



Filtering method in wireless sensor network management based on EMD algorithm and multi scale wavelet analysis

Qihong Zhang[#] and Lei Lei[@]

[#]College of Computer and Information Engineering, Nanyang Institute of Technology, Henan Nanyang, China
[@]School of Software, Nanyang Institute of Technology, Henan Nanyang, China

ABSTRACT

Time frequency analysis method based on EMD is an adaptive frequency analysis method, the data need a total of two basic steps: firstly, it decomposes the signal into several basic function component, then the time-frequency analysis using Hilbert transform. Wavelet transform is a time-frequency localization methods, time-frequency window area fixed but may change shape, which has higher frequency resolution in the low frequency part and the low time resolution, high time resolution in the high frequency part. Multi scale analysis and discrete wavelet transform is the core content of the wavelet analysis. The paper proposes the Filtering method in wireless sensor network management based on EMD algorithm and Multi scale wavelet analysis. The simulation experiments show that the method is effective to tradition WSN management.

Keywords: Wavelet transform, Empirical Mode Decomposition (EMD), Wireless Sensor Network.

INTRODUCTION

Wireless sensor network node energy consumption is normally provided by micro battery, battery energy is very limited, but because of the wireless sensor network node is large in scale, the working environment is often relatively poor, the node battery cannot be replaced or recharged, so want to prolong the lifetime of sensor networks, we must in every link network design, first consider the problem of energy saving [1]. Through the analysis of the energy consumption of nodes, we know that the energy of sensor nodes is mainly consumed in the wireless communication module, that is to say the performance of network layer routing protocol design of wireless sensor network will play an important role in the WSN.

The empirical mode decomposition (EMD) method is essentially a signal to smoothly, the result is different scale fluctuations or trends in the real signal unbundled, produce a series of different characteristic scales of data sequence. Each sequence is called a basic mode component (Intrinsic Mode Function), referred to as IMF component. Time frequency analysis method based on EMD is an adaptive frequency analysis method; the data need a total of two basic steps: firstly, it decomposes the signal into several basic function components, then the time-frequency analysis using Hilbert transform.

Wavelet transform is a time-frequency localization methods, time-frequency window area fixed but may change shape, which has higher frequency resolution in the low frequency part and the low time resolution, high time resolution in the high frequency part and the low frequency resolution, so called "mathematical microscope". Multi scale analysis and discrete wavelet transform is the core content of the wavelet analysis.

WSN application is the goal of perception, acquisition and processing of network coverage area of perceptual object information, and sent to the observer, so the three elements which are sensor, object and the observer. So we can say

that WSN will be the information world with the physical world of logic together, changed the human self interaction with natural world. Random distribution of a network of sensors, data processing unit and communication module of tiny nodes can self organize to form, with the nodes in the built-in various sensor located in the surrounding environment, red hot outside, sonar, radar and seismic wave signal.

Wireless sensor network according to the demand of network users to the design of network architecture, its own characteristics, provides a unified technical specification and algorithm of network protocol standard, which can meet the needs of users. Sensor network architecture with a two-dimensional structure, namely horizontal layer communication protocol and sensor network management longitudinal surface. Communication protocol layer can be divided into physical layer, link layer, network layer, transport layer, application layer, and the network management can be classified as mobility management, energy management, and task management. The paper proposes the Filtering method in wireless sensor network management based on EMD algorithm and Multi scale wavelet analysis.

2. Application of EMD Method in the Wireless Sensor Network Management

Wireless sensor network is deployed in the monitoring area by the large number of cheap micro sensor nodes, through wireless communication to form a multi hop self-organizing network system, the aim is cooperative sensing, collecting and processing the network coverage area perceived objects, and then send to the observer. Sensor, object and the observer constitute the three elements of wireless sensor network.

While the EMD method based solely on the basis of the data itself information decomposition, compared with wavelet analysis not only has all the advantages of wavelet analysis and wavelet analysis, can eliminate the ambiguity of the resolution, can accurately reflect the physical features of the original signal. Because the EMD method than the Wavelet method and the existing all other signal processing methods have stronger local characteristics, therefore intermittent signal in the treatment received, the EMD method is the best one.

