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The Design of the Multi-Scale Data Fusion Algorithm Based on Time Series Analysis

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Abstract

Time series is an indicator at different times on different values, arranged in chronological sequence. The basic idea of the multi-scale analysis by orthogonal transformation, and it is such as wavelet transform signal decomposition analysis on different scales. The timing analysis method is achieved through the model method. The process parameters of the dynamic data time-domain analysis method is a parametric model to fit the observed data, and then use this model to analyze the observational data and produce data system. The paper presents the design of the multi-scale data fusion algorithm based on time series analysis. Finally, the advantages of the new algorithm are elaborated from the estimation accuracy and simulation demonstrated the effectiveness of the new algorithm.

Keywords*: Multi-scale, Time Series Analysis, Data fusion*

1. Introduction

The basic idea of the multi-scale analysis by orthogonal transformation, and it is such as wavelet transform signal decomposition analysis on different scales. Decomposed into coarse scale signal is usually referred to as the smoothing value, while the difference between the original signal and the smoothed value become detail. Optimal estimate of fusion estimated using the measured values of these smoothed values and details, and finally reconstructed estimate at different scales, we want the original signal.

From a statistical sense, the so-called time series is an indicator at different times on different values, arranged in chronological sequence [1]. This series due to the impact of the various causal factors, tend to exhibit certain randomness, this statistical dependencies between each other. Here the order of either the time sequence, and may be a physical quantity having a different significance, such as representative of the temperature, velocity, or other physical quantity to monotonically increasing value.

The wavelet analysis Fourier analysis of the epoch-making development results, booming in the past 20 years fully reflects the double meaning that it has a far-reaching theory and application of a wide range of. Wavelet analysis is widely recognized as the latest time - frequency analysis tools too many scholars at home and abroad, has been favored. Wavelet analysis have "mathematical microscope" feature, so that in the time and frequency domains have the dual ability to characterize the local signal characteristics; make use of it can describe the random process or signal in the short, medium and long-term changes in characteristics.

The so-called time series is a collection of observations in chronological order. Various time sequences can be obtained in accordance with the study of the phenomenon or different. Annual output value of national income, the sales volume of a commodity in a market, a commodity in the market price changes in the economic field, or the social sphere, the population of a region, the number of hospital patients , railway traffic, or natural areas of sunspot numbers, monthly precipitation, rivers, *etc.*, to form a time

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sequence. The basic point of all of these sequences is that each sequence contains all the information to generate the sequence of historical behavior. Especially driven by the trend of global economic integration and it is all walks of life since the 1980s the rapid development of the globalization process. With the rapid development of the global information technology and other high-tech, economic and financial development will be further accelerated.

As estimated by the Kalman filter and wavelet transform method in a state of dynamic process random signal analysis has its own advantages, their lack Therefore, if the model-based dynamic analysis method based on the statistical characteristics of multi-scale signal transform methods organically combine real-time multi-scale analysis of the system will be achieved. The paper presents the design of the multi-scale data fusion algorithm based on time series analysis.

2. Time Series Analysis

Video tracking technology usually two algorithms thought: track and moving target detection by identifying targets to be tracked. The former algorithm ideas by identifying each frame of image tracking target to determine if the moving target position and tracking; the algorithm idea contains two parts of the target identification and target matching [2]. Latter by detecting and found moving target tracking algorithm ideas and determine the position of the moving target to be tracked, the method does not need to consider the shape, size of the target, any object can be detected.

A random process is actually a binary function of sample points and parameters. When fixed is a normal function, called him for a random process "or a sample function. Corresponding to different corresponding to different sample function, all possible outcomes overall constitutes a random process. When fixed, is a random variable [2]. When all the fixed time is a value and it is random process state.

According to the research object to the number of points, and it is one Yuan of time series and multivariate time series. Sales series as a commodity, that is, a time series of $; if the object of study not only this series, but more than one variable, such as the year-on-year, sort on the order of temperature, air pressure, rainfall data, each moment corresponds to more than one variable, such a sequence of multivariate time series. Multiple time series not only describes the variation of each variable, but also reveals the dynamic regularity of the interdependent relationship between the variables.

Traditional time series analysis is a quite mature discipline, has a set of analytical theory and analysis tools, and is the main method of time series analysis. Time series analysis research aims to forecast the time sequence of the future development of the situation; composition of the basic trends in the analysis of time series items, seasonal items and random items; analysis of specific data collection, a mathematical model, the model structure analysis and empirical research, as is shown by Figure1.

