u>0.920272</u>	0.865015	0.624398	0.723428	3
E tester	0.505662	0.716049	0.76913	0.746929	0.699684	4
F tester	0.616577	0.739706	0.793058	0.714351	<u>0.884497</u>	6
G tester	0.708257	<u>0.965969</u>	<u>0.800351</u>	0.909625	0.81129	3
H tester	0.602614	<u>0.999576</u>	0.798845	0.637119	0.693266	3
I tester	0.597241	0.837411	0.939523	0.745409	0.743188	4
J tester	0.626713	<u>0.910739</u>	0.67334	0.656151	0.724672	3
K tester	0.654922	<u>0.989118</u>	0.837623	0.729306	0.749597	3
L tester	0.618624	<u>0.813089</u>	0.795212	0.696824	0.800855	3
M tester	0.804377	0.820304	<u>0.746154</u>	0.773245	<u>0.905107</u>	6
N tester	0.579103	<u>0.92885</u>	0.722335	0.763979	0.739087	3
O tester	0.627098	0.837256	<u>0.951731</u>	0.714486	0.760365	4
P tester	0.672912	<u>0.96151</u>	0.819655	0.660346	0.729521	3
Q tester	0.689573	0.836576	0.89064	0.690894	0.692523	4
R tester	0.84744	0.803318	0.802712	0.829916	0.773762	1
S tester	0.644007	<u>0.983918</u>	0.825085	0.740552	0.742243	3
T tester	0.575173	<u>0.836336</u>	0.795565	0.656559	0.619998	3

Table 7: 20 testers calculate Gray relation and optimal insole sorting (five insoles).

In order to get more detailed sorting, remove the No. 2 insole for all testers. The bottom line of the data is gray-relation data. The red data is the most suitable for diabetics.

Analysis of Grey Relation Results in Comfort Evaluation

From (Table 5), the optimal insole sorting of the six insole Gray relation is ranked. The No. 2 insole is most suitable for the feet of most experimenters. The No. 2 insole is the thickest and Medium hardness in all insoles. In order to contact the plantar area, it has a flat shape, so it can be moulded according to the shape of the individual's foot. It is a modern latex material, also called a memory material. Through experiments, this type of insole can best reduce the impact of foot pressure. From this point, it can also be proved that the increase in the thickness of the insole mentioned by Livery [6] will directly affect the pressure of the sole and achieve the pressure reduction effect.

Verification (Table 6,7) are the best insole rankings. we can find that the ranking of the insole No 2 is discarded. It does not mean that its position will be replaced by the second order from which it can be seen that when using Grey relation analysis, reduce one test sample, the entire parameter variable operation is about to change, and recalculate and sort. Diabetes patients use Grey relation analysis and calculations, with six insoles as sample validation, the same best for insoles is also No.2, the result may be concluded, diabetic patients in the 0-level condition, the foot has not ulcer disease, will not affecting its shape and the function of the arch. This experimental result can also verify the parameters of the study hypothesis that affect the full pressure, including the contact area. When the plantar contact area changes, the foot pressure will reflect different data. Experiments with a full-touch insole have found that there is considerable effect on reducing the foot pressure. This test fit to the feet of diabetic patients and of course to general foot types.

The R tester (Hidden Diabetic Patient) which is most suitable for the insole is the No. 1. After subtract of the No. 2 sample insole The No. 1 insole is also made of latex material and has no foot arch support. Compared with the No. 2 insole, it is relatively thin. It can be known that the insole of diabetic patients is soft and can be regarded as the first requirement according to the shape of the foot. As for the insole plus other support functions, it does not reduce the apparent effect of plantar pressure in primary diabetic patients.

Wisdom Grouping: Neural Networks Apply

Neural Networks Model Establishment

Wisdom grouping is the sample. put the tester's foot pressure distribution data and insole style as a neural network training.

The iterative learning is performed by the Back-Propagation Neural Network algorithm. The purpose is to make the neural network have recognizable foot pressure. to automatically group the input tester's foot pressure data, find the suitable insole style from the existing insole samples. The Back-Propagation Neural Network (BPNN) technology used in this study. mainly transforms The expert experience and systematic analysis techniques into mathematical models, so that designers can through the clustering results calculated by the neural network, the design decision can be made correctly, the design cycle can be shortened, and the individual needs of diabetic patients can be met [13].

