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Prediction Model of Driving Performance Indicators in Center Control Screen Location Layout Based On BP Neural Network

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Abstract: The research on the design layout of on-board central control screen which meets the requirements of driving safety and operating comfort is of great significance to automobile manufacturers. In this paper, driving simulation test method is adopted to carry out the experiment. 32 sampling points are selected in the feature constraint space for the test. By collecting the data of driving performance indexes in ergonomics and using BP neural network for prediction modeling, it lays a foundation for the optimization of the position layout of central control screen in the future. This study has guiding significance for the optimization of other indexes in ergonomics.

1. Introduction

Internationally, ergonomics is defined as a science-based discipline that combines anatomy, physiology, psychology, engineering and statistics, so that design can give full play to people's strengths and abilities and avoid their shortcomings as much as possible [1].

Since the 1970s, China's ergonomics began to flourish and it has formed a fairly complete theoretical system after decades of development. The initial application field of ergonomics research is the design of aircraft cockpit - through the establishment of three-dimensional human body model and virtual simulation of the cockpit, design an efficient, comfortable and safe driving operation panel for the pilots to make sure that they can rapidly get information in the complex flight process, fully grasp of the body status and flight environment, rapidly strain under low load as far as possible to realize accurate aircraft [2].

The design of automobile cockpit, which is closely related to people and environment, is very special and complex, and also very core, so it is another important field of ergonomic application. Almost every powerful large-scale automobile manufacturer has its own ergonomic research department, such as PSA group, ford group, Volvo automobile, etc., all of which have rich theoretical basis and empirical research on ergonomic design optimization [3-5]. The digitization and intelligentization of automobile cockpit has become an irreversible trend. Drivers will be accustomed to using map navigation, music radio, air conditioning settings, communication and social functions through the vehicle central control screen while completing the main driving task operation in the driving process [6-8]. This change in interactive mode, compared with the traditional touch-tone operation, will bring additional physical and psychological load to the driver [9], and even affect the driver's driving behavior. Therefore, it is an inevitable mission of automobile manufacturers to optimize the position and layout of on-board central control screen based on ergonomic methods to meet the requirements of driving safety and operating comfort, which has high theoretical significance and application value.

In the ergonomic optimization of vehicle central control screen, the most concerned evaluation dimension is the driving safety and operating comfort in the process of using vehicle central control screen. In our work, the layout of central control screen in automobile cockpit is optimized by means of experiment and mathematical modeling. With the help of the on-board screen built in the simulated driving laboratory and cockpit, the experimental environment required by the ergonomic experimental method can be conveniently set up. Abundant operational data and environmental data can be collected and the mathematical model can be set up to lay a foundation for the later optimization of the position and layout of the central control screen.

2. **Methods**

Artificial neural network is a widely parallel interconnection network composed of simple units, which is an abstraction, simplification and simulation of human brain [10].

BP (Back Propagation) neural network is a multi-layer feed-forward network composed of nonlinear transformation elements, which is a training algorithm based on error inverse Propagation [11]. The transmission of BP neural network includes two processes, the positive information transmission and the reverse error transmission. The signal is processed layer by layer from the input layer through the hidden layer to the output layer, and then the weight and threshold of the network are adjusted according to the gap between the output and the expected output to make the predicted output approximate to the expected output.

Before using BP neural network, data training is needed to determine the basic parameters of the model, so that the model has the function of memory and prediction. In this study, this process includes the following seven stages:

(1) Network parameter initialization: according to the input and output data, set the learning times t=0, the number of nodes in the input layer is set to 3, the number of nodes in the hidden layer is set to 13, and the number of nodes in the output layer is set to 1. The initial connection weight is set, and the initial value of each threshold and weight is set as a random number within the interval of (-1, 1).

(2) Output calculation of hidden layer:

A) Input training primitives (X_k, T_k), $k \in \{1,2,\dots,N\}$, N is the total number of training primitives

B) Calculate the output value of the hidden layer

$$Y_j^2 = f\left(\sum_{i=1}^{n} w_{ij}Y_i^1 - \theta_j\right) = f\left(\sum_{i=1}^{n} w_{ij}X_{ki} - \theta_j\right), j \in \{1,2,\dots,n_1\} \quad (1)$$

(3) Output calculation output layer:

$$Y_k^3 = f\left(\sum_{j=1}^{n_1} w_{jk}Y_j^2 - \theta_k\right), k \in \{1,2,\dots,m\} \quad (2)$$

(4) Error calculation: the prediction error of the neural network is calculated according to the predicted output and expected output:

