Team Number :	80589

Problem Chosen :	A

2018 APMCM summary sheet

Abstract

As people age, their mobility will decline significantly. The exercise capacity of the elderly is generally weak, and it is easy to fall, but the fall is likely to cause other complications, which in turn exacerbate the physical exhaustion of the elderly. Therefore, it is of great significance to study the exercise data of the elderly and give reasonable suggestions.

For the first problem, 32 characteristics including center of gravity displacement, knee bending degree and foot deviation angle were summarized by calculating the exercise data of the elderly. Subsequently, the existing features were preprocessed accordingly, and the random forest method was used to select the 25 features that best determine whether the elderly would fall [1, 2].

For the second problem, the artificial neural network is used for mathematical modeling, and the existing sports characteristics data of the elderly are used to train the network to obtain an effective model. Finally, establish an evaluation system for the athletic ability of the elderly.

For question three, according to the age of the elderly, BMI and other physiological indicators, the balance ability is scored, the score results and the medical history are comprehensively analyzed, and the effects of various types of diseases on the balance ability of the elderly are summarized, and rationalization suggestions are put forward.

Key works：ANN; Random Forest; Evaluation system of balance ability

Real-time training model for elderly people balance ability

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Catal

1 Introduction

1.1Background

The decline in the balance of the elderly, the weakening of muscle strength and the reduction of flexibility are the main problems faced by many elderly people predicting the balance of risk of fall and the development of gait functional assessment in the elderly. The phenomenon and consequences of the fall of the elderly due to gait instability and balance ability disorders cannot be ignored. Falling can cause many complications in the elderly because their recovery is generally poor and side effects can exacerbate body failure. At the same time, falls can also have a negative psychological impact. Therefore, we constructed a mathematical model to assess the balance of the elderly, thereby assisting the elderly to exercise, correct posture, and prevent accidental falls.

1.2 Restatement of The Problem

Falls are common in the elderly population.it is of great realistic importance to make a balance ability assessment for elderly people with a view to assisting them in mobility status, correcting postures and preventing accidental falls.

A research institute made a random sampling test by deploying 42 monitoring points on the body of the elderly subjects.

To this end, we need to solve the following three problems:

(1) Analyze the balance features of elderly people based on the data in Annex 2. Build a feature extraction model based on an analysis of steps, the center of gravity and motion. A system consisting of the 42 monitoring points is applied to the extraction of 25 body balance features in order for a comprehensive body balance assessment for elderly people.

(2) Build a balance risk assessment system based on 25 indicators to assess the balance ability of elderly people. Give advice accordingly.

(3) Make an analog computation and a comparative analysis of the body balance force based on the actual data provided. Give effectual advice to elderly people with weak balance ability.

2. Problem Analysis

2.1 Analysis of Problem 1

Based on steps, the center of gravity and motion， We looked up the relevant literature and learned some physical indicators of the body's balance ability, such as step size, step width, center of gravity, knee joint, ankle joint, hip joint and so on. These indicators can more intuitively reflect the body's ability to balance. The raw data provides 42 points of monitoring data for the human body. Based on the correlation between these monitoring points, we carefully convert the coordinate data of these points into the above physical indicators. Then perform an integrated analysis of multiple indicators.

2.2 Analysis of Problem 2

In the case of large amount of monitoring data and complex index relationships, it is necessary to establish a complete mathematical model to fit the given data and assess the body balance ability of the elderly. Therefore, we use a random forest algorithm to process the data. The specific operations will be detailed later.

2.3 Analysis of Problem 3

Annex1 provides information on the height, weight, and blood pressure of the elderly. We have quantified this information and obtained a score of the body balance ability of each elderly person. Comparing the score results with their medical history, the relationship between balance ability and medical history was obtained.

Based on the relationships obtained and consulting the relevant literature, we have made some suggestions for some elderly people with weak balance.

This problem uses the data in Annex1 to analyze the data of multiple elderly people in the data separately, and obtain the results of small samples. Then, the integrated analysis is carried out, and the medical history is compared and analyzed to obtain effective suggestions.

