



## Application of interactive multiple models and EMD analysis in signal management of wireless sensor network

Yonghong Ma<sup>#</sup> and Xuefeng Quan<sup>@</sup>

<sup>#</sup>School of Computer & Information Engineering, Nanyang Institute of Technology, Henan Nanyang, China  
<sup>@</sup>Department of Health Management, Nanyang Medical College, Henan Nanyang, China

---

### ABSTRACT

Interactive multiple models algorithm assumes that the switching model system is Markov. The basic idea of interacting multiple model algorithm is in every moment, suppose a model in the present moment effective condition, through a moment before mixing all filter state estimation of initial conditions to obtain filter matched with this particular model. Interactive multiple model Kalman filter has been successfully applied in multi sensor and multi target tracking. EMD decomposition is linear and complete, and EMD decomposition is superior to the traditional method. The paper presents application of interactive multiple models and EMD analysis in signal management of wireless sensor network. Simulation results show that the average performance is better than the traditional algorithm on system.

**Keywords:** Interactive multiple models, Wireless sensor network, EMD analysis.

---

### INTRODUCTION

The special environment of wireless sensor network constraints on the system performance requirements, people propose a clustering of wireless sensor network structure model, through the classification method can overcome the shortcomings of planar structure, to improve the network capacity, network management, routing optimization and enhance the network scalability purposes [1]. Hierarchical structure commonly used clustering algorithm divides the network into different sub network, cluster consists of cluster heads and cluster members.

Wireless sensor network is usually large, self-organizing, random deployment; environment is complex, the limited resources of sensor nodes, network topology changes frequently. These characteristics make the topology control has become a challenging research topic. As we know, the interference signal strength, range of communication and radio transmission between wireless sensor nodes of wireless receiving device receives ability and external environment. In an ideal situation, the signal strength sensor nodes to transmit is isotropic, the communication range is to the node as the center of the circle.

EMD can be decomposed into IMF and residual form; also can be the perfect reconstruction without any loss and distortion. EMD can be separated with the highest frequency, or empirical mode frequency can exist in different time, and the traditional Fourier transform does not allow the signal spectrum changes in time.

Stochastic system model is nonlinear or system noise changes in large, delay and false alarm will make serious bias estimation motion pattern recognition system on the conventional Kalman filtering algorithm, which affect the accuracy and stability of the filter. Multiple model algorithm is an effective method for solving the nonlinear system filtering problem, the interactive multiple model algorithm is considered to be the most ideal method for performance and computational complexity and has been widely applied in noise, proved highly maneuvering state and system is big, the interacting multiple model filtering algorithm is better than conventional Kalman filter.

Wireless sensor network architecture usually consists of sensor nodes, sink node (sink node), external network and user interface. A lot of sensor nodes are randomly deployed in a sensing area (sensor field) within or near, can pass the self-organized network, sensor nodes will collect the data along the other sensor nodes hop by hop transmission, the acquisition and transmission in the process of data may be dealt with a number of nodes, through multi hop routing to the sink node, then by the sink node through the network to send data to the processing center for centralized treatment. The paper presents application of interactive multiple models and EMD analysis in signal management of wireless sensor network.

## 2. Research on Interactive Multiple Models in Management of Wireless Sensor Network

Wireless sensor network consists of three types of nodes: information of a wireless terminal node is needed to collect; wireless router nodes collect common node in the data and storage, processing, upload; wireless service node wireless router node processing center and a network connection and other external network. Three kinds of node hardware structure is basically the same, each sensor node has data acquisition, simple data processing, short distance wireless communication and networking capacity.

Interacting multiple model algorithm in the conventional model of transfer probability is entirely man-made determined a priori, and did not use the information for the current time in measurement, studies have shown that the filter parameters, a priori information selected is switching and mode switching condition without compromise, the mode information of the current system of the current volume in the measurement, so we should make full use of the current measurement, parameter online derivation of multiple model filtering.

Using the posterior information to modify the prior information, the transition probability distribution model more practical, in the mode switching is more forgetting the information of non matching model, while amplifying the matching model of information to improve the switching speed of the system, the algorithm can effectively solve the contradiction between the two model estimation accuracy and the switching speed of multiple model estimation, weaken the negative influence brought by uncertain prior information.