According to the comfort evaluation calculated by the Gray Relation, it is possible to obtain the most suitable insole style for each tester. In the final experimental, the tester's foot pressure distribution data and the sample insole are used as training samples for the neural network. It is the iterative learning of the "foot pressure - insole" data through the Back-Propagation neural network. The purpose is to enable the neural network have the ability to identify the pressure data, automatically group the input pressure data, and find the insole style suitable for the testers from the existing insole samples. In the foot pressure data of the training sample, the pressure type with a large defect is excluded, and the remaining 4 groups are screened for the network training sample [14]. In order to make the neural network have better learning results, we refer to the above-mentioned " neural network learning verification" section, through the data expansion, 100 calculations for each set of pressure data, resulting in 100 sets of new training sample. used for neural networks learning First for the 20 testers, total of 80 training samples, the formalization of the data (formula1), that is, the appropriate encoding of the data, as an exegesis of Back-Propagation neural network Taking the R tester as an example, the foot pressure data and the pressure distribution map (Figure 8-10) were obtained by the Tek-Scan system, and then converted to (Figure 11). (Figure 12,13) Foot pressure distribution matrix diagram. A set of original foot pressure data is a 21×50 matrix, which is shaped into a row vector 1050×1 matrix as an input sample of the network.

In addition, the Back-Propagation neural network is a non-linear conversion function using a hyperbolic tangent function and a double-bend function as a neuron. The output of the conversion function will be between (0, 1), so the network output value. The range of values must also fall between (0, 1). In addition, there are six (first learning) and five insole types for the study (the second insole is deducted for the second time), so the output of the network is defined: R tester (Diabetes), using two different insoles, constructing a matrix of 6×1 and 5×1 , and then using the maximum element in the matrix as the result of network prediction (Get the best insole style)

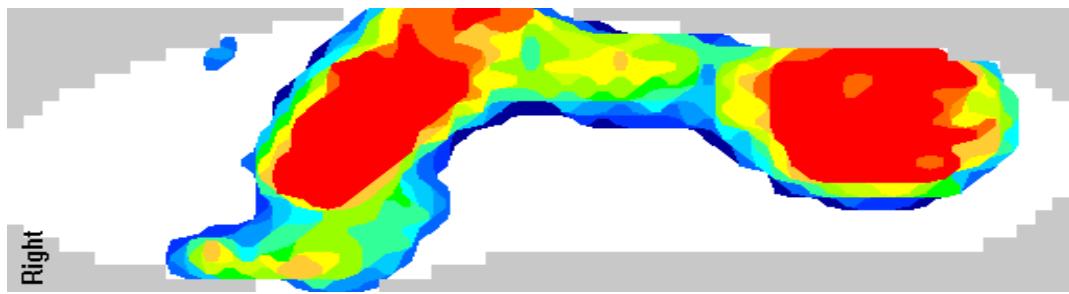


Figure 8: Diabetes patients bare foot pressure distribution map.

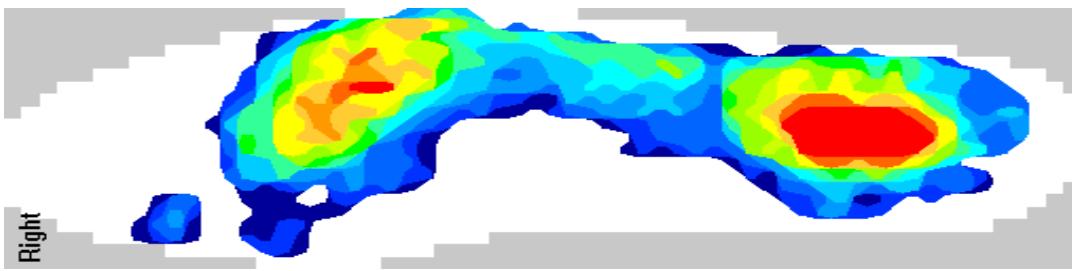


Figure 9: wearing No. 2 insole foot pressure distribution map (6 insole).

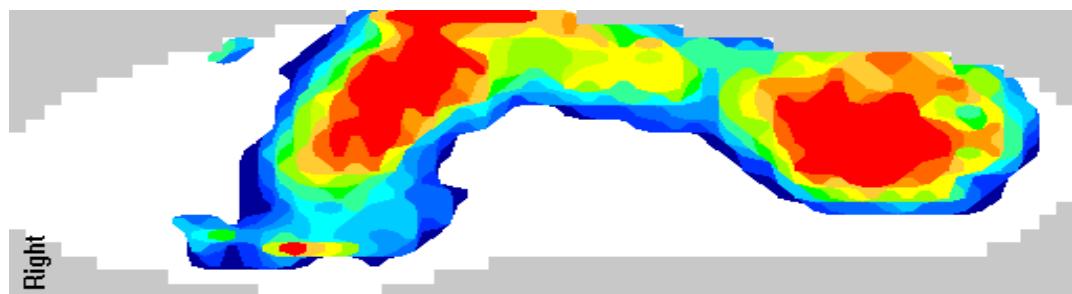


Figure 10: wearing No. 1 insole foot pressure distribution map (5 insole).



Figure 11: Bare foot pressure distribution matrix of diabetic patients.