3.Symbol and Definitions

25 feature representation symbols

Serial number	Symbol	Description
1	sd	width of step
2	sl	length of step
3	ssize	size of step
4	fa	Foot angle
5	sf	frequency of step
6	sspeed	speed of step
7	arma	Swing arm amplitude
8	armf	Swing arm frequency
9	gl	Change in center of gravity
10	gv	Vertical change in center of gravity
11	kb	Knee bending
12	all	Left ankle horizontal change
13	alv	Left ankle vertical change
14	arl	Right ankle horizontal change
15	arv	Right ankle vertical change

16	hl	Head level change
17	hv	Vertical change of head
18	hipll	Left hip level change
19	hiplv	Left hip vertical change
20	hiprl	Right hip level change
21	hiprv	Right hip vertical change
22	kll	Left knee level change
23	klv	Left knee vertical change
24	krl	Right knee level change
25	krv	Right knee vertical change
26	shll	Left shoulder level change
27	shlv	Left shoulder vertical change
28	shrl	Right shoulder level change
29	shrv	Right shoulder vertical change
30	hbd	Humpback degree
31	r	Rear foot slope

4.The Model Assumptions

To simplify the problem and make it convenient for us to simulate real-life conditions, we make the following basic assumptions, each of which is properly justified.

(1) We consider that all data in annexes are from real patients and they are reliable.

(2)The indicators in Annex I.xlsx are independent of each other.

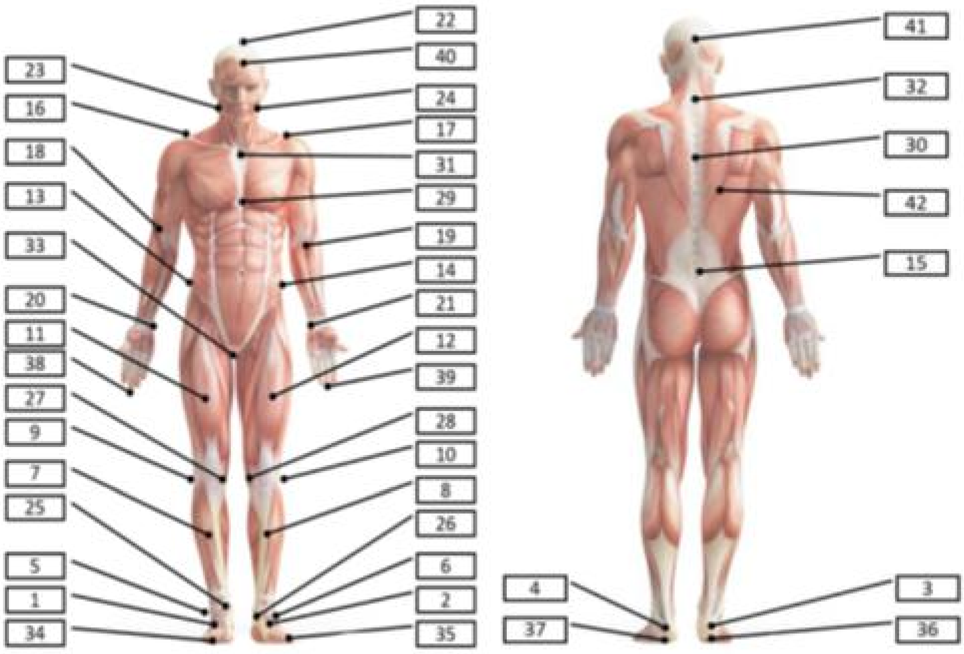
(3)We ignore the impact of other unmentioned diseases on the data in the human body.

5. Establishment of the Model

5.1Modeling Establishment and Solution for Problem 1

Analyze the balance features of elderly people based on the data in Annex 2. Build a feature extraction model based on an analysis of steps, the center of gravity and motion. A system consisting of the 42 monitoring points is applied to the extraction of 25 body balance features in order for a comprehensive body balance assessment for elderly people[3].

We reviewed the human gait information, the influencing factors of the elderly's body balance, and other related literatures [3, 4], and found that the balance ability of the elderly is related to factors such as step width, step size, and hunchback.



