

# The Co-Pilot Position of Vehicle Noise Quality Prediction Based on SVM

**Xiaojuan Zhang**

School of mechanical engineering, Dalian Institute of Science and Technology Dalian, China

dalianxiaojuan@163.com

**Abstract.** In three different types of domestic cars for example, the paper studied interior noise sound quality when engine idle at a constant speed in different speed operation. Noise test using HEAD Acoustics multi-channel noise test system, sound quality subjective evaluation experiment was carried out in a semi-anechoic. Vehicle sound quality was studied using support vector machine (SVM) model, the results showed that car interior sound quality mainly by four psycho-acoustical parameters: A-weighted sound pressure level, loudness, roughness and jitter degree. The support vector machine forecasting method can guarantee the accuracy of prediction results for small sample data, which has higher accuracy in predicting, error lower.

## 1. Introduction

As people's requirements increasing to acoustic environment quality about vehicle interior, engine noise problem is particularly prominent. Vehicle interior sound quality has become an important index of vehicle performance. The engine noise is main noise source on the interior of vehicle, which accounts for 50% to 70% [1]. In order to evaluate the level of vehicle interior noise, it is needed to systematic study on sound quality of engine noise, and given enough attention. Based on psychoacoustics theory, establishing sound quality prediction model of engine idle at a constant speed in different speed operation, which is important for comprehensive evaluation of vehicle performance.

## 2. Test Equipment and Points

In this paper, noise samples come from three different models domestic vehicle, which tested in the semi-anechoic chamber. Noise test points were set in vehicle cab near firewall and microphone pointing to engine. Studying its effect on sound quality of vehicle cab by collecting acoustic signal of engine idle at different constant speeds. Test equipment used HEAD Acoustics multi-channel noise test system, which consists of SQLab II data collected recorder, data collected front, HMS III (Head Manual System) binaural information collector, Artemis (Advanced Research Technology for Measurement and Investigation of Sound and Vibration) measurement and analysis software and acoustic sensors. The system has higher accuracy than similar products, which can guarantee noise test reliability and accuracy.

## 3. Test Conditions

Engine noise signals were collected by test equipment under different idle speeds of engine, each test condition tests 3 times, and test time sustains 10 seconds.

Further processing of noise samples through samples collected, intercept, equal-loudness processing, it can obtain 15 noise samples. The noise sample conditions were 1000r/min, 2000r/min,



3000r/min, 4000r/min, 5000r/min, their time length was 5s, which for subjective evaluation experiments. Noise samples contents as shown in Table 1.

**Table 1.** Test Condition of Noise Samples

Sample Number	1	2	3	4	5
Test Condition (r/min)	1car-2000	1car-3000	1car-4000	1car-5000	2car-3000
Sample Number	6	7	8	9	10
Test Condition (r/min)	2car-4000	2car-5000	3car-1000	3car-2000	3car-3000
Sample Number	11	12	13	14	15
Test Condition (r/min)	4car-4000	4car-5000	2car-2000	1car-1000	2car-1000

#### 4. The Basic Theory of SVM

Support Vector Machines (SVM) is a new method for data mining, which a new tool by means of optimization method to solve machine learning problems, it is putted forward by Vapnik [2]. SVM method is based on seeking structural risk minimization to improve learning machine generalization ability, and achieve empirical risk and confident range minimization. It can obtain good statistical law under a small amount of statistical samples.

Assume that training samples are  $\{(x_i, y_i), i=1, 2, \dots, N\}$ ,  $N$  is number of samples,  $x_i$  is input value,  $y_i$  is expected value.

Support vector machine (SVM) regression model is:

$$f(x) = \omega \Phi(x_i) + b \quad (1)$$

In formula:

$\omega$  is weighted vector;

$b$  is threshold value,  $b \in R$ ;

$\omega \Phi(x_i)$  is two vectors' inner-product;

Define  $\varepsilon$  is insensitive loss function,

$$|y - f(x_i)|_\varepsilon = \begin{cases} 0 & |y - f(x_i)| \leq \varepsilon \\ |y - f(x_i)| - \varepsilon & |y - f(x_i)| > \varepsilon \end{cases} \quad (2)$$

$\varepsilon$  is crucial to the numbers of support vector,  $\varepsilon$  increasing, the regression curve become flat, calculation accuracy will become lower,  $\varepsilon$  value for 0.01.