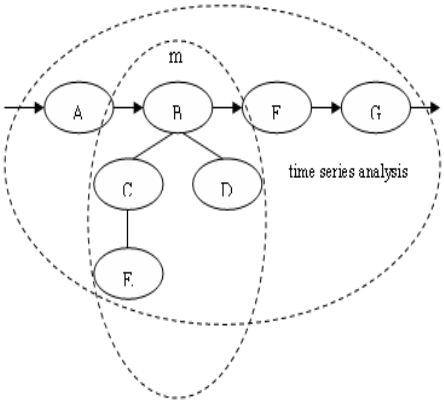

Figure 1. A Time Series Analysis Research Figure

Time series analysis of the object of study is a bunch of changes over time but interrelated dynamic data sequence. The conventional timing analysis method is estimated in the time domain of the autocorrelation function of the observed data to estimate its power spectrum function or in the frequency domain [3]. However, the data we obtained only been observed random phenomenon limited data, it is impossible to get an infinite length of the complete sequence of sample values, therefore, virtually impossible by observing the data calculated from covariance function and spectral function true value, and the only sample auto covariance function and the sample from the spectral function, with the theoretical value of the deviation and the low frequency resolution.

Since the power spectral density function of the stationary sequence represents the power of the course in accordance with the allocation of the frequency, it means that any one implementation can be decomposed into a set of harmonic and each implementation corresponds to a different set of harmonics, visible spectral analysis the sequence as numerous frequency having a random amplitude and random phase the superimposition of the periodic oscillations, *i.e*. oscillation amplitude of oscillation at a certain frequency cycle by the mean of the intensity of reflected in sequence in the frequency at the power spectral density values.Therefore, in the curve of the power spectral density function, if a clear peak at a certain frequency point, can determine the intensity of the frequency components in the original sequence.

But it also exists the inevitable drawbacks, *i.e*. represent a signal with Fourier transform only the frequency resolution without a time resolution of the FOURIER coefficients is a weighted average of the signals in the time domain, in order to use their coefficients to reflect the local properties of the signals in the time domain is impossible, the local nature of the signal, regardless of the theoretical research, or in actual application is very important, as is shown by equation 1.

$$C_{j-1} = H'C_j H + G'D_j^h H + H'D_j^v G + G'D_j^d G$$
$$(J = J, J-1, J-2, \cdots, 1) \tag{1}$$

Wavelet, wavelet the term first French geophysicist JM orlet in the early 1980s, which kicked wavelet theory matured prelude [4]. In 1984, J. Morlet analysis of the seismic data, seismic waves according to a determined function stretching expand pan Department, his AG rossman jointly study the development of the continuous wavelet transform geometric system. In 1985, French mathematician Meyer first proposed the smooth wavelet orthogonal basis.

Wavelet analysis is a time - scale (time - frequency) signal analysis method, it has the characteristics of multi-resolution analysis, but also in the time-frequency domain has the ability to characterize the local signal characteristics. In the low-frequency portion having

a higher frequency resolution and lower time resolution in a high frequency part having a high time resolution and the low frequency resolution, it is suitable for the analysis of non-stationary signals, and detect abnormal signal entrained transient abnormal signals and analyze the composition, it is known as the analysis of signal microscope.

Traditional time series analysis in the time domain and frequency domain, and it is wavelet scale analysis of the time series. Corresponds to the concept of scale in the concept of frequency domain analysis is in the frequency and scale analysis [5]. Typically, the frequency domain analysis of time series (spectral analysis) tools can find the corresponding scale analysis tools, such as power spectral density function, period gram cross spectrum, respectively, corresponding to the wavelet variance, scale and wavelet covariance. Long memory processes of self-similarity can also be used wavelet method is well described. Addition wavelet can be used to smooth the period gram analysis the multiracial form of time series, time series forecasting and seasonal fluctuations in separation.

Estimation problem often encountered in the field of automatic control, and it communications, aviation and aerospace science. Estimated it is to extract useful information from the observed data with random interference. In order to measure the quality of estimated, there must be a measure of the standard, this measure is estimated criteria. Estimates are often based on estimated performance reaches maximum "as standard. Estimation criteria can be varied. Commonly used estimation criteria: minimum variance criteria, the maximum likelihood criterion, and it is the maximum posterior criterion linear minimum variance guidelines, and least squares criterion. Select a different estimation criteria, have a different estimation methods, estimation methods and estimated criteria are closely related, as is shown by equation2.

$$MEAN = \sum_{i=0}^{M-1}\sum_{j=0}^{N-1} F(i, j)/(M \times N) \tag{2}$$

And the time sequence is an objective record of the historical behavior of the system studied, and therefore it contains system structure characteristics and operating rules. So we can understand the structural features of the system studied by time series; reveal the laws governing the operation, and then used to predict and control their future behavior.

