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The Evaluation Model of Drone Appearance Design

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Abstract

The major objective of this paper is to establish a drone's appearance design evaluation model based on BP neural network, so as to make the drones appearance design more scientific and meet the actual needs. Evaluation criteria for drones' visual styles using design based neural networks is to establish a comprehensive evaluation index system, organize experts to evaluate and score the samples, obtain the training and inspection data of neural network, assess the relative significance of each index by MATLAB simulation, and extract the nonlinear relationship reflecting each metric used in evaluating, and the overall assessment's findings. Model for testing BP neural networks reduces the effect of subjective factors in the evaluation process of comprehensive assessment method and analytic hierarchy process, can objectively and comprehensively evaluate the drone's appearance design, and provides an effective reference for selecting the optimal drones appearance design scheme.

Keywords: BP neural network; Drones appearance design; Evaluation model; industrial design

Introduction

With the improvement of modern control theory and electronic control technology, the drones has made great progress, autonomous flying drones may be used in various industries in the future (Baytas et al., 2019). Initially, drones were for non-civilian use, due to its small size, high mobility and strong anti-reconnaissance capability, the drones are now widely deployed in the military field, such as the war between Ukraine and Russia. With the increasing portability of drones technology and computing hardware, drones are widely used in civil, industrial and building areas with special geographical environment and dangerous working environment, which not only improves work efficiency but also ensures the safety of staff (Funk, 2018). Drones are increasingly involved in people's lives. In the past 10 years, they have even become toys for some enthusiasts, so the design requirements for its working ability, appearance design and other aspects are getting higher and higher. In the current drones design process, function is the first factor that most manufacturers consider, but we need also think about appearance design, color selection, material application, user experience and others (Han et al., 2021). Many manufacturers believe that product appearance design is the fastest way to improve homogeneity and achieve brand differentiation.

At present, the methods of appearance design mainly include the following aspects: (1) Optimize the appearance design of products through modular digital modeling of 3D product models and structural parameter design (Ge, 2012). This method needs to rely on previous experience for parameter adjustment, which is difficult to master. (2) Through a large number of finite element calculations to optimize the design algorithm for appearance optimization design (Weiwei et al., 2012). This method takes a lot of time, and the results are full of uncertainty, it is impossible to ensure that all the results are optimal. In response to the above problems, this study presents a comprehensive evaluation strategy using neural networks in simulation to evaluate the drone's appearance design scheme. Combining quantitative evaluation and qualitative evaluation, more reliable and real evaluation results can be obtained, which provides reliable support for the development and application of drone's appearance design.

The artificial neural network imitates the learning state of judging and analyzing things in the process of human brain understanding things, and finally solves the problems in different fields. The artificial neural network has good fault tolerance, and the nonlinear relationship between the weight description variable and the target can be studied through its good nonlinear approaching ability (Zhao et al., 2010). In the field of model evaluation, many scholars use neural networks to evaluate different situations. An artificial neural network algorithm commonly used to solve nonlinear problems is a three-layer a neural network based on BP data. As one of the most studied neural network models, the BP (back propagation) neural network is a multilayer feedforward network that is trained using an error back propagation technique (Zhao et al., 2010). On the basis of these existing explorations, GA to BP neural network, and introduced how to use GA to optimize the connection weight of neural network (Ding et al., 2011). The BP neural network model of directional propagation to eliminate the influence of season on actual wind speed data by adjusting the season index, and created a new method of wind speed prediction (Guo et al., 2011). The convolutional neural network to the owner's gesture recognition algorithm, which was first realized by the smart bracelet on the mobile end (Li et al., 2021).