In sensor networks, by airplane dispenser, artificial arrangement of nodes, deployed in the perceived object within or near it [2]. These nodes by self-organized wireless network, in a collaborative manner perception, acquisition and processing network coverage information specific to the region, can realize the acquisition, processing and analysis of information at any time any place. This constitutes a self organization network, by multi hop relay the data to sink node (relay nodes), finally, with the help of sink link will be the regional data to remote control center for centralized treatment.

$$E\{v_i(kT_i), v_j^T(IT_j)\} = R_i(kT_i)\delta_{ij}\delta_{kl}, \quad (1)$$

The wireless sensor network connection mechanism, with local visual information with high traffic volume characteristic quantity and large data to have a clear semantic concept in the form of the communication connection, and it is low communication bandwidth visual collaborative. Routing algorithm based on semantic and information holography, this algorithm is an optimal path inquiry for user search algorithm. Routing algorithm should fully consider the query semantics, the coding information holographic compression may query and global routing table, finally realizes the fast searching.

Interactive multiple model Kalman filter has been successfully applied in multi sensor multi target tracking. Although the traditional filtering method with different model corresponding to the target of different states, but each time only a model filter in action, different models according to the statistical test filter between the target state monitor and switch, though it can also adapt to the change of target maneuver, but the motor test total lag, and fast switching models it may reduce the reliability of the filter.

$$\phi_{j,i} = 2^{j/2} \phi(2^j t - i), \quad i \in Z \quad (2)$$

Sensor nodes on the object in the environment perception and appropriate treatment, and it are the measured value of wireless transmission to the monitoring center. Therefore, the basic function of sensor nodes is: collect environmental parameters, and preliminary processing, alarm affection of be in danger; receiving monitoring center data request command, the collected data are sent to monitoring center.

Wireless sensor network excessive routing void consumes a lot of unnecessary energy, reducing the efficiency of the entire network communication. In order to reduce or avoid the routing void node topology information, need to

know more; this is Geographical energy aware and whole avoids routing mechanism based on it [3]. The basic idea is to query message, nodes choose the next hop node not only consider the generation of value minimum neighbor nodes, but considering the two hop information. The neighbor node is a collection of all the nodes one hop communication range can reach.

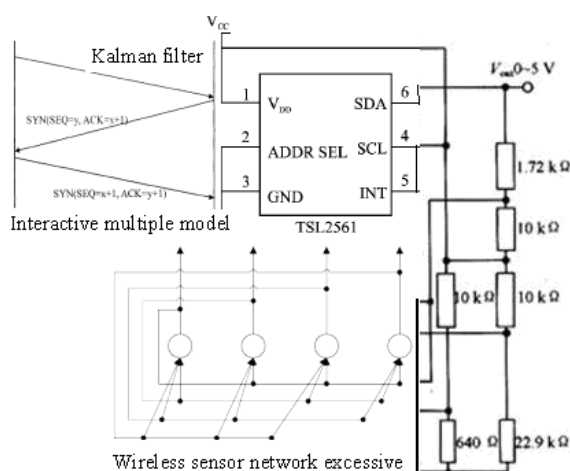


Fig. 1. Structure of Interactive Multiple Models in Management of Wireless Sensor Network

Wireless network technology, the network node by using self organizing network. These applications do not need high bandwidth, but requires very low energy consumption, thereby prolonging the service life of the battery. Because the embedded processor / wireless sensor nodes usually with limited memory controller, so the stack size is also put forward strict requirements. In addition, in the security, nodes automatically configuration, dynamic reorganization of the network, there are many requirements.

In wireless sensor networks, each sensor node has the wireless communication function, each sensor unit, used for measuring parameters of here, and the components of a wireless network, the measured data by the network to wirelessly transmit to the monitoring center. Compared to wired sensor network system of wireless sensor networks and traditional, has low cost, convenient installation, maintenance and updating of low cost advantages, is very suitable for the arrival of regional, staff can not difficult areas and some of the temporary situation of remote monitoring.

Interacting multiple model algorithm assumes that the switching model system is Markov, Markov prior transition probability is given in advance. Because of the uncertain prior information, is not accurate, so in the filtering process improvement information to the test, to accord with the actual situation. The specific method is, according to the rate of change of the model error than two compressions; adjust the Markov transition probability matrix in the filtering process, using the Markov parameters of the adaptive information.

