PROBABILITY SENSING MODEL BASED ENHANCEMENT

OF COVERAGE FOR VIDEO SENSOR NETWORKS

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Abstract- With the foundation of the video probabilistic sensing model that sensing direction is steerable, the study on path coverage enhancement algorithm for video sensor networks has been improved, analysis the position of effective center of mass in the sensor's model, the network calculates the gravitation between the target track points and the trace nodes, and the repulsive force between both trace nodes of the target track points, then the trace node adjusts its sense direction, make the probability of the target track points which is perceived by the sensor network equals or exceeds the perception threshold. The simulation result shows that, this improved algorithm has make further improvement on the perception of the target which is move in the coverage area, it uses more fewer directional video nodes, but the video sensor networks is fully and high effectively covering the target trajectory.

Keywords: **Probability sensing model; video sensor nodes; virtual force.**

I.　INTRODUCTION

WSNs (Wireless Sensor Networks) [1] can monitor, sense and collect information of all kinds of environments and monitored objects with the collaboration of various types of integrated micro sensors, Such as the application in warfare surveillance of military battlefield, maintenance and management of civil public facilities, inspection and maintenance of industrial equipment, scientific observation of gathering place of animal and plant, etc. Coverage problem is a basic problem of any type of WSN, and is closely related to sensor node deployment which has a direct influence on the coverage performance of network. Sensor node deployment reflects the cost and performance of wireless sensor network, and reasonable deployment scheme can greatly enhance the sensing effect of wireless sensor network (WSN) and reduce the use cost [2][3]. The current research of coverage control is focused on omnidirectional sensing model [4][5] . However, the way of sensing targets and acquiring the target information for some sensor nodes, such as video sensors, infrared sensors, ultrasonic sensors and so on, is obviously directional, which are called directional sensor nodes. In the practical application, the sensing probability of targets sensed by directional sensor network is different with the change of time and location, namely, the node detects targets according to a certain probability. The directional sensor is affected by various factors, so the target detection probability is not guaranteed, may even make false alert.

Boolean perception model is mostly used in the current research of directional sensors. Lu kezhong and Feng Yuhong [6] propose a kind of greed iterative algorithm aiming at the problem of enhancement of the sensor network coverage. In each iteration, adjust the sensors' direction so that the total coverage of a sensor network increases; repeat the iterative process until the total coverage can no longer increase with adjusting the direction of any node. According to Voronoi diagram and the direction adjustable characteristic of directional sensors and without global information of network, a distributed greedy algorithm is designed by Sung[7], which divides sensor nodes into Voronoi polygon, and considers the contribution degree of convex polygon and the overlap coverage ratio of each neighbor node in the sensing direction, finally makes the node working direction the best to expand the coverage effect. The literature[8], aiming at the problems of node energy waste and coverage redundancy

which occur in current directional sensor network algorithms when the sensing direction of the sensor is adjusted to achieve the maximum coverage of targets, puts forward a distributed clustering algorithm to complete the maximum coverage of the target with the least nodes and reduce the node energy consumption. The literature[9] presents two greedy algorithms based on priority to optimize the coverage area. In this algorithm the node needs convey messages many times to determine its working status and priority, so that the node energy consumption is increased. However, the detection probability of actual sensor nodes to target is usually uncertain, and the node's perception probability is varied with different distance. Deterministic sensing is approximately equivalent to the situation that the nodes based on probabilistic sensing model work in the ideal environment.

In order to reduce the complexity of time, the literature[10] , combining the virtual force with the concept of node centroids, proposes a enhancement algorithm based on sensing connected subgraph, in which the centroid position is adjusted on the action of virtual force and then the sensing direction of directional senor node is adjusted to rotate and optimized, to reduce the covered hole and overlapped coverage of network. The literature[11] , researching on the problem of coverage to the target path, presents PFPCE(Potential Field based Path Coverage Enhancement) algorithm，which analyses the virtual force between node centroids and trajectory points and between the centroids of neighbor nodes, enhances the detection and tracking of directional sensor network to targets, but it uses deterministic sensing model. The literature[12] , by utilizing the repulsion force between the centroids of the effective monitored area and the overlapped area and that between the centroids of the effective monitored area and the barrier area, proposes a dynamic optimization algorithm of coverage ratio without blind area coverage based on virtual force. The algorithm solves the problem of network coverage limitation when obstacles exist in the monitoring area , optimizes the coverage of the video sensor and reduces blind area coverage, but at the stable instant of network, due to the virtual force still acting on "centroid", nodes exists the phenomenon of shock and new nodes are awakened , so the algorithm is needed to be re-executed and some nodes need to re-rotate, maybe resulting in greater energy consumption . J. Zhao[13] et al. present a algorithm to optimize the directional sensor network coverage based on virtual force. The algorithm closes the redundant nodes by analyzing the overlapped coverage ratio od