Press time the continuity of the time series can be divided into two kinds of discrete-time sequence and continuous time series. If the sequence value of each of a sequence corresponding to the time parameter is a discontinuous point, the sequence is a discrete-time sequence, and if a certain sequence of each sequence of values corresponding to the time parameter is a continuous function, the sequence is a continuous time series. We mainly study the sequence of discrete time, continuous time series by interval sampling so transformed into discrete time series.

On the surface, the timing analysis aside memory causal relationship between system variables and structural relationships, but in fact, due to the timing have occurred in all causal relations and structural relations are reflected in the timing analysis from the total of visit, to illustrate the combined effects of various forces. Therefore, when we are concerned about the impact of complex factors or data cannot be obtained directly using him as a variable integrated instead of these factors [6]. Time as a clear argument to enter the model, is expressed on the surface of its significance due to variable change spontaneously over time, actually represents a decided change in the dependent variable, the joint impact of various factors.

Proposed, the earliest of the wavelet analysis method should be put forward in 1910 Haar orthonormal basis, but did not appear the word "wavelet". In 1936, Littlewood and Paley binary frequency components grouped theory of Fourier series, binary division of the frequency of its Fourier transform phase change does not affect the size of the function, which is a multi-scale analysis of the thinking of the earliest sources.1946 Gabor

windowed Fourier transform (or short-time Fourier transform) played a certain role to make up for the deficiencies of the Fourier transform, as is shown by Figure2.

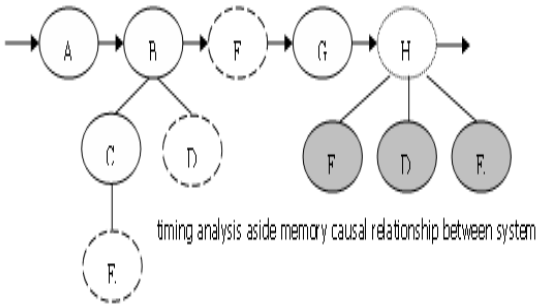

Figure 2. The Timing Analysis Aside Memory Causal Relationship between System Variables

For the smooth process of the power spectral density function of the variance of the process depending on the frequency decomposition, and this corresponds to the wavelet variance decomposition of the variance of the process in accordance with the scale, which is very useful for the analysis of changes in physical phenomena at different scales: wavelet variance and power spectral density function of the concept is closely related to the specific scale corresponds to a specific band wavelet variance of the power spectral density function in the band together, so this band can be calculated by the wavelet variance the average power spectral density function, power spectral density function of the characteristics of this band is not obvious (little change), the resulting estimates of the power spectral density function of the band; easier for the wavelet variance unbiased estimator. So when the sample variance unbiased poor, or process with infinite variance, the sample variance is not a particularly useful statistic.

Maximum likelihood estimation method was first proposed by Gauss (CF Gauss), 1912 (RA Fisher), Fisher proved some properties of this method and named for maximum likelihood estimation. Maximum Likelihood likelihood estimation method of thinking is: the actual event is the biggest event of probability if multiple results A This is the maximum likelihood principle. Intuitive idea of the maximum likelihood principle is: a randomized trial, B, C,. In one test, if the A appears, the test conditions on the emergence of A is generally considered the most favorable, *i.e.*, the probability of occurrence of A maximum, as is shown by equation3 [7].

$$F(t)=\sum_{k=1}^{k} W_k h(\frac{t \quad b_k}{a_k}) \tag{3}$$

One is the change process has a form to be determined, or that has the inevitable variation, mathematical language, the change process can be used for one or several of the time t to determine the function to describe this type of process is called deterministic process [8]. For example, when the capacitor discharges through the resistor, the potential of the voltage across the capacitor changes over time is a deterministic function. And changes in the form of another type of process is not determined, that is, each time its measurement result is not a determined variation is the use of mathematical language, such things as changes in the process can not be used one or several times determine the function to describe the type of process is called a random process.

According to the statistical properties of the sequence, stationary time series and non-stationary time series two categories. If the probability distribution of a time series in the time-independent, it is the sequence for strict (narrow) stationary time series. If the sequence of the first two moments exists, and to meet any time:

a) The mean is a constant;

b) Defend differential function as the time interval;

Claimed that the sequence for the wide-stationary time series, also called generalized stationary time series to the contrary, does not have the smoothness of that sequence mean or assist in the defense of poor time-related sequences called non-stationary series [9].