In wireless sensor networks, does not require the use of IP. In wireless sensor networks, often used for tens of thousands of sensor nodes, IP routing is fixed based on geographical location information, and the path in the sensor network building mode is based on demand, according to a data or a task to carry out, so need to maintain routing tables according to the topology of IP is not feasible for wireless sensor networks. But for the wireless sensor network constantly changing topology, to maintain routing tables need to spend a lot of time and energy, so the wireless sensor networks require a brand-new for control and routing protocols for their nodes.

To calculate the expected resolution increment by using Kalman filter, Kalman filter is preserved because the object state and state estimation error. In the standard Kalman filter, the covariance estimation depends only on the measurement uncertainty, uncertainty and model uncertainty, is not directly dependent on the measurement or the state itself. Therefore, in the Kalman filter of the standard, the uncertainty and the desired resolution increment on the target maneuver is not sensitive to the existence, thus reducing the sensor management system efficiency.

Ensure network connectivity. Sensor network is usually large, so the sensor nodes sense data to multi hop transmission to the sink node. This requires the topology control must guarantee the connectivity of the network [4]. If at least to remove the K sensor nodes to make the network disconnected, said the network is K. connected, or network connectivity topology for the K. Like the asymptotic coverage, sometimes also discuss connected asymptotic sense, namely when the deployment region tends to infinity, the possibility of network connectivity to

number 1 in the network edge as little as possible, send the energy of nodes as small as possible.

$$Z = \begin{bmatrix} \frac{\partial I}{\partial x} \\ \frac{\partial I}{\partial y} \end{bmatrix} \begin{bmatrix} \frac{\partial I}{\partial x} & \frac{\partial I}{\partial y} \end{bmatrix} = \begin{bmatrix} g_x^2 & g_x \cdot g_y \\ g_x \cdot g_y & g_y^2 \end{bmatrix} \quad (3)$$

Interactive multiple model Kalman filter to maintain all the models, each model corresponds to a different process noise level, is based on a "soft handover" maneuvering target tracking method. Different motion state of this method to different target motion or the same target, and it is using different filter model, and use probability calculation of the output of these models.

Node localization in mobile wireless sensor network system is possible and more than 3 different beacon. So we can use more nodes to get the redundant information to calculate the unknown node position [5]. Maximum likelihood estimation of multilateral measurement on the use of the above method, the known coordinates of N node, respectively (X1, Y1), (X2, Y2), (X3, Y3),... , (Xn, Yn), they are to the unknown node D distance were DL, D2, d3,... At DN, and it is coordinate, assumption that nodes for D (X, Y).

The real demand of WSN mainly authentication in the point-to-point message authentication and broadcast, the former refers to any one node in the received from another node information, true to be able to verify the news sources, not be forged or counterfeit. The latter solution is a single node to the authenticity of a group node sends a unified notice of confirmation, availability requirements for wireless sensor network can at any time according to the preset working styles to legitimate users access system provides information service, but an attacker can copy, counterfeit and signal interference, the sensor network is in part or whole paralysis, as is shown by equation4.

$$E = -\sum_{i=0}^{L-1} p_i \log_2 p_i \quad (4)$$

First a contains more than one model to describe motion modal system may be interacting multiple model estimation, model set up to meet the Bayesian completeness and independence principle, and assuming that the transfer model between the Markov process. Filter matching each system model of parallel work, using the output of each filter residual information and prior information of the model, on the basis of some hypothesis testing rules, to obtain the corresponding to each filter model for the probability of the current model matching time system (called model probability), the overall estimation system is the probability weighted each filter output state estimation fusion.

Construction of three kinds of node hardware platform in wireless sensor network is basically the same, the wireless terminal nodes can remove display module, serial communication module and alarm unit, in order to save node energy [6]. The main control part load operating system for sensor networks, implementation of each module, and the module of data processing; power module for power supply system; wireless communication module to realize wireless data transmission functions; serial communication module can be used to communicate with the host computer, also can be used for system configuration; sensor module is collected by the sensor data, and digital to analog conversion to the main controller; data storage module is used for temporary or permanent data storage system for reference.

