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# Design and implementation of monitoring and management system based on wireless sensor network hop estimation with the moving target Kalman prediction and Greedy-Vip

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ABSTRACT

Recent advances in wireless sensor networks (WSNs) technologies and their incorporation with geographic information system (GIS) technologies offer vast opportunities for development and application of environment monitoring data communication. This paper analyzes the method of predicting the location of moving target with the Kalman filter and Greedy-ViP approach to establish WSN flat network routing and the data management system. Simulation results demonstrate that the predicted information collection node locations by the proposed method are consistent with the majority of real ones, the hops tend to straight lines, the hops count is the least, lower repetition rate of the nodes on different hops, and the environment monitoring data can be saved and queried.



## 1. Introduction

Plant germplasm resource is also known as a genetic resource. Protection of germplasm resources is to prevent the carrier of genetic information loss and species extinction. Due to rapid population growth, over-exploitation of crop germplasm resources, invasion of alien species and environmental pollution and so on, the loss of crop germplasm resources becomes increasingly serious. Most researches on germplasm focus on seed conservation and germplasm resource information storage using database technology [9]. They can only realize the browsing and query of static information but are short of dynamic real-time monitoring of crop growth environment.

Wireless sensor networks (WSNs) are useful in applications such as environmental data acquisition, target tracking and monitoring. WSN nodes are battery-powered, so WSNs are necessary to effectively capture and transfer data, and also take into account the energy conservation [1]. The node plays the role of data communications and routing in multi-hop WSNs. The electricity shortages of nodes or services change, may lead to the structural changes of the network topology and the network restructuring. And the network routing often needs to re-choose [1]. Taking into account that the energy consumed by the sensor collecting signals each time can be controlled around in 1 nJ, the energy needed by the processor running a directive can be controlled within 1 nJ, the RF communication mechanisms need to consume about 100 nJ when transferring 1 bit data in approximately 10–100 m [2,3], so it has an important significance for saving network energy to reduce the burden of network communication.

Collecting and transmitting data is an important task for WSNs. Efficient data dissemination approach helps to improve communication efficiency of the large-scale WSNs [4]. Cooperative communication in data transmission can also improve electrical energy utilization efficiency of WSNs, and ensure the stability and reliability of the network [5].

The researchers proposed a number of communication protocols, such as class-based negotiation protocol, directional published class protocol, multi-hop class protocol, communication protocol routing class and data-centric routing algorithm. WSN routing protocols are generally divided into four categories, including flat routing protocol, hierarchical routing protocol, geographic-based routing protocol, the routing protocol based on data flow model and quality of service. The geographic-based routing protocol, considering the location information of nodes, can determine the direction and regions of the packet transmission, and substantially reduce the transmission range of the data packet. This kind of routing protocol has considered the network topology changes, due to the changes of nodes [6].

The routing design method, based on monitoring object characteristics or movement characteristics, can effectively improve the communication efficiency and performance of networks, and extend the life of networks. In this paper, the moving objectives are as the network-

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aware monitoring objects. According to the motion characteristics of the monitoring object and the discrete Kalman filtering methods, the method can predict the position of moving objects. It estimates the next monitoring node, and establishes the hop between the perception nodes and sink nodes, based on the Greedy-ViP routing algorithm. This method is different from the study of the delay-constrained information coverage problem in mobile wireless networks, which takes advantage of the node mobility for information collection when a node moves into the proximity of stationary base stations [7]. And it is also different from intelligent agent-based routing method for mobile sinks in data collection, which has better performance [8]. We use the static nodes to make the collected moving target information to transmit to the sink nodes. The rest of the paper is organized as follows. Section 2 reviews the Kalman filter algorithm. Section 3 includes three parts: the first part introduces virtual-location-based Greedy-ViP WSN communication routing method; the second part first shows extensive simulation results of the Greedy and Greedy-ViP algorithms, then it presents the extensive simulation results of the Kalman-filter-based moving target prediction, finally it shows extensive simulation results of the hop of the moving target detection; and the third part demonstrates the performance of the proposed algorithms. The design and implementation of the data management system are described in Section 4. Section 5 concludes this paper and suggests some future work.

## 2. Related researches

Kalman filter [19] is useful in applications of the discrete data forecasting of the wireless monitoring and target tracking. The extended Kalman filter based measurement of orientation determination for an inertial measurement unit that is integrated with a tri-axial magnetic sensor was exploited, the results of computer simulations and experimental testing show that the performance of the algorithm is good [10]. Because the extended Kalman filter method does not require more time consuming, it can be exploited in Wireless Local Area Network for indoor positioning [11], and the method combined with K-NN algorithm is also employed in indoor tracking [12]. In the field of applied electronics, Kalman filter even can be used to do the channel estimation and tracking method for the wireless OFDM systems [13].

