FORCASTING OF FINANCIAL TIME SERIES BY A DIGITAL FILTER AND A NEURAL NETWORK

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ABSTRACT

The approach to predict time series without neglecting the fluctuation in a short period is tried by using a digital FIR filter and a neural network. The differential waveform of the Nikkei average closing price is filtered by the FIR band-pass filter of 101 length. It is filtered into the five frequency bands of 0-1Hz, 1-2Hz, 2-3Hz, 3-4Hz and 4- 5Hz by setting the sampling frequency 10Hz. The each filtered waveform is learned and forecasted by the neural network. The neural network of the back propagation method is adopted in the learning the waveform. By inputting the data of 20 days in the past, the prediction of 10 days ahead is carried out. After learning the time series of each frequency band by the neural network, the predicted data for each frequency band are obtained. The predicted waveforms of each frequency band are synthesized to obtain a final forecast. The waveform can be forecasted well as a whole.

1 INTRODUCTION

In signal processing, the function of a filter is to remove unwanted parts of the signal, such as random noise, or to extract useful parts of the signal. A digital filter has excellent characteristics showing wide flat pass band and steep roll-off. It is possible to separate the signal of 1000 Hz and 1001 Hz. A digital filter is programmable and the cut-off frequencies can be easily changed. The digital filter is widely used in many electrical equipments for signal separation, signal compression, noise reduction and etc[1].

Although the digital filter has a excellent characteristics, it has not been used for the data processing of financial time series. Usually, the financial time series have been predicted by smoothing them using moving average method, where the fluctuation in a short period has been considered to be a noise. Actually, the fluctuation of short period is important for trading financial commodities such as stock, foreign exchange and etc. Therefore it should not be neglected by smoothing.

In this study, the feasibility of the prediction without neglecting the fluctuation in a short period is investigated by the approach that uses a digital FIR band-pass filter and a neural network. But it has a problem to use a digital filter for a data processing for the financial time series. The problem is that it is impossible to obtain the some filtered data for the last part of the financial time series. The last part of the financial time series is the most important for the prediction. To improve the problem, the data processing by use of a neural network is carried out.

2 LEARNING AND PREDICTION OF NIKKEI STOCK AVERAGE WITH BAND-PASS FILTER

2.1 Digital filter (FIR band-pass filter)

The band-pass filter passes the input waveform from the lower cutoff frequency f_{BL} (Hz) to the upper cutoff frequency f_{BH} (Hz) by constant amplitude ratio 1 and it is zero outside the pass-band.

The equation to obtain the filtered value F_0 from the sampled value T_m of the waveform is

$$F_0 = \sum_{m=-n}^{n} T_m * H_m$$

where H_m is the filter coefficients (impulse response sequence) that is obtained from the sampling frequency f_s (Hz) and the cutoff frequencies.

$$H_m = 2\cos(m\frac{\omega_{BH} - \omega_{BL}}{2}) * (\sin(m\frac{\omega_{BH} + \omega_{BL}}{2}) \Big/ m\pi)$$

where

$$H_0 = (\omega_{BH} + \omega_{BL})/m\pi$$

and

$$\omega_{BH} = 2\pi\frac{f_{BH}}{f_s},\ \omega_{BL} = 2\pi\frac{f_{BL}}{f_s}.$$

The $2m+1$ sampled data from T_{-m} to T_m are used for the filtering and the number "$2m+1$" is called the filter length. In case of filtering at the designed frequency, the characteristics become better showing steep roll-off as the filter length becomes longer.

Fig.1 is the FFT analyzing of the waveform of 555 days of Nikkei stock averages from July 2, 1997 to October 1, 1999 where it is set the sampling frequency 10 Hz (the actual sampling period is 1 day).