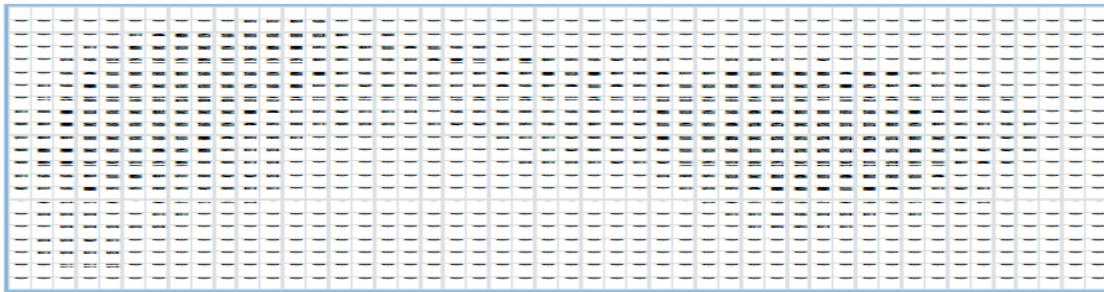


Figure 12: wearing No. 2 insole foot pressure distribution matrix (6 insole).

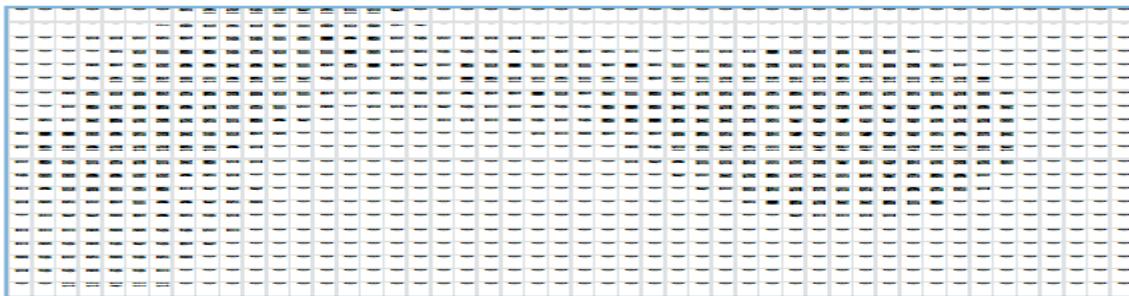


Figure 13: wearing No. 1 insole foot pressure distribution matrix (5 insole).

Before the input layer neurons receive the input samples, they will perform the value range transformation of the data. This is called normalization of the variable data. The purpose is to avoid the difference in the value range of the input samples, so that the importance of the small-valued samples cannot be displayed. The embarrassment caused by the large-valued sample control of the learning process of the entire network affects the learning effect. In this paper, the interval mapping method is used to reflect the minimum and maximum values in the sample to the expected maximum and minimum values. The steps are as follows:

Find the minimum (Min) and maximum (Max) of all the same-state output parameter. Set the expected output variable to the maximum value (D_{max}) and minimum value (D_{min}) after normalization.

Normalize the data using (formula 3.)

$$V_{new} = D_{min} + \frac{V_{old} - Min}{Max - Min} (D_{max} - D_{min}) \quad (3)$$

After normalizing and adjusting all data matrices into a row vector of 1050×1 , we randomly selected the data of the five testers I, J, Q, R, and T, each with 4 strokes and a total of 20 training samples, as a research test sample. The verification sample input of each neural network is the foot pressure data of the column vector 1050×1 . The data of the remaining 15 testers is expanded by the data set, and the results are input into the Back-Propagation neural network model, so that the learning process is repeated until the network reaches the maximum number of generations or the minimum gradient performance of the training. The Back-Propagation neural network architecture for training includes an input layer, a hidden layer and an output layer. The number of neurons is determined according to the training sample pair, and the number of hidden layers is determined according to the (formula 2), and the calculated

neurons are obtained by $\sqrt{1050 \times 6} = 79$. The number is 79.

$$N = \sqrt{N_{in} \times N_{out}}$$

N is the number of suggested neurons, N_{in} is the number of neurons in the input layer, and N_{out} is the number of neurons in the output layer.

In order to verify the influence of different transfer functions on the network prediction results, conducted experiments on two different combinations of conversion functions: (1). The learning of the a-structure network, hidden layer is a Hyperbolic Tangent Sigmoid Function, and the output layer is a log-sigmoid transfer.

Function (2). The learning of b-structure network, hidden layer is a log-sigmoid transfer. Function, the output layer is also a log-sigmoid transfer. Function. Other related network learning parameters are set as follows:

Training parameters (Table 8)

Epoch	2000
Performance Goal	0
Learning Rate	0.01
neurons	79
Momentum Constant	0.9
Minimum Performance Gradient	1.00E-10
text	10

Table 8: Training parameters.