A) Calculate the error of output layer node:

$$\delta_k = (T_k - Y_k^3)Y_k^3(1 - Y_k^3), k \in \{1,2,\dots,m\} \quad (3)$$

B) Calculate the error of hidden layer node:

$$\delta_j = Y_j^2\left(1 - Y_j^2\right)\sum_{k=1}^{m} \delta_k w_{jk} \quad (4)$$

(5) Weight update: according to the prediction error, adjust the network connection weight and node threshold:

A) Modify the connection weight and threshold between between hidden layer and output layer:

$$w_{jk}(t+1) = w_{jk}(t) + \alpha\delta_k Y_j^2 \quad (5)$$

$$\theta_k(t+1) = \theta_k(t) + \beta\delta_k \quad (6)$$

B) Modify the connection weight and threshold between the input layer and the hidden layer:

$$w_{ij}(t+1) = w_{ij}(t) + \alpha\delta_j Y_i^1 \quad (7)$$

$$\theta_j(t+1) = \theta_j(t) + \beta \quad (8)$$

According to the judgment condition, make the algorithm repeat the above process until the end condition is met.

BP neural network is the most influential form of the current neural network model, and 80-90% of the current artificial neural network applications are BP neural network or its variation form [12]. BP neural network is widely used in pattern recognition, image processing, prediction and fitting of nonlinear equations.In this project, BP neural network will be used to establish the mapping relationship between the 3d coordinates of the central control screen and driving performance indicators, which will establish a reliable basis for the optimal location selection of genetic algorithm.

3. Experiment

This platform provides the driver driving environment simulation, the main task and driving time task evaluation parameter acquisition function. In addition to the redesign transformation of control of interactive system based on the existing DS5 test car, it can also access any level of passenger cars into the laboratory, and we could drive the car in a simulated driving road.

The structure of the simulated driving simulation platform is shown in Fig. 1, which is mainly composed of simulated cockpit, simulated driving environment and data acquisition system. The simulated cockpit includes the actual vehicle, the modified vehicle motion control system, and the central control screen platform for testing. The simulated driving environment includes a variety of driving scenes, such as city, suburb, high speed and congested road surface, which are controlled according to the input of the vehicle motion system in the simulated cockpit. Data acquisition system is recorded based on the central computer of the vehicle data storage and sub-task completion of the storage.

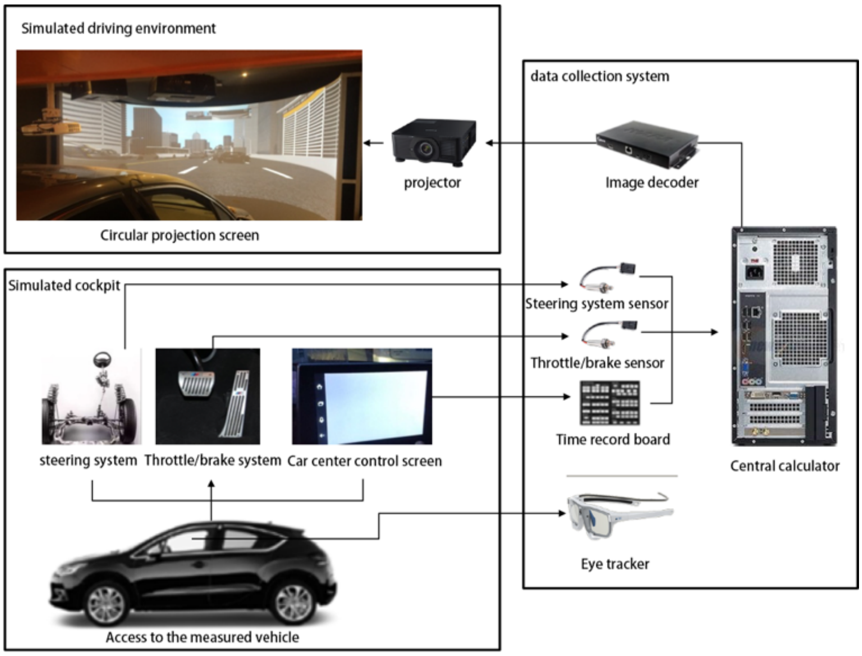

Figure 1. Structure of Simulation driving simulation platform

Based on the definition of manual interface in ergonomics and the situation of screen layout in the current automobile market, we constrain the position characteristics of the central control screen:

$$200mm < x < 550mm$$

$$450mm < r < 800mm$$

$$\theta < -6°$$

Here, x represents the translation distance relative to the center of the eye ellipse along the direction of the wheel axis; θ is the angle of rotation around the x-axis; r is the distance from the x-axis.