In order to solve problem introducing penalty factor  $c$  and slack variable  $\xi, \xi^* (i=1, 2, \dots, N)$ , so regression model (1) changing to:

$$\begin{aligned} \min & \frac{1}{2} \|\omega\|^2 + c \sum_{i=1}^N (\xi_i + \xi_i^*) \\ \text{s.t.} & y_i - \omega \Phi(x_i) - b \leq \varepsilon + \xi_i \\ & \omega \Phi(x_i) + b - y_i \leq \varepsilon + \xi_i^* \\ & \xi_i, \xi_i^* \geq 0 \quad (i=1, 2, \dots, N) \end{aligned}$$

Using Lagrange multiplier method and introducing GAUSS RBF kernel function

$K(x_i, x_j) = \exp(-g \|x_i - x_j\|^2)$  ( $g$  is radial basis function, which can transform high-dimensional space into low dimensional space function calculation. It can obtain support vector regression machine function follow as:

$$f(x) = \omega \Phi(x_i) + b = \sum_{i=1}^N (a_i - a_i^*) K(x_i, x) + b \quad (3)$$

In the formula, penalty factor  $c$  and RBF kernel function  $g$  have a great influence on model precision. If support vector machine (SVM) model is unable to correctly choose parameters  $c$  and  $g$ , prediction result's error may larger. This paper selects the optimal kernel parameter using web search method, to evaluating prediction result basis on multi-terms error analysis.

## 5. Subjective Evaluation of Sound Sample

### 5.1. Subjective Evaluation Experiment

There are twenty university students for this subjective evaluation, evaluators hearing is good. Using grouped pair-wise comparisons in this experiment, voice samples including 105 pairs i-j comparison and 8 pairs i-i comparison, a total of 113 samples. Evaluation vocabulary is preferences, evaluators given result according to listening. Sample continuous 5s, the interval of 2s between samples in the same sample. It takes 23min to finish s set of evaluation, that meets abroad sound quality evaluation time requirement.

The experiment is carried in semi-anechoic room, whose background noise is 34dB, which can ensure experiment without disrupt.

### 5.2. The Effective Analysis of Subjective Evaluation

During experiment, judgment of evaluator's is taken subjective sense. If evaluators don't pay enough attention, using different standards lead to result unstable. Thus, subjective data need to be arranged, computed, statistics, and eliminating high false rate evaluators ensure correctness of data post-analysis. In this experiment use A-A same event test and triangular cyclic error check test. By triangular cyclic error check test theory compile matlab program; compute times of every evaluator false judgment which is data effectiveness validity check foundation.

Using Kendall proposed weighting consistency coefficient to inspect Misjudgment result's right, inspecting subjective evaluate data's effectiveness and repeatability.

Weighting false judgment rate is:

$$C_w = \frac{C_1 E_1 + C_2 E_2}{(E_1 + E_2)^2} \quad (4)$$

Weighting consistency of coefficient is:

$$\xi_w = 1 - C_w \quad (5)$$

In formula:

$C_w$  is weighting misjudgment rate,  $E_i$  is possible times of misjudgment,  $C_i$  is actual misjudgment rate,  $\xi_w$  is weighting consistency coefficient.

The same sound sample's misjudgment times is 8, triangle circular misjudgment times is 91, calculating the consistency coefficient is presented in table2.

**Table 2.** The Weighting Coefficient of Consistency

evaluators	consistency coefficient	evaluators	consistency coefficient	evaluators	consistency coefficient	evaluators	consistency coefficient
Tp1	0.808	Tp6	0.795	Tp11	0.898	Tp16	0.981
Tp2	0.846	Tp7	0.635	Tp12	0.794	Tp17	0.898
Tp3	0.821	Tp8	0.961	Tp13	0.955	Tp18	0.936
Tp4	0.572	Tp9	0.770	Tp14	0.834	Tp19	0.821
Tp5	0.821	Tp10	0.757	Tp15	0.891	Tp20	0.930

The other evaluators' consistency coefficient is above 0.75 except TP4 and TP7 who own low consistency coefficient. To further testing effectiveness of evaluation result, using Pearson correlation

coefficient in SPSS. By calculation, the Pearson correlation coefficient is above 0.85. The higher evaluators' correlation coefficient is meaning evaluation data is effective and reliable.