nodes and the force situation of centroid, and the experiment indicates that compared with PFCEA, this algorithm improves coverage quality of sensor network greatly and reduces the amount of calculation. The literature[14] defines the attractive force of uncovered points in the area to the node and proposes a distributed virtual force algorithm, which makes the node moving, reduces the overlapped coverage, minimizes overlapped area, makes sensors observe in the direction that users are interested in and can quickly converge within 5~6 iterations to achieve the expected coverage effect. The literature [15] discusses the three-dimensional model with the existence of obstacles, and eventually schedules the sensor network with initial low coverage and low connectivity through composite virtual force for a network with high coverage rate, heavy connectivity. Meanwhile the algorithm calculates the node movement energy consumption and discusses the termination conditions of the algorithm control. The literature[16] proposes a deployment algorithm based on the electrostatic field theory for mobile wireless sensor networks. The nodes and obstacles in the deployment area are taken as the charged particles; and the particles will move due to the Coulomb's force from other particles or obstacles. Finally, the nodes automatically spread to the whole area by the resultant action and complete the deployment. The literature [17] focuses on the wireless sensor network communication radius in the high density of sensor nodes deployed randomly and two times smaller than the sensing radius; put forward a distributed k coverage multi connected node deployment algorithm based on grid. That can guarantee the wireless sensor network coverage and connectivity can reduce the number of the active state nodes effectively, prolong the wireless sensor network lifetime. The coverage holes recovery algorithm aiming at the coverage holes in wireless sensor network is designed in literature[18]. The nodes movement is divided into several processes, in each movement process according to the balance distance and location relations move nodes to separate the aggregate nodes and achieve the maximum coverage of the monitoring area. In a given sensing range, the video sensor can get some information of the target, but because of the distance from the target to the sensor, the pixel resolution of video and so on, it can not monitor the specific appearance of the target. That is to say, video sensor nodes can determinately sense the target points within a given range, and with the increase of distance, the perceptive ability of sensor nodes to the target point will have a certain decline. The

current study of video sensor network mostly adopts deterministic perception model, which is not in accordance with the actual situation, so the paper uses probabilistic sensing model to explore the deployment of video sensor network.

In this paper, the probabilistic sensing model and virtual force algorithm are adopted to control the video nodes within the network. The detecting probability and sensing effect of video nodes to the path of targets entering into the monitoring area are enhanced by the fusion of the sensing probability of the node and its neighbor node to the target trajectory points. The simulation results indicate that the algorithm makes the network realizing the fully efficient coverage to target moving path, and making full use of sensor probabilistic sensing area to achieve detection   and   monitoring of the target.

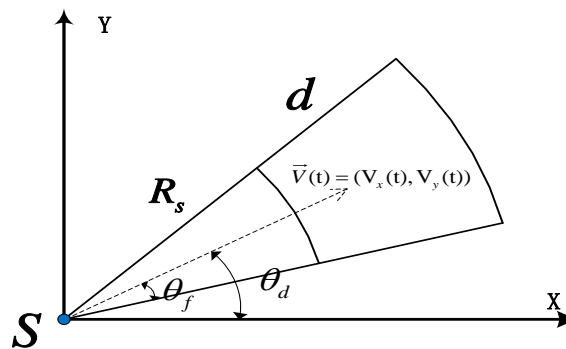## II. SENSING MODEL

2.1 Directional sensor model

Fig. 1 The model of probabilistic sensing of directional sensor sector

Fig. 1 shows the model of probabilistic sensing of directional sensor. In order to denote the probabilistic sensing range of directional sensor, a new probabilistic range parameter d is added into the information of sensor nodes. Therefore, the node information can be represented by $< S, R_s, \vec{V}(t), \theta_f, d >$, where s is the position coordinate, represented by (x_s, y_s); R_S is the effective sensing radius; $\vec{V}(t) = (V_x(t), V_y(t))$ is the sensing direction at time instant t; $\theta_d (0 \le \theta_d \le 360)$ in Fig. 1 is the angle value between node sensing direction

and horizontal direction at time instant t; $2\theta_f$ is the effective sensing angle, called viewing domain of directional sensor, represented by fov; d is the probabilistic sensing range and its value is related with power and hardware design of nodes.

Define a set $S = \{s_1, s_2, \ldots, s_i, \ldots, s_n\}$ to denote n nodes in directional sensor network, $1 \le i \le n$. p is the target point in the monitoring area, located by the coordinate (x_p, y_p); s_i is the ith node in the video sensor network, located by the coordinate (x_{s_i}, y_{s_j}); $P_{\text{st}}(s_i, p)$ is the sensing probability that target p is sensed by video sensor node s_i; $d(s_i, p)$ is the Euclidean distance between target point p and node s_i.

When $d(s_i, p) \le R_s$, $P_{\text{st}}(s_i, p) = 1$; $d(s_i, p) = R_s + d$, $P_{\text{st}}(s_i, p) = 0$; and $R_s \le d(s_i, p) \le R_s + d$, the probability is expressed as

$$P_{\text{st}}(s_i, p) = -\frac{d(s_i, p)^2 - R_{far}^{\ 2}}{d^2 + 2R_s d} \qquad (2)$$

Therefore, sensing model of directional sensor can be described mathematically as

$$P_{\text{st}}(s_i, p) = \begin{cases} 1 & d(s_i, p) \le R_s \quad and \quad \theta_d - \theta_f \le \theta_{ps\ x} \le \theta_d + \theta_f \\ -\dfrac{d(s_i, p)^2 - R_{far}^{\ 2}}{d^2 + 2R_s d} & R_s < d(s_i, p) \le R_{far} \quad and \quad \theta_d - \theta_f \le \theta_{ps_i x} \le \theta_d + \theta_f \\ 0 & other \end{cases} \qquad (3)$$

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Fig. 2 shows probability sensing diagram of target p sensed by video sensor node s_i.
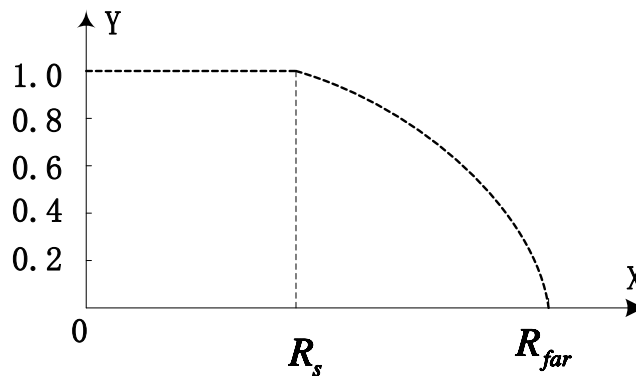

Fig.2 The probability sensing diagram of video sensor

2.2 Equivalent centroid calculation

We adopt two ways to control and adjust the deployment of the network in order to get better coverage to monitoring area and guarantee the quality of services of network. One way is to increase the scale of node deployment, which can make up for the deficiencies of quality of network services. Another way is to adjust the position of sensor nodes based on the existing network. The movement of the traditional sensor network is only aiming at the node itself, and when the node is moved by the action of the external force, the sensing range is moved. Due to the characteristics of irregular and incomplete symmetry, the movement of directional sensor network is special. In order to study the mobile characteristics, the method of equivalent centroid[12,19] of directional sensor, which is put forward according to the previous literatures that research on wireless sensor, is used widely.