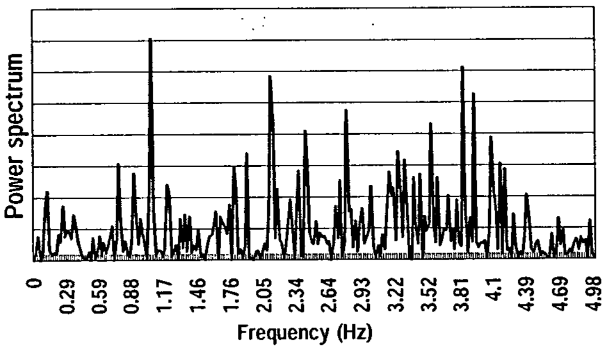

Fig.1 FFT analyzing of the Nikkei stock average

Fig.2 shows the FFT analyzing of the waveform obtained by filtering the above data with the 1-2 Hz band-pass filter of length 101.

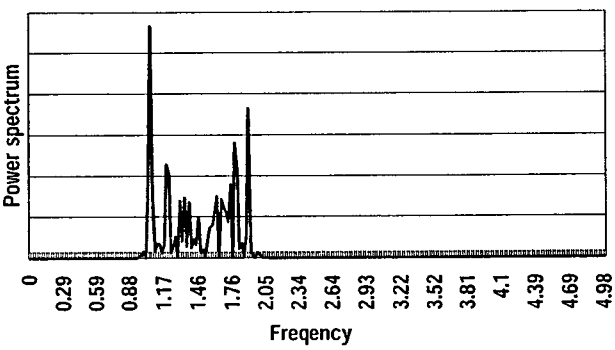

Fig.2 FFT analyzing of the Nikkei stock average filtered by 1-2 Hz band-pass

2.2 Filtering of Nikkei Stock Average with Band-pass Filter

The differential waveform of the Nikkei stock average closing price is filtered by the FIR band-pass filter of 101 length with Hamming window. As the number of the length of FIR filter becomes longer, the characteristics of the filter become better. The FIR filter of 101 length shows an excellent characteristic with a flat pass band and a sharp edged cutoff frequency. In this study, it is filtered into the five frequency bands of 0-1Hz, 1-2Hz, 2-3Hz, 3-4Hz and 4- 5Hz by setting the sampling frequency 10Hz. (the actual sampling period: 1 day) The divided waveforms can be returned to the former waveform by synthesizing them. Fig.3 shows the waveform of 50 sampled data of Nikkei stock averages from July 22, 1999 to October 1, 1999 and Fig.4 shows the band-pass filtered waveforms by 4-5Hz.

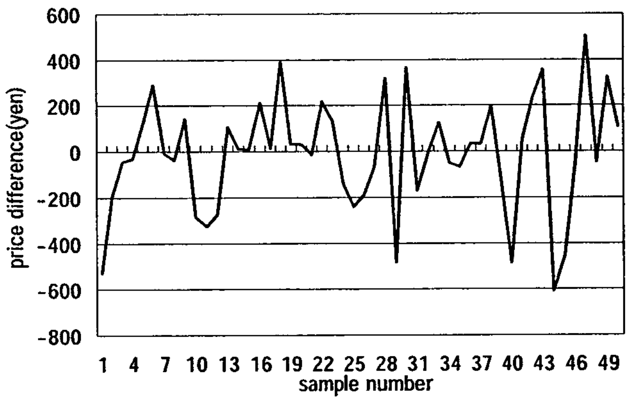

Fig.3 Nikkei stock averages

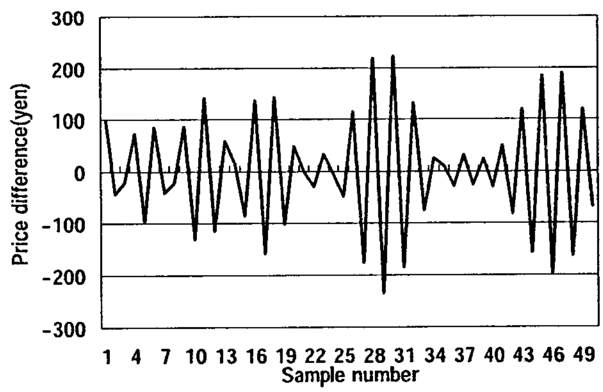

Fig.4 The filtered waveforms in 4-5Hz

The filtered waveform is more sinusoidal as compared with the former one. Therefore it is considered that the learning with the neural network becomes easier.