EMD can be obtained through a cluster can represent the time scale IMF decomposition for nonlinear and non-stationary signals, as each IMF is a narrow band signal, so we can analyze the effective HS. Adaptive signal decomposition is based on principal component analysis (PCA) thinking. PCA is different from EMD, the former is based on the statistical characteristics of the signal, and the EMD is deterministic, is based on the local characteristics.

A complete wireless sensor positioning system design process includes 3 aspects: the node hardware design, positioning node software design and PC software design. The hardware system with positioning the hardware platform for the design, node software design mainly completes the data transmission process of locating wireless transceiver module, PC software to receive wireless data collection, complete the positioning using specific algorithms, and display the dynamic positioning results.

$$\delta_{kj} = \begin{cases} 1 & k = j \\ 0 & k \neq j \end{cases} \quad (1)$$

Analysis and management of wireless sensor networks is an important and difficult research and application in wireless sensor networks, network needs analysis and management support to a back-end system. Wireless sensor network is more similar to a tool, like computers, many industries are in need of such technology to conduct their research and deploy them, which leads to every kind of demand is the [2]. Can interactive graphical user interface customization will be very convenient to use, for example: do the construction monitoring of the need for GUI in the collected data is also capable of signal processing, spectral transform and wavelet transform is convenient.

To generate the envelope to extrema signal in EMD, so as to get the IMF, due to the different fitting method, the same extreme point to have the envelope will be not the same. Already mentioned the use of spline interpolation, in practice, we often use three spline interpolation. Three times spline curve, between two points of the curve segment is composed of a three polynomial fitting, the spline curve by three order polynomial curve segments, polynomial segments with different coefficients.

$$C(k) = \sigma_{s(k)}^2 \beta(k) \beta(k)^T + \Sigma_{\varepsilon(k)} \quad (2)$$

The EMD decomposition method itself determines that it is complete, i.e. signal can be obtained by the basic mode component and trend all the function of the safety of reconstruction, without any loss of. The same data were

analyzed by using the EMD decomposition method to obtain the basic mode component reconstruct signals and discrete wavelet transform of the original signal components are reconstructed, the reconstruction error of the former than the latter reconstruction error is much smaller.

Wireless sensors with wireless communication, data acquisition and processing, collaborative work and other functions, wireless sensor network is composed of many of these sensor nodes that cooperatively organized. A large number of sensor nodes are randomly deployed in monitoring region inside or near, can self organized network. Sensor nodes monitoring data along the other sensor nodes hop by hop for transmission, the monitoring data in the transmission process may be dealt with a number of nodes, after a multi hop routing to the sink node, finally through the Internet or satellite to a management node. User configuration and management of sensor network node through management, release monitoring tasks and collect monitoring data.

The EMD decomposition method is a kind of innovation in the basis function theory. The basis function is different from the traditional decomposition method (such as Fourier, wavelet decomposition, wavelet packet decomposition) basis function obtained [3]. Fourier decomposition of the matrix is the sine and cosine function is a series of constant amplitude and constant frequency, while the EMD decomposition of the matrix is the sine and cosine function is a series of variable amplitude and variable frequency (or a series of amplitude modulation function), as is shown by figure1.

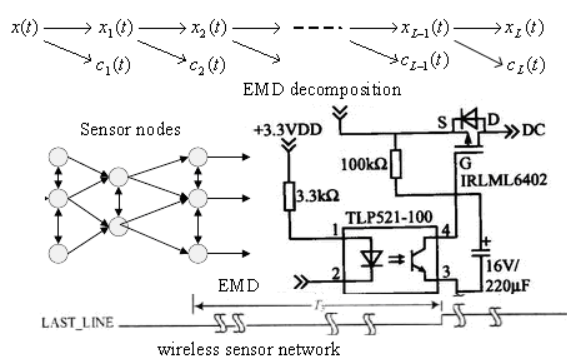


Fig. 1. Application of EMD Method in the Wireless Sensor Network Management

In wireless sensor network, the largest energy consumption process is the communication process of self organization. Sensor nodes can self composed of randomly deployed network, forming self configuration monitoring of HOC large area. Nodes through the layered protocol and a distributed algorithm to coordinate the inductance network can be applied to various fields. Different from the traditional network unified model, the wireless sensor network is not generally used for sensor embedded processor and memory. These sensors have the computing ability, can complete some work of information processing. However, due to the limited capacity of embedded processor and memory capacity, so the processing power of the sensors is quite limited.