Neural Network Training Architecture:

Network Training Framework Using 6 Sample Insoles Network a Training One By One

The first group uses a network structure of 6 sample insoles. (Figure 14), firstly, 15 sets of training samples are input the network for learning. When the network reaches the convergence condition, the verification samples are sequentially input to the neural networks that has completed the learning, and referring to

the calculation results of the previous grey relational comfort, calculates the correct rate of the network classification and records them in (Table 9,10). Since the output layer transfer function uses a Log-Sigmoid Function, the output of the network will be a real matrix of size between 0 to 1 and 6×1 , Set the neuron to 79 and output layer to 6.

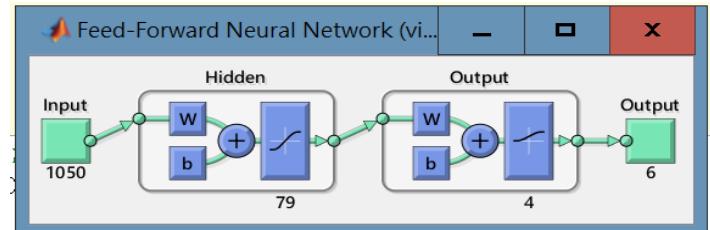


Figure 14: Network a, learning architecture diagram (6 insoles).

In the study, the largest value of the matrix is taken as the classification result of the output. For example, if the output of the network is (0.2, 0.6, 0.4, 0.5, 0.3, 0.1), the classification result is interpreted as the second (the insole number 2). According to this method, 10 independent program experiments are carried out, and the gradient performance of the network learning process is referred to (Figure 15). The correct rate of network output is to compare the results of the network output with the results of previous grey relational calculations, find all the matching results, and calculate the proportion of the network as the correct grouping rate of the network.

	I .tester				J .tester				Q. tester				R tester				T tester			
Grey Relational Calculated	4	4	4	4	2	2	2	2	2	4	4	4	4	4	2	2	2	2	2	2
1 verification	4	4	4	4	3	3	3	4	4	4	4	4	4	3	4	4	4	4	4	4
2 verifications	4	4	4	4	3	3	3	4	4	4	4	4	4	3	4	4	4	4	4	4
3 verifications	4	4	4	4	3	3	3	4	4	4	4	4	4	3	2	3	2	4	4	3
4 verifications	6	3	6	6	3	3	3	4	4	4	4	4	4	3	3	6	3	4	4	4
5 verifications	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	3	4	3
6 verifications	4	4	4	4	3	3	3	4	4	4	4	4	4	3	2	4	2	4	4	4
7 verifications	4	4	4	4	3	3	3	3	4	4	4	4	4	3	4	4	4	4	4	4
8 verifications	4	4	4	4	3	3	3	3	4	4	4	4	4	3	2	3	2	4	4	4
9 verifications	3	3	4	4	3	3	3	3	4	4	4	4	4	3	3	4	3	4	4	4
10 verifications	4	4	4	4	3	3	3	3	4	4	4	4	4	3	3	3	3	4	4	4

Table 9: Network a 10 independent program experiments (6 sample insoles).

Randomly select five testers to learn as neurological samples

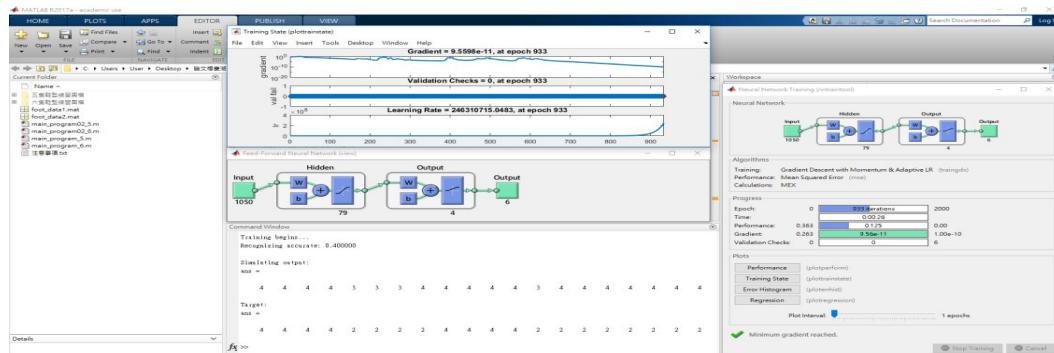


Figure 15: Neural network training Interface platform.

Upper (Gradient and Epoch Curve) right (Execution Window)
lower (Screening Results)

	Recognizing accurate	Gradient	epoch
1	40%	9.56E-11	933
2	40%	9.75E-11	674
3	50%	9.50E-11	1135
4	20%	9.93E-11	940
5	10%	9.93E-11	1426
6	50%	9.87E-11	634
7	40%	9.99E-11	1354
8	50%	9.59E-11	856
9	30%	9.78E-11	1175
10	40%	9.92E-11	1173
average value	37%	9.78E-11	1030

Table 10: Network a. 10 independent program experiments (6 sample insoles).