2.3 Learning and Forecasting of Waveform by Neural Network

The each filtered waveform is learned and forecasted by the neural network[2][3]. The neural network of the back propagation method is adopted in the learning the waveform. The construction of the neural network is composed of four layers, where the cell number of input layer is 20, the hidden layer1 17, the hidden layer2 14 and the output layers 10.

By inputting the data of 20 days in the past, the prediction of ten days ahead is carried out. After learning the time series of each frequency band by the neural network, each predicted data are combined. The combined data are compared with the actual stock data.

A set of the filtered sample data of 30 days is the learning data. The former data of 20 days are the input data and the latter data of 10 days are the teach data.

The data are 777 samples from August 6, 1996 to October 1, 1999 and the data from October 4, 1999 to October 18, 1999 are predicted.

In a final prediction (Fig. 5) that is obtained by combining the predicted data of each frequency regions, the waveform is overall corresponding.

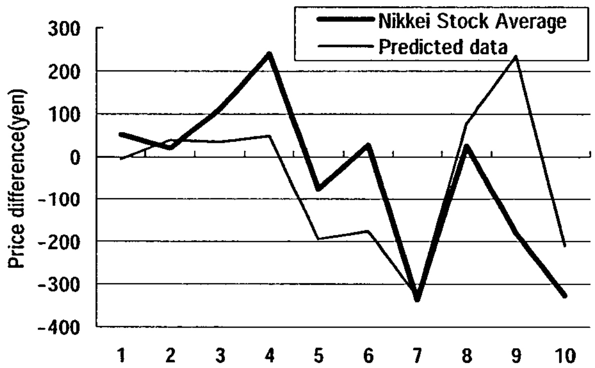

Fig.5 Prediction of 0-5Hz

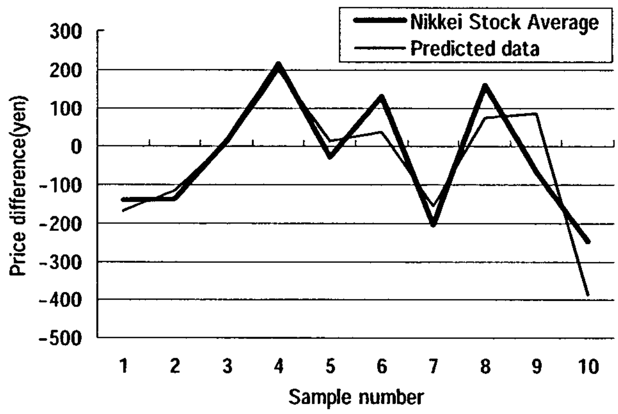

Fig.6 Prediction of 1-5Hz

However, it shifts downward due to the error in the prediction of 0-1Hz. In the synthesis of waveform from 1-2Hz to 4-5Hz except for 0-1Hz (Fig. 6), it can be said that it is predicted in considerably good coincidence.