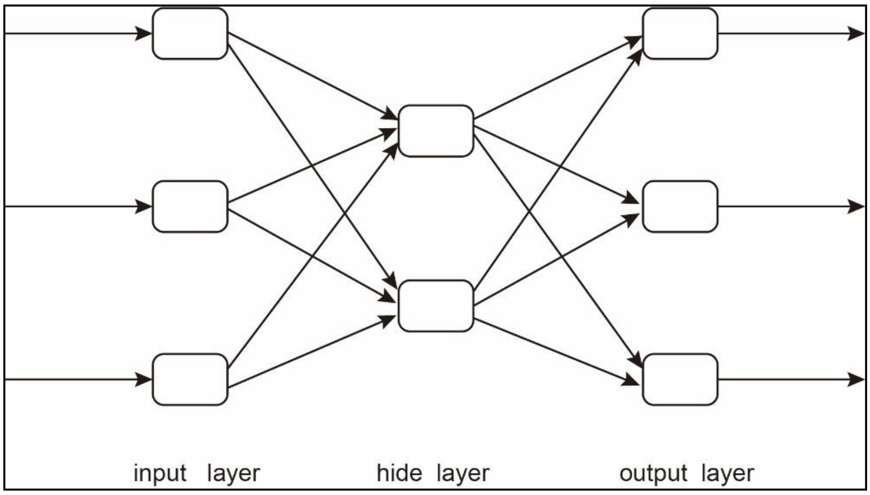

Figure 1. *BP networks structure*

A typical BP network has a tri-layer structure, as depicted in Fig. 1. It is the job of the input layer to receive data from the output layer, hidden layer and the final layer of a chain of processing. There is a fixed logical relationship between the three layers of topology. In this case, communication between neurons on the same layer is limited to connections with cells in the adjacent layers. Between layers, there is no feedback connection (Zhao et al., 2010). If we want to get the weight of the connection between related neurons and reflect the interaction between various factors and results of problems in different fields. First, obtaining the sample data for the related problem to use as the neural network's training sample is the first step in training the network to solve the problem. Then, the characteristic parameter description of the target problem is used as the numerical input of the neural network. The output problem of neural network is the result to be solved. The neural network algorithm is then used to solve the problems that it was trained to solve (Suliman & Zhang, 2015).

MATLAB is a commonly used mathematical simulation calculation software, mainly used in data analysis, image simulation, motion simulation, system control, signal processing and other fields. MATLAB has hundreds of built-in function packages and 30 tool kits. One of the neural network toolboxes provides many functions of neural network design, training and simulation. As long as users call relevant functions based on their own requirements, they can easily design as well as simulate neural networks, and avoid interference with compiling complex and huge algorithm routines. Through the simulation of a specific motor, the waveform that achieves the desired effect is given, and the rationality and effectiveness of the algorithm are proved (Liu et al., 2009). Ijemaru et al. (2021) used a matrix laboratory (MATLAB-based analytics) to evaluate various image processing techniques. They believe that, compared with traditional technologies, the technology based on MATLAB provides simple debugging, extensive visual data analysis, and convenient algorithm testing without recoding (Ijemaru et al., 2021). MATLAB can process and create static images and dynamic video simulation through enhanced calculation code.

There is an optimization algorithm called Trainlm Levenberg – Marquardt in MATLAB. When processing large network data, by adjusting the mem reduction parameter, the method will split the Jacobian matrix into numerous smaller matrices, which will decrease the amount of memory used yet speed up the learning process. There are significant benefits to using the LM optimisation method as opposed to the classic BP algorithm or even some of the more recent improved techniques. In addition to improved consistency and higher accuracy, it also requires less iterations (Krishan et al., 2013). Consequently, there are benefits to using the LM optimization technique when learning a BP network. The MATLAB neural network simulation tool's BP neural network training function defaults to LM. Because of its simple operation, convenient operation, less calculation process and strong parallelism, many researchers regard it as the preferred algorithm for the network.

Methodology

One of the most popular types of neural network is the artificial neural network. The construction of the multi index comprehensive evaluation model requires four steps: (1) establishing the evaluation index system and refining the influencing factors of the problems to be solved; (2) The normalization of multiple indicators is mainly to reduce the adverse impact of different dimensions on the final evaluation results; (3) The normalized evaluation index is input and the evaluation result is output. The coefficient weight of each evaluation index of the neural network is obtained after full training by the neural network; (4) As a result of the attribute value of the evaluation index and the neural network training, it may acquire the value of the problem to be evaluated, which is the objective evaluation result. The experts give the best plan through objective evaluation results, their own experience and subjective judgment. When applying BP neural network to evaluate the target model with multiple indicators, the evaluation results can not only meet the requirements of subjectivity of practical problems, but also meet the requirements of objectivity.