Network B Training for One Time (Six Sample Insoles)

Next, the research is conducted on the b-architecture network (Figure 16). Learning and verification, like a frame a-. Structure. According to the Matlab program, the network learning process is changed from successive training to one operation, and ten training results can be obtained, and result data can be obtained. The gradient performance change and network aliasing graph are like to the a-architecture diagram and will not be described. Only the learning results and learning accuracy of the b network architecture are listed in the figure below (Figure 17) (Table 11).

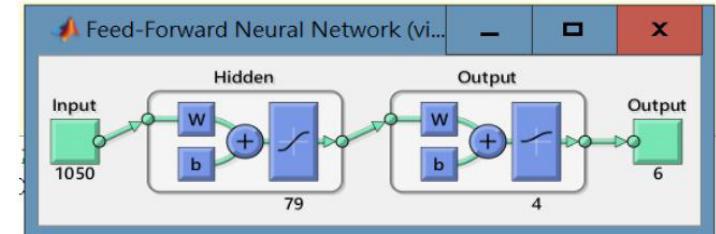


Figure 16: Network b learning architecture diagram

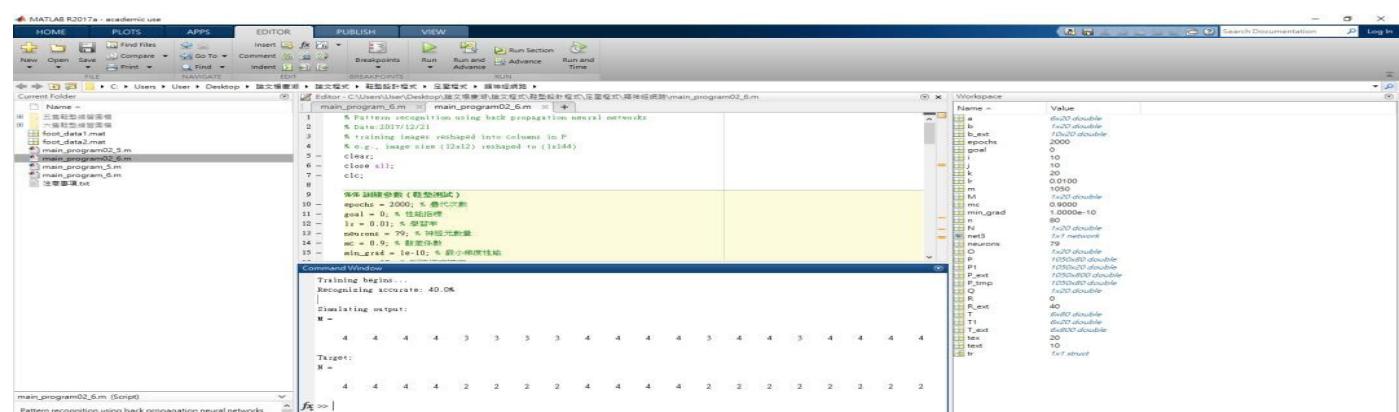


Figure 17: Network b learning change chart.

	I. Tester				J. tester				Q. tester				R. tester				T. tester			
Grey Relational Calculated insole	4	4	4	4	2	2	2	2	4	4	4	4	2	2	2	2	2	2	2	2
One-time learning verification	4	4	4	4	3	3	3	3	4	4	4	4	3	4	4	3	4	4	4	4
Recognizing accurate : 40.0%																				

Table 11: Network b learning once - correct rate (6 sample insoles).

From the above (Table 9,10), it can be found that the average correct rate of 10 independent learning is only 37%, and the correct rate of one learning is only 40%. The reason for the low accuracy rate is that this study considers the problem of learning samples. For the reasons, the number of test testers is too small. Due to the limitation of the number of test subjects, the solution is difficult to change except for data expansion. Therefore, choose to change the number of second test insoles. The original insole sample is 6 pieces, which will be suitable for the majority of the tester's No2 insole screen, the insole number is supplemented, the neuron is also determined according to the formula (2), $\sqrt{1050} \times 5 = 72$, the calculated nerve The number of neuron is 72, and the output layer is 5.

The Following Is the Re-Learning Results After the Sample Number Is Changed

Network architecture training using 5 sample insoles.

Network A Training One by One

	I. tester				J. tester				Q. tester				R. tester				T. tester			
Grey Relational Calculated insole	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	2	2	2	
1 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	4	3	4	4
2 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	3	3	3	3
3 verification	3	3	3	3	2	2	2	2	4	3	3	3	1	1	1	1	3	3	4	3
4 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	5	5	5	5
5 verification	1	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	3	3	3	3
6 verification	3	3	1	1	2	2	2	2	3	3	3	3	1	1	1	1	1	1	1	1
7 verification	1	3	3	3	2	2	2	2	3	3	3	3	1	3	3	3	3	3	4	3
8 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	1	1	1	3
9 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	2	2	4	2
10 verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	2	1	1	1

Table 12: Network a successive training results (5sample insoles).

