

# The Combined Forecasting Model Based on Wavelet Analysis in the Application of the Civil Aviation Passenger Traffic

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**ABSTRACT:** China's civil aviation passenger traffic was taken as the research object, the yearly passenger traffic with the theory of wavelet analysis is based on the multi-scale analysis on the time sequence to get the sequences of coefficient on different scales in order to reduce the randomness of the original sequence. And then the time sequence forecast respectively after the re-factored was based on the Grey forecasting model and exponential smoothing model. After the series of passenger traffic time series characteristics and sequence were analysis, the combination model on the wavelet analysis of non-stationary time series of Grey prediction model and exponential smoothing model was set. Finally the model for passenger traffic was applied to an empirical analysis of China's civil aviation passenger traffic. The results show that the model has higher prediction precision and small relative error, so it provides a new method to handle the original non-stationary time series prediction.

**KEYWORD:** Wavelet Analysis; Grey forecasting model; Exponential Smoothing Model; Passenger volume forecast; Relative error

## 1 INTRODUCTION

Wavelet analysis is developed in the mid-80. It is a new theory and method of mathematics. It is considered a crystallization of harmonic analysis in nearly half a century. Wavelet analysis is a powerful signal analysis tool. It is proposed by Morlet in the 1980 s, it is the interaction of multiple disciplines, such as the Fourier transform, spline theory, numerical analysis. Wavelet transform is a novel mathematical analysis tool, it is a signal of time - scale (time - frequency) analysis method. It has the ability of denoting local signal characteristics in both time and frequency domain, namely in the low frequency part has high frequency resolution and low time resolution, in the high frequency part with high temporal resolution and lower frequency resolution. It is a local transformation of time and frequency, so it can effectively extract information from signal. And through the scale and translation operation functions such as the function or signal, it can process multi-scale refinement analysis. So it solves many problems that the Fourier transform can't solve[1]. It is suitable for normal signal detection in the midst of transient abnormal phenomenon, then shows their ingredients, so is regarded as a microscope analysis of signals. Therefore it can carry on the analysis, judgement

and prediction. By the wavelet theory, civil aviation passenger traffic this time series is analyzed by wavelet decomposition on the different scale in order to reduce the randomness. Then we predict the sequence of approximation coefficients and detail coefficients. After wavelet reconstruction, we use Grey prediction model and exponential smoothing model to forecast the approximation coefficients and detail coefficients sequence. It has a great effect on the regional economic development and transportation enterprise decision makers.

In terms of passenger traffic forecast, domestic and foreign scholars have used different prediction methods. Jian zhang in 1987 studied Shanghai 16 auxiliary wharf and forecast the passenger traffic volume by Grey information prediction theory, the results found that Grey prediction model has less samples, simple calculation, high precision [2]. In 1995 YueMin Zhu studied three exponential smoothing model for predicting the passenger traffic in xi 'an station [3]. Hongbin Yin studied gravity model in Guangzhou in 2001 for a prediction of the highway passenger rail passenger traffic, the study found that highway passenger quantity has relationship with line distance, and gravity model reflected this change in distance more sensitively [4]. In 2007 Jing Xu studied highway passenger traffic volume forecasting model based on wavelet analysis

to predict the Heilongjiang province highway passenger transport, the study found that based on the theory of wavelet, multi-resolution analysis of wavelet method can well capture the inherent regularity, passenger traffic based on wavelet analysis of passenger volume forecast is simple, feasible and effective[5]. In 2011 Limin Hou etc studied based on the gray linear regression combination model of railway passenger traffic forecasting model to predict the railway passenger traffic in Henan province. Through comprehensive gray model and regression model it reduced the prediction error, improved the prediction precision [6]. In 2013 HaiTian Rui etc studied based on exponential smoothing method and markov model in Anhui province in 2010 and 2012. With a prediction of the highway passenger quantity, by exponential smoothing preliminary prediction of highway passenger quantity, and then combining the forecasting results are modified markov model, relative error is small, this method can meet the demand of practical application [7]. It concludes that the gray theory and exponential smoothing model is widely used in passenger traffic forecast, but the civil aviation passenger traffic this time series after wavelet decomposition, then gray projections for the decomposition of different scales and exponential smoothing model prediction research is not in-depth study. Based on civil aviation passenger traffic this time series decomposition, then the article fully considers the sequence characteristics of the gray prediction and time sequence cycle characteristics and internal information. It has carried on the forecast analysis to our country on the basis of the civil aviation passenger traffic.

## 2 THE COMBINED FORECASTING MODEL BASED ON WAVELET ANALYSIS

$x(t)(t=1,2,\dots,n)$  is a time series, then on the wavelet decomposition by MATLAB, and the time series are respectively re-factored, decomposition layers can be obtained:

$$x(t) = D_1 + D_2 + \dots + D_J + C_J \quad (1)$$

$D_i(i=1,2,\dots,J)$  are high frequency detail coefficients sequences after reconstruction;  $C_J$  is the low-frequency approximate coefficient sequences decomposed after re-factored.

The low-frequency approximate coefficient sequences after reconstruction is predicted by the exponential smoothing model, the high frequency detail coefficients after reconstruction is forecast by gray prediction model.