Point C in Fig. 3 is the centroid of probabilistic sensing model of video sensor. The position of centroid varies with the different value of probabilistic sensing range parameter d, but it must be located in the angle bisector of viewing angle of the video sensor.
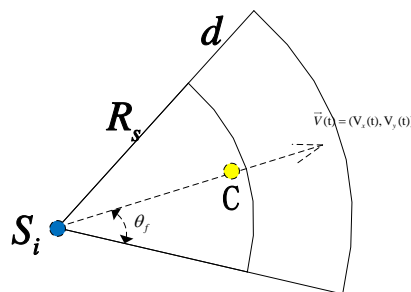

Fig. 3 Centroid of probabilistic sensing model of video sensor

In order to calculate the centroid of the directional sensor based on the probabilistic sensing model, assume that the probability of sensed any point by the sensor is the density function in the sector area. Since the probability that sensed by the node within the sensing area is nonuniform; that is, the quality of the sensing sector area is nonuniform, we find the position of centroid in the symmetry axis of the directional sensor ,and the distance from the vertex is d_{cen} :

$$d_{cen} = \frac{\iint_D x P_{st} d\sigma}{M} = \frac{\iint_D x P_{st} d\sigma}{\iint_D P_{st} d\sigma}$$

$$= \frac{\int_{-\theta_f}^{\theta_f} \cos\theta d\theta \int_0^{R_s} \rho^2 d\rho + \int_{-\theta_f}^{\theta_f} \cos\theta d\theta \int_{R_s}^{R_{far}} -\frac{\rho^2 - R_{far}^2}{d^2 + 2R_s d} \rho^2 d\rho}{\iint_{D_1} d\sigma + \iint_{D_2} P_{st} d\sigma} \qquad (4)$$

$$= \frac{\int_{-\theta_f}^{\theta_f} \cos\theta d\theta \int_0^{R_s} \rho^2 d\rho + \int_{-\theta_f}^{\theta_f} \cos\theta d\theta \int_{R_s}^{R_{far}} (-\frac{\rho^2 - R_{far}^2}{d^2 + 2R_s d}) \rho^2 d\rho}{\int_{-\theta_f}^{\theta_f} d\theta \int_0^{R_s} \rho d\rho + \int_{-\theta_f}^{\theta_f} d\theta \int_{R_s}^{R_{far}} (-\frac{\rho^2 - R_{far}^2}{d^2 + 2R_s d}) \rho d\rho}$$

where $\rho = d(s_i, p)$, p is the point located within the sector sensing range of s_i, and $d(s_i, p)$ is the distance between p and s_i.

Equation 4 indicates that when the probability of all the points monitored in the sector area is 1, the probabilistic sensing model is equivalent to the deterministic sensing model. The centroid is located in the symmetry axis and the distance from the circle center is $2(R+d)\sin\theta_f / 3\theta_f = 2R_{far}\sin\theta_f / 3\theta_f$。

2.3 Target trajectory

The red dotted line in Fig. 4 is the target moving trajectory from left to right, which is denoted by L.

Definition 1　sample the trajectory L with interval Δl uniformly and each sampling point is called a trajectory point[11] of the target. m is the total number of trajectory points, so trajectory points of the target can be represented as a set $T = \{t_1, t_2, t_3, ..., t_i, ...t_m\}$, $i = 1, 2, 3, .., m$ and the value of m can be calculated by the expression 5 (just take the integer part).

$$m \approx L/\Delta \qquad (5)$$

Definition 2　the region , whose distance from target moving trajectory is less than or equal to R_{far}, the farthest perception distance of the video sensor trajectory, is called as trajectory

belt[11]. Black solid lines represents the trajectory belt of the deterministic sensing model, while the black dotted line denotes the trajectory belt of probabilistic sensing model adopted in this paper; that is, the area between the black solid line and dotted line is the monitoring area which is expanded based on the improved algorithm in this paper .

Definition 3 The video nodes within the trajectory belt are called tracking nodes, represented by the set $S_k = \{s_1, s_2, \ldots, s_i, \ldots, s_k\}, i = 1, 2, \ldots, k$, $k \leq n$ and $S_k \in S$.
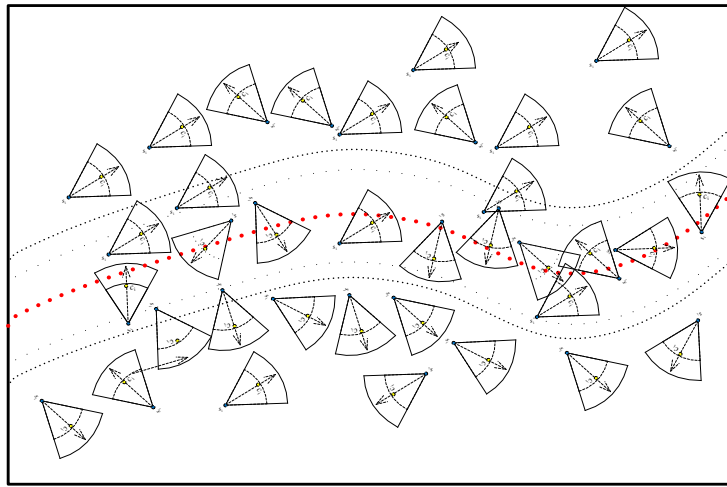