State estimation is an important part of the Kalman filter. In the case of having random interference and noise, the linear minimum variance estimation method is used to calculate the best estimate of the states [14].

Kalman filter estimates the process state based on the feedback system consisting of time updates and status updates. The equations of this system are as follows.

$$\hat{x}_k^- = A^*\hat{x}_{k-1} + B^*u_{k-1} \tag{1}$$

$$P_k^- = A^*P_{k-1}{}^*A^T + Q \tag{2}$$

$$K_k = P_k^-{}^*H^T{}^*\left(H^*P_k^-{}^*H^T + R\right)^{-1} \tag{3}$$

$$\hat{x}_k = \hat{x}_k^- + K_k{}^*\left(z_k - H^*\hat{x}_k^-\right) \tag{4}$$

$$P_k = (I - K_k{}^*H)^*P_k^- \tag{5}$$

Where, $\hat{x}_k^-$ is a priori state estimate of time $k$. $\hat{x}_{k-1}$ is a posteriori state estimate of time $k$. $P_k^-$ is a priori estimate error covariance of time $k$. $P_{k-1}$ is a posteriori estimate error covariance of time $k-1$. $u_{k-1}$ is an input control function of time $k-1$. **Q** is a process noise covariance. The $n*n$ matrix **A** is the state at time step $k$ to the state at step $k+1$, in the absence of either a driving function or process noise. The $n*l$ matrix **B** relates the control input $u$ to the state $x$. $K_k$, **H**, and **R** are measurement noise covariances. **I** is the identity matrix. $z_k$ is the observed measurement of time $k$.

The time update equations can forward calculate the current state variables and error covariance estimates, which is for a priori estimate of the next time state. The measurement equation can combine priori estimates and new measurement variables to construct improved posteriori estimations. The time update equations make priori estimates to timely map to the measurement update equation. The measurement update equation corrects priori estimates to obtain posteriori estimations of the status. The time update equations can forward calculate the state estimation and covariance estimated from the time $k-1$ to the time $k$.

If the relationship between estimated processes and measure processes is nonlinear, it can linearize the expectation and variance, which form an extended Kalman filter [14].

WSN can be used to monitor and track moving targets. There are two methods to establish hops when networks real-timely transfer the moving target information to the sink nodes. One is to establish routings fast. The other is to establish the routing between this node and sink node before the moving target reaching the feasible sensing nodes. The second approach needs to effectively predict the movement path of the target, so it can use the Kalman Filter to predict the position of the moving target in the next moment, with starting the corresponding node and establishing the hop through some routing algorithms.

## 3. Remote monitoring based on WSN

Geographical Adaptive Fidelity (GAF) protocol can be adapted to the motion of nodes or target, but the energy saving effect is not good in the sparse network [15]. Taking into account energy conservations, Geographical and Energy Aware Routing (GEAR) protocol limit the information diffusion region within a smaller range to reduce the number of intermediate nodes and reduce the energy consumption of routing establishment and data transfer [16].

WSNs with random deployment of nodes or less accuracy deployment of nodes, due to empty holes in undeployed node regions, may result in failure of the network routing. Virtual position based Greedy-ViP method can solve this problem to some extent. It reflects the transmission direction of the adjacent nodes, and improves the success rate of the data routing in sparse network without improving significantly the computational costs [17,18].

The virtual coordinate of node N is the average of the coordinates of all adjacent neighbors within its communication radius. If the node N has a neighbor set of $n$, namely, $V_N = \{V_{N,1}(x_{N,1},y_{N,1}),\ldots V_{N,n}(x_{N,n},y_{N,n})\}$, where $V_{N,i}(x_{N,i},y_{N,i})$, $i = 1,2,\cdots n$, is $i$th node of node N, $(x_{N,i},y_{N,i})$ is its coordinate, then the virtual coordinates of node A can be expressed as Eq. (6) [18].

$$(x_A^v, y_A^v) = \frac{1}{n}\sum_{i=1}^{n} x_{A,i} \quad , \quad \frac{1}{n}\sum_{i=1}^{n} y_{A,i} \tag{6}$$

Greedy-based routing algorithm and Greedy-ViP-based routing algorithm will choose a different node as its hop handling the same area.

In this paper, take the Greedy and Greedy-ViP routing algorithm as examples, using the Kalman filter method to predict the position of moving objects, establishing the hop between the sensing nodes and sink nodes, transferring the sensing object information to the sink node.

According to the location information of the sensor node, it can make coordinate virtualized, and calculate the virtual coordinates of each node. Using the Kalman filter method and WSN routing, it can establish the optimal hop between the moving target and sink node. Specific steps are as follows.

Step1: Obtaining the location coordinates of the nodes in the region, $(x_i,y_i)$, $i = 1,2,\cdots,M$, where $M$ is the number of nodes in the region.