The covariance matrix of information increment used and it is using the covariance matrix of standard Kalman filter. The use of this chapter is the covariance matrix of the interacting multiple model in Kalman filter. But in the calculation of the covariance matrix of the interacting multiple model in Kalman filter, transfer probability interacting multiple model used is completely artificial determined a priori, and did not use the information for the current time in measurement, resulting in the lack of measurement algorithm of the uncertainty in the process of adaptation, the estimate of the state also have a greater deviation.

### 3. Using EMD Algorithm to Signal Management of Wireless Sensor Network

The decomposition of EMD according to the characteristics of the scale parameter of fundamental mode component screening of data obtained has clear physical meaning, which characterize the fluctuation and the range of frequency signals in a characteristic length scale parameters. EMD decomposition layers of screening, which was ordered scale from small to large component. According to this characteristic, we can construct a new way of filtering time scale

filter.

Wireless sensor networks different applications for synchronization, synchronization to keep the length of time, the synchronization region size requirements vary, such as collaborative sleep need the whole network time synchronization accuracy remained millisecond: for target tracking applications require only local node target nearby keep micro second synchronization precision, dwell time synchronization continues and the target is proportional to the time. Diversity of sensor network leads to the diversity demand synchronization time synchronization mechanism, not a time to satisfy all the requirements.

$$G(x, y, \sigma) = (2\pi\sigma^2)^{-\frac{1}{2}} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right) \quad (5)$$

At present, the wireless network including the common mobile communication network, wireless local area network, Adhoc network, and the main features of these networks is to provide point to point connection is established, the network communication and operation, provide correct, reliable transmission for data sharing [7]. Wireless sensor network is composed of tiny sensor nodes are generally to the needs of a particular design, is a kind of wireless network based applications, to a variety of environmental or monitoring collaborate in real-time monitoring, sensing and collecting network of regional distribution of information, and the data processing, transmitting it to the users who need the information.

For the data of a longer sequence and it is continue to abandon ends according to the extreme point of the data to ensure that envelope it, but for short data sequence, and this method is not feasible. When the EMD method is mentioned according to the characteristics of wave of original data sequence extension, but no specific method given suitable wave, proposes the EMD method also has developed an effective data continuation method.

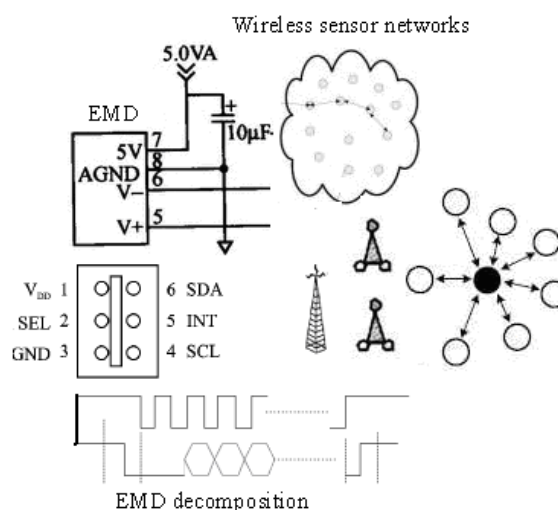


Fig. 2. Using EMD Algorithm to Signal Management of Wireless Sensor Network

Introduction of mobile nodes in wireless sensor networks, can enhance the function, by combining several unknown node to the network node density is relatively sparse regions in order to make up for the deficiency of the uneven distribution of node density. This paper mentioned the use of mobile reference node and the RSSI (received signal strength indicator) to locate the unknown node method, but in the real environment, temperature, obstacles, mode of transmission conditions are often change, so RSSI technology is still difficult in practical application. Especially the nodes on the energy consumption, volume stringent requirements, more time and can not use the range based localization technology. A range free localization algorithm does not need to measure the distance between nodes, but the use of distance vector routing, network connectivity or GPS location theory proposed a distributed localization method, range free, it reduces the cost of network.

The sensing unit for sensing detection, access to information in the region, and convert it to a digital signal, which comprises a sensor and a digital / analog conversion module; the processing unit is responsible for the control and coordination of joint work, storage and processing of the collected data and other nodes to the data, which is composed of embedded system, including the processor, memory, wireless transceiver unit; responsible for the communication with other sensor nodes, the exchange of control information and send and receive data, it consists

of wireless communication module; the power supply unit to provide the necessary energy for the normal work of the sensor node energy, usually using micro battery.