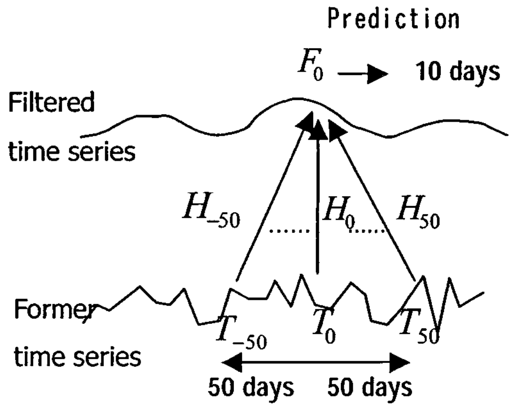

Fig.7 Prediction with 101 length band-pass filter

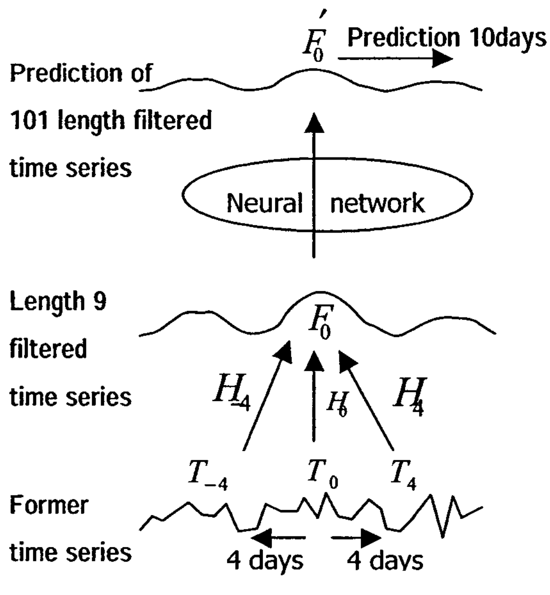

Fig.8 Prediction of the waveform obtained by the length 101 filter from length 9 filter

3 THE POINT OF ISSUE OF BAND-PASS FILTER OF LENGTH 101 AND ITS MEASURES

3.1 Problem of Prediction

As the length of the band-pass filter is 101 at the prediction with the band-pass filter previously described, the data of the back and forth the 50 days(samples) are used for filtering. Therefore, the prediction on the ten days has a serious problem which is insignificant, as shown in Fig.7.

At first, the data are filtered by the band-pass of length 9. The neural network is constructed to predict the waveform in case of filtering by the band-pass of length 101 from the data that was obtained by the band-pass of length 9. In this case, the data of the forth and back 4 days are used as shown in Fig.8.

3.2 Learning and Forecasting of Waveform by Neural Network

The neural network by the back propagation is used in learning as well as the previous section. The construction of the neural network is composed of four layers, where the cell number of input layer is 20, the hidden layerl 19, the hidden layer2 18 and the output layers 20. The waveform of 20 days filtered by the length 9 is obtained and the waveform filtered with length 101 on the same day is predicted by this neural network.

The input data are the data for 20 days that are filtered by the band-pass filter of length 9 to the 5 frequency bands as same as subsection 2-2. The teach data are the data filtered by length 101 of the same day. The learning data are 777 samples from June 6, 1996 to July 30, 1999 and the data from September 2, 1999 to October 1, 1999 are predicted.

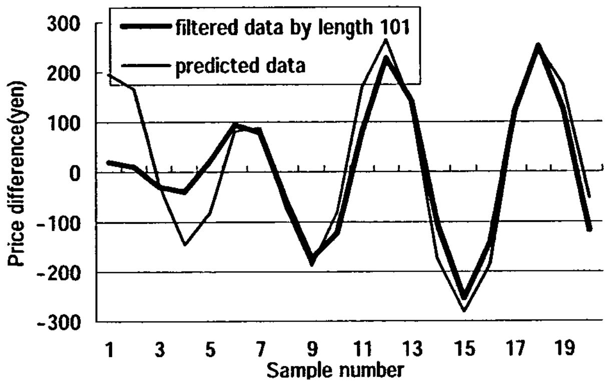

Fig.9 Comparison between the target waveform and the predicted data(1-2Hz)

As the result of the prediction, there are the cases that are good coincidence to the waveform filtered by length 101 and the other cases that has the shift partly. Generally, the good coincidence is obtained for the high frequency bands. Fig.9 and 10 show the predicted waveform for 1-2 Hz and 3-4 Hz in the same sequence.

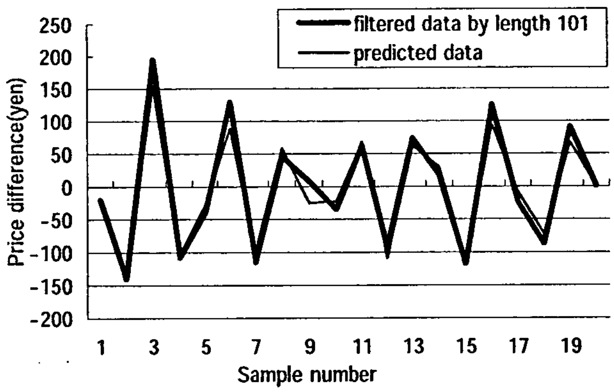

Fig.10 Comparison between the target waveform and the predicted data(3-4Hz)

