Technical Analysis of Extended Kalman Filter in High Frequency Trading

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Abstract. obtaining to the method with the least prediction error is one of the challenging issues of financial and investment markets analyzers. In high frequency trading strategies predicting the most accurate price of the securities is the only way to benefit from the markets. This paper presents a new approach to set the functional parameters of the Kalman filter, dynamically according to the market environment changing with respect to the technical analysis indexes, the parameter Q is measured by simple artificial neural network. And feed to the EKF algorithm to predict the next price for the securities. The method is experimented on the securities of the Iran stock exchange market to show its desirability in short-term prediction.

1. Introduction

Today's, investing in stock is an important part of society and economy, in the other hand, stock price volatility in the all stock exchanges is commonplace. Stock prices affected by external and internal factors like political, economic and etc, so the stock price prediction for capitalists is very important to be able to return most of their investment will earn (Francis, J.C,1972).

Meanwhile, given the unavailability of accurate information about the factors affecting stock market fluctuations and of unknown factors affecting stock price changes, due on bringing people to predict price changes by the companies but this simply not possible.

Generally there are two viewpoints of analyzing: Technical analysts and fundamental analysts (Pring, Martin J.,1998). Technical analysts can calculate the intrinsic value of stock. They believe that the market has undergone a pseudo psychological mode and history is always repeatable and patterns at any time cause reputation of trends of price. Therefore by studying the past trend, the future could be predicted (Fugence,F. Fama.,1970). But in terms of fundamental analysts, the stock market has no memory and prices are changed randomly.

As noted, the main purpose of technical analysis is predicting trends of stock price. However, predictions are often not correct and have some errors that the rate decreases with increasing of information. The other comment which was raised said: technical analysis based on the weak principles. For example, the expectation that some of historical patterns of the securities prices will be repeated in the future may not necessarily occurs, because market conditions will change over time (Donald B., Keim.,1983).

Also, according to the new strategies of trading like high frequency trading, the sequence of trading and characteristics of the market is changing quickly, so there must be very accurate, sharp and smart method of anticipation which should be swift conformity to the market environment to predict the minuscule changes precisely in short-term positions for no miss of opportunities (López de Prado, Marcos M.,**2011**).

Many methods in time series models used for predicting the prices (Todd F., M.. Correa, A.,2007). But, as mentioned previously, one of the effective method is, predictive model, named Kalman filter which simultaneously fuses information of technical and fundamental analysis presented to forecast the price in the stock exchange markets (H. Haleh, and others, 2011) And extended version of Kalman filter is appropriate for the nonlinear systems (Qi, M. & G.S. Maddala,1999).

But, one of the challenging issues of using extended Kalman filter (from the time series family) is, how to initiate or set its parameters like Q, R and P- for more efficiency of the predictions. Some do that with statistical methods, some set them practically, and in most of the applications, they are constant (McMillan, D. G.,2001). But they should be variable because the financial and economic series characteristics used for the stock markets environments are "high frequency" which means that the conditional variances of the process is not constant over the time and they consists of daily weekly and intraday observations (Aldridge, Irene,2010).

Technical Analysis indexes like: RSI, %K, MACD _ because of rich information about the trends of the prices_ are the appropriate parameters that can be used for showing the dynamic environmental changes.

This paper introduces how to use technical analysis indexes, to calculate the EKF parameters effectively for all kinds of the securities in the stock exchange markets, without any need to manually initiate the parameters for each one.

Then as a real test, the model implemented for the securities of some of industrial companies in Iran. Finally, the obtained results will be compared with constant initiating method result to shows its desirability in short-term predictions.

2. Extended Kalman Filter

Kalman filter is created from the name Rudolf E. Kalman in an article which was published in 1960 that presents recursive solution to filter the linear discrete data (Kalman,R.E,1960).

Kalman filter actually is a set of mathematical equations that is type of optimally estimator, predictor and corrector which sensibly minimizes the estimation error covariance (Maybeck,P.,1979). This filter is effective for normal distributed data (Welch, G., Bishop,G.,2001). So the first step is to prove the normal distribution of the prices in the market, according to the standard tests the changing of the prices are normally distributed (Namazi. M; Z. Shoushtarian;1996).