Fig. 4 The target moving path and the node distribution map in the monitoring region

2.4 Coverage model

The target appears and passes through in the monitoring area and the trajectory is formed. The points on the trajectory are selected uniformly, represented by a set $T = \{t_1, t_2, t_3, \ldots, t_i, \ldots t_m\}, i = 1, 2, 3, \ldots, m$. t_j is the jth target trajectory point and s_i is the ith directional node. We definite $P(s_i, t_j)$ to denote the perceived probability of s_i sensing t_j and $P_{st}(t_j)$ to denote the perceived probability of sensor network sensing t_j such that we get the joint perceived probability[20] that all the sensor nodes $S = \{s_1, s_2, \ldots, s_i, \ldots, s_n\}$ of the network sense each target trajectory point in the monitoring area:

$$P_{st}(t_j) = 1 - \prod_{i=1}^{n}[1 - P(s_i, t_j)] \quad i = 1, 2, 3, \ldots n. \tag{6}$$

Let the threshold of sensing probability be P_{th}. If $P_{st}(t_j) \geq P_{th}$, the trajectory point is judged to be sensed, namely, the trajectory point t_j is covered by the network; Otherwise, the trajectory point is judged not to be covered. $P_c(t_j)$ denotes the perceived probability of sensor network sensing the trajectory point t_j, expressed as follow:

$$P_c(t_j) = \begin{cases} 0 & if \quad P_{st}(t_j) < P_{th} \\ \\ 1 & if \quad P_{st}(t_j) \geq P_{th} \end{cases} \quad (7)$$

η_{cov} represents the coverage ratio that the target trajectory point is covered by sensor network, and its value is the ratio of the number of trajectory points sensed and the total number of target trajectory points, expressed as follow:

$$\eta_{cov} = \frac{t_{dis}}{m} = \frac{\sum_{j=1}^{m} P_c(t_j)}{m} \quad (8)$$

Where t_{dis} is the number of trajectory points which are judged to be sensed by network, and

$t_{dis} = \sum_{j=1}^{m} P_c(t_j)$. The value of η_{cov} is related with t_{dis} and m which is the trajectory points

number obtained by sampling the target trajectory

Thus, by calculating the number of all the target trajectory points sensed by sensor network, we can get the situation of the detected target when moving in the monitoring area.

III.   PATH COVERAGE ENHANCEMENT ALGORITHM FOR VIDEO SENSOR NETWORK BASED ON PROBABILISTIC SENSING MODEL

3.1 Algorithm assumption

To simplify the simulation, some assumptions are given:

(1)All the nodes have the same sensing radius R_s and the same communication radius R_c

($R_c = 2R_{far}$). In additional, the probabilistic sensing range of video sensor nodes is the same;

(2) The video sensor is deployed randomly. The nodes go to sleep when not working, which is

controlled by the network;

(3) After random deployment, the video sensor node knows the coordinate of itself, sensing direction of itself and the location information of all the neighbor nodes;

(4) The position of the video sensor nodes cannot be moved, but its sensing direction can do a circumferential movement around the node;

(5) The communication of video sensor nodes is omnidirectional. Set any two points in the network as s_i and s_j, and s_j is not in the current sensing direction of s_i. The distance between the two nodes is $d(s_i, s_j)$. If $0 \leq d(s_i, s_j) \leq 2R_{far}$, the two nodes can communicate with each other.

3.2 Virtual force analysis

(1) Attractive force between the target point t_j and the tracking node s_i

As shown in Fig.5, $d(s_i, t_j)$ denotes the Euclidean distance between t_j and s_i. If and only if $d(s_i, t_j) \leq R_s + d$, the attractive force between t_j and s_i is $\overrightarrow{F(s_i, t_j)}$.

Based on the probabilistic sensing model, the attractive force model can be described as :

$$\overrightarrow{F(s_i, t_j)} = \begin{cases} k_a \dfrac{1}{d(c_i, t_j)^a \square P_{st}(s_i, t_j)} \cdot \overrightarrow{a_{ij}} & d(s_i, T_j) \leq R_{far} \\ 0 & otherwise \end{cases} \qquad (9)$$

Fig.5 the attractive force between the trajectory of target and the node

where k_a, a is gain coefficient，$d(c_i, T_j)$ is Euclidean distance between centroid c_i of node s_i and trajectory point c_i and $\overrightarrow{a_{ij}}$ is unit vector. Attractive force $\overrightarrow{F(s_i, t_j)}$ is inversely proportional to the probability that trajectory point sensed in equation 9， that is, the greater the sensing probability is, the smaller the attractive force is. $F_{\perp}(s_i, t_j)$ and $F_{\Box}(s_i, t_j)$ is the components of attractive force $\overrightarrow{F(s_i, t_j)}$. $F_{\perp}(s_i, t_j)$ is the component force pointing to the node, while $F_{\Box}(s_i, t_j)$ is the component force along the tangential direction. Since the node does not move, only $F_{\Box}(s_i, t_j)$ makes the node rotating.
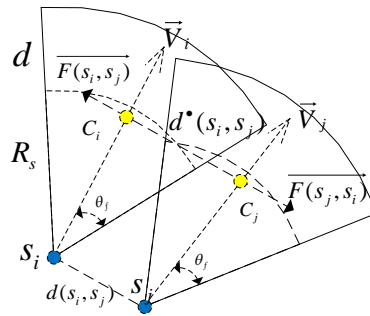