The data of 42 monitoring points for elderly people walking for 3s are provided in the title. The positions of 42 monitoring points are shown in the figure [1]. Based on the given monitoring data, we can calculate some physical indicators. For example, the vertical distance between 22 and 36, 37 points is the height, and so on.We found

31 features from the data in Annex2, as shown in Table [1], which is calculated as:

sd=y(36)-y(37)

Two-point y-axis coordinates when the z-coordinate is minimum

sl=x(36)-x(37)

Two-point x-axis coordinates when the z-coordinate is minimum

ssize=x2(36)-x1(36)

When the z coordinate is the smallest, the x coordinate of the second z minimum and the x coordinate of the first z minimum

fa=（y(34)-y(36)）/（x(34)-x(36)）

When the z coordinate is the smallest, the coordinates of each point

sf=1/2*((t2(36)-t1(36))+(t2(37)-t1(37)))

T2 is the time when the second z coordinate is the smallest, and t1 is the time when the first z coordinate is the smallest.

sspeed=ssize*sf/2

arma=x(20)-x(21)

When the z coordinate is maximum, the coordinates of the point

armf=1/(t2(21)-t1(20))

T2 is the time when the second z coordinate is maximum, and t1 is the time when the first z coordinate is the largest.

gl=ymax-ymin

gv=zmax-zmin

k1=(z(11)-0.5(z(19)+z(27))/(x(11)-0.5(x(19)+x(27)))

k2=(z(25)-0.5(z(19)+z(27))/(x(25)-0.5(x(19)+x(27)))

kb=|(k1-k2)/(1+k1*k2)|

krl=((x2(9)+x2(27))-(x1(9)+x1(27)))/2

kll=((x2(10)+x2(28))-(x1(10)+x1(28)))/2

krv=((z2(9)+z2(27))-(z1(9)+z1(27)))/2

klv=((z2(10)+z2(28))-(z1(10)+z1(28)))/2

arl=((x2(25)+x2(5))-(x1(25)+x1(5)))/2

all=((x2(26)+x2(6))-(x1(26)+x1(6)))/2

arv=((z2(25)+z2(5))-(z1(25)+z1(5)))/2

alv=((z2(26)+z2(6))-(z1(26)+z1(6)))/2

shrl=x2(17)-x1(17)

shll=x2(16)-x1(16)

shlv=z2(17)-z1(17)

shrv=z2(16)-z1(16)

hl=(x2(40)+x2(41))-(x1(40)+x1(41)))/2

hv=(z2(40)+xz(41))-(z1(40)+z1(41)))/2

hipll=x2(14)-x1(14)

hiprl=x2(13)-x1(13)

hiplv=z2(14)-z1(14)

hiprv=z2(13)-z1(13)

r=(z(37)-z(35)/(x(37)-x(35)))

Preprocessing the data is very helpful for feature selection and network training. Before the feature selection, a total of 32 features were summarized. First, the data was normalized and converted into values in the range of (0, 1).The standardized formula is: $x^* = \frac{x - \min}{\max - \min}$

The data variation with very small variance is very insignificant, so the value of the data is not very large. In the second step, we remove the feature with very small variance and reduce the feature to 26. Finally, we use the random forest method often used in machine learning to extract and select the first step.

A random forest is a classifier with multiple decision trees. Random forests can be used to calculate the importance of a single feature variable, so that we can use the importance to sort the features and pick out the features with the highest importance.

The calculation of the importance of a feature x in a random forest is as follows:

1. For each decision tree in the random forest, use the corresponding OOB (out of bag data) data to calculate its out-of-bag data error, denoted as errOBB1

2. Randomly add noise interference to the feature X of all samples of the out-of-bag data OOB, and then randomly change the value of the sample at feature X, and

calculate its out-of-bag error again, denoted as errOOB2

3. Assuming that there is an Ntree tree in the random forest, then the importance of the feature X is : $\text{importance} = \sum(\text{errOOB2} - \text{errOOB1}) / Ntree$

The reason why this expression can be used as the importance measure of the corresponding feature is because if the accuracy of the bag is greatly reduced after the feature is randomly added to a feature, it indicates that the feature is very impressive for the classification result of the sample. That is to say, its importance is relatively high.