The multi-index comprehensive assessment model consists of a BP neural network and a data preparation stage. Normalize the corresponding indicators according to certain rules and reduce the impact of different indicators and dimensions on the final evaluation results, that is, the data preprocessing of the evaluation model; the three-layer BP neural network is divided into input layer, output layer and hidden layer. The number of evaluation indexes determines the number of nodes m in the network input layer; the amount of calculation and the accuracy of evaluation results in the process of problem solving are determined by the number of cells in the hidden layer; the evaluation result chooses n=1 as the number of nodes in the output layer. As a result of this empirical formula, we may calculate the optimal number of cells for the covert layer (Yuan Song et al., 2013):$L = (m \times n)^{1/2}$. Figure 2 shown for the structure of the three-layer neural network used in the multi-index comprehensive evaluation model.

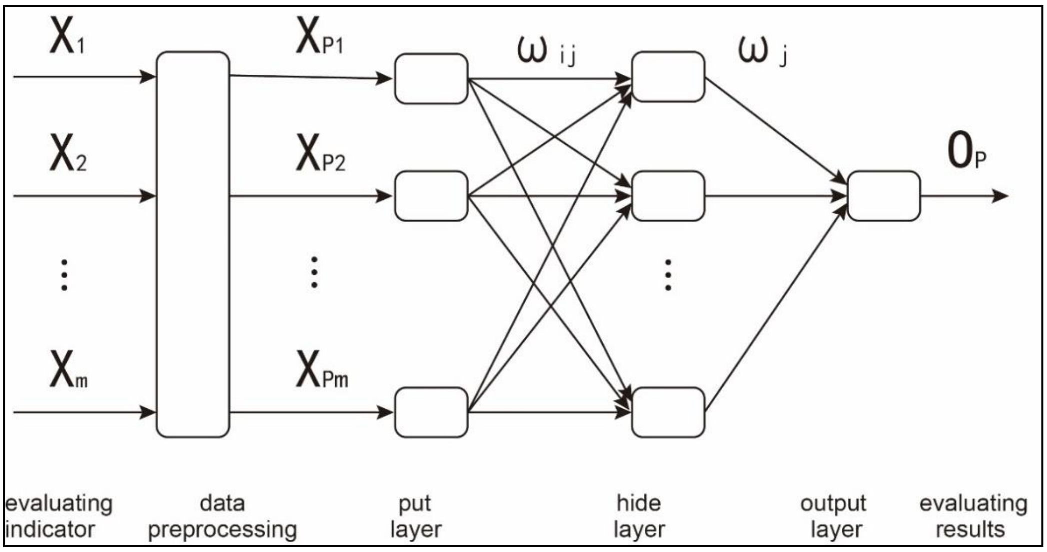

Figure.2 *Topological structure of multi index comprehensive evaluation model.*

The attribute values for each evaluation indicator are usually normalized by the mapping principle, including quantitative indicators and qualitative indicators. Quantitative indicators usually refer to different orders of magnitude and dimension. Benefit indicators are positively correlated with the attribute values of indicators, while cost indicators are negatively correlated with the attribute values of indicators. There are obvious differences among various indicators of multiple evaluation indicators, which have different orders of magnitude and dimension. In order to map the attribute values of each indicator to the closed interval [0,1] in the evaluation system, the extreme values U_{max} and U_{min} of each indicator in the evaluation system need to be obtained first. The extreme values will be normalized according to the following principles:

Cost type indicators:

$$r_i = \frac{U_{max} - U_i}{U_{max} - U_{min}} \quad (1)$$

Benefit indicators:

$$r_i = \frac{U_i - U_{max}}{U_{max} - U_{min}} \quad (2)$$

U_i is the relevant evaluation indicator set.
Interval:

$$\begin{cases} r_i = \frac{U_i - U_{min}}{U_{avg} - U_{min}} \ (U_{min} \le U_i \le U_{avg}) \\ r_i = \frac{U_i - U_{max}}{U_{avg} - U_{max}} \ (U_{avg} \le U_i \le U_{max}) \\ r_i = 0 \quad (U_{max} \le U_i, U_i \le U_{min}) \end{cases} \quad (3)$$

U_i is the relevant evaluation indicator set.