Fig. 6 The repulsion between centroid points of node s_i and s_j

(2) Repulsive force between tracking nodes s_i and s_j

$d(s_i, s_j)$ represents the distance between s_i and s_j. When $d(s_i, s_j) \le 2R_{far}$, repulsive force exists between s_j and s_i, which acts on the centroid of tracking node s_i, as shown in Fig.6. $\overrightarrow{F(s_i, s_j)}$ is used to denote repulsive force between nodes, so repulsive force model is described   as

$$\overrightarrow{F(s_i, s_j)} = \begin{cases} k_b \dfrac{1}{d^{\bullet}(s_i, s_j)^b} \cdot \overrightarrow{a_{ij}} & d(s_i, s_j) \le 2R_{far} \\ 0 & otherwise \end{cases} \qquad (10)$$

Where $d^\bullet(s_i, s_j)$ is Euclidean distance between centroid C_i of s_i and centroid C_j of s_j, k_b and b is gain coefficient, $k_b \leq k_a$, $\overrightarrow{a_{ij}}$ is unit vector pointing from C_j to C_i. If and only if $d(s_i, s_j) \leq 2R_{far}$, that is, they are neighbors，virtual repulsive force exists between C_i and C_j. The repulsive force makes nodes move towards the direction in which the overlapped area is decreased. $\overrightarrow{F(s_i, s_j)}$ is inversely proportional to Euclidean distance $d^\bullet(s_i, s_j)$ and the repulsive force on centroids is inversely proportional to the distance between C_i and C_j in equation 9. $F_\perp(s_i, s_j)$ and $F_\square(s_i, s_j)$ is the components of repulsive force $\overrightarrow{F(s_i, s_j)}$. $F_\perp(s_i, s_j)$ is the component force pointing to the node, while $F_\square(s_i, s_j)$ is the component force along the tangential direction. Similarly, only $F_\square(s_i, s_j)$ makes the node rotating.

(3) Resultant force acting on the centroid of node s_i

   Repulsive force and attractive force jointly act on node s_i, and $\overrightarrow{F_i}$ represents resultant force on the centroid, expressed as follow:

$$\overrightarrow{F_i} = \overrightarrow{F(s_i, t_j)} + \overrightarrow{F(s_i, s_j)} \tag{11}$$

$\overrightarrow{F_i}$ can be divided into two components, $\overrightarrow{F_{i\perp}}$ and $\overrightarrow{F_{i\,\square}}$, and the node rotates on the action of component $F_{i\,\square}$.

(4) Moving rules

If the perceived probability, tracking node sensing trajectory point t_j, $P_{st}(s_i, t_j) \geq P_{th}$, namely $P_{st}(t_j) \geq P_{th}$, the node cannot move anymore; If $P_{st}(s_i, t_j) < P_{th}$, calculate the force acted on the node.

If the virtual force, with the value F, along the tangent direction, makes the node rotating a angle $\Delta\theta$, given the value of $F_{i\,\square}$, we get the expression as follow:

$$\theta_{m\,o\,v} = \frac{F_{i\,\square}}{F} \times \Delta\theta \tag{12}$$

Before rotating, it is necessary to calculate the new perceived probability $P_{st}^{\bullet}(t_j)$ of the sensor network to target trajectory point t_j according to formula (6). If $P_{st}^{\bullet}(t_j) \geq P_{th}$, the node moves; If not, the node stays in its original place.

3.3　Algorithm description

The situation of part of the monitoring region is shown in Fig.7. Before deployment, roughly estimate the number of nodes required for network deployment, as a basis for deployment in the monitoring area.

Step1：After all the video sensor nodes are deployed, initialize parameters of nodes and the nodes exchange information to confirm the location of itself and the neighbor node, then go to Step2；

Step2：calculate the coverage ratio $\eta_{cov}^{'}$ of all the nodes in the set S to the monitoring area. Marked the working state of all the nodes 0 and Let $n_{work} = 0$, go to Step3；

Step3：Define L to represent a route randomly selected through the monitoring area. Choose target trajectory points with interval Δl randomly and uniformly, and the number of target trajectory points can be calculated according to expression (5). Find out all the nodes with vertical linear distance to route L less than R_{far}, give each node a number, and save the nodes as a set S_k, then go to Step4；

Step4：The centroid position of tracking node is calculated by formula (4), then go to Step5；

Step5：from formula (6) , calculate the joint perceived probability of trajectory point t_j sensed by all the nodes which can track t_j. According to the movement rule, if the trajectory point don't need to rotate, let $n_{work} = n_{work} + 1$；repeat the same work to next trajectory point t_{j+1}；if the trajectory point need to rotate, calculate the repulsive force between the centroid of this node and that of its neighbor node, the attractive force of the centroid of the node and the trajectory point, and the rotation angle. Go to Step6；

Step6: assuming the positive direction is clockwise, sensor s_i turn the corresponding angle with the action of $\overrightarrow{F_{i\square}}$ which is the component force of $\overrightarrow{F_i}$ along the tangential direction on centroid c_i, such that the node can reach the corresponding position. Go to Step7 ;

Step7: excute Step5 and Step6 circularly until all the trajectory points of the target set $T = \{t_1, t_2, t_3, ..., t_i, ..., t_m\}$ are adjusted and then go to Step8 (distributed greedy strategy) ;

Step8: calculate the number of working nodes n_{work}, coverage ratio η_{cov}' of all the nodes in set S to the monitoring area and the coverage rate η_{cov} of tracking nodes in set S_k to all the trajectory points in set $T = \{t_1, t_2, t_3, ..., t_i, ..., t_m\}$.