Definition of basic model based on function, we can mean periodic functions are obtained by method of calculating function local maxima (average cycle = data length / local maximum number). A set of uniformly distributed white noise is decomposed by EMD, respectively [4]. Through the local extreme points of each component, calculation of the average cycle corresponding. After repeated experiments found that: the number of extreme points of any one of the basic model components almost exactly half of a component, the average period is two times the previous one, this feature does not change with the length of data.

In the calculation of the local maximum average envelope defined with local minima, and it is used three times spline interpolation. Three times spline interpolation will swing in two endpoint signal, and the swing of the results will increase as the level of decomposition and gradually inward "pollution" the entire data sequence, the obtained results serious distortion. In addition, the Hilbert transform, signal ends will also appear serious end effect.

The sensor node consists of low power microprocessor, wireless RF module and vehicle platform etc, it first collects the various analog signals, the analog signals into digital signals, after monolithic integrated circuit processing, via wireless RF module transmits data to the sink node. The sink node processor using ARM9 S3C2410, it also includes the GPRS module, RF module, network interface, its main function is to all sensor nodes send the data receiving nearby, and through the Internet or GPRS modules uploaded to the monitoring software. The hardware system of mobile node localization of wireless sensor network system needs to establish a suitable sensor system according to the requirements of mobile nodes, sensor designed by low power microprocessor, RF module, sensor interface, a power supply module and vehicle platform is composed of 5 parts.

$$F(\theta) = \sum_{n=0}^{N-1} A_k e^{j(\kappa n d \sin \theta + n \alpha)} \quad (3)$$

Propose a two-dimensional screening process using reconstruction operator and radial basis function in mathematical morphology, the one-dimensional EMD are used in the 2D image processing to extract image texture extraction, two-dimensional IMF, this new image multiscale analysis method called by bidimensional empirical mode decomposition (Bidimensional Empirical Mode Decomposition, BEMD). In the process of bidimensional empirical mode decomposition, can be the image of each row and each column as a one-dimensional signal, using the method of one-dimensional signal they were decomposed, thus propose the image texture in horizontal and vertical direction.

In wireless multi hop Ad hoc networks, media access control (MAC) layer protocol is mainly responsible for the two functions. One is to establish a network structure. Because tens of thousands of sensor nodes with high density distribution in the tested area, MAC layer mechanisms need to provide efficient communication links for data transmission, and the characteristics of self-organization network structure of wireless communication in multi hop transmission and network [5]. The second is for the sensor nodes effectively and reasonably allocate resources. Bluetooth and mobile Ad hoc network may be the existing network is most close to the sensor network. However, Bluetooth, the star network topology, and uses the time division multiplexing mechanism of centralized distribution, wireless sensor networks which often adjust for topology need is not favorable.

The data center, in wireless sensor networks, numerical people usually only care about a region of an observation of the target, and not to care about a single node data. Data centric features this is the wireless sensor network, addressing the process which is different from the traditional network, can quickly, efficiently organize the information of each node and extract useful information fusion are sent directly to the user. The data itself as the query or transmission clues of the habits of thought and closer is to natural language communication, as is shown by equation4.

$$H = [u_1 \ u_2] \cdot \text{diag}(\lambda_1, \lambda_2) \cdot [u_1 \ u_2]^T \quad (4)$$

In the process of EMD, due to the need to fit the upper and lower envelope, fitting method and the commonly used is three times spline interpolation. In order to satisfy the IMF condition, the mean determined needs much iteration; and with the increase of decomposition level, the amount of calculation will rapidly increase, this will reduce the effectiveness of algorithm. And because of the length of the signal is usually limited, so in the two signals cannot be effective to determine the extreme points.

For self-organizing sensor network wireless, network topology control has special significance. Through the topology control good network topology automatically, can improve the efficiency of routing protocol and MAC protocol, and lay the foundation for data fusion, time synchronization and object localization and so on many aspects, conducive to save node energy and prolonging the network lifetime. Therefore, topology control is one of the core technologies of wireless sensor networks. Sensor network topology control is the primary research question is the prerequisite to meet the network coverage and connectivity, the power control and the backbone network node selection, unnecessary wireless link between nodes or eliminated, generating an efficient data forwarding network topology structure.