Several layers of artificial neural neurons make up the BP neural network with S function as the transfer function between its neurons. The BP neural network may implement any nonlinear mapping between input and output. The training algorithm flow of BP neural network is as follows(yuan song et al., 2013): (1) initialize the weights among neurons; (2) The training samples and expected output set are obtained by preprocessing the sample data of the corresponding problem; (3) Obtain the output of each layer in the neural network; (4) Obtain the error of each layer in the neural network; (5) Back propagation is used to adjust the neural network's weights and thresholds; (6) Get training samples and output sets again, and return to (2), and calculate the results until they meet the preset accuracy requirements; (7) If the set accuracy requirements or minimum training times are not met, return to (6).

Establishment of BP network model

3.1 Establish evaluation index of drone's appearance design

The evaluation of drones appearance design is mainly carried out from 9 aspects: functionality, economy, symbolism, innovation, manufacturing process feasibility, environmental adaptability, artistic aesthetics, sustainable development, and man-machine coordination (Khakimov et al., 2019). Combined with the previous design research, the evaluation index system is composed of 23 evaluation indexes, including cruise ability and hover ability. Table 1 lists the detailed evaluation indicators.

Table 1. *Comprehensive evaluation index of drones' exterior design*

Evaluation criteria	Evaluation indicators
functionality	Navigational capacity Hovering ability Take-off and landing performance Ceiling
Economy	production costs Use cost economic performance
Symbolic	Symbolic function Semantic extension
Innovation	Principle structure
Manufacturing process feasibility	Process difficulty Development value
Environmental adaptability	Suitable environment Green and environmental protection
Artistic aesthetics	modelling color decorate
Sustainability	Power source Material application
Human machine coordination	human-computer interaction interface User experience

3.2 Sample design of the network

This paper chooses 50 drones from 10 mainstream brands in the drone market as the primary sample of the model. An expert group was formed by inviting 10 members who are familiar with drones. The expert group includes two industrial designers, one engineer, four drones enthusiasts and three design master students. The appearance, performance and characteristics of 50 drones were analyzed using KJ method. Through comparison of evaluation indicators, the drones with high similarity were eliminated, and 24 DRONESs with typical characteristics were finally selected.

Figure 3. *Drones exterior design sample.*

The expert evaluation method is used to organize experts to evaluate the appearance design of 24 selected typical drones. Based on the mastered data of drone appearance design, the selected drone appearance is comprehensively evaluated according to the comprehensive evaluation index. Parts samples participating in the evaluation model are shown in Figure 3.

This research adopts expert evaluation method to evaluate the appearance of drones. The expert team mainly includes drones' enthusiasts, designers, engineers, sales personnel and other personnel related to drones. The data is mainly collected by questionnaire. A random sample of 185 surveys was used to collect 170 usable responses. The questionnaire is effective in 92% of cases. The fifth order Likert scale was used to evaluate the design indexes of 24 typical DRONESs in the questionnaire. The scale mainly includes five different levels of strength description scores: 1,2,3,4,5. There are five possible responses: 1 point for strong disagreement, 2 points for disagreement, 3 points for neutral, 4 points for agreement, and 5 points for strong agreement. The selected tester uses this so-called five-point system to evaluate and score the 23 design indicators of the drones. Count the scoring grades of experts and take the average value to obtain the design effect evaluation results. After the results are normalized, Table 2 displays the outcomes of the expert evaluations. The evaluation's first 16 sets of data are used to train the neural network, and the last 8 groups of data in the evaluation results are used for network verification.

Table 2. *The results of expert evaluation*

Sample No	**1**	**2**	**3**	**4**
Evaluation Score	0.548	0.392	0.814	0.721
Sample No	5	6	7	8
Evaluation Score	0.512	0.796	0.731	0.612
Sample No	9	10	11	12
Evaluation Score	0.486	0.793	0.784	0.627
Sample No	13	14	15	16
Evaluation Score	0.638	0.853	0.392	0.614
Sample No	17	18	19	20
Evaluation Score	0.688	0.612	0.792	0.784
Sample No	21	22	23	24
Evaluation Score	0.615	0.742	0.615	0.712

3.3 Algorithm Steps of BP Neural Network Model

Based on the comprehensive evaluation indexes of drones appearance design listed in Table 1 and 23 neurons are determined in the neural network model, so there are 23 evaluation indexes in the input layer. According to the empirical formula $L = (m \times n)^{1/2}$, number of neurons in the neural network's hidden layer is determined to be 3. Determine a generation value in the neural network output layer [0,1] in the neural network model, so there is only one neuron. [0,1] represents the evaluation result of the drones appearance design evaluation model. This scheme's appearance design for drones is superior and more reasonable the closer the value is to 1.