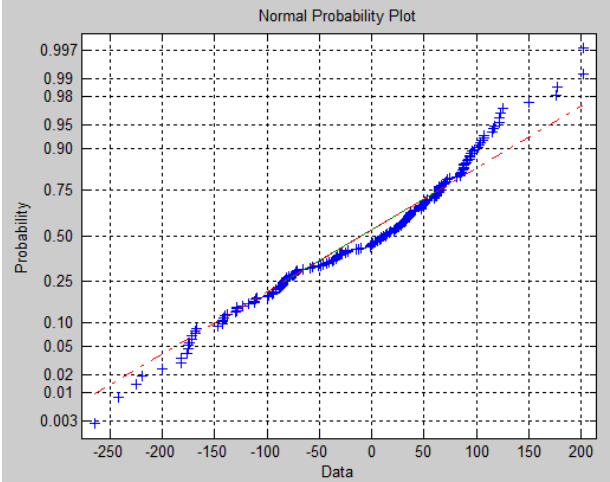

Fig1. Normal distribution of the price in market

Kalman filter is trying to understand the general issues which are to estimate the state of $X \in R^n$ discrete-time control process that has linear differential function. Now what happens if a process that should be estimated and (or) relationship with the measurement process is nonlinear? Many successful and interesting applications in the Kalman Filter are in these conditions. The Kalman filter that linear mean and covariance of states is known extended Kalman filter (EKF) (Haykin, Simon, 2001).

Assume that the process has $X \in R^n$ state vector. and process given with a nonlinear random differential equation.

$$x_k = f(x_{k-1}, u_{k-1}, w_{k-1}) \quad (1)$$

By measurement $z \in R^m$ in which:

$$z_k = h(x_k, v_k) \quad (2)$$

Where the random variable w_k and v_k represents the process and measurement noise. In this equation, nonlinear function of f in the differential equation 1 related to the state in the previous time step to current time k .These are also include function parameters u_k and zero mean noise process (w_k). Nonlinear function h in measurement equation 2 is related to the state x_k to the measurement z_k (Huang , Shian-Chang,2008).

$$K_k = P^- C_k{}^T (C_k P_K^- C_k{}^T + R)^{-1} \quad (3)$$

$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - h(\hat{x}_k^-, 0)) \quad (4)$$

$$P_k = A_k(I - K_k C_k H) P_k^- A^T{}_k + Q \quad (5)$$

As mentioned in the previously the Kalman filter performance need the use of parameters like Q , R , W_k and V_k . These parameters are always set practically. Now let's calculate the statistical parameters by using available data. Q Is covariance of process noise. To calculate Q according to the parameters definition, an interval stock price changes should be calculated. For this purpose, in a specified period (one year) change in stock price is calculated by the formula [16].

$$e_i(n) = price(n) - h_i(n) \quad (6)$$

$$Q = Var(e_i) \quad \text{(Statistically)} \quad (7)$$

3. Technical Analysis Indexes

In this section there will be announced some of the technical indexes which are used in the stock market analysis (William L.Jiler,1990).

Technical indexes will show the trends of the price in the short-term and mid-term periods. Like RSI, this is criterion for measuring the speed of the price changes.

$$RSI = 100 - \frac{100}{1+RS} \quad (8)$$

(, where RS is the daily ratio of average closing increasing price to average closing decreasing price in the same period.)

If RSI reach to less than 30, this is the sign that the stock price will reach to the floor price in the near future and increase the possibility of price growth. Or if the RSI exceed the 70, this shows that there will be a ceiling price for the securities in the near future and increase the possibility of price reduction.

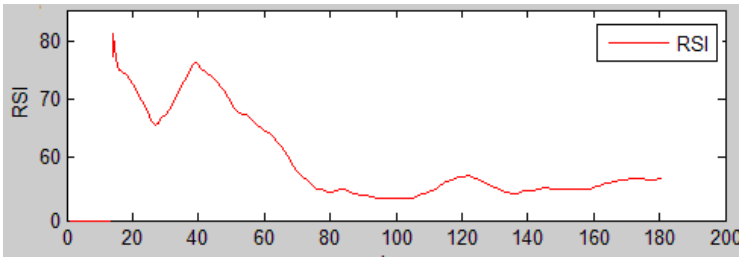

Fig2. 14 day's RSI

MACD is the other method of technical analyzing which is from the oscillator's family. Any divergence between price chart and MACD chart shows the inverse in the trend of the prices in the near future (H.Panahian,2011).