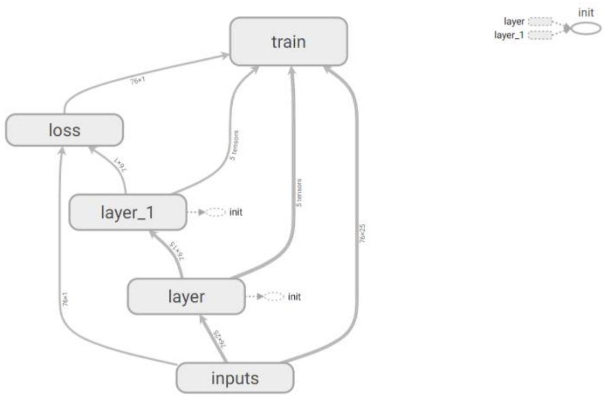
feature	importance	feature	importance	feature	importance
all	0.14393	krv	0.03819	gv	0.02192
kb	0.11442	sw	0.03778	armf	0.02189
sspeed	0.08201	hlv	0.03062	arl	0.01912
gl	0.06503	arma	0.03008	fa	0.01747
alv	0.05091	klv	0.02207	sl	0.0168
sf	0.0452	sll	0.02199	krl	0.01678
hrv	0.01263	hl	0.01234	kll	0.00779
ssize	0.00766	hv	0.00516	hrl	0.0036

5.2Modeling Establishment and Solution for Problem 2

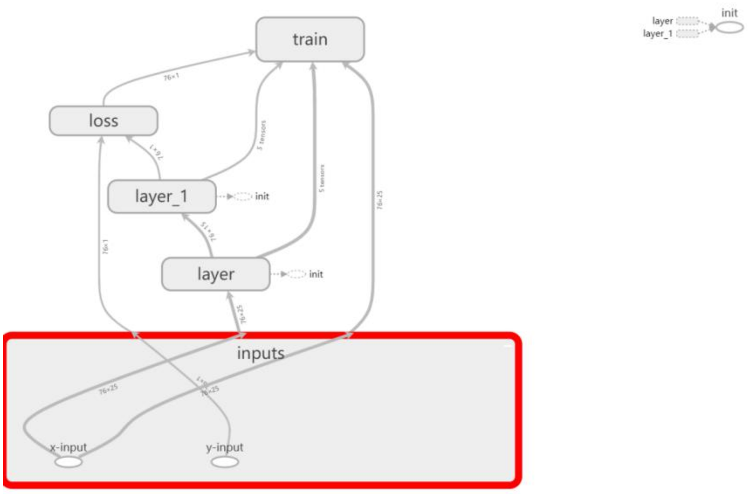
Based on the 25 features previously extracted, we obtained 76 sets of different sports characteristics data for the elderly. For the elderly who have experienced the fall, the mark is 1 and for the elderly who have no experience of falling, the mark is 0, thus completing the pair. The marking process of the sports characteristic data of 76 groups of elderly people, and then we will use the existing data to judge whether the old people's sports will fall, and convert them into classification problems for processing.

The artificial neural network model is a very powerful model that originated from algorithms that try to make machines mimic the brain. At the same time, it is a very complicated model, which leads to a very large amount of calculation. In recent years, thanks to the improvement of computer hardware capabilities, it has become increasingly popular [5]. Artificial neural networks have self-learning, self-organization, self-adaptation and strong nonlinear function approximation ability, and have strong fault tolerance. The nonlinear function approximation ability of artificial neural networks is brought by the activation function. Common activation functions are tanh, relu, sigmoid and so on.

We use Google's open source framework, TensorFlow, to build an artificial neural network (ANN). The specific structure of the network is shown below.



The characteristics of the elderly and the corresponding marker data will be imported into the network, respectively, as x-input, y-input, and we will use this data to train the artificial neural network.

