Sound-Quality Prediction for Vehicle Cooling fan Noise Based on BP Neural Network Model

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ABSTRACT: Based on the complexity and non-linear characteristics of vehicle cooling fan sound quality evaluation, the problemabout the application of BP neural network in sound quality prediction is discussed. Combining the basicprinciples and models with examples the complete implementation process is presented. The self-learning ability of thisprediction method is so strong that each connection weight could generate itself via network learning with a moreobjective and accurate predicted result. Then BP neural network evaluation method is compared with the existingprediction methods, and the conclusion shows that in interior vehicle subjective and objective noise evaluation, theprediction effect of the former method is much better. To a large extent the method could be used to improve thedecision-making accuracy, which is of great importance to the evaluation, analysis and control of fan noisenowadays.
Keywords: fan; sound quality; BP neural network; predict model

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I. INTRODUCTION

Many products and applications employ or includefans, for example Information Technology (IT) devicesand products, household appliances, air-conditioningsystems and automotive applications. Low-noisedesign is a key purchase requirement in all of thesefields, where often the main noise source is a fan. Forgiven constraints, such as fan dimensions and coolingperformance, it is not possible by technical means toachieve an arbitrary low-noise design.the effective characterization of fan noise is achallenge in acoustic and sound quality measurement.In general, the product sound quality does not dependonly on the emitted noise level or frequency-weightedlevel like A-weighted level or loudness. Tonal components,howling sounds and modulated signals are oftenthe cause of customer complaints.

Loudness has been introduced as a more hearingrelatedparameter than the A-weighted level in the lastdecades. Several methods exist in internationalstandards for measuring the loudness of stationarysignals (ISO 532 B and DIN 45631). DIN 45631 willbe extended with respect to loudness of time-varyingsignals (DIN 45631/A1, draft version published inJanuary 2008). This is an important step, because in practice we almost always have to deal with time-varying signals.

Besides time-varying loudness, other psychoacoustic parameters like sharpness and roughness can be used for sound quality evaluation. Sharpness considers the amount of high frequency components of a noise (DIN 45692, draft version published in April 2007), and roughness evaluates modulation characteristics. In addition, a metric combining modulation spectral analysis with loudness calculation has been introduced.for a long time, researchers have been trying to explore the establishment of accurate objective quality parameters to describe people's subjective sense of sound quality evaluation model..Because of the randomness of human subjective evaluation and the existence of some non-linearity between objective parameters, the existing linear regression model of sound quality can not map the complex nonlinear relationship between subjective and objective evaluation. To the desired level. Artificial neural network is a kind of forecasting method with good application effect, and it is widely used in automobile industry.Neural network is a adaptive nonlinear dynamic system composed of a large number of simple neurons and has many advantages compared to other methods:

This paper starts with the subjective evaluation experiment and the psychoacoustic parameters metrics. Then a BP neural network is applied to pridict the radiator fan sound quality.

II. SUBJECTIVE EVALUATION EXPERIMENT

Pairwise comparison method is a more commonly used subjective evaluationmethod, which makes it easy for the evaluation subject to obtain the relative comparison result between the evaluation samples.However, when the number of samples is evaluated, the amount of evaluation effort required by the paired comparison method in the general sense will become very large.In this paper, an improved pairwise comparison method, which is a group comparison method, which is suitable for more evaluation samples, is put forward and applied to the actual subjective evaluation experiment.Group comparison method can greatly reduce the workload of

subjectiveevaluation, and make the evaluation experiment more practical and get more stable evaluation results.

2.1 Sample collection and processing

The evaluation sample is a sample of the in-vehicle noise samples recorded using the simulation head. The sample samples the noise samples of the front and rear seats of the car at different fan speeds. A total of 34 samples, each sample length of 5s.Many studies have shown that loudness differences have a significant effect on the evaluation results, and their correlations are about 90%. Therefore, the loudness of the evaluation samples is equalized to obtain the correct evaluation results of the evaluated parameters.