If  $x(t)\{t < n\}$  is known, the high frequency approximation coefficient sequences is forecast by gray prediction model( $GM(1,1)$ ), namely:

$$x(t+1) = D_{1,t+1} + D_{2,t+1} + \dots + D_{J,t+1} + C_{J,t+1} \quad (2)$$

## 3 THE EMPIRICAL ANALYSIS OF THE PASSENGER TRAFFIC FORECAST MODEL BASED ON WAVELET ANALYSIS

This article selects between January 2013 and June 2013 in our country's civil aviation passenger traffic as raw data; in July 2014, the civil aviation passenger traffic is set as the model test data. The combining passenger traffic forecast model of the wavelet analysis theory, the gray prediction model and exponential smoothing model method is set up.

### 3.1 The wavelet decomposition and reconstruction

First standardization of monthly passenger traffic time series, with Daubechies wavelet as the wavelet basis function, time series process wavelet decomposition. The selection of wavelet basis function is db4, after decomposition the sequence has 4 layers. The passenger traffic time series  $x(t)$  is decomposed into four high frequency detail signals  $cd1, cd2, cd3, cd4$  and a low frequency approximation  $ca4$ , shown in Figure 1. Then the above details on high frequency signal and the low frequency approximation are processed by inverse transformation of wavelet transform, signal decomposed into high frequency detail signal and low frequency approximation signals are reconstructed, the signal and the original signal reconstruction error is  $1.1546 \times 10^{-9}$ , the original signal and the reconstructed signal are shown in Figure 2.

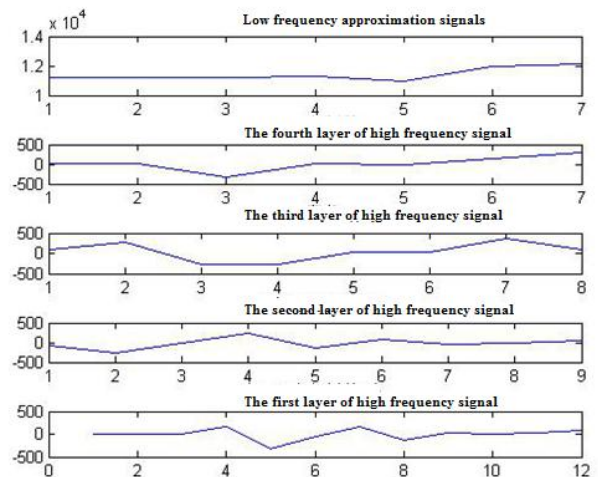


Figure 1. Db4 wavelet four dimensions of the signals

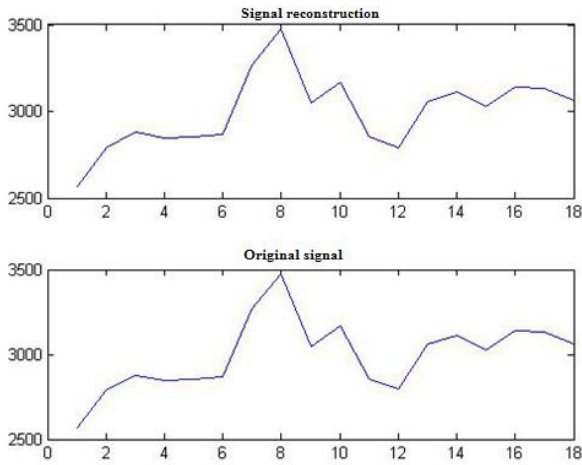


Figure 2. Original signals and re-factoring

### 3.2 Single reconstruction of wavelet coefficient

The high frequency detail signal  $cd1, cd2, cd3, cd4$  and low frequency approximation signals  $ca4'$  are respectively single re-factored, the reconstruction of the five different frequency signals  $d_1, d_2, d_3, d_4, c_4$  can be obtained. The fourth layer  $c_4$  corresponds to low frequency approximation signals after wavelet decomposition of signal, the first to fifth layers of high frequency detail signal  $d_1, d_2, d_3, d_4$  is shown in Figure 3.

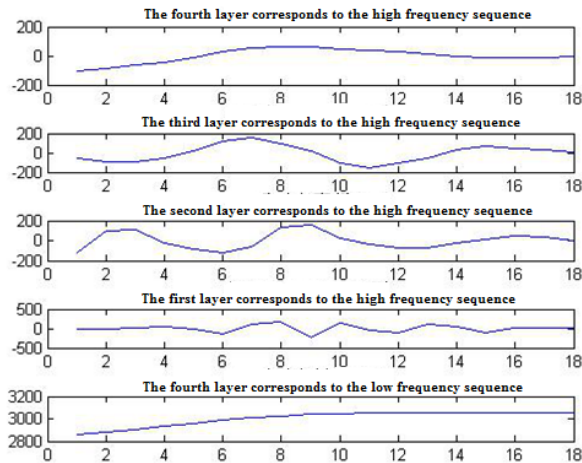


Figure 3. Wavelet coefficients single reconstruction

### 3.3 Exponential smoothing model of low frequency sequence after reconstruction

Reproducing low-frequency signal  $c_4$  is predicted by the exponential smoothing model. First standard reproducing low-frequency signal, standardized formula is:

$$y_t = \frac{x_t - \mu}{\sigma} \quad (3)$$

$y_t$  is the time series after standardized;  $x_t$  is the original time series;  $\mu$  is the mean value of the original time series;  $\sigma$  is the standard deviation for the original time series.