The function training is carried out by using the common tool MATLAB, and Trainscg is determined as the training function. Every layer, from input to hidden to output, has 23 nodes, 3, and 1. Finally, the learning accuracy of the network is set to 10^{-7}.

The first 16 sets of data in Table 2 are used to train the neural network, and the continuous cycle iteration of function training is carried out through MATLAB tool, which stops after meeting the learning accuracy requirements. Through training the neural network, find out the mapping function of nonlinear connection between input and output, and learn how each index in a neural network is weighted. Training data for the neural network are shown in Table 3. Input the last 8 groups of data in Table 2, and get the comprehensive evaluation results according to the last 8 groups of calibration data, as shown in Table 4.

Table 3. *The training results of neural network*

Sample No	**1**	**2**	**3**	**4**
Training results	0.539	0.376	0.813	0.723
Expected output	0.548	0.392	0.814	0.721
Sample No	5	6	7	8
Training results	0.503	0.791	0.730	0.610
Expected output	0.512	0.796	0.731	0.612
Sample No	9	10	11	12
Training results	0.488	0.795	0.781	0.631
Expected output	0.486	0.793	0.784	0.627
Sample No	13	14	15	16
Training results	0.638	0.854	0.391	0.614
Expected output	0.638	0.853	0.392	0.614

Table 4 shows that the maximum error is about 8.6%, and the minimum error is about 0.16%. The difference between the network output results and the expert evaluation results is very small. This shows that the trained neural network is adaptive to the problem of drones appearance design evaluation, and this method can be used to comprehensively evaluate drones appearance design.

Table 4. *The testing results of neural network*

Sample No	1	2	3	4
Training results	0.714	0.602	0.805	0.743
Expected output	0.688	0.612	0.792	0.784
Relative error%	-3.78	1.63	-1.64	5.23
Sample No	5	6	7	8
Training results	0.614	0.658	0.602	0.694
Expected output	0.615	0.742	0.615	0.712
Relative error%	0.16	8.63	2.11	2.53

Discussion and Conclusion

This paper creates a BP neural network evaluation model to evaluate 23 design indexes of drones appearance design, and verifies whether the evaluation model of BP neural network can be applied to drones appearance design evaluation by comparing it with the evaluation data of the expert group. Then select 24 models of the drones from 10 mainstream brands in the drone market by KJ method. In the validation process, we first built the DRONES evaluation system indicators, used the KJ method to select 24 typical DRONES models from 10 major brands in the DRONES market, and used the expert evaluation method to evaluate and score 24 typical DRONESs through questionnaires to obtain expert evaluation data.

Then, according to the BP neural network model, the product is put into MATLAB again for preference test, and the results obtained are compared with the results of expert evaluation to determine whether the appearance design indicators of the DRONES can be evaluated using the BP neural network model. Through comparison, it can be found that the maximum error of the difference between expert evaluation results and computer aided results is about 8.6%, and the minimum error is about 0.16%. Although the results of this study are not all composite expectations, and some relative errors exceed the evaluation range, most of the relative errors remain within 5%. From this, we can draw a conclusion that we can use BP neural network model to evaluate the appearance design indexes of DRONES. In the subsequent evaluation process, attention should be paid to the rationality of parameter selection to improve the accuracy of the neural network evaluation model.

BP neural network can be used to evaluate the appearance design of drones. Using MATLAB tools to simulate and calculate the weight relationship between the indicators, the trained neural network has adaptability and reliability to the problem of drones appearance design evaluation, which provides a mathematical basis for the uncertainty factors in the process of drones appearance design, thus helping to reduce the design risk, while improving the practicality of the mathematical evaluation model in the optimal selection of the appearance design scheme. It is believed that with the rapid development of computer aided design technology, BP neural network evaluation system will be more perfect, its application scope will become more extensive, and more diverse methods will be obtained in computer aided product design.

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