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RFID Based Fast Tracking Algorithm for Moving Objects in Uncertain Networks

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Abstract. Mobility model is used to describe the mobility mode of nodes in the network and determine the mode of node movement. The selection of mobile model and its parameters is also of great significance to simulation results. Therefore, a fast tracking algorithm based on RFID is proposed. The performance evaluation based on RFID network related protocols and algorithms plays an important role in improving the network performance. The spatial distribution of nodes in various mobile models is studied and compared. The effects of velocity, velocity of different distribution, pause time of different distribution and simulation area on the spatial distribution of nodes are obtained. After summarizing the defects of fast tracking of network moving targets, based on the random direction motion model, the fast tracking algorithm of uncertain network moving targets is completed by setting the running time of nodes and changing the speed of nodes in different time periods. Through experimental analysis, it is shown that the RFID based fast tracking algorithm has uniform spatial distribution and good performance Low energy consumption.

Keywords: RFID · Uncertain network · Moving object tracking

1 Introduction

With the progress of information technology, mobile communication technology has also been a long-term development. New mobile communication technologies such as cellular communication, WiFi technology, Bluetooth communication are emerging. With the help of these technologies, people's life becomes very convenient, and the wireless communication technology is also promoted by them. Generally speaking, mobile communication technology adopts centralized control, that is, centralized control [1]. This kind of wireless network needs to deploy the infrastructure in advance to be able to use, for example, the cellular mobile communication system, which needs to rely on the support of the infrastructure such as base station and mobile switching center to operate; Access point and limited backbone network are the general working modes of WLAN. But for some special occasions, it is impossible to deploy fixed facilities in advance, so the above working mode can not be used. For example, rescue and disaster relief, field survey, marginal mine operation, temporary meeting, etc. [2]. In this case, we need a mobile communication technology that can quickly and automatically network temporarily. To sum up, the mobile model is to build a mobile network. Network

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simulation and test environment is one of the important parts of the environment [3]. The consistency between the mobile model and the real scene is an important factor affecting the reliability of network simulation results. Designing a mobile model in line with the real situation can provide a reasonable node mobile scene for mobile RFID network simulation. At the same time, studying the physical characteristics of the mobile model and its relationship with the network topology changes will help to better understand the simulation results, And on this basis, improve and perfect the relevant protocols and algorithms.

This method collects the characteristic data of uncertain network moving objects, and divides the structure according to the characteristic data; On this basis, the frequent activity pattern distance measurement based on sequence alignment is used to accurately track the moving objects; The tracking target is completed according to the time variation characteristics of regional activity heat.

2 Fast Tracking Algorithm for Moving Objects in Uncertain Networks

2.1 Feature Collection of Mobile Objects in Uncertain Network

Mobile RFID network is composed of a group of mobile terminals with wireless transceiver devices, and does not rely on fixed infrastructure, so it can not provide centralized control. Mobile RFID network is a kind of wireless network which is set up for fixed purpose. In mobile RFID network, nodes not only act as hosts, running user oriented applications, but also act as routers to find routes and forward data according to routing protocols [4]. At the same time, due to the limited communication range of nodes in RFID network, the source node and destination node of communication will not be within the scope of direct communication, so they need to have intermediate nodes to forward data for communication, that is to say, its routing is generally composed of multi hop, so adhc network is sometimes called wireless multi hop network [5]. Its multi hop characteristic is also the most fundamental difference between RFID network and other mobile communication networks. Mobile RFID network has flexibility. The network can be constructed at any time and anywhere. As long as there are two or more nodes connected with each other, they can communicate with each other if they are in the communication range of each other, and they can communicate with each other through intermediate mobile nodes when they are beyond each other's traffic range [6]. Because of the advantages of RFID network, such as flexibility, self-organization without infrastructure, easy maintenance and cost-effectiveness, it can be widely used in many fields, such as wireless sensor network, which has very important strategic significance. This also makes mobile RFID network become an important part of wireless network and research hotspot. Network nodes can be divided into three parts: host, router and wireless transceiver [7]. Among them, the host is used to run applications, complete data processing and other functions; the router is used to run routing protocols, complete routing, forwarding packets and so on. The wireless transceiver is used to complete the function of data transmission [8]. In terms of physical structure, nodes can be divided into single access, multiple access, single access and multiple access (Fig. 1).