In addition to the position of the No. 1 insole, the number of insoles in 3, 4, 5, and 6 are all moved forward. Because the training results are suitable for the number of insole for diabetic patients is No1, this study does not change the number of other training insoles, overall analysis, these normal foot type is still more suitable for the original No4 insole. The results of learning and training with the six insoles are the same.

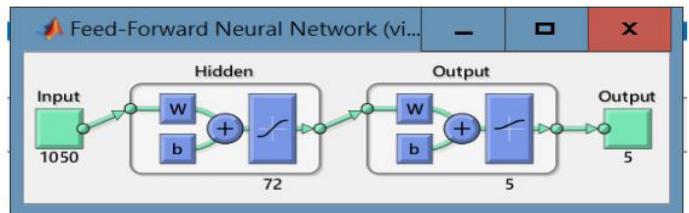


Figure 18: Network a learning architecture diagram (5 sample insoles).

	Recognizing accurate	Gradient	epoch
1	80%	9.76E-11	818
2	80%	9.67E-11	1437
3	75%	9.64E-11	1024
4	75%	9.51E-11	867
5	80%	9.55E-11	1394
6	65%	9.55E-11	1405
7	60%	9.93E-11	831
8	80%	1.00E-10	1083
9	95%	9.60E-11	711
10	85%	9.68E-11	865
average value	77.5%	9.69E-11	1043

Table 13: Network a. 10 independent program experiments (5 sample insoles).

Network B Training for One Time (Five Sample Insoles)

The study conducted experiments to the b-architecture network (Five Sample Insoles), (Figure18), the program is like a-frame network learning training and verification. obtain The best fit for insoles and results data. The gradient performance and network Algebraic number curve are also like to an architecture, and will not be described. The learning results and learning accuracy of the b network architecture are listed in the figure below (Table 14).

	I. Tester				J .tester				Q. tester				R. tester				T .tester			
Grey Relational Calculated insole	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	2	2	2	2
One-time learning verification	3	3	3	3	2	2	2	2	3	3	3	3	1	1	1	1	1	1	3	1
Recognizing accurate : 80.0%																				

Table 14: Network b learning once - correct rate (5 sample insoles).

Discussion

Analysis of The Effectiveness of Comfort Evaluation

The physiological pressure is used as the object to explore the comfort of a foot-type insole. The purpose is to evaluate the results of the comfort for the intelligent algorithm to obtain the desired result. The mechanics experiment is to provide an analysis of the comfort evaluation, so the causal relationship is analyzed and discussed together as follows:

This study proposes that “when the insole style is closer to the shape of the foot, the total pressure and peak value will de-

crease.” After the mechanical experiment, it can be observed by the results of the Relation sequence of the A tester (Table 15). The No. 2 insole is best suited to the feet of most experimenters, which does accord the assumptions previously set. It should also be proved by Xie Yueyun, (1997) and others. The proposed parameters affecting the foot pressure include the contact area. When the plantar contact area changes, the foot pressure will reflect different data. Because the No. 2 insole is a flat, thick material, Medium hardness and latex material Bottom layer. that changes with the shape of the sole, allowing for a larger contact area and a more even distribution of the foot pressure.

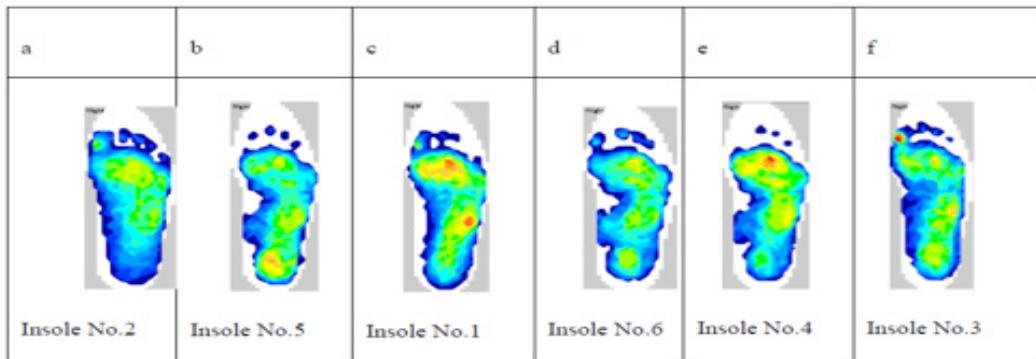


Table 15: Grey Relational ranking of A testers (six insoles).

From the (Figure 19) diabetic foot pressure and the normal bare foot pressure, it can be seen that the bare foot pressure peak occurs in the first palm area and the heel area is higher, and the toe area is Very small numbers, which validate previous assumptions.