Due to the Fourier transform of the above defects, for a long time, mathematicians and engineers trying to find a function-based function space LZ (R), both to maintain the advantage of the exponential function-makes this function base, but also to compensate for the exponential function base insufficient, and hope that this function base is generated by a function that has a smooth, compactly supported and higher vanishing moments through the dilation and translation functions family. Now we call this function base wavelet basis, its existence, structure and nature of the study will constitute the contents of the wavelet analysis research, as is shown by equation4.

$$\delta I_i = \begin{cases} I(\mathrm{P}) & I(\mathrm{P}_i),\ i = 0,1,2,3 \\ I(\mathrm{P}_i) & I(\mathrm{P}),\ i = 4,5,6,7 \end{cases} \tag{4}$$

Therefore, since the wavelet analysis was born ten years time, up to now, but in areas such as geophysical prospecting, signal information processing, image processing, speech segmentation and synthesis, fault diagnosis, the radar signal analysis to obtain the best effect. From a mathematical point of view, the development of wavelet analysis, the numerical solution of differential equations, integral equations, statistics and other disciplines has injected new vitality. Wavelet analysis in fluid dynamics model and to strike a numerical solution, cell recognition of Medicine, linear system calculates the physics analysis, time series analysis, application engineering calculations [10]. Neural network with wavelet analysis combined fractal geometry combined with wavelet analysis is one of the hotspots on the international.

Time series analysis is not based on a variable with the static relationship between the other variables to predict future changes of the variables, but according to the predictor variables or other variables variation to predict future changes [11]. University time series analysis, it is based on the variation of the variable to predict future changes. Because whether it is a natural phenomenon and the social and economic phenomenon, is a law of the dialectical process of development.

3. Designing of Multi-Scale Data Fusion Algorithm

In recent years, random signal decomposition and estimates estimation theory, communication and signal processing hotspot. For example, in signal processing usually based on measured values of a (identified or unidentified) signal estimate and depending on the resolution of its decomposition. Therefore, we need the optimal estimation algorithm and the measured values obtained by the decomposition technique processing optimal or sub-optimal estimate of the dynamic system.

With the continuous development of the multi-scale system theory, wavelet analysis theory and Kalman filtering technique to combine and effectively used in the research and application in the estimate of the dynamic system has also been the concern of the related fields of scientific research and technology workers, and made a number associated with this research [12]. Professor L. Hong based Haar wavelet study a class of dynamic systems and distributed estimation fusion algorithm research system is given by a single equation of state, as well as multiple measurement equation measurement system consists of multiple sensors, are in different the scale on the system for measurement, and a 2-fold decreasing relationship between the sampling rate of the sensor adjacent scales.

We will be given based on the single sensor single model system a new multiscale filter - multi-scale the sequence block Kalman filter (MSBKF), multi-sensor situation will be discussed in chapter IV below. MSBKF in the estimate of the state not only has the

traditional Kalman filter with real-time and recursive, it also has the ability to multi-scale analysis of the system. It overcomes the above 1) and 2).

1) re-described initial state equation and the measurement equation of the form of blocks, and the block noise of this description is not relevant, so that it overcomes the noise block-related problems in the literature;

2) Status blocks decomposition using wavelet transform to a different scale, and so multi-scale system in the time domain and frequency domain analysis;

3) On the basis of the state of the system after the above sub-block and wavelet transform, to take the idea of sequential Kalman filter to achieve MSBKF algorithm, and prove that this algorithm is real-time, recursive.

At different scales characterize and analyze the state of the system, we need to find a combination of time-domain analysis of frequency-domain methods, wavelet analysis appears to be a suitable choice [13]. Below, we first introduced with orthogonal wavelet transform block system (3-13), and then transformed into the frequency domain, and to establish the relationship between the block measuring, so that the following analysis, as is shown by Figure3.