In this experiment, the grouping method is used. The method is to participate in the evaluation of 34 sound samples (according to l-34 on its series) To select one of the sound samples as a reference to the (anchor) sample, that is, each group contains reference sound samples.In the case of grouping the samples, the uniform distribution of the evaluation characteristics of each set of samples will result in a better consistency of the evaluation results between the groups.

2.2 The numerical results of the evaluation

After the evaluation result of the evaluation subject is obtained, it is digitized. In this experiment, it is assumed that the comparison of the amount of the sample before the sample is greater than the subsequent sample, its assignment is 1; otherwise, the assignment is -1; that the two are equal when the assignment is 0.The evaluation of the poor performance of the data were removed, because A, B, C three groups of samples and evaluation is relatively independent, so the results of the main body removed also maintained its relative independence, each other is not necessarily linked.

2.3 Evaluation results

After the scores of each group are analyzed, the results of each group need to be combined to obtain the sorting results of all the samples.The results of each group can be combined based on the reference samples designed in the evaluation experiment.

Table 1 Subjective and objective evaluation results of cooling fan noise

Sample number	Loudness	Sharpness	Roughness	Fluctuation Strength	results
1	14.6789	2.2873	0.1498	1.0703	11.25
2	16.0532	2.2802	0.1558	1.1389	31.54
3	17.1067	2.3077	0.15	1.1268	30.95
4	19.6523	2.3065	0.1647	1.1096	25.83
5	20.7133	2.3081	0.1628	1.0834	22.46
6	18.1014	2.2991	0.1584	1.0815	21.08
7	15.2848	2.2983	0.1605	1.1056	17.71
8	12.4518	2.2422	0.1276	1.0833	13.04
9	9.87	2.2177	0.1185	1.097	8.33
10	17.1994	2.2654	0.1479	1.1487	3.91
11	8.5849	2.1854	0.108	1.0863	1.91
12	9.29824	2.181	0.1146	1.1414	1.16
13	11.6437	2.2317	0.1368	1.1077	18.87
14	13.1256	2.2274	0.1373	1.051	13.75
15	13.7708	2.2444	0.14	1.0643	10.75
16	14.5246	2.2622	0.1413	1.1101	3.29
17	16.3905	2.2469	0.1537	1.1261	3.62
18	18.5851	2.2158	0.1499	1.0731	6.25
19	19.8767	2.2343	0.1757	1.1209	13.04
20	21.0267	2.2157	0.1747	1.0714	24.66
21	22.9601	2.126	0.192	1.1165	27.7
22	8.2883	2.0241	0.1151	1.0749	32.83
23	9.5909	1.9831	0.1262	1.0745	30.7
24	11.1065	1.957	0.1294	1.0858	28.33
25	12.4215	1.9629	0.1279	1.0831	26.87
26	14.3233	1.9503	0.1454	1.1183	22.62
27	15.3147	1.9444	0.1609	1.0915	23.91
28	16.0041	1.9841	0.1561	1.0206	17.25
29	16.631	2.0039	0.1621	1.1196	20.04
30	17.2932	2.0199	0.1627	1.119	15.75
31	18.7892	2.0001	0.1694	1.1118	10.45
32	19.0838	2.0265	0.1651	1.0981	11.25
33	20.6017	2.0316	0.1791	1.1098	6.04
34	21.5704	2.058	0.1713	1.0806	2.92