As the sensor node computing ability, storage ability, communication ability and energy are limited, topology information of each node can only acquire the local network, and its run on the network protocol can not be too complex. At the same time, the sensor dynamic topology, cyber source is also changing; the network protocol put forward higher requirements. Node sensor network protocol is responsible for the individual to form a multi hop data transmission network, the current study focuses on the network layer protocol and data link layer protocol. The routing protocol in the network layer determines the transmission path monitoring information; data link layer medium access control infrastructure used to construct the underlying, communication process and the working mode control of sensor nodes. In wireless sensor networks, routing protocol not only for single node energy consumption, more concerned about the whole network energy consumption [8].

$$S_x(\omega) = \lim_{T \rightarrow \infty} \left\{ E \left[ \frac{X_r(\omega)^2}{2T} \right] \right\} \quad (6)$$

Take extreme point followed by the time interval between the local oscillation mode time scale, because it is better to local oscillation mode not only the resolution, but also can be used for single symbol data, namely data can be positive or are negative, whether or not the zero crossing point. In order to put the various wave patterns extracted from the data, based on the empirical mode decomposition method (EMD) or vividly called "screen" process.

Sensor query and data dissemination protocol database SQDDP to sensor networks as the temporal and spatial change, provide effective interfaces to support returns the attribute name or location named data query and based on the results, a sensor query and task distribution language (Sensor Query and Tasking Language, SCTL) can be used to provide a series of service. The transport layer for the maintenance of the sensors in the network data flow is an important part to ensure the communication quality of service. We refer to the communication protocol of wireless sensor network to carry on the analysis: when the sensor networks need to connect with other types of networks, such as the connection between the base station node and task management node can use the traditional transmission control protocol.

The main purpose of EMD decomposition is to Hilbert transform, so we can get about Hilbert signal energy, frequency and time spectrum. Therefore, Hilbert transform is performed on the IMF in the EMD after can get on the amplitude frequency time spectrum to Hilbert, so the Hilbert spectrum can characterize a signal change at the time of the law.

#### 4. Application of Interactive Multiple Models and EMD Analysis in Signal Management of Wireless Sensor Network

Time division multiplexing (TDMA) is a mechanism for each wireless sensor network node distribution independent time slots for data transceiver, and the node into sleep state in other free time slot. Compared with the random access mechanism, time-division multiplexing mode itself can save more energy, is the realization of channel allocation is simple and mature mechanism, because the radio work time is shortened, and the overhead of no competition and conflict.

Traditionally, signal filtering is achieved in the frequency domain; this method has a good effect on the analysis of stationary signal, but for the analysis of non-stationary signals, but a lot of trouble. With the time scale filtering characteristics of EMD decomposition, the filtered results can fully retain the non-stationary signal inherent, not easy to cause distortion.

$$\begin{aligned} \mathbf{M} &= \sigma_{s|a}^2 = \text{cov}(s(\hat{k}) | a(\hat{k})) \\ &= E\{[s(\hat{k}) - \mu_{s|a}]^2 | a(\hat{k})\} \\ &= \boldsymbol{\beta}(\hat{k})^T \boldsymbol{\Sigma}_{\varepsilon(\hat{k})}^{-1} \boldsymbol{\beta}(\hat{k}) + \sigma_{s(\hat{k})}^{-2} \end{aligned} \quad (7)$$

The sensor module is the module of real contact with the external signal to the hardware platform, includes two parts the sensor probe and transmission system, probe collects outside temperature, luminosity and magnetic field sensor information, sent to the transmission system, which completes the physical quantity of the original signal system can recognize, and through the plastic processing integrated circuit, amplifying circuit, the a/d is converted into digital

signal and send the processor module.

For each motion model, in addition to state estimation, and it is interacting multiple models Kalman filter keeps estimating a probability, the probability estimates are used to describe the target motion with each model consistency. Covariance with interacting multiple models Kalman filter can predict the maneuvering target increases, so when a sensor is assigned to a maneuvering target, the desired resolution incremental increase. In addition, also can effectively estimate target motion model using interacting multiple models Kalman filter, which is another factor affecting expected resolution incremental. In the sensor management, these factors can be used to allocate sensors to a positive start maneuvering targets.