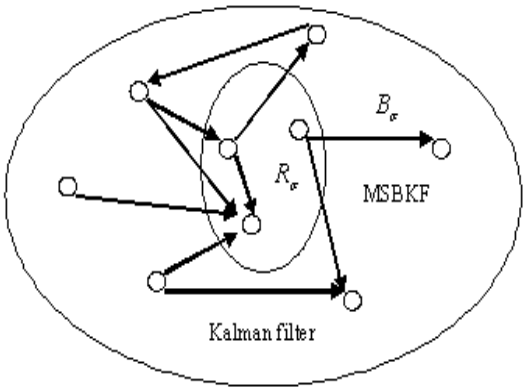

Figure 3. The Idea of Sequential Kalman Filter to Achieve MSBKF Algorithm

From the estimation process, you can see that the multi-scale block Kalman filter only piece of the measured values are to run the algorithm is a semi-real-time, but in the process of estimated MBKF estimated wavelet coefficients of the algorithm is based on the multi-scale estimated.

In order to facilitate the understanding of the algorithm, in the process of the establishment of the algorithm, we also gives two filters associated with it, *i.e*. the sequential block Kalman filter (Sequential Block Kalman filter (SBKF)) and multi-scaleblock Kalman filter (multiscale block Kalman filter (MBKF)). And MSBKF SBKF is in real time, recursively, however, it will not be able in multi-scale domain analysis state; while MBKF although able to state in the multi-scale domain analysis, but this estimate analysis process is not real-time.Will be given of the detailed derivation process of MSBKF the derivation of SBKF and MBKF therewith similar, and therefore omitted, as is shown by equation 5 [14].

$$E[(X(k)-G(k))^2]=E\left[\left\{X(k)-\frac{\sum_{i=1}^{N}u_iZ_i(k)}{\sum_{i=1}^{N}u_i}\right\}^2\right] \tag{5}$$

The Kalman filter can be through the use of the observation information in real time, recursive and optimal estimation of the target state, coupled with the algorithm is easy to implement, *etc*., so it has been widely applied in the estimation of dynamic systems [15].

However, Kalman filter is based on the goals established in the time-domain dynamic model and observation model, it did not take into account the multi-scale characteristics of the target, and therefore, it lost the ability to multi-scale analysis of the target state.

Assume that the measured values of the state of the system in different scales from different resolution sensor, the predictive value of a moment when at some point the state is estimated to be worth to the traditional Kalman filtering, then the Haar wavelet this predicted value decomposition to different scales, and this decomposition value as to the predicted value of the state of the system on the scale, while retaining the decomposition overlooked detail; next use of the measured values of the sensors on different scales the predicted value, respectively update the smoothed values of the scale, resulting in a partial update values; Next reconstruct the updated value of the local reservations details on the finest scale local optimum estimate.

Adjacent state block process noise is related, that is, the algorithm block system noise is colored noise, it changed the white noise properties of the original system, the standard Kalman filter implementation, however, requires that the system noise must be white the text is still the colored noise as white noise, it is not rigorous, resulting in the algorithm is not optimal [16].

Algorithm is still not a real-time text proved optimal estimated value of the various elements in the block status is the product of a constant matrix block estimate its estimation process, however, is still similar to L. Hong algorithms are in the entire block the measured values are only after to update predictive value, the local estimated to run.

4. The Design of the Multi-Scale Data Fusion Algorithm Based on Time Series Analysis

The basic characteristics of time series analysis are the study of the sequence pattern of development over time. Different from the one of the statistical analysis is explicit attention to the importance of the order, that the observations are made according to a certain order, and keep the same order, the only way to ensure the process of the historical development of the research phenomenon unchanged [17]. Secondly, there are certain dependencies between time series of observations. In a sense, the time series analysis is the quantitative description of this dependency.

Modern timing analysis method is achieved through the model method. Parametric time-domain analysis methods to deal with dynamic data, a parametric model to fit the observed data, and then use this model to analyze the observational data and produce data system, in order to understand more the nature of the internal data structures and system dynamic characteristics, which can take advantage of the observational data of the past to predict the future value and control. The basic idea is to establish timing model that the same variable in the observations of the present moment in time, with the previous observations are linked.

Algorithm only smoothed values L. Hong algorithm update and retain the irrationality of the details of the signal, and also updates the essence of the algorithm, however, is to give up the details in the smoothing process, so get noticed simply obtained in the coarse scale estimation value the details of the value is taken as zero recapturing [18]. And the reconstructed value of the estimated value of the smoothed signal obtained by the respective sensors in the finest scale fusion, which is clearly unreasonable, as is shown by equation6.

$$B^{-1}(R-Ax(0))=-(QB+B^{-T}S)^{-1}Ax(0)$$
$$R=[I-(Q+B^{-T}SB^{-1})^{-1}Q]Ax(0) \quad (6)$$

The least squares method is a fundamental way to deal with a variety of observational data measurement adjustment, is a commonly used method of mathematical statistics, widely used in industrial technology and other scientific research. It is the one do not need

any of this a priori knowledge of the parameter estimation method [19]. The following describes the precise definition of the least squares method, and how to find empirical formula approximate linear relationship between x and y. Assumed experimentally measured data between variables, can be obtained points, this graph is called a "scatter plot", these points is generally scattered in the vicinity of a straight line can roughly be seen from the figure, we believe that between and approximated as a linear function, the following describes solving steps.