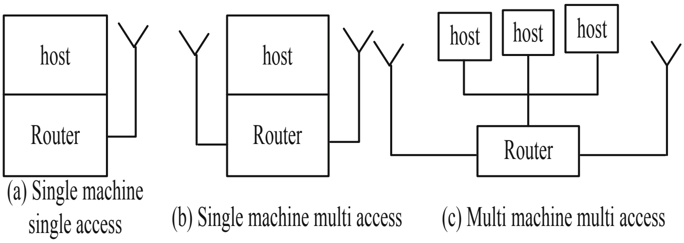

Fig. 1. Characteristic structure of uncertain network nodes

The advantage of hierarchical network is that cluster members do not need to maintain the information of road and mountain, and update the table of road and mountain. In this way, the number of road and mountain control information in the network will be greatly reduced, and the hierarchical form can have good scalability [9]. Its disadvantage is that maintaining hierarchical structure requires nodes to implement cluster head selection algorithm and maintenance mechanism among cluster members, which makes the calculation more complex; Cluster heads need to forward data centrally, which is a heavy task and may become the bottleneck of the network. Plane structure and hierarchical structure have their own advantages and disadvantages, which requires us to consider comprehensively when building the network and choose the appropriate network type. The following table lists the properties of the planar and hierarchical structures (Table 1).

Table 1. Network plane structure and hierarchical structure

Plane structure	Hierarchical structure
The status of all nodes is equal	Nodes are divided into cluster heads and cluster members
Fully distributed network	Network composed of multiple clusters
There is no network bottleneck, suitable for small and medium-sized network	Good scalability, suitable for large-scale network
Poor scalability	Cluster head nodes may become network bottlenecks

Mobile RFID network is a wireless communication network without any infrastructure, so it has different characteristics from traditional communication network. RFID network has the following main characteristics. In the RFID network, there is no control center, the nodes in the network have equal status, and it is a peer-to-peer network, so its invulnerability is also very strong. Network is a kind of communication network that can be constructed at any time and any place without any infrastructure. Due to the limited communication range of nodes in the RFID network, each node in the network may not be able to establish direct communication with other nodes. Therefore, when a node wants to transmit data with other nodes beyond its communication coverage, it needs to use the intermediate node to forward data and realize the required communication connection through the intermediate node. That is to say, the communication from the source node to the destination node is through multi hop connection [10] (Fig. 2).