III. BP NEURAL NETWORK MODEL

BP network is a multi-layer feedforward network with single hidden layer trained by back propagation algorithm. It is a mature and widely used artificial neural network. It is a kind of multi-layer forward feedback neural network with error back propagation .In theory, a three-tier BP network can approach any nonlinear function.
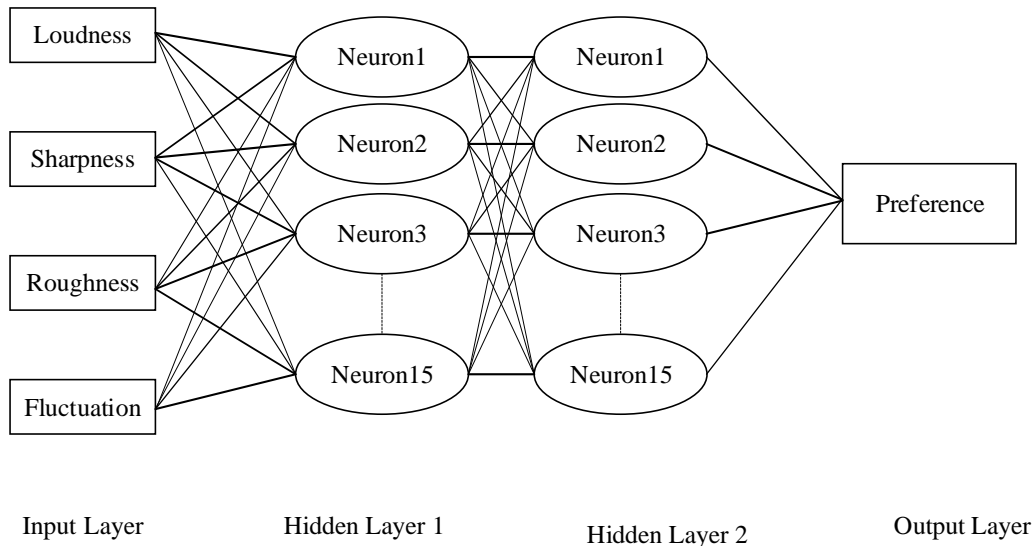

Fig.1 Network structure

The topology of the BP neural network is 4-15-15-1, and the structure of the network model is shown in Fig.1.

A total of 24 data from 1 to 24 in Table 1 were selected as training samples, and data of 25 to 34 were selected as test samples.The use of software MatlabR2007 neural network toolbox (NeuralNetwork Toolbox) newff function to create BP training network; use traingdm as a training function,The function is studied by the gradient descent method, and the learning rate is adaptive.
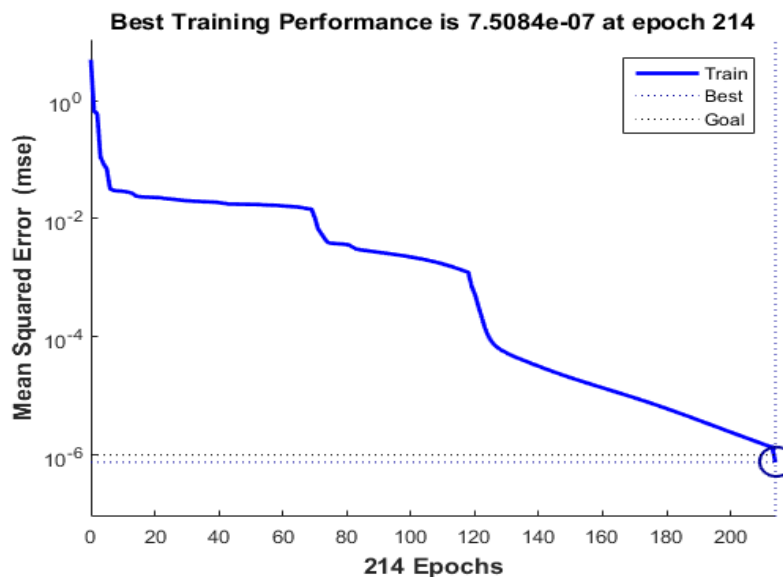

Fig.2 Training error curve

It can be seen from Fig.2 that the established BP neural network prediction model shows good prediction accuracy and fast convergence speed (after 214 training, the network error is required).

IV. CONCLUSIONS

Based on the BP neural network, the acoustic quality prediction of the vehicle noise can be considered as a quantitative factor, which can be a quantitative factor or a qualitative or uncertain factor, which can solve the nonlinear problem in the acoustic quality prediction.The BP neural network prediction model, which is

established in this paper, not only provides some guidance for the prediction of the noise quality in the vehicle, but also proves the feasibility of the model of noise prediction in the vehicle noise.

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