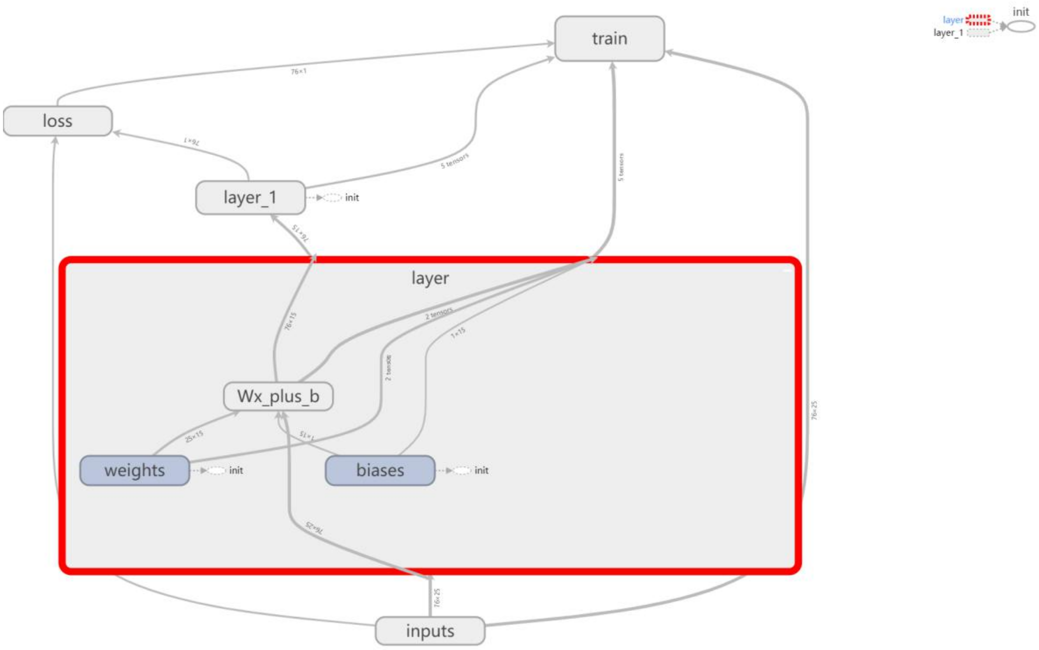


We use a two-layer artificial neural network. The training data will output a value through a two-layer artificial neural network. 0 means the old man will not fall, and 1 means the old man will fall.

The number of inputs in the first layer is 25, and the number of outputs is 15. First, the input variables correspond to the 25 sports characteristics of the elderly. The input variable will be multiplied by the weight matrix, and after adding a certain offset, the output will be added after the nonlinearity is activated by the activation function, which is the operation result of the first layer artificial neural network.

$$\begin{matrix} x_1 \\ x_2 \\ \cdots \\ \cdots \\ x_{25} \end{matrix} * \begin{matrix} w_1^1 & w_2^1 & \cdots & \cdots & w_{15}^1 \\ w_1^2 & w_2^2 & \cdots & \cdots & w_{15}^2 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ w_1^{25} & w_2^{25} & \cdots & \cdots & w_{15}^{25} \end{matrix} + \begin{matrix} b_1 \\ b_2 \\ \cdots \\ \cdots \\ b_{25} \end{matrix}$$

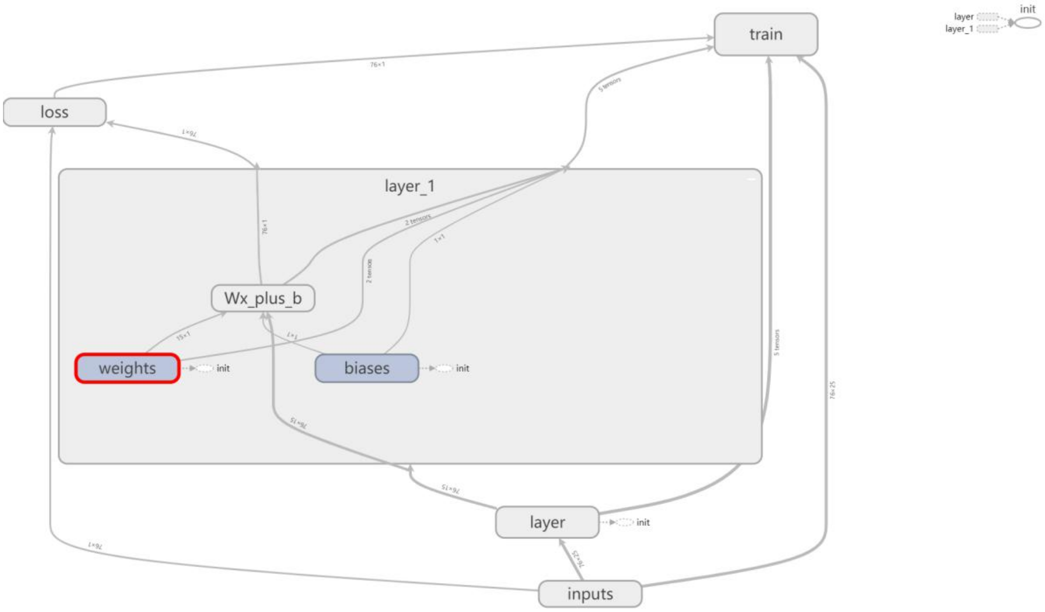
The operation process of the first layer artificial neural network is as shown in the above figure, where w_n^m is the weight corresponding to the first layer and b_n is the offset corresponding to the first layer.