Note:

(1) Due to deterministic sensing model adopted in the literature[13], if the distance between nodes s_i and trajectory point t_j is less than the sensing radius of the sensor, after node s_i adjusting the angle of view, s_i can cover point trajectory t_j definitely with the action of virtual force . While probabilistic sensing model adopted in this paper, so after the node rotates, the sensing probability of the node to the target is uncertain. Therefore, it is necessary to calculate the sensing probability firstly and then carry out the adjustment to reduce the times of rotating viewing angle and to achieve the purpose of energy saving;
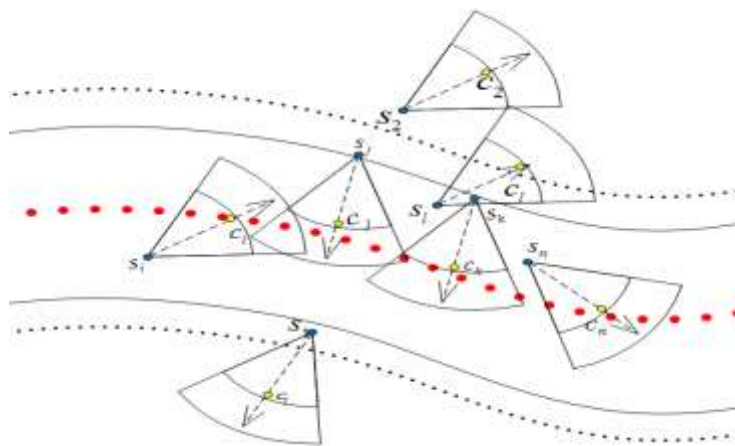

Fig. 7 The situation of part of the monitoring region

(2) The tracking nodes involved by adjacent trajectory points t_j and t_{j+1} need adjust the angle of view multiple times.

(3) The tracking node makes the adjustment of rotation with the moving of the target point so as to guarantee that the sensing probability of network to trajectory points is greater than P_{th}. But after rotation adjustment, the total coverage ratio of nodes to the monitoring area may be decreased.

IV. SIMULATION ANALYSIS

This paper simulates the algorithm in MATLAB platform, and the simulation parameters are set as follows: monitoring area S_{area} is $500m \times 500m$, sensing radius R_s of the sensor nodes is 40m, sensing angle of view fov is $2\theta_f = \pi / 2$, probabilistic sensing range d of sensor nodes is 10m，$R_{far} = R_s + d = 50m$，$k_a = 3$、$k_b = 1$，the number of nodes deployed is 80, threshold P_{th} of sensing probability is 0.85, rotation angle $\Delta\theta = 5°$, sampling interval $\Delta l = 10m$， and trajectory points coverage ratio η_{req} is greater than or equal to 90%. The simulation results are compared with those of PFPCE algorithm.

Adopting probabilistic sensing model, the number of nodes used can be significantly reduced. After the deployment of the same number of nodes, the initial coverage ratio of nodes is significantly greater than that of deterministic sensing model. The same as algorithm PFPCE, there are two main parameters affecting the performance of the improved algorithm, and they are initial coverage ratio of network η_{cov}' and the discrete degree of trajectory points of the target, which is related with sampling interval Δl.

Fig.8 indicates that the relation between the number of nodes and coverage ratio in the same monitoring area, adopting PFPCE algorithm and the algorithm used in this paper respectively. As shown in the diagram, with the increase of working nodes number, the coverage ratio of the two algorithms are raising, but the raising speed using the algorithm in this paper is faster , and when $n \geq 300$, the raising speed becomes slow and tends to be stable.

Fig.9 shows that the effect of the number of nodes on coverage ratio η_{cov} in PFPCE and this algorithm respectively. With the increase of the number of nodes, they move in the coverage area, without running the algorithm, namely without rotation adjustment of nodes, we can see the advantage of using a probabilistic sensing model, in which average 40 nodes per increase, the coverage ratio of nodes using probabilistic sensing model is 3% greater than that without using it. When the number of nodes is about 300, coverage ratio based on the model of this paper is $\eta_{cov} \approx 94\%$ and that based on PFPCE is stable at 90%. The coverage ratio of target tracking point tends to be stable with continuing to increase the number of nodes.
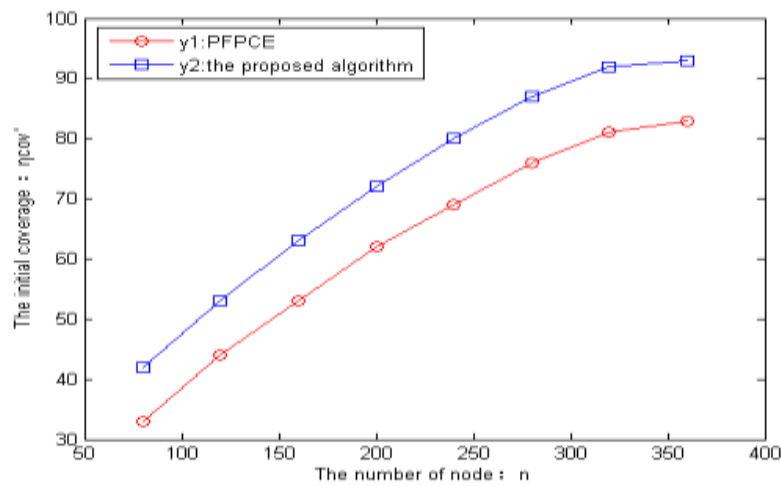