In the constraint space of the layout of the central control screen, 32 coordinate positions are taken as the center point of the central control screen, so that the 32 points can basically divide the constraint space into the same subspace, as shown in Fig. 2.

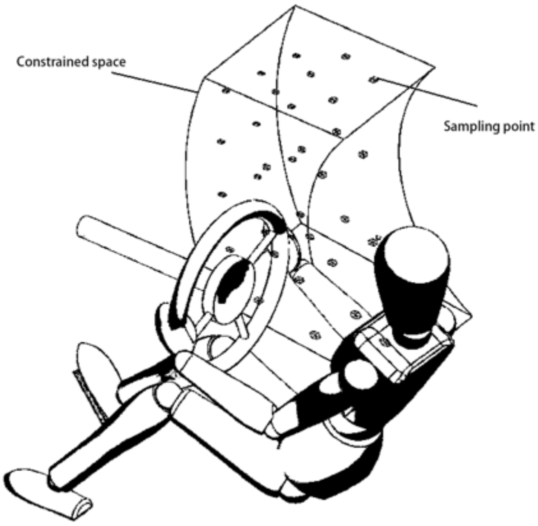

Fig. 2 Screen position coordinates of 32 sample points

We recruited 16 testers with 11 males and 5 females to participate in the simulated driving test in a paid way. Their height and arm length data were taken as the reference with the population data at the position of 50%, and the error was no more than 2cm. The age distribution is between 22 and 38 years old, and the driving experience is between 2 and 10 years. The 16 subjects need to click the orange origin randomly appearing at any position on the screen for 5 times in a row in 32 different on-board central control screens and keep the vehicle speed at 60 km/h to complete the task as one driving time. At each position, they need to repeat the driving task seven times.

4. Results and analysis

We evaluated the driving performance of the tester in turn by observing whether there would be fluctuations of speed and road deviation during the sampling period of the tester's operation with the central control screen.

Fig. 3 (a) shows the longitudinal average velocity of the tester's screen interaction with 32 sampling points of the central control screen under the driving condition without sub-task, and the deviation amount compared with the driving speed of the target at 60km/h.

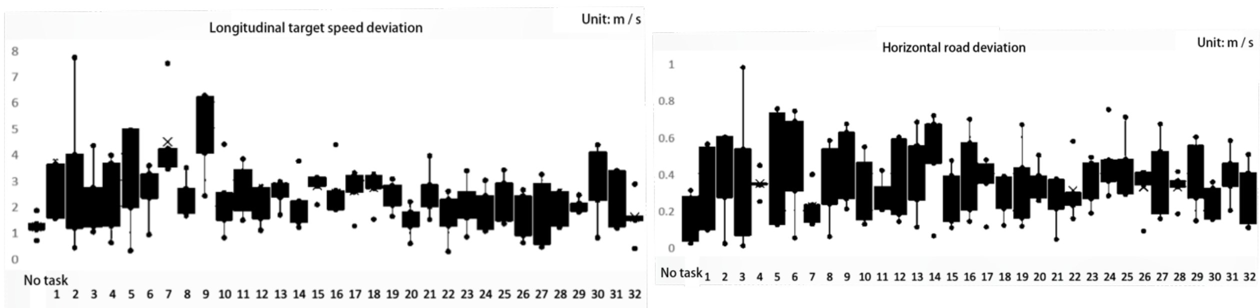

Fig.3 (a) Longitudinal target speed deviation (b) lateral road deviation.

When the tester is driving without tasks, the average longitudinal speed is only 1.2 km/h compared with 60 km/h. During the driving operation of a task, the difference value significantly increases. This indicates that the operation of sub-task has a significant impact on the speed control ability of the driver.

By comparing the 32 sample screens, it can be found that if the longitudinal distance between the middle control screen and the tester is too large (screen sample no. 1-9), the driver's ability to control the speed will significantly decrease and the target speed will significantly deviate. Combined with the subjective evaluation of the tester in the test process, the possible reason is that when the screen distance is too large, the tester needs to straighten his arm, or even bend his upper body forward, in order to interact with the screen; the forward inclination of the upper body will have a greater effect on the pedal control of the lower body.

If the middle control screen is too close to the longitudinal distance of the tester (screen sample no. 22-32), the driver's ability to control the speed will also be affected, which is reflected in the increased dispersion of the difference between the target speed and the control screen, that is the poor consistency in the speed control. Maybe it’s because that when the screen distance is too large, the tester needs to focus more on the screen, which has an impact on the road condition and speed.