The number of input in the second layer is 15, and the number of outputs is 1. The input of the second artificial neural network is the output of the first artificial neural network. The second layer of neural network performs operations similar to the first layer of neural networks. The input is multiplied by the weight matrix and biased, and then the activation function is used to produce the final result. Unlike the first layer of neural networks, the second layer of artificial neural networks uses the sigmoid activation function in order to better achieve the goal of classification.

$$\begin{matrix} a_1 \\ a_2 \\ \ldots \\ \ldots \\ a_{15} \end{matrix} * \begin{matrix} w_1^{'} \\ w_2^{'} \\ \ldots \\ \ldots \\ w_{15}^{'} \end{matrix} + \begin{matrix} \mathrm{b}_1^{'} \\ \mathrm{b}_2^{'} \\ \ldots \\ \ldots \\ \mathrm{b}_{15}^{'} \end{matrix}$$

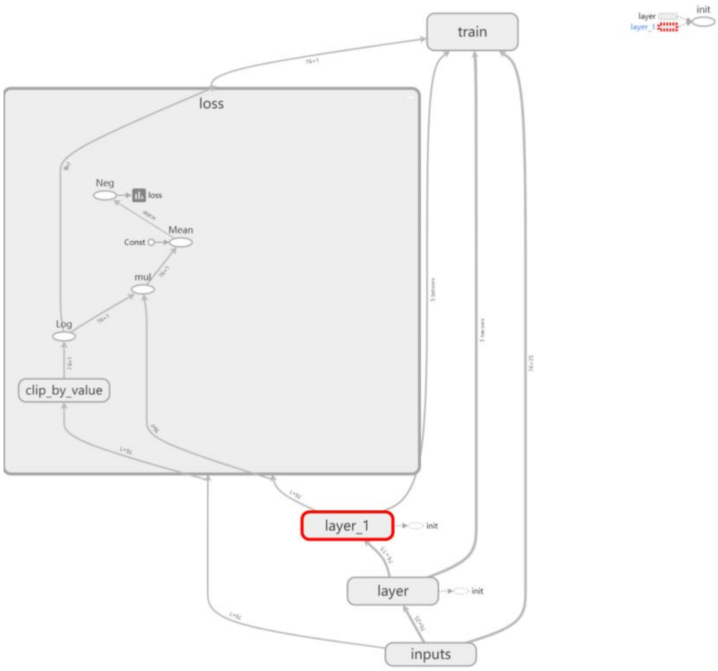
The operation performed by the second layer artificial neural network is as shown above, where a_n is the output of the first layer artificial neural network, $\mathrm{w}_{\mathrm{n}}^{'}$ is the weight corresponding to the second layer, and $b_{\mathrm{n}}^{'}$ is the offset corresponding to the second layer.



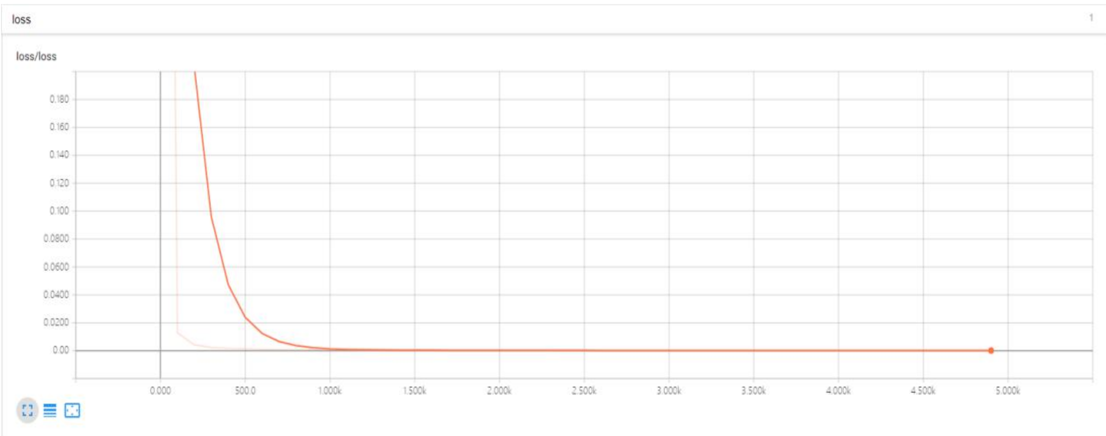
The core part of the training is the cost function. Cross entropy is often used to evaluate the quality of a classification model.