The reproducing low-frequency signal is analyzed by SPSS19.0 with exponential smoothing model, the predicted results is shown in Figure 4.

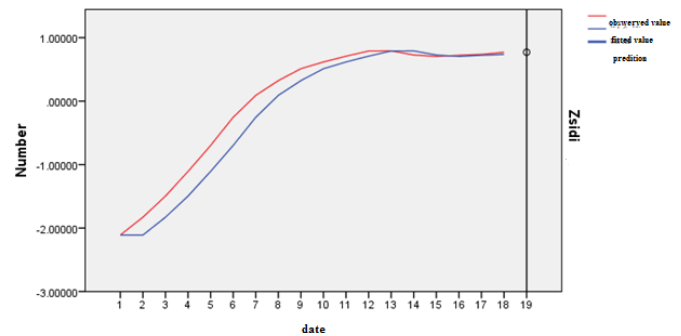


Figure 4. Forecast figure of low frequency signal after reconstruction

The initial data of exponential smoothing model is standardized data, therefore the model predicts the measured values which need process the standardization, according to the predicted value of standardized formula:

$$x_t = y_t \cdot \sigma + \mu \quad (4)$$

$y_t$  is the time series of standardized;  $x_t$  is the original time series;  $\mu$  is the mean value of the original time series;  $\sigma$  is the standard deviation for the original time series.

Table 1. The actual value compared with the predicted value

	Standardize the actual value	Standardize predicted value	error
2013.1	-2.11	-2.11	0
2013.2	-1.83	-1.83	0
2013.3	-1.50	-1.55	0.05
2013.4	-1.11	-1.16	0.05
2013.5	-0.70	-0.72	0.02
2013.6	-0.25	-0.29	0.04
2013.7	0.09	0.19	-0.10
2013.8	0.32	0.44	-0.12
2013.9	0.51	0.56	-0.05
2013.10	0.62	0.70	-0.08
2013.11	0.71	0.72	-0.01
2013.12	0.79	0.80	-0.01
2014.1	0.79	0.87	-0.08
2014.2	0.73	0.79	-0.06
2014.3	0.70	0.66	0.04
2014.4	0.72	0.68	0.04
2014.5	0.74	0.74	0
2014.6	0.77	0.75	0.02

### 3.4 Reconstruct the high frequency sequence for gray prediction

The high frequency approximation signals after reconstructed are predicted by gray prediction model  $GM(1,1)$ , by GTMS3.0 available forecasting model is:

The first layer prediction model of high frequency approximation signal is:

$$\hat{x}_{t+1}^{(1)} = 390.4172e^{0.015t} - 497.7272 \quad (5)$$

The second layer prediction model of high frequency approximation signal is:

$$\hat{x}_{t+1}^{(1)} = 404.5575e^{-0.0174t} - 464.4995 \quad (6)$$

The third layer prediction model of high frequency approximation signal is:

$$\hat{x}_{t+1}^{(1)} = -146.3522e^{-0.0477t} + 20.1922 \quad (7)$$

The fourth layer prediction model of high frequency approximation signal is:

$$\hat{x}_{t+1}^{(1)} = 769.3333e^{0.0003t} - 773.4415 \quad (8)$$

By the above four forecasting model high frequency approximation signal prediction can be respectively obtained in the first floor to the fourth layer, shown in Table 2.

Table 2. Gray prediction of high frequency approximation signals

	The first floor	The second floor	The third floor	The fourth floor
Predictive value	0.2308	5.6405	-4.4223	5.5671

## 4 MODEL TEST

The data in July 2014 is set as the test samples. Comparing the model prediction, the actual passenger, gray model prediction and exponential smoothing model prediction, prediction accuracy is shown in Table 3.

Table 3. China's civil aviation passenger traffic forecast comparison (unit: ten thousand)

Actual value	portfolio model prediction	gray model prediction	exponential smoothing model prediction
3580	3426	3140	3076
relative error (%)	4.3	12.3	14.1

## 5 CONCLUSIONS

Due to the original time series is volatile, it can reduce a certain degree of prediction accuracy. The deviation of the predicted values has great. And the original time series is decomposed in the different scale, it get some behavior characteristics and results of the original time series information. The gray forecasting model based on wavelet analysis in civil aviation passenger traffic forecast has achieved good results. Wavelet analysis, gray theory and exponential smoothing model are combined to build a portfolio model for prediction of China's civil aviation passenger traffic. It is compared with grey forecasting model and exponential smoothing model predicted results. The results show that the original time series process the wavelet analysis decomposition and conversion, then the signal after reconstruction is estimated by gray forecasting model and exponential smoothing model. On the prediction precision it is far higher than that of pure gray forecasting model and exponential smoothing model.

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