## 6. Prediction of Sound Quality Model Based on SVM

The paper collects 15 sound samples at engine idling for 5 uniform operations; in operation cab of different types of domestic vehicle. The sound samples objective parameter analysis using Head Artemis10.0, as shown in table 3.

**Table 3.** Objective Parameters and Subjective Evaluation Results of Sound Samples

Sample number	SPL dB	SPL(A) dB(A)	Loudness Sone	Roughness Asper	Sharpness Acum	Fluctuation strength Acum	Preference
1	76.2	60	12.2	0.655	1	0.0406	10.13
2	77.6	66	17	1.14	1.16	0.0579	6.75
3	84	71.5	27.5	1.69	1.3	0.0617	5.38
4	94.1	81.5	45.9	2	1.36	0.0881	1.75
5	84.4	66.9	21	1.33	1.35	0.0531	5.81
6	84.6	71.5	28.5	1.96	1.52	0.0621	3.44
7	87.1	76.3	38.5	2.6	1.79	0.0719	1.50
8	82.5	54.7	7.71	0.354	0.587	0.0429	10.19
9	82.1	61.7	15.1	0.701	1.06	0.0452	8.25
10	82.2	70	21.8	1.13	1.27	0.0587	5.44
11	82.8	70	21.8	1.13	1.27	0.0587	1.94
12	87.2	78	33.7	2.04	1.45	0.0705	0.38
13	82.1	59.4	13.6	0.665	1.13	0.0446	9.19
14	77.1	53	7.24	0.313	0.848	0.0379	11.75
15	74.7	49.3	6.16	0.321	1.01	0.0317	12.55

In order to obtain accurate results of correlation analysis, to determine what objective parameter has a significant effect on sound quality index of automobile engine speed under uniform speed running state, then setting up sound quality evaluation model with vehicle interior, which described through objective parameters has high correlation with subjective evaluation results.

According to the statistics related theory, using software SPSS to calculate the correlation coefficient between preference of subjective evaluations and objective parameters, Calculation results are shown in table 4.

It can be seen from table 4, there is negatively correlated between objective parameters and preference. Among them, A weighted sound pressure level, loudness, roughness and fluctuation strength and preference have high correlation, its absolute value is above 0.9; there is little correlation between sound pressure level and preference; as the engine is at uniform speed in the idle state, the correlation between sharpness and preference is not high.

**Table 4.** Pearson Correlation between Subjective Evaluation and Objective Parameters

		SPL	SPL(A)	Loudness	Roughness	Sharpness	Fluctuation strength
Preference	correlation coefficient	-0.788	-0.961	-0.906	-0.905	-0.833	-0.911
n=15	two-tailed test	0.0005	0.0000	0.0000	0.0000	0.0001	0.0000

Therefore, this paper takes four objective parameters including A weighted sound pressure levels, loudness, roughness, fluctuation strength as input, takes subjective evaluation results preference as output, using support vector machine to establish the vehicle interior engine sound quality prediction model. According to the theory of support vector machine algorithm, related procedures are compiled to achieve prediction of sound quality model in Matlab environment.

Using the samples 1-12 in table 3 as training samples, for the establishment of vehicle interior sound quality SVM prediction model; and using the sample 13, 14, 15 as test samples, to test the correctness of the prediction model. The paper selects to optimize the SVM parameters, uses cross validation method to find out the optimal parameters combination ( $c$ ,  $g$ ). When penalty factor  $c$  and radial basis kernel function  $g$  were optimized, this paper choose the optimal  $c = 5.6569$ ,  $g = 0.044194$ . Using the trained the vehicle interior sound quality SVM prediction model to predict the test sample, the results shown in figure 3. Thus it can be seen, the relative error of the predicted value is in the range of 0.5%, the prediction result is comparatively ideal.

## 7. Conclusions

7.1 By analyzing the correlation of subjective evaluation results and objective parameter, it showed that sound quality and A sound pressure level loudness, roughness, fluctuation strength has a high negative Correlation relationship, so using these parameters to description driving indoor sound quality is feasible.

7.2 Under the condition of automobile engine idle state uniform operation, collect the car sound samples and subjective evaluation experiment.

7.3 On the basis of the small sample training data, by using the SVM model to predict the vehicle sound quality, Prediction results are accurate and the prediction error is low.

## 8. References

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