MSBKF algorithm analysis is not only recursive, real-time, it also has the ability to multi-scale analysis, which means that it provides details of the estimated value of the state at all levels as well as the final layer of smooth estimate. Based on this, it is possible to obtain the estimated value of the initial state and the state at different scales.

SBKF, MBKF well MSBKF filter on the steps in this section will be estimated by theoretical analysis of the principle of minimum error covariance to compare them and in accuracy between the BKF performances. In order to facilitate the proof, based on the block Kalman filter (BKF) on the estimated value in mind to do, the estimation error covariance is recorded in the target state block vector block based on previous observations, the initial state and system model, as is shown by equation7.

$$C = \sum_{i=0}^{L-1} p_i \log_2 \frac{p_i}{q_i} \tag{7}$$

500 Monte Carlo simulation of the system given above, combined with the MSE definition given above, this paper gives the MSE of the estimated position and velocity from MSBKF, Kalman filtering, and Hong algorithms, simulation results show that the time from Kalman filtering obtained MSE converges to a value from MSBKF Hong's algorithm will converge in the block form, and therefore is given in the table from the start the system estimates the MSE.

Both position and speed, MSE of get by MSBKF MSE than the other two algorithms, must be small; Hong algorithm the MSE is smaller than the Kalman filter in position, but has to speed. MSBKF the accuracy is higher than is in MSBKF algorithm, the estimated value of the block contains the smoothed value of the state Kalman filter, which uses the measurement information of the back of the status block; than the algorithm of the Hong optimal because the latter stars block technology enables the system to colored noise, resulting in imprecise derivation, and therefore cannot be the optimal estimation, as is shown by Figure4.

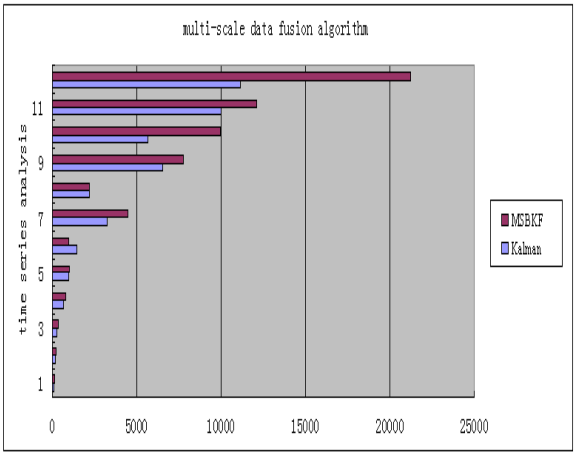

Figure 4. The Design of the Multi-Scale Data Fusion Algorithm Based on Time Series Analysis

The paper presents the design of the multi-scale data fusion algorithm based on time series analysis. First, the basic concepts of time series and classification is described, then introduced the basic idea of their analysis and frequency domain analysis principles; then made a presentation on wavelet applications in time series analysis. Finally, it is the two parameter estimation methods frequently used in scientific fields. From this sense, it can compensate for the deficiencies of the Kalman filtering method. However, due to the multi-scale wavelet analysis method is only over a period of time to obtain the signal block analysis, and therefore does not have a real-time and recursive features, thus losing the ability to conduct real-time analysis of stochastic processes.

5. Conclusions

Based on Kalman filtering estimation algorithm and wavelet analysis theory given MSBKF algorithm and it's two types of algorithm, sampling first single model single-sensor system are analyzed in detail, for the advantage of existing fusion algorithm as well as the presence of insufficient to carry out the research of a new multi-scale hybrid data fusion algorithm, and finally from the estimation accuracy expounded the advantages of the new algorithm and simulation demonstrated the effectiveness of the new algorithm. The paper presents the design of the multi-scale data fusion algorithm based on time series analysis. The time series is the objective of the system historical behavior record, which contains all the information of the system dynamic specially. This information is the specific performance of the statistical correlation between the time series observations. Thus, it can be a statistical correlation study time sequence value to reveal the dynamic structure of the corresponding system characteristics and the law of development.

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