4 FINAL PREDICTION OF NIKKEI STOCK AVERAGE

The predicted data obtained in section 2 and 3 for each frequency band are combined in order to predict the Nikkei stock average. The neural network used for the prediction is the same as the one used in section 2. The input data are ones of 20 days that are predicted for each frequency band in section 3 from September 2 to October 1 and the data from October 4 to October 18 are predicted finally. However, because the input data predicted in section 3 uses the band-pass filter of length 9, a substantial prediction becomes after the fourth day.

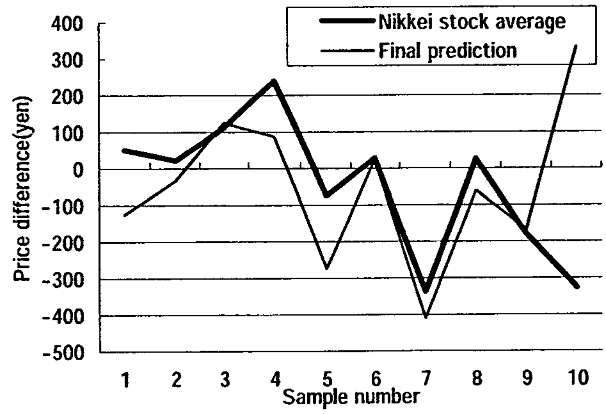

Fig.11 Final prediction (0-5 Hz)

The prediction is done for each frequency band(0-5 Hz), and all the predicted waveforms are synthesized to obtain the final prediction. Fig.11 shows the final prediction.

Though there is a slight shift downward due to the error in 0-1Hz, an overall waveform can be forecasted well as a whole.

Fig.12 shows the result of 1-5 Hz except for 0-1 Hz. In this case, the good coincidence with the Nikkei stock average is obtained as compared with Fig.11. If the waveform in a low frequency band such as 0-1Hz is filtered into narrower frequency band, it is considered that the learning and the prediction by the neural network become better. In this case, it is necessary to use more sampled data.

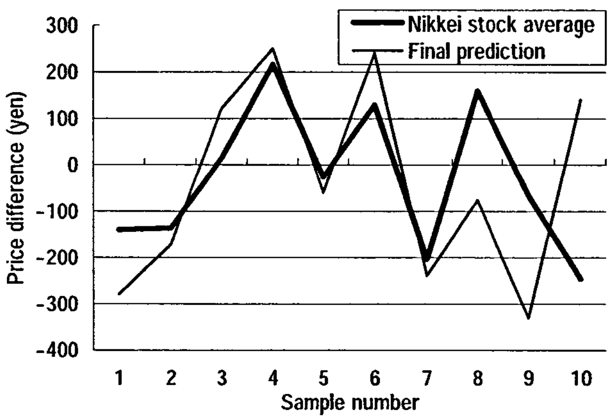

Fig.12 Final Prediction (1-5 Hz)

5 CONCLUSIONS

In this study, the forecast using the FIR digital band-pass filter and the neural network has carried out. An overall waveform can be forecasted well as a whole. As for the prediction of the each filtered waveform, the good results are obtained except for the low frequency bands. This is because the waveform in the high frequency bands which are processed with the band-pass filter is almost sine wave, and therefore the prediction becomes easy. On the other hand, it is difficult to find the regularity of the waveform of the low frequency bands by the neural network. If the waveform in a low frequency band is filtered into narrower frequency bands by using lots of data, it is considered that the learning and the prediction by the neural network become better.

By using the neural network, it is possible to estimate the data which would be obtained by the filter of long length from the data obtained by the filter of short length.

It can be said that the prediction of the Nikkei stock average is possible to some extent. It is considered that the mid and long-term prediction is also possible by this method which uses FIR filter if the data are sampled weekly or monthly.

Improvement of the accuracy of the estimation having the function of filtering to neural network itself are the next subject of this study.

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