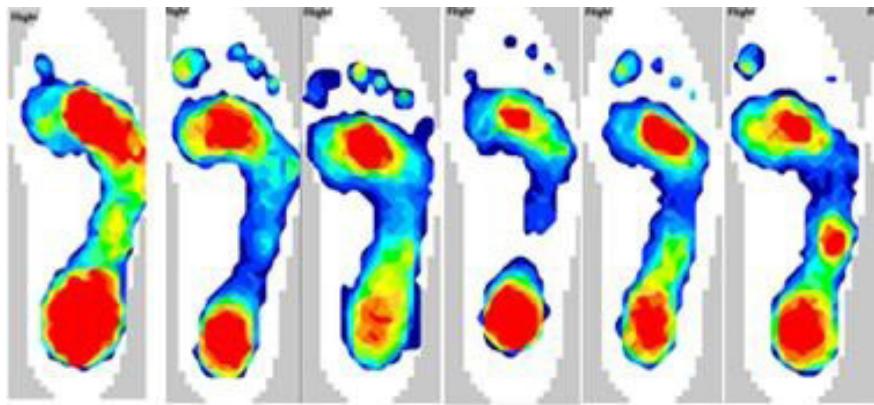


Figure 19: Diabetes patients (first place) and other normal bare foot pressure.

According to (Figure 20), the bare foot pressure map of the diabetic patient is compared with the pressure on the insole. It can be found that the optimal insole No. 2 selected by the gray relation calculation is compared with the original bare foot pressure, and the pressure of the No. 2 insole is relatively average. And significantly reduced a lot. Therefore, the No 2 insole can indeed achieve the purpose of improving comfort. The gray relation calculation selected Insole No. 1-foot pressure also has a tendency to decrease After subtracting of the No. 2 insole, this also proves Zhu Jiawei, (1999). The proposed experiment using a full-touch insole has a considerable effect on reducing the foot pressure. Because the No. 2 insole and the No. 1 insole, although the thickness is different, the material is exactly the same made of latex, the insole and the foot contact surface are also in a flat contact type, and are all shaped according to the softness of the material.

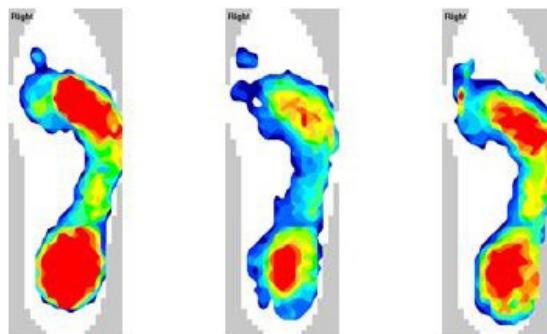


Figure 20: Comparison of pressure distribution between Barefoot and No.1 insole No.2 insole in diabetic patients.

Wisdom Grouping Effectiveness Analysis

To verify the wisdom grouping effect of Back-Propagation Neural Network, the results are as follows:

The research process found that the network architecture a made of six insole samples were trained one by one, and the average correct rate was 37.5%. Switch to a multiple training study, the training rate was changed to 50%. From this data, it can be seen that different The conversion function does affect the learning result. Then take the No. 2 insole and use the network structure an of the five insole samples train and learn one by one. The average accuracy rate is 87.5%. Instead of using a multi-training study, the correct rate is 80%. It can be seen that the learning data all meets the correct rate of a multiple learning training. However, the researchers still suggest use a neural-like self-learning function do more training to get more accurate results.

Application Method Analysis

People's psychology is versatile. If the answer is obtained only through questionnaires, there are multiple conflicts. Because people are susceptible to emotions, physiology, or other factors, the black box situation is generated when the questionnaire is conducted. Therefore, objective gray theory is used. In the assessment method, a large number of unclear unknown psychological factors can be turned from black to white. This study uses foot pressure as a gray correlation calculation to evaluate the comfort factor. Through this theory, the most appropriate answer can be obtained. In the experimental measurement, the diabetes patients were included, and the other parties were not aware of each other, these factors were also considered.

This experiment is only a small sample. If you simply use the gray correlation, you can get the insole selection of the demand. However, when the method and concept are provided to the designer in the future, in order to shorten the design and increase the efficiency, only the gray correlation analysis cannot give the best results. due to the practical application, the number of samples is large. If the gray correlation is regarded as expert knowledge and education, the most suitable insole selection sorting data is obtained, and then the characteristics of learning, prediction and recognition through the neural network are constructed, the timeliness and accuracy are good far more than use gray correlation.

Conclusions

The mechanical test was carried out with the pressure generated by the standing of the human foot and the set sample insole, and the result was used as a verification case. Then apply the gray correlation theory to the comfort selection, and select the insole that is most suitable for the patient's foot type through multiple calculation processes. The calculation part is based on the MATLAB program. Subsequent Back-Propagation Neural Network characteristics for comfort data learning, and as a predictive system for finding the most suitable insole, that is, the different foot pressure

and insole style data, through the program operation, according to the neural network Data prediction, intelligent learning, automatic grouping and pattern recognition, etc., cross-learning, to complete the ultimate goal of this study. It can omit the negligence and time consuming of man-made judgments, and can also provide future design references. This study applied the theory of biomechanics to the design of pathological insoles. Through the measurement of the foot pressure of diabetic patients, automated measurement and analysis, comparison, and the insole samples provided from the experiment, find the most suitable insole for the patient. This system can be used as a basis for the subsequent rapid customization of medical insoles for many diabetic patients.