Node 3 functional types of wireless sensor network gateway location, respectively (Coordinator), reference node (router) and the blind node. The gateway has a crucial role in the whole system, it will send the receiving host computer's command, open network, and wait for other types of nodes in network, the effective data then receives the feedback of nodes and transmitted to the upper machine software. The reference node is a kind of static known its position, it is the task of the receiving band RSSI (Received Signal Strength Indicator) value of the packet and calculate the RSSI average, culminating in the blind node packing the RSSI average, send it to the gateway, returns the PC monitoring software. The blind node is a mobile node; reference node can be arbitrary in the area enclosed by the move.

3. Method of Wireless Sensor Network Management based on Multi Scale Wavelet Analysis

One of the signal processing tasks is to recognize the essential characteristics of signal exists in the objective world, and find out the rules. To know, from a different point of view of signal is helpful to understand the essential characteristics of signals. The signal is the first time (space) in the form of expression. In addition to time outside, frequency is one of the most important ways to signal characteristics. The frequency of the said method is based on

the analysis of Fu Liye (Fourier Analysis) on the basis of the analysis, because Fu Liye is a global transformation, or completely in the time domain, or completely in the frequency domain, time-frequency local property and therefore cannot describe the signal time-frequency local property, and just is the most basic and the most important properties of a non stationary signal [6]. In Fu Liye's theory, proposed and developed a new theory of signal analysis: wavelet transform.

From the mathematical theory of wavelet transform, it is a shining example of the Fu Liye transform of the perfect combination of pure mathematics and applied mathematics. From a purely mathematical point of view, wavelet analysis is the crystallization of harmonic analysis this important subject for almost half a century; from science and technology point of view, wavelet transform is the computer application, signal processing, image analysis, nonlinear science and engineering technology important breakthrough in methods in recent years.

$$\overline{\bigcup_{j=-\infty}^{\infty} V_j} = L^2(R), \quad \bigcap_{j=-\infty}^{\infty} V_j = \{0\} \tag{5}$$

After the sensor nodes are deployed, with electric start, waiting for the wireless sensor network gateway to join orders; administrator to the gateway node through the server sends the starting command, the startup parameters allows for wireless sensor network; gateway sends the starting command to each sensor node in the network; node receives the starting command to join the network, short address information of the network, to configure the local link address, routing; node to the gateway node for global unicast address prefix, the distribution of the gateway node global unicast address, node configuration parameters through the gateway and stored in the server database.

The traditional wired network and wireless network for data transmission, wireless sensor network is application oriented, with tasks and data center. Network traditional design method is no longer applicable in wireless sensor networks, but still can refer to the traditional layered network protocol stack, as shown in figure 2. It includes two levels: Communication plane and management plane. Communication plan is composed of the physical link layer, data link layer, network layer, transport layer and application layer, management layer by the power management, mobile management and collaborative management. Implementation of network transfer of information between nodes communication plane; management plane is responsible for detection and control node; management plane to detect and control nodes, so that it can work.

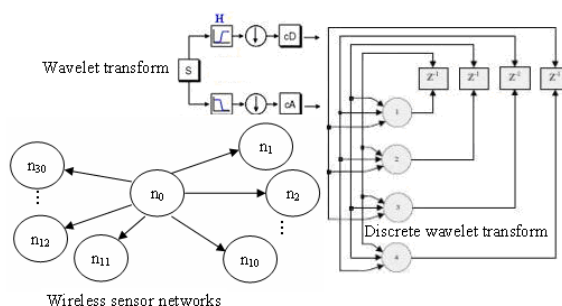


Fig. 2. Method of Wireless Sensor Network Management based on Multi Scale Wavelet Analysis

Wavelet transform is a time-frequency localization methods, time-frequency window area fixed but may change shape, which has higher frequency resolution in the low frequency part and the low time resolution, high time resolution in the high frequency part and the low frequency resolution, so called "mathematical microscope". Multi scale analysis and discrete wavelet transform is the core content of the wavelet analysis.