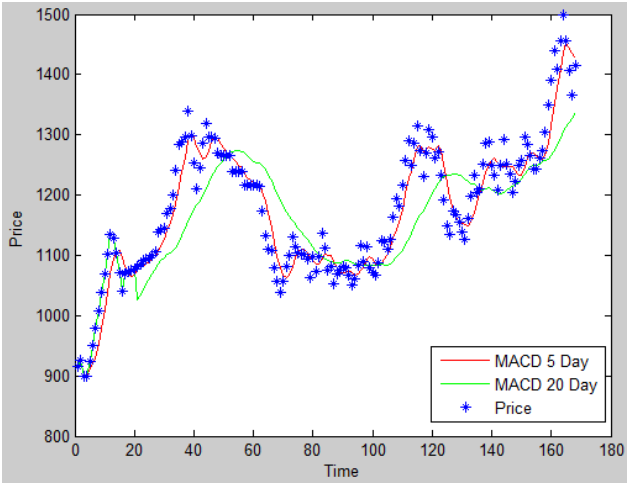

Fig3. 5-Day and 20-Day MACD chart

4. Technical Analysis indicators in EKF parameter setting

These parameters can give to the analyzing system a good knowledge of the market environment. In this application RSI, MACD values will be used for setting the Q parameter. Q in Kalman filter is a parameter which shows the process error variance. Q is calculated statistically by using available data. This parameter is always set practically and constant. But what makes the EKF adaptive for all the stock market conditions all the time is how it can change its status of forecasting. One of them is setting Q parameter that recognizes the changing of the prices in the next periods.

As noted, technical indexes like RSI, MACD can show the trends of the price changing in the near future, and Q will affect the forecasting price in the future market price environmental. So we find a nonlinear relation function between RSI index value and price changing as below to use it for setting Q.

But according to the nonlinear relation, a type of artificial neural networks which is called generalized regression neural network designed to estimate the changing rates. The network was designed with MATLAB neural network tool.

To improve neural network's capabilities, a compound of technical and fundamental factors related to the market environment is used as inputs over different time period [18]. The fundamental index which affects on the price of the securities is the market return rate. This is another environmental variable which affect on the changing of the securities price. This is related to the parameter called β. If the β coefficient of the asset was more than 1 then the fluctuations of the return rate will be very dependent to the market return rate and if it was less than 1 then the relation is reverse. The relation is shown in the below equation:

$$\beta_i = \frac{\mathrm{cov}(r_i, r_m)}{\sigma^2(r_m)} \qquad (9)$$

(Where ri is return of the securities and rm is the return of the market.)

The other fundamental parameter which affects to the prices in the market environment is the total index market (TIM); this parameter shows the trading index of the market. In Tehran Stock market it is called TEPIX.

The network trained by supervised method of learning with the result of equations 6 and 7 in 170 episodes.

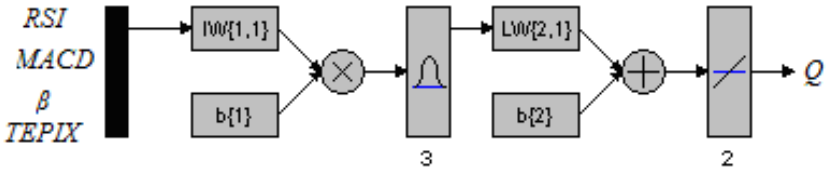

Fig4. Designed neural network for estimating Q with respect to RSI, MACD, β and Price