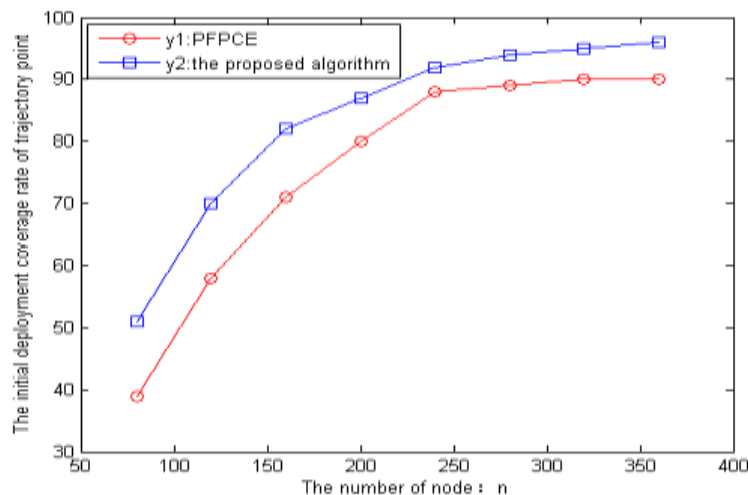**Fig. 8** the effect of the number of nodes to regional coverage in PFPCE and this algorithm

Fig. 9 the effect of the number of nodes to η_{cov} in PFPCE and this algorithm

Fig.10 shows the relation between the number of nodes and coverage ratio of trajectory points after running PFPCE and the algorithm adopted in this paper respectively.

Deploying the nodes of 80, after running the algorithms, PFPCE enhance by 38.24%, while the algorithm in this paper increases by 31%. But finally the coverage ratio to the trajectory point got by the algorithm in this paper is 87.52%, which is higher than that of PFPCE algorithm with 85.71%. With the increasing of the number of the nodes, when the number of nodes reaches 300, the coverage ratio based on the algorithm used in this paper can reach about 95%, while that based on PFPCE is about 91%. If the number of nodes is kept on increasing, the coverage ratio tends to be stable. The reason is that when the number of nodes is larger, the target can always be detected whenever it enters into the monitoring area.

From Fig.8, Fig.9 and Fig.10, it can be concluded that: initial coverage ratio of the area η_{cov}' increases; the improved degree of coverage ratio to the target trajectory points decreases with the increase of η_{cov}'; if the value of η_{cov}' is less, namely less nodes, the coverage hole is more, and if the moving distance of target trajectory points Δl is larger, the probability of blind zone coverage is relatively large along the path. After running the two algorithms, they all improve coverage ratio of the trajectory point, and the final area coverage ratio is stable with the increase of η_{cov}'. If nodes are deployed more so that the monitoring area is fully covered, there is not so much improvement after running the two algorithm when targets pass though the monitoring the area.
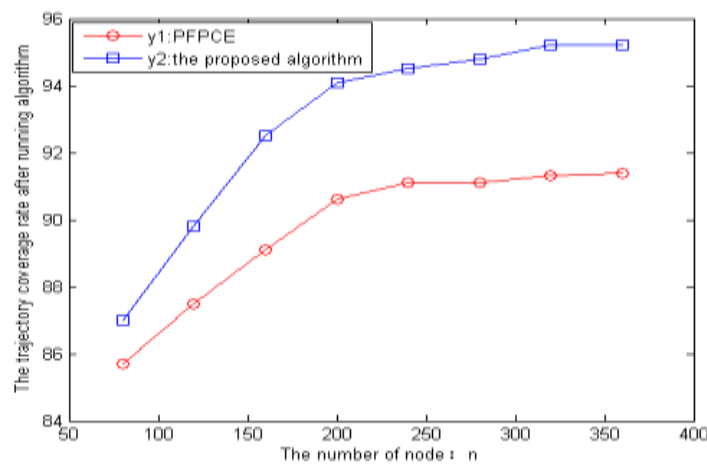

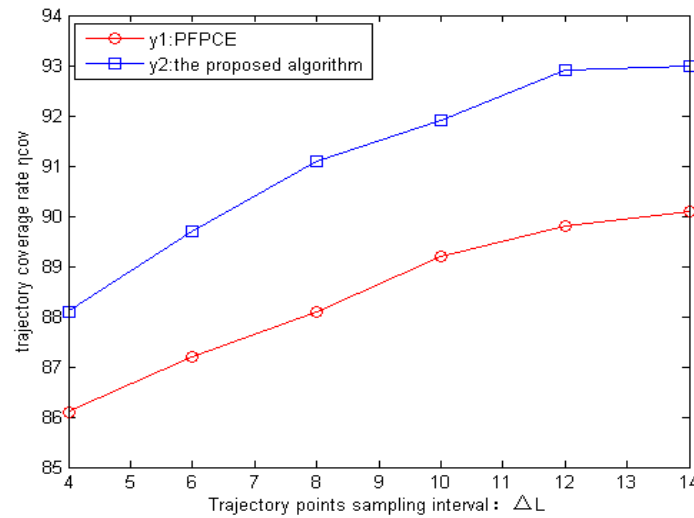**Fig. 10** the effect to the η_{cov} of trajectory after running PFPCE and this algorithm

Fig. 11 The relationship between sampling interval Δl and trajectory coverage rate η_{cov}

Fig.11 shows the relationship between sampling interval Δl and trajectory coverage ratio η_{cov}.

When the node number is less, the smaller the sampling interval Δl is, the smaller the detected probability of target points is. Because fewer nodes are deployed randomly, the nodes fail to maintain good coverage. When sampling interval Δl is increased, the coverage ratio of the tracking nodes is increased, and the algorithm in this paper is better than the PFPCE algorithm. When the nodes are gradually increasing, with the same sampling interval Δl, the detected probability of the target detected by the nodes within the trajectory belt is gradually increased. The algorithm in this paper has a larger coverage ratio, and with the continuous increase of nodes, the growth of trajectory coverage ratio is gradually decreased, and ultimately achieves 93%.