Continuous wavelet transform is a representation of the signal, the expansion parameters and shift parameter is taken over the whole real axis [7]. The continuous wavelet transform is often used in theoretical analysis and research, in solving practical problems and needs to be realized by computer, often need of continuous wavelet transform the expansion parameters and shift parameters were two into the discretization.

Discrete wavelet transform can be expressed as the composition of a low-pass filter and high pass filter of a tree. The original signal is through a filter that decomposition is called a level decomposition. The decomposition process of the signal can be iterative, meaning it can decompose [8]. If the high-frequency components of the signal are no longer decomposition, and the low frequency components of the continuous decomposition, the low frequency component will get lots of low resolution, a big tree. This tree is called the wavelet decomposition tree (wavelet decomposition tree). How much depends on the decomposition series is analyzed to data and users. The wavelet

decomposition tree to represent only the signal of low frequency is components of the continuous decomposition.

As with DWT, MODWT can also form MRA, but unlike DWT, MODWT is not affected by the initial point, namely the original sequence cycle moving arbitrary amount, MODWT details and smooth also move the same amount of circulation. In addition, unlike DWT, filter MODWT details and smoothing and 0 phase correlation, so it is easy to make the feature of MODWT in MRA and the original sequence in the corresponding.

$$\begin{aligned} f : R^3 &\longrightarrow R^2 \\ (X, Y, Z)^T &\longrightarrow (x, y)^T \end{aligned} \quad (6)$$

Computing resources and storage resources of the sensor network are very limited, and often the data transmission quantity is not great. So, for sensor networks, whether you need to transport layer is a question. The transmission control protocol (TCP) is known as a based on global address end-to-end transmission protocol, and for sensor networks, the design of TCP attribute based naming scalability for sensor networks is not necessary too large, and the data validation mechanism also need to consume a lot of memory, the transport layer protocol therefore suitable for Sensor Networks will be more similar to the UDP protocol.

Analysis of variance: on a set of data, in addition to the need to understand the average level of their outside, also often need to know the size of their fluctuations (i.e. deviation from average size). To measure the size of the fluctuation of data quantity is called the variance of the data set, a set of data variance is greater, that this group of data larger fluctuation. The multi resolution analysis of random signals and it is the orthogonal wavelet decomposition for the various components of different scales. The energy spectrum of wavelet variance of each scale formation scale domain, is the analysis of variance based on scale, can describe the characteristics of a single scale signal, relative relations and the overall complexity can reflect the signal in each scale.

4. Filtering Method in Wireless Sensor Network Management based on EMD Algorithm and Multi Scale Wavelet Analysis

Wireless sensor networks usually densely deployed in the detection area of large, the number of nodes and the density of wireless ad hoc networks become magnitude to improve. It does not rely on a single device capability, but to improve the quality of system working through collaborative work a lot of redundant nodes. Due to the adoption of the wireless channel, distributed control, the network more vulnerable to passive eavesdropping, active intrusion attack. Therefore, very important communication security and network security, encryption, anti-interference, user authentication and other security measures need special consideration, in order to prevent the monitoring data acquisition monitoring information theft and forgery.

EMD decomposition is based on the following assumptions: (1) signal at least two extreme points, a maximum value and a minimum point; (2) the characteristic time scale is between the extreme points of two adjacent intervals defined; (3) if the lack of data points but deformation, can be obtained through differential extremism data once or several times, and then through the integral to obtain the decomposition results. The essence of this method is to obtain the intrinsic fluctuation patterns through the characteristic time scale of data, and then on the basis of the decomposition of the data, the basis functions decomposition is based on the data itself.

In the digital signal real transformation using a filter, the data obtained will be two times the original data. Then, according to Nyquist (Nyquist) sampling theorem is proposed under sampling (downsampling) method, namely, in each channel for each of the two sample data from a discrete wavelet transform, coefficient of (coefficient) are expressed by cD and cA .

Discrete wavelet transform is developed by Mallat in 1988, called the Mallat algorithm. This method is actually a signal decomposition method, in the digital signal processing called dual channel subband coding. The concept of implementation of discrete wavelet transform filter [9].

Each IMF represents a different time scale feature of original signal components, and the residual signal represents the trend of the amount of information in the original data. Under normal circumstances, based on the EMD method to get the first few IMF often focus on the original signal is most prominent, the most important information, which is decided by the nature of the IMF signal, so EMD is also known as a principal component analysis method.