In wireless sensor networks, sensor nodes often need external time synchronization, which requires the time main nodes and external network communication, thus obtains the world standard time value. Usually choose base station as the time main nodes by default, because it can obtain better energy support, and is convenient to connect with the external network and communication. Time main node selection can be used for node ID minimal strategy.

The EMD analysis software, otherwise the EMD decomposition method will be of no effect. Three times spline interpolation problem is the overshoot and undershoot, we will as the endpoint appears to swing and spread to the middle section signal data and destroy the entire data characteristic behaviour called "edge effect", if the edge effect problem can't be solved, then the EMD method also loses its meaning.

By the two algorithm simulation diagram of the target position can be obtained: the trajectory model transition probability estimation online case IMM can well reflect the target based on. The model transition probability determined a priori case the target displacement, speed and acceleration estimation and state error is relatively large, and the transition probability model online estimation under the error is relatively small.

Since the target displacement resolution is relatively small, so that the two case, the effect is not very obvious; while the target speed and acceleration of the resolution is relatively large, the effect more obvious. The paper presents application of interactive multiple models and EMD analysis in signal management of wireless sensor network. The simulation results also proved that, the root mean square error model of transfer probability estimation online case of IMM than the model transition probabilities are determined a priori condition much smaller, as is shown by figure3.

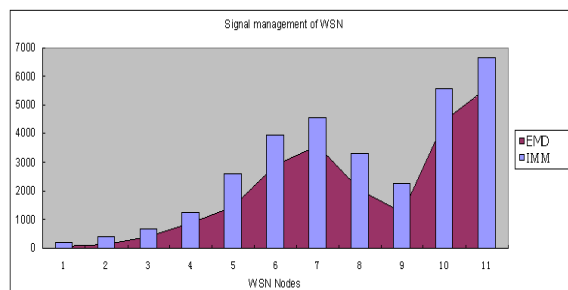


Fig. 3. Comparison results of signal management wireless sensor network based on IMM with EMD analysis

Different design method of wireless sensor network is the existing wireless network. For example, because of the sensor nodes in a sensor network intensive distribution, so the data management and processing technology of large range. Secondly, a node in wireless sensor networks are usually deployed in human to reach and maintain contact area, which makes the sensor network node is facing great challenges. In addition, the power consumption is a very important issue, wireless sensor node is a tiny device, can only be equipped with a limited power supply, in some applications, replace the power supply is almost impossible. This makes the sensor node lifetime depends largely on the life of the battery, so reducing power consumption to extend the lifetime of wireless sensor network is the most important problem.

## CONCLUSION

WSN node sleep / added node, may request the local router immediately sent the router advertisement. Since the WSN nodes are usually short work time and sleep time is long, so to some extent, the transmit frequency can reduce the "router advertisement" message, and the node active request, especially in the application of the scene node number less, such measures can reduce the energy consumption of the router. The covariance matrix of information increment used and it is using the covariance matrix of standard Kalman filter. This paper will use the covariance matrix of multiple models in Kalman filter, computing information increment, allocation of sensor resources. EMD

decomposition is linear, complete, shift and local orthogonality is satisfied; simultaneous EMD decomposition with local, adaptive signal decomposition method is superior to the traditional.

#### REFERENCES

- [1]X.R.Li. *IEEE Transactions on Aerospace and Electronic Systems*,**2001**,37(1),273-280.
- [2]LIANG Yan; CHENG Yongmei. Analysis on the performance and properties of interacting models algorithm, *Control Theory and Applications*, **2001**, 18(4):487-492.
- [3]Wang Guohong;He You;Yang Zhi. *Chinese Journal of Electronics*,**1999**,27(2),125-132.
- [4]Min Lu ; Mi Zhao. *Journal of Chemical and Pharmaceutical Research*, **2014**, 6(2), 110-116.
- [5]P Flandrin. *IEEE Signal Processing Letters*, **2004**, 11(2), 112-114.
- [6]Ronghua Gao; Huarui Wu; Cheng C. *AISS*, **2013**, 5(9), 743 - 750,.
- [7]Nunes, J C; Bouaoune Y; Delechelle E. *Machine Vision and Application*, **2005**, 16(3), 177-188.
- [8]Yan Cao, Sen Cao and Jiang Du. *Journal of Chemical and Pharmaceutical Research*, **2013**, 5(11), 80-83.