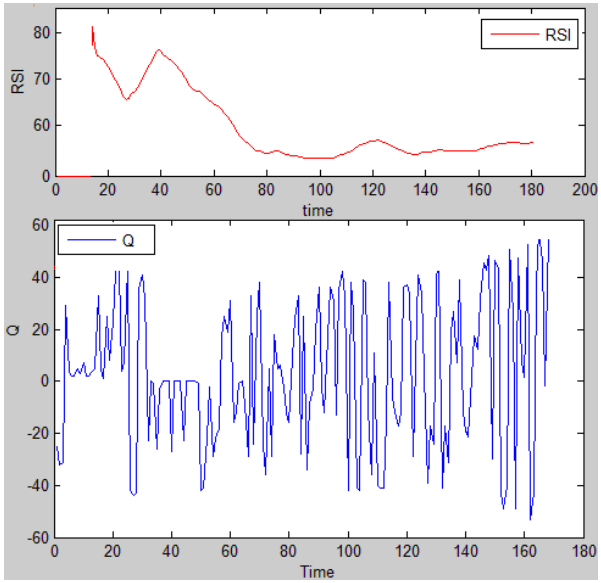

Fig5. Relation between dynamic Q and RSI by ANN

After learning, the Q is generated in each market situation according to the technical indexes by the time of prediction and then feed to the EKF model for exploring the next price of the securities in the next trade. The experiments were done on the securities of Iran stock exchange Market to show the efficiency of the method.

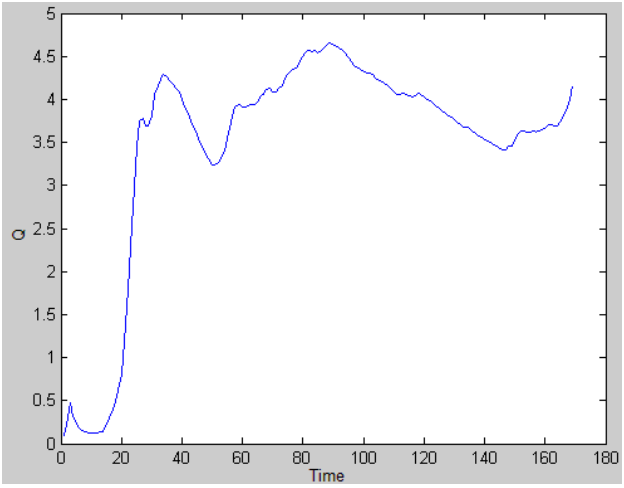

Fig6. Result of Q estimation with ANN while training the network

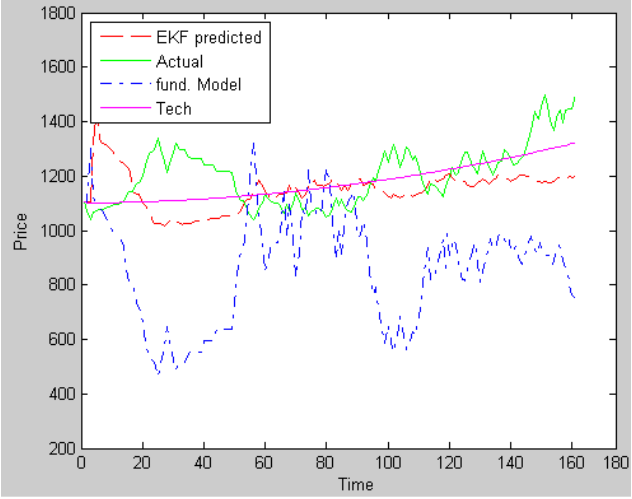

Fig7. Stock price prediction

5. Conclusions

Extended Kalman filter is one of time series family forecasting method. According to the variable condition and high frequency fluctuations in the financial markets, for efficient forecasting, it is essential to obtain a good knowledge of the market environment. This paper tries to forecast the securities price with EKF model which dynamically set the Q parameter according to the technical analysis indexes. This is done by using an artificial neural network to find a relation between RSI, MACD and β with the continuous changing of the market environment which leads to efficient forecasting. Table 1 shows the comparison result by MSE and MAE criteria's for two types of constant and dynamic Q, using in different and sequential prediction of EKF model in stock exchange.

Table1. Error comparison with different Q's

EKF Predict with	MSE	MAE
Constant Q	25.9	156.76
Dynamic Q with ANN	20.3	110.43

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