The wavelet variance can scale a determine the variance decomposition based on random process, then according to this we according to the variance of different scales of physical phenomena characteristic of. Second, the wavelet

variance is close with the spectral density function of the concept linked, because the wavelet variance has the advantages of simple structure, we can study it instead of the power spectral density function. Third, when research for a deterministic process, can use the wavelet variance can replace the process variance, that is to say, the wavelet variance estimator can be sampling variance replacement process, because sometimes the sampling variance is difficult to show the sampling characteristics.

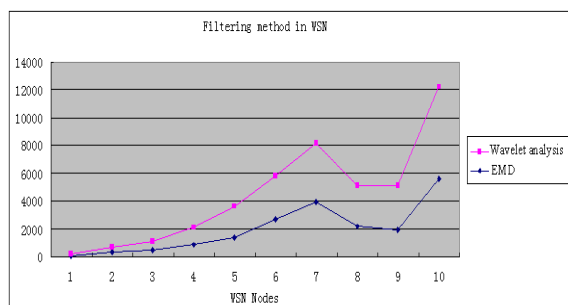


Fig. 3. Comparison design of Filtering Method in WSN Management based on EMD Algorithm with Multi Scale Wavelet Analysis

In wireless sensor networks is the use of the process, there are several reasons cause the sensor network topology change: adding the new node; environmental factors or power sensor node depletion caused by the failure of the three elements; this sensor, object and the observer of the sensor network may change with mobility; the environmental conditions may result in a wireless communication link bandwidth changes, even when the phone. Application oriented network, sensor network has a very broad application prospects, for various sensor network applications for different physical quantities, so the application system for sensor networks also have a variety of requirements. The hardware platform, software systems and network protocols are very different. For each specific application of sensor networks, the sensor network design characteristics different from traditional networks.

Orthogonality of the EMD decomposition method is satisfied in all practical significance, but in theory does not guarantee. Should be in the local orthogonal to each other through all the intrinsic mode functions and it is because each basic mode components are from the original signal and the local mean difference to it.

CONCLUSION

Wavelet analysis is a new and rapidly developing discipline, it has profound theoretical significance and wide application, is the epoch-making outcome of Fourier analysis development. Wavelet analysis is internationally recognized up to the new time - frequency analysis tool. The paper proposes the Filtering method in wireless sensor network management based on EMD algorithm and Multi scale Wavelet analysis. Basis function of wavelet decomposition is determined in advance, such as Haar, Daubechies, Morlet wavelet function, using different wavelet basis, the analysis results have great differences. Because the wavelet decomposition of the effect depends on the choice of basis functions, so can not guarantee the optimal decomposition effect, and the basic function of EMD decomposition is uncertain, is adaptively obtained from signals, for different signal, basis function is different, can be said to be broad based adaptive.

REFERENCES

- [1]Wu Z; N E.Huang. A Study of the Characteristics of White Noise Using the Empirical Mode Decomposition Method, *Proc. Roy. Soc., London. A*, **2004**, 460: 1597-1611.
- [2] Hae-KyungJung; Yun-hong Noh; Do-un Jeong. *JCIT*, **2013**, 8(11), 660 -668.
- [3]Nunes, J C; Bouaoune Y; Delechelle E. *Machine Vision and Application*, **2005**, 16(3), 177-188.
- [4] Zhou Jun. *Journal of Chemical and Pharmaceutical Research*, **2014**,6(2), 589-591.
- [5] Craigmile P.F; Percival D.B; Gutorp P. Trend assessment using the discrete wavelet transform, Technical Report , *atonal Research Center for Statistics and the Environment* , University of Washington ,Seattle,**2000**.
- [6] Niu Weihong. Research on Improved Topology Control Technology of Wireless Sensor Network, *JCIT*, **2012**, 7(16), 331 - 339.
- [7]Yanqin Fan. *IEEE Transactions on Information Theory*, **2001**, 149, 516-521.
- [8]Xiaoqing Lu; Ruyun Tian ; Ying Cui. *Journal of Chemical and Pharmaceutical Research*, **2013**, 5(11), 549-555.
- [9] ZHAO Yuan-qing; SUI Dan. *JDCITA*, **2012**, 6(14), 125 - 132.