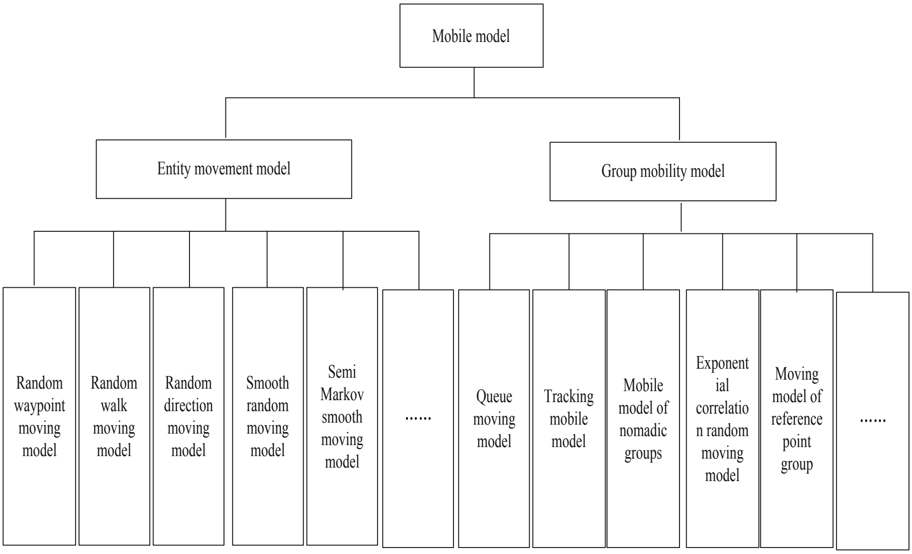

Fig. 2. Network mobility model classification

Because the nodes in the RFID network move all the time and are no longer fixed in the same location, the links between nodes can not be maintained all the time, which means that the network topology can not be stable and always changes dynamically with time[11]. At the same time, because the movement of nodes is random, it can not be predicted. Therefore, the change of network topology is unpredictable [12]. RFID network is a distributed network, its bandwidth resource is very limited, and its bandwidth is much lower than wired channel, and the quality of wireless channel is poor. At the same time, the communication process will be subject to various kinds of interference, such as electromagnetic wave, noise interference, collision, channel interference and other factors. The actual bandwidth that the mobile terminal can get will be far less than the theoretical maximum bandwidth, so it is necessary to save the network bandwidth resources as much as possible.

2.2 Moving Object Tracking Algorithm in Uncertain Networks

The uncertainty network mobile model can be used in RFID network to capture the correlation between time and speed of nodes. In this model, at the beginning, each node is given a speed, including the rate v and direction A. every time interval $\triangle t$ is fixed, the node updates the speed and direction once, and the update is based on the previous time, for example, the speed and direction of time n are calculated on the basis of time n-1, The specific calculation method is as follows

$$v_n = \alpha v_{n-1} + (1-\alpha)\overline{v} + \sqrt{1-\alpha^2}\omega_{v_{n-1}} \tag{1}$$

$$\theta_n = \alpha\theta_{n-1} + (1-\alpha)\overline{\theta} + \sqrt{1-\alpha^2}\omega_{\theta_{n-1}} \tag{2}$$

By adjusting a to control the randomness of nodes, the model is widely used. When a = 0, the state update of nodes does not depend on the previous state, that is, no memory, so it is consistent with RW model; When a = 1, it is consistent with the previous state, and the node will run in a straight line; 0 < a < 1, the nodes will be in between two states, and the movement has a certain correlation. At the same time, the location of the node will be updated in the following way:

$$x_n = x_{n-1} + v_n \cos\theta_{n-1} \tag{3}$$

$$y_n = y_{n-1} + v_n \sin\theta_{n-1} \tag{4}$$

The frequent activity patterns of moving objects are identified from activity sequences by using sequence mining algorithm. These patterns represent the hidden behavior habits of moving objects. Then, the distance measure of frequent activity patterns based on sequence alignment is defined to calculate the similarity between two frequent activity patterns. Finally, all the frequent activity sequences of moving objects are integrated to calculate the similarity (Fig. 3).

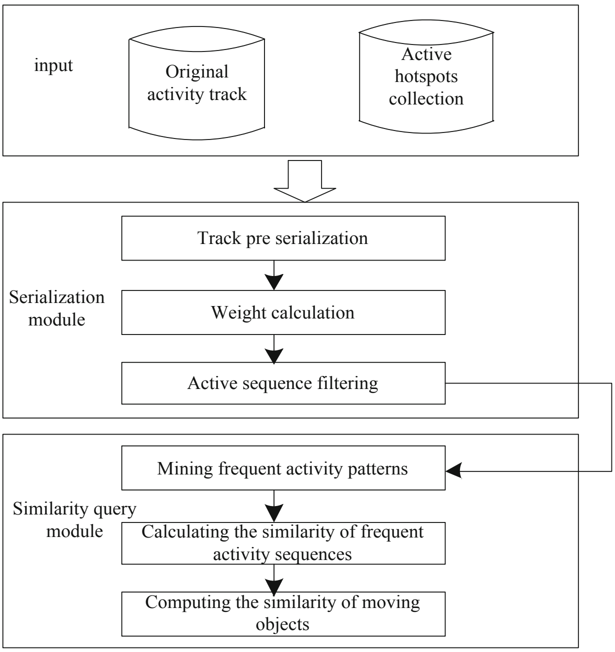

Fig. 3. Framework of network moving object tracking

Although mobile models have their own advantages and algorithms are relatively simple, they also have defects, and each node in the model is not connected and independent, which is inconsistent with the reality. Therefore, it is necessary to improve the model or propose a new model to make it more similar to the reality. The following table shows the performance comparison of entity mobility models (Table 2).