$$\mathrm{loss} = -y\log(\hat{y}) - (1-y)\log(1-\hat{y})$$

Where y is the real label of the sample, which $\hat{y}$ is the label generated by the data. When the predicted value is very close to the true value, the loss will be small, so we optimize the model by the gradient descent method.



Before the training starts, all the parameters of the model are initialized to random numbers obeying the normal distribution. Before the training, the network's cost value is 2.8319. After 5000 iterations, the descendant value is reduced to 5.78883e-5, which is in line with expectations.



5.3Modeling Establishment and Solution for Problem 3

Analyze the Annex1 table, pre-process the data, and layer the discrete data, so that pre-processing layering will make the results more reliable. According to the relevant literature, the normal elderly BMI index is in the range of 18.5 to 24.9, and the normal blood pressure interval is: hypertension interval: 90 to 140, and low pressure interval is 60 to 100. The normal heart rate range is between 55 and 85 [6]. For each age, BMI index, high and low blood pressure, heart rate, and number of falls, each older person with complete data was scored. Among them, the age is 1 point in the 65 to 75 range, the age is 0 points below 65 years old, and the age is 2 points in the age of 75 years. The BMI index is 0 points between 18.5 and 24.9, less than 18.5 for 1 point, and greater than 24.9 for 2 points. Score Fu Fufu, and score 1 point for one time. The high pressure is recorded as 0 in the normal range and 2 points in the normal range. The low pressure is recorded as 0 in the normal range and 2 points in the normal range. The heart rate is 0 in the normal range and 2 points in the abnormal state. Get the scores in the table below.

yanzuozhou	5	chenfue	2	niuzhenhang	5
zhangzuoyin	4	cuizhenhua	1	yangchengyu	7
guanpeihua	10	gaoyuling	18	zhujianguo	4
zhaojinhua	7	hanyingchun	6	cangyongli	4
zhaoshurong	11	liuzaoheng	3	ruanshuyin	6
tongyuhua	6	maguicheng	3	yangbaoling	3
zhangzhundao	4	liwenlong	4	qijianming	5
aizhenjiang	1	zhangzuowen	8	zhaojie	5
lijinjin	4	zongkeqin	2	songfang	5
wangjiuhong	1	pengruiying	4	lijianke	1
zhaoshufen	4	sunxingjian	7	litongsheng	2
wangxiong	6	cuixiulan	4	maochengai	2
hanyongchang	7	jianglimin	2	zonglanfang	5
wanghancai	8	weixiurong	5	liuyuexian	3
jinyan	6	lvjun	1		

A comprehensive analysis of the final score and the medical history of each elderly person can be found that the balance ability of the elderly is related to the following factors.

1.Age

Age is a significant factor in the patient's fall. The organs of the elderly have gradually decreased, slowed down, and responded poorly with age, which has become a major factor in the fall of the elderly [8].

2.BMI

In medicine, the body mass index (BMI) is commonly used to indicate the physical state of the body. With the increase of age, the incidence of osteoporosis in the elderly increases, the curvature of the spine is deformed, the height is shortened when the height is younger, and the adipose tissue in the body is increased, which makes the BMI correspondingly higher, which makes the body of the elderly more likely to fall.

3.History of vestibular organs

In addition to the cochlea, there are three semicircular canals, elliptical sacs and balloons. The latter three are called vestibular organs, which are the receptors for the body's own movement and head position. Studies have shown that vestibular sensory input becomes critical in maintaining balance when both body sensation and visual information input are blocked or input abnormalities. When hearing is declining, the balance ability of the elderly becomes poor and it is easier to fall.