V.   CONCLUSIONS

Based on the probabilistic sensing model in this paper, the algorithm of path coverage in video sensor network is proposed. By processing the taget information obtained by the node and its neighbour node, making full use of redundancy of sensor network and adopting target sensing joint probability to integrating data, when a large number of nodes available in the monitoring area, namely very high initial coverage ratio, the high detected probability can be guaranteed. Compared with the PFPCE algorithm, the algorithm in this paper saves the energy of nodes, extends the lifetime of network, enhances the target sensing probability. The

simulation results show that The improved algorithm uses fewer sensor nodes, and can get more efficient coverage of video sensor network.

REFERENCES

[1] Ren Feng-yuan, Huang Hai-ning, Lin Chuang, "Wireless Sensor Networks ," [J]. Journal of Software, vol.14(7), pp.1282-1291, 2003.

[2] You-Chiun Wang, Yung-Fu Chen, Yu-Chee Tseng, "Using Rotatable and Directional (R&D) Sensors to Achieve Temporal Coverage of Objects and Its Surveillance Application ," [J]. IEEE Transactions on Mobile Computing, vol. 8(11), pp. 1358-1371, 2012.

[3] Cheng Wei-fang, Liao Xiang-ke, Shen Chang-xiang, "Maximal Coverage Scheduling in Wireless Directional Sensor Networks ," [J]. Journal of Software, vol.20(4), pp. 975-984, 2009.

[4] S.Mini, Siba K.Udgata, Samrat L. Sabat, "Sensor Deployment and Scheduling for Target Coverage Problem in Wireless Sensor Networks ,"[J]. IEEE Sensors Journal, vol.14(3), pp.636-644, 2014.

[5] Zhao Chun-Jiang, WU Hua-rui ,Liu Qiang, Zhu Li, "Optimization strategy on coverage control in wireless sensor network based on Voronoi ,"[J]. Journal on Communications, vol.34(9),   pp.115-121, 2013.

[6] Lu Ke-zhong, Feng Yu-hong, Mao Rui, Luo Qiu-ming, Liu Gang, "A Greedy Iterative Algorithm of Coverage Enhancing Problem in Directional Sensor Networks ,"[J]. Acta Electronica Sinica, vol.40(4), pp. 683-694, 2012.

[7] Tien-Wen Sung, Chu-Sing Yang, "Voronoi-based coverage improvement approach for wireless directional sensor networks ,"[J]. Journal of Network and Computer Applications, vol.39, pp. 202-213, 2014.

[8] Md.Mofijul Islam, Md.Ahasanuzzaman, Md.Abdur Razzaque, Mohammad Mehedi Hassan, Atif Alamri, "A Distributed Clustering Algorithm for Target Coverage in Directional Sensor Networks ," [C]. 2014 IEEE Asia Pacific Conference on Wireless and Mobile, 2014, 8, pp.42-47.

[9] C. K. Liang, C. H. Tsan, T. H. Chu, "Coverage enhancing algorithms in directional sensor networks with rotatable sensors ,"[C]. In Proc. IEEE Asia-Pacific Services Comput. Conf,

2011, 12,　pp.377-383.

[10]Tao D, Ma H.D, "Coverage-Enhancing algorithm for directional sensor networks ,"[J]. Mobile Ad-Hoc and Sensor Networks, vol.4325,　pp.256-267, 2006.

[11]Tao Dan, Ma Hua-dong, Liu Liang, " Study on Path Coverage Enhancement Algorithm for Video Sensor Networks ,"[J]. Acta Electronica Sinica, vol.36(7), pp. 1291-1296, 2008.

[12]Jiang Yi-bo, Wang Wan-liang, Chen Wei-jie, Zheng Jian-wei, Yao Xin-wei, "Coverage Optimization of Occlusion-Free Surveillance for Video Sensor Networks ,"[J]. Journal of Software, vol.23(2), pp. 310-322, 2012.

[13]J. Zhao, J. C. Zeng, "A virtual centripetal force-based coverage enhancing algorithm for wireless multimedia sensor networks ,"[J]. Sensors Journal, vol.10(8), pp.1328–1334, 2010.

[14]M. Amac Guvensan, A. Gokhan Yavuz, "A New Coverage Improvement Algorithm Based on Motility Capability of Directional Sensor Nodes ,"[J]. Ad-hoc Mobile and Wireless Networks, vol.6811,　pp.206-219, 2011.

[15]Liu Hui, Chai Zhi-Jie,Du Jun-zhao, Wu Bo, "Sensor Redeployment Algorithm Based on Combined Virtual Forces in Three Dimensional Space ,"[J]. Acta Autoumatica Sinica, vol.37(6), pp.713-723, 2011.

[16]Jiang Xu ,Huanyan Qian , Wenhao Ying ,Jun Zhang, "A Deployment Algorithm for Mobile Wireless Sensor Networks Based on the Electrostatic Filed Theory,"[J]. International Journal on Smart Sensing and Intelligent Systems,Vol.8(1),pp516-537,2015.

[17]Yin Zhouping, "Nodes Control Algorithm Design Based Coverage and Connectivity of Wireless Sensor Network,"[J]. International Journal on Smart Sensing and Intelligent Systems,vol.8(1),pp272-290,2015.

[18]Hengchang Jing, "Coverage Holes Recovery Algorithm Based on Nodes Balance Distance of Underwater Wireless Sensor Network,"[J]. International Journal on Smart Sensing and Intelligent Systems,vol.7(4),pp1890-1907,2014.

[19]Tao Dan, Ma Hua-dong, "Coverage