Table 2. Performance comparison of entity mobility models

Mobile model	RD model	RW model	RWP model	GM model	SMS model	SR model
Parameter	Speed, direction, time	Speed, direction	Speed, destination	Speed, direction	Speed, direction, time	Speed, direction
Mobile phase	Move, pause	Move, pause	Move, pause	Move	Accelerate, smooth, decelerate, pause	Move, pause
Smoothness	No	No	No	Yes	No	Yes
Velocity attenuation	No	-	Yes	No	No	No
Description angle	Macroscopic	Macroscopic	Macroscopic	Microcosmic	Microcosmic	Microcosmic
Is the node uniform	No	Near	No	Yes	Yes	Near
Controllability	Low	Low	Low	Middle	High	Middle

In the entity mobile model, there is no connection between nodes, while in the group mobile model, the movement of nodes has a certain connection, which is not completely independent and has a certain correlation. The common group mobility models include: queue mobility model, tracking mobility model, nomadic group mobility model, reference point group mobility model, etc. The queue movement model is that the nodes line up and move along a specific force, and each node can move in a small range. The model can well simulate the process of scanning and searching. In the queue mobility model, node location updating can be described as the following process:

$$R_m(t) = R_m(t-1) + x_n r_m(t) \tag{5}$$

$$P_m(t) = R_m(t) + \mathrm{y}_n p_m(t) \tag{6}$$

Where, Rm(t) is the position of the reference point, Rm (t−1) is the position of the reference point in the previous state, and Pm (t) is the displacement vector of the reference point. The following figure describes the movement mode of the node in the queue movement model, in which the black dot is the reference point, and the white dot is the node. From the figure, we can see that the reference points of the nodes are all in a straight line, and the nodes are all around the reference points (Fig. 4).

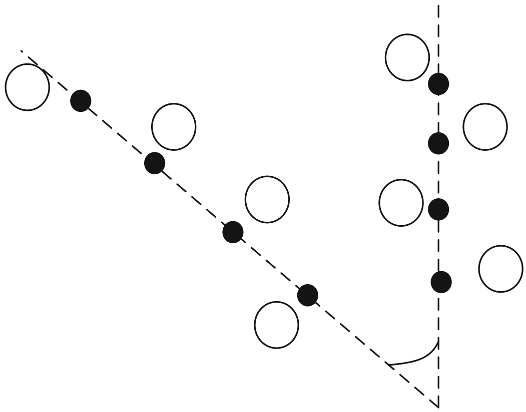

Fig. 4. Moving object tracking arrangement model

In the exponential correlation random mobility model, the mobility of a group is determined by creating the mobility function of the node. The node location is updated in the following way:

$$D(t) = D(t-1)P_m(t)e^{\frac{1}{\tau}} + \left(Q\sqrt{1-\left(R_m(t)e^{-\frac{1}{\tau}}\right)^2}\right)r \tag{7}$$

Where e is the adjustment amount of the node's current time and the previous time position, and r is a Gaussian variable with variance Q. the motion mode of the model node is changed by adjusting the parameters.

2.3 Fast Tracking of Uncertain Mobile Network Objects

The location tracking of moving objects is based on the continuous location update to obtain location information. In urban road network, because of the continuous movement of moving objects, the position in the server database must be updated constantly to improve the real-time accuracy of location data. A large number of position update strategies and algorithms are proposed, but most of the algorithms are based on the basic update strategies first proposed. In addition, the basic strategies are improved and optimized by adding some other driving variables and parameters of moving objects. Forwarding mechanism is in the opportunity network, when meeting nodes, which strategy or standard will trust other nodes also called routing algorithm. At present, the forwarding mechanism of mobile opportunity network can be divided into two categories: information forwarding to zero information transfer assistant forwarding, and the classification is shown in the figure (Fig. 5):