4.Blood pressure

Hypertension is a common disease in the elderly. Some elderly hypertensive patients may also have hypotension during the course of treatment, which is very dangerous. Patients with hypotension often have dizziness, unstable standing, etc., easy to fall, and easily cause fracture after falling.

5.Heart rate

Fast heartbeat can cause the body to supply insufficient oxygen, causing the brain to stun and become more likely to cause the elderly to fall.

6. Osteoporosis

Muscle strength plays an important role in maintaining balance. Studies have shown that the knee muscle strength of the lower extremities affects the balance ability, and the balance function is also poor.

Based on the above analysis, we consulted the relevant literature. We have the following suggestions for improving the balance of the elderly:

1. Adjusting weight: First of all, we must pay attention to the prevention of obesity. In order to prevent the risk of excessive exercise on the elderly, we recommend that the elderly change their lifestyle to lose weight, such as reducing the intake of sugar. In addition, you can do some moderate exercise to adjust your weight.

In short, when choosing the way to lose weight, the elderly should choose their own according to their own situation [7,8].

2. Improve the function of the front hall: Some studies have suggested that Tai Chi soft ball exercise can promote aerobic metabolism of the whole body, improve cerebral blood flow, and help the blood supply and support of the big, cerebellum and vestibule, so that the function of the vestibular organs of the brain is improved, especially It is effective in enhancing the stability of the body's center of gravity in the horizontal displacement, developing the body control ability in the rotary motion, and improving the body's ability to sense in the lifting movement, which can enhance the balance ability of the trainer and improve the quality of life [7,8]

3. The balance ability of the elderly has a certain relationship with age, body shape, vestibular organs, proprioception, muscle strength, vision, drug factors, oral hygiene, etc. It is the result of a combination of various factors. It is still inconclusive as to which interventions can more effectively improve the balance of the elderly. Therefore, to improve the balance of the elderly, it is necessary to start from a multi-faceted and multi-faceted perspective, and comprehensive consideration can achieve the purpose of preventing falls and achieve good control effects.

6.Model evaluation and improvement

6.1Evaluation of the modle

According to the existing sports data, related mathematical principles and related literatures, after calculation and summarization, the relevant kinematic characteristics of the elderly can be obtained. These characteristics have an important influence on the balance ability of the elderly, which can help us understand the movement of the elderly more intuitively. The complete process. However, there may be high redundancy between some data, which will cause unnecessary waste of computing resources in the modeling process.

After obtaining the relevant kinematics, the data was preprocessed. The methods used include data standardization and removal of smaller variance data, which greatly assists in the selection of features. However, due to the high sampling frequency of this data, the degree of change between data is likely to be very small, so the use of conventional data with small variance removal may result in the loss of some key data. After the data is pre-processed, the features of the random forest are used to select the features, and the existing features are sorted according to the degree of importance. The first 25 features are selected as the basis for modeling. The random forest method has the advantages of fast processing speed, high accuracy of the generated classifier, and can handle a large number of input variables. However, random forests also have certain drawbacks, that is, the output results are random, so the 25 features selected are relatively optimal. It cannot guarantee absolute optimality.

Using the 25 features of random forest selection, the artificial neural network method was used to establish a two-layer artificial neural network model. The cross entropy was used as the standard of the evaluation model, and the model was further optimized. The optimization result was expected. The model structure using artificial neural network can help the expansion of the model in the future, and it is convenient to increase the depth of the network. However, as the data increases, the training speed may decrease significantly.

6.2Improvement of the model

When collecting the sports data of the elderly, a unified three-dimensional coordinate system is adopted to further unify the data specifications and improve the reliability of the data. And fixed-cycle sampling can be used to facilitate the calculation of certain speed-related features and improve the accuracy of the features.

The characteristics affecting the balance ability of the elderly can be further explored to expand the candidate range of the feature, and the calculation process is optimized to improve the application value of the feature to improve the accuracy of the model.

In terms of feature selection, a variety of selection algorithms can be used to score features, with scores as the criteria for feature selection, and corresponding inspection links can be added to further improve the reliability of feature selection.

In the established artificial neural network, a data addition module can be written to facilitate the expansion of data in the future, and further improve the accuracy of the model. Moreover, the test problem of the model should also be taken into consideration to prevent the model from over-fitting, to augment certain data, and to ensure the accuracy of the model by means of cross-validation.

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