Fig. 3 (b) is the amount of lateral road deviation for the tester to interact with the screen at 32 sampling points of the central control screen in the driving state without sub-task. When the tester is driving without tasks, the average deviation of the lateral road is only 0.15m. During the driving operation of this task, the lateral road deviation significantly increased. This indicates that the operation of this task has a significant impact on the speed control ability of the driver.

By comparing the 32 sample screens, it can be found that if the horizontal distance between the central control screen and the driver is too large (screen sample no. 6, 9, 12, 14, 17, 23, etc.), the driver's ability to control the horizontal position of the vehicle will decrease obviously, and the road deviation will be large. The possible reason is that when the horizontal distance of the screen is too large, the tester needs to extend his arm to the right, which has a great impact on the operation of the steering wheel.

The significance test of the difference between the above two groups of data in the driving state without sub-task and the data in the 32 sample points shows that the significance of the difference between the tester in the 32 sample points is $p<0.01$, which is significantly different from the driving state without sub-task. The parameters of these 32 sampling screens will become the training samples of BP neural network.

As described in method, BP neural network is used for training to establish the relationship between the three-dimensional coordinates of the central control screen and the longitudinal velocity deviation value. Similarly, the relationship between the 3D coordinates of the central control screen and the lateral road deviation is also established. The maximum training times are both set to 50000, the learning rate is set to 0.015, and the expected error is 6.5 x 10^$^{-4}$.

The predicted and tested values of the two groups were compared respectively in Fig. 4, and the trends in each group between the two parameters were basically consistent, indicating that the fitting degree was very high and the training was relatively successful.

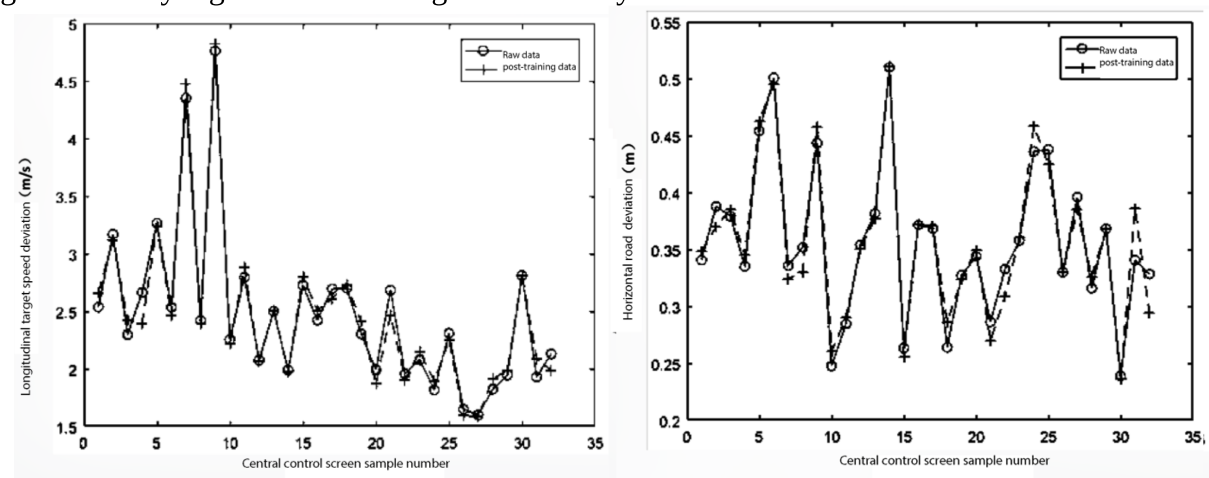

Fig. 4 Comparison of original data and training results of 32 sampling screen according to (a) the relationship between the three-dimensional coordinates of the central control screen and the longitudinal velocity deviation value and (b) the relationship between the 3d coordinates of the central control screen and the lateral road deviation.

5. Conclusion

Based on the research of mental load in the field of ergonomics and automotive engineering, this paper refined the evaluation method of mental load into manipulation performance index, psychophysiological signal index and subjective scoring index, and determined the optimal index parameters to be collected in the ergonomic experiment. The ergonomics experiment was designed and simulated driving test method was adopted to carry out the experiment. The location points of the central control screen were sampled in the constrained space. Testers were recruited to conduct simulated driving. BP neural network was used to model the prediction of multiple indexes. The two driving performance indicators, vertical road deviation and lateral road deviation, were compared by box-plot. The difference significance analysis and the prediction modeling of BP neural network both obtained good fitting results, which laid a foundation for the optimization model of genetic algorithm.

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