The study uses the pressure of foot and various data to predict the comfort has achieved the expected results, providing the most suitable pathological insole options for diabetic patients. After example, the comfort data can be grouped with neuro-learning to achieve a correct rate of about 80%. This proves that if the learning data reaches a certain amount in the future, the gray-related part operation can be omitted, and the most suitable insole can be found as long as inputting the foot pressure. This method can also be used by shoe designers to improve decision-making quality and help the general consumer find a suitable insole use the foot pressure measurement data to find out the pathological insole suitable for diabetic patients, and understand the material characteristics as a reference for future design. The experimental study found that the material is Medium hardness, the surface is flat, the thickness is deep, and it is malleable. It does not need special arch support. This insole is suitable for all foot types and is more suitable for diabetic patients. The design elements are foamed, can be moulded on the bottom, and do not add extra devices on the surface and bottom. The ideal thickness is 5.2mm-14mm. The ideal hardness is 20-36HV. The data is set based on the size of the experimental sample and the space reserved for the midsole.

The pathological insole design elements obtained from the experiment, this study believes that this material is placed on the sole of the shoe, acting as a midsole pad, and pre-processing, which can save the cost of re-purchasing the insole in the future, and can also be customized. To the general-purpose product that not only let diabetics to have safe and secure footwear, but also let ordinary consumers to have a pair of comfortable shoes at any time. In this study, many different data are obviously used in the system operation process. As the insole and human foot sample increases, it will inevitably produce more and more complex data. How use, manage or search for these materials depends on pre-establishing a complete database system and applying the intelligent methods of analysis and calculations in this study in order to get the best results.

References

1. Boulton AJ, Jude EB (2004) Therapeutic Footwear in Diabetes The good, the bad, and the ugly?. *Diabetes Care* 7: 1832-1833.
2. Gordois A, Scuffham P, Shearer A, Oglesby A, Tobian JA (2003) The

health care costs of diabetic peripheral neuropathy in the US. *Diabetes Care* 6: 1790-1795.

- 3. Jeffcoate WJ, Harding KG (2003) Diabetic foot ulcers. *The Lancet* 361: 1545-1551.
- 4. Armstrong DG, Abu-Rumman PL, Nixon BP, Boulton AJM (2001) Continuous activity monitoring in persons at high risk for diabetes related lower-extremity amputation. *J Am Podiatr Med Assoc* 91: 451-455.
- 5. Maciejewski ML, Reiber GE, Smith DG, Wallace C, Hayes S, et al. (2004) Effectiveness of diabetic therapeutic footwear in preventing reulceration. *Diabetes Care* 27: 1774-1782.
- 6. Lavery LA, Armstrong DG, Wunderlich RP, Tredwell J, Boulton AJ (2003). Predictive value of foot pressure assessment as part of a population-based diabetes disease management program. *Diabetes Care* 4: 1069-1073.
- 7. Kuo Y, Yang T, Huang GW (2008) The use of a grey-based Taguchi method for optimizing multi-response simulation problems. *Engineering Optimization* 40: 517-528.
- 8. Rupérez MJ, Martín C, Guerrero JD, Monserrat C, Alcañiz M (2012) Artificial neural networks for predicting dorsal pressures on the foot surface while walking. *Expert Systems with Applications* 5: 5349-5357.
- 9. Hashemi SH, Karimi A, Tavana M (2015) An integrated green supplier selection approach with analytic network process and improved grey relational analysis. *Int. J. Production Economics* 159: 178-191.
- 10. Healy A, Naemi R, Chockalingam N (2013) The effectiveness of footwear as an intervention to prevent or to reduce biomechanical risk factors associated with diabetic foot ulceration: A systematic review. *Journal of Diabetes and its Complications* 4: 391-400.
- 11. Brown M, Rudicel S, Esquenazi A (1996) Measurement of Dynamic Pressures at the Shoe-Foot Interface During Normal Walking with Various Foot Orthoses Using the FSCAN System 3: 152-156.
- 12. Chapman JD, Preece S, Braunstein B, Hohne A, Nester CJ, et al. (2013) Effect of rocker shoe design features on forefoot plantar pressures in people with and without diabetes. *Clinical Biomechanics* 28: 679-685.
- 13. Shieh MD, Yeh Y E (2013) Developing a design support system for the exterior form of running shoes using partial least squares and neural networks. *Computers & Industrial Engineering* 4: 704-718.
- 14. Mitchell RK, Agle BR, Wood DJ (1997) Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review* 22: 853-86.