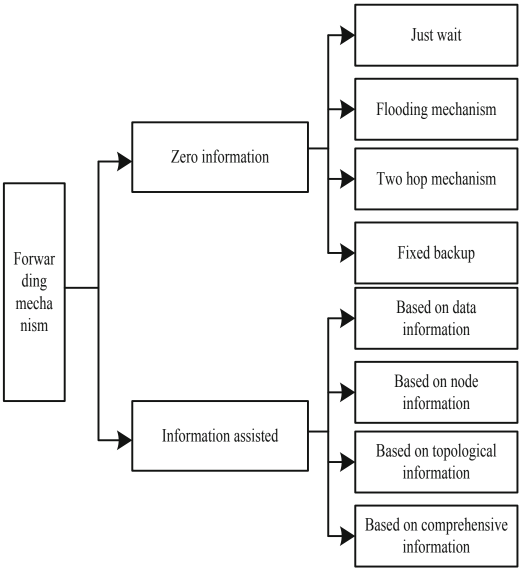

Fig. 5. Classification chart of mobile tracking object information

The original data is usually a two-dimensional coordinate with location information, or a three-dimensional coordinate with time information. For illustration, it is assumed that the moving object is a 2D coordinate point. To illustrate the distance measurements, the basic symbol definitions are given below. Define two moving objects as A and B, and the representation method is as follows:

$$A = a_1, a_2, \ldots, a_i, \ldots a_m (1 \leq i \leq m) \tag{8}$$

$$B = b_1, b_2, \ldots, b_j, \ldots b_n (1 \leq j \leq n) \tag{9}$$

Where m and n are the length of moving objects A and B, respectively. The moving object point is a two-dimensional position coordinate point without time information, as shown in the formula.

$$\Delta a_i = \left(Aa_i^x - Ba_i^y\right)/D(t) - 1 \tag{10}$$

Moving object data is spatiotemporal data, which is a series of sequence values with temporal and spatial information. Therefore, the method used to calculate the similarity of moving objects can not be used for static data in conventional algorithms. There are more general methods for distance measurement of static data, which can be used to calculate the similarity of moving objects. The Euclidean distance between two points a(x1, y1) and b(x2, y2) on the two-dimensional plane is calculated as follows.

$$d(a, b) = \Delta a_i \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{11}$$

The Euclidean distance between two points in three-dimensional space is calculated as follows.

$$\Delta d(a,b) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \tag{12}$$

The calculation method of Euclidean distance between two n dimensional vectors is shown in the formula

$$S = \sqrt{d(a,b)\sum_{k=1}^{n}\left(x_k - x_k'\right)^2} \tag{13}$$

The regions with dense moving objects are potential active hot spots, which are called candidate hot spots. Firstly, the active space is meshed, and the general information of the moving objects is saved in the corresponding grid. The candidate hot spots with dense moving objects are identified by multi-density grid clustering. The clustering object is a grid with the profile information of moving objects, and its scale is much smaller than that of moving objects, so it can significantly improve the efficiency of candidate hot spots detection. The candidate hot spot regions find the regions with relatively dense moving objects, which do not consider the activity characteristics of moving objects. In the hot area filtering stage, this paper proposes a region heat calculation method based on the structure of moving objects to measure the activity heat of moving objects in candidate regions, and filters out the final active hot areas according to the time-varying characteristics of the activity heat (Fig. 6).

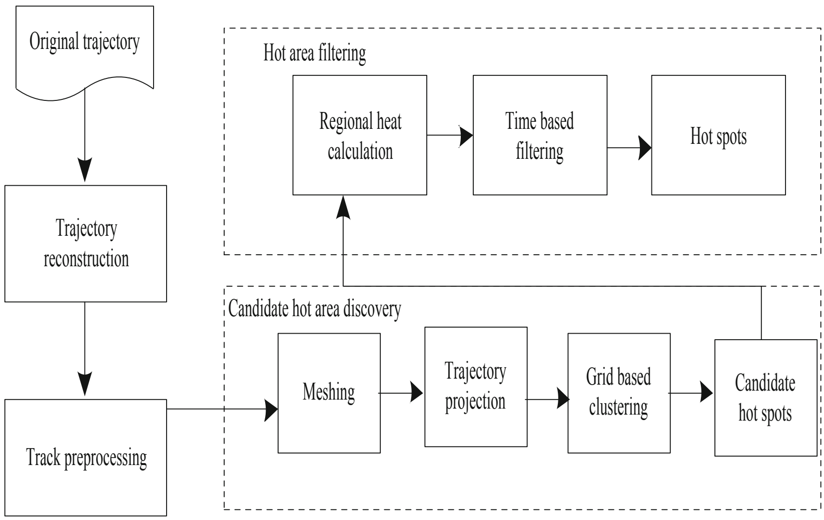

Fig. 6. Time variation characteristics of regional activity heat

Dense moving objects is a sufficient and unnecessary condition for dense activities. The basic idea of HSTS is to use the candidate region discovery algorithm to identify the dense regions of moving objects from the data of moving objects as candidate regions, and then further filter them according to the activity characteristics of moving objects, so as to improve the tracking efficiency and accuracy.

3 Analysis of Experimental Results

This experiment is carried out on the real Geolifev1.30 data set. The Geolife data set contains 182 moving objects in five years, a total of 17621 moving objects, with a total length of more than 1.29 million km. Further verify the effectiveness of TSPM. Speed is a very important parameter in the mobile model. The change of speed will affect the spatial distribution of nodes, and then affect the performance of the mobile model and the performance of the whole RFID network. The final simulation results will also change. Therefore, it is necessary to study the influence of the change of speed on the spatial distribution of nodes in the mobile model of RFID network (Table 3).

Table 3. Comparison of activity pattern mining results

	Time	PatternNwn	AvgPattemNwn	AvgLength
Filter ($\delta w = 0.015$)	411	227	4.54	3.87
No filtering ($\delta w = 0$)	1368	243	4.86	4.11

Because the verification of the effect based on WiFi P2P location tracking experiment needs a lot of energy and time to achieve, it needs users to install apps, to achieve in the real road network, and need to negotiate to participate in the forwarding of opportunistic network, which can not be achieved under the current realistic conditions, but some performance data can be obtained through the measurement between several mobile phones, These performance data can provide reference for further research in the future. The performance data are as follows: the time of device connecting to WiFi P2P is about 3–8 s; the distance between devices and WiFi P2P can reach 150 m; Average transmission rate: 1.1 m/s. Next, we will study this in two simulation regions, so that we can not only get the spatial distribution of nodes in different speed mobile models, but also compare the impact of different simulation regions on the spatial distribution of nodes. Since most of the mobile models used in RFID network are entity mobile models, this paper also uses entity mobile models RW model, RD model, RWP model, GM model and SMS model for simulation to explore the spatial distribution of nodes under different speeds of mobile models and the influence of different simulation areas on the spatial distribution of RFID network nodes. In order to calculate the spatial distribution of nodes, it is necessary to divide the simulation area. The following will introduce the partition method of rectangular simulation area and circular simulation area used in the experiment and the calculation method of probability density of mobile model nodes (Fig. 7).

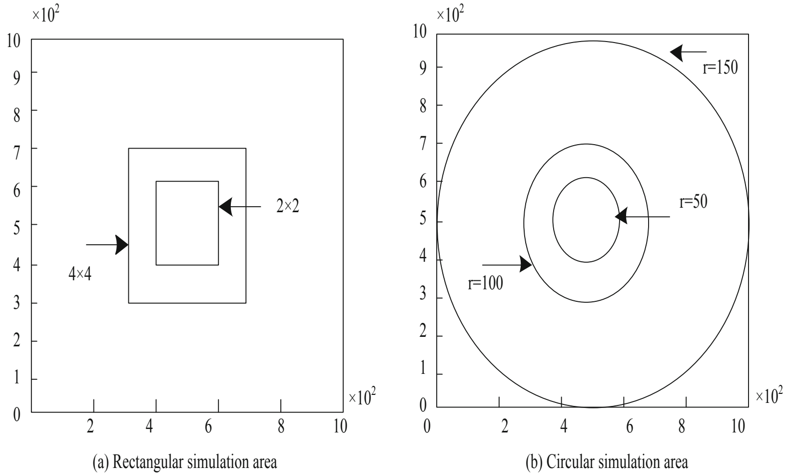

Fig. 7. Simulation area of uncertain network tracking object

As shown in the figure, the statistical information of moving objects in the two candidate regions numbered # 56 and # 76 is normalized for each attribute (Fig. 8).

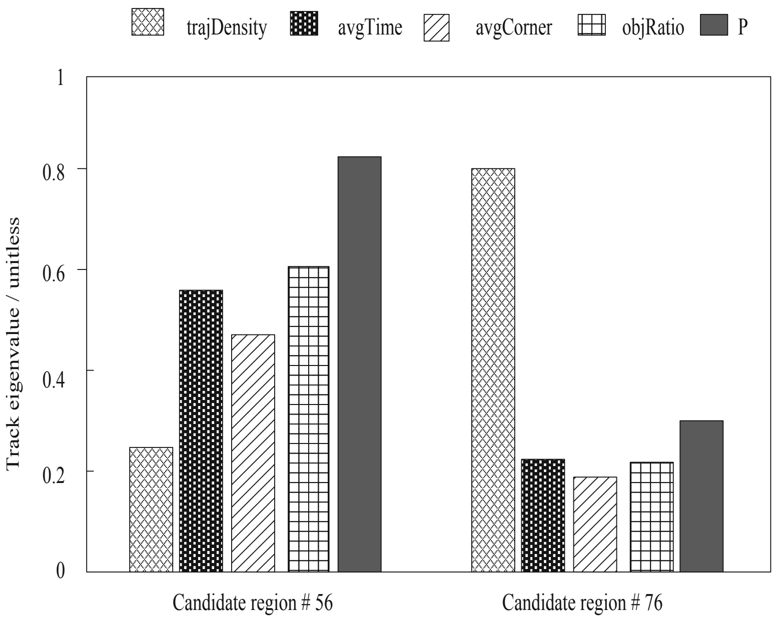

Fig. 8. Comparison of trajectory structure characteristics of moving objects in candidate regions

It can be seen from the figure that although the density of moving objects in the # 56 area is relatively low, it is shown that the area is more suitable for the characteristics of the active area in terms of the time, rotation times and object coverage of the moving object. Although the density of moving objects is high, the activity characteristics of moving objects are not obvious, which indicates that # 76 may only be the necessary place for traffic intersections. The region heat calculated based on the structure of moving objects reflects the difference of moving object activity between the two candidate regions. The regional heat of candidate region is calculated in the total time. In order to further verify the necessity of time filtering for candidate regions, this paper selects two candidate regions with close overall regional heat degree, namely, 1.09 and 1.13 respectively. The work history heat of these two candidate regions is calculated by using the month as the time interval. The active moving objects are serialized by AWTS, and the average length of the activity sequence is calculated under different activity thresholds (Fig. 9).

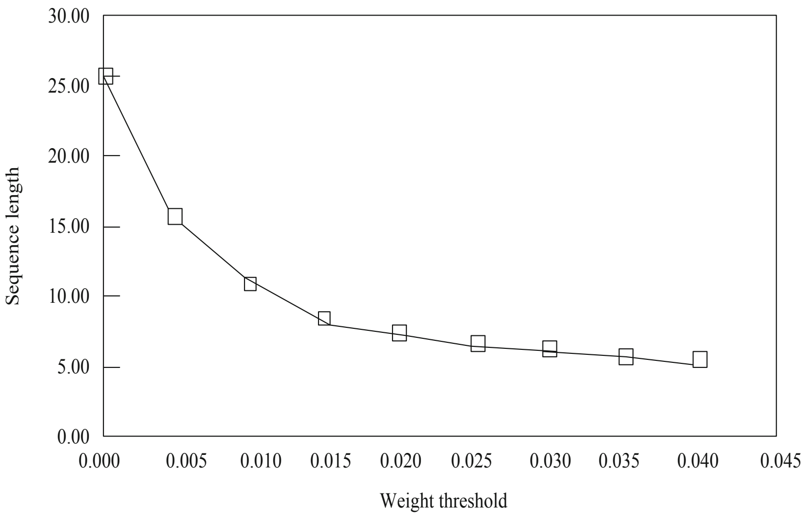

Fig. 9. The serialization result of tracking object trajectory

The following figure shows the comparison of frequent activity pattern recognition effects under different scale of moving objects (Fig. 10).

From the moving object graph and location graph of nodes, we can see that the change of node direction in the improved random direction moving model does not only occur at the edge of the region, but also within the region. And it can be seen that the distribution of nodes is small, and then there are more edges and less questions, but they are more evenly distributed in the whole simulation area (Fig. 11).

When the weight threshold aw is higher and higher, more and more hot spots are filtered out in the moving object sequence, so the average length of the sequence will be shorter and shorter. When the threshold value of activity weight is less than <0.015, the activity weight of hot spots is mainly concentrated in the range of [0,0.015), so a large number of low activity weight location points will be filtered out, which leads to

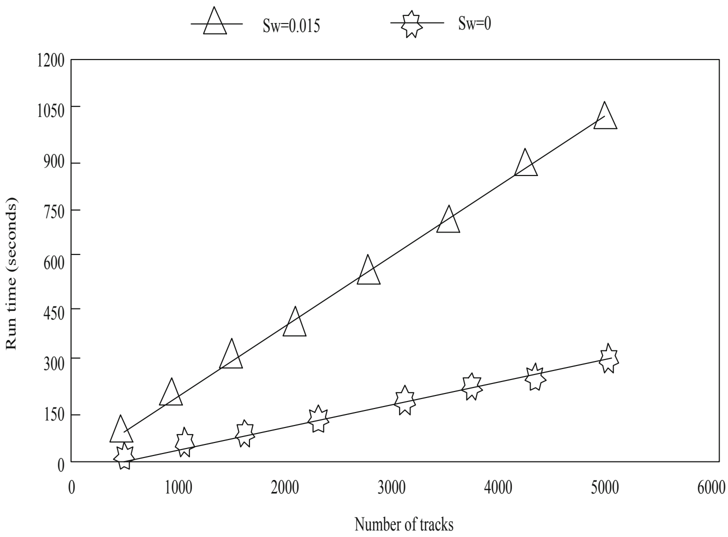

Fig. 10. Time complexity of mining activity mode

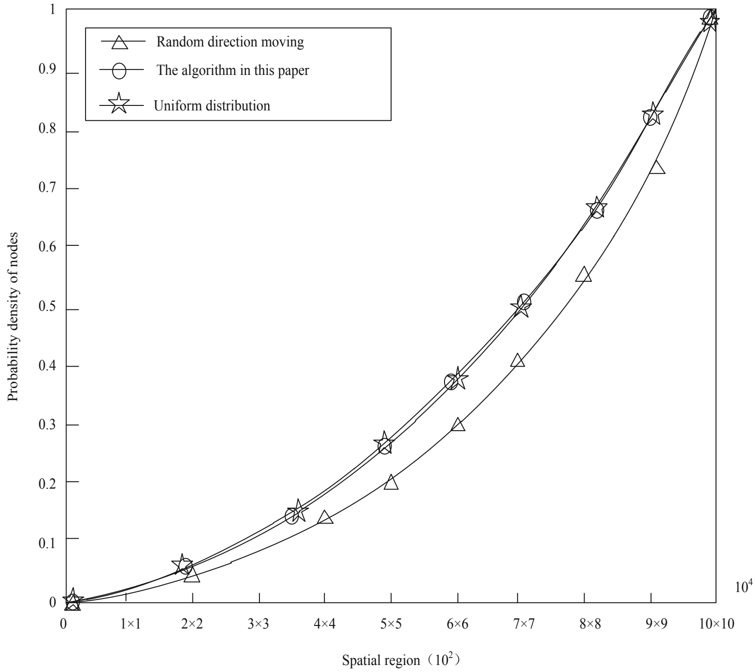

Fig. 11. Tracking effect contrast detection

the rapid shortening of the average length of activity sequence. The weight threshold is greater than 0.015, and fewer active hotspots meet the threshold conditions. Therefore, the less the filtered location points are, and the average length of the activity sequence decreases slowly.

4 Conclusion and Prospect

With the rapid development of intelligent devices in recent years, GPS, GSM network and WiFi Positioning Technology has been widely used, it is easy to track mobile objects, resulting in a large number of spatio-temporal data. How to effectively discover valuable information from these massive spatio-temporal data has become an important research topic. Similarity query of moving objects has broad application prospects in the fields of spatiotemporal data mining and location-based services. This paper focuses on the phase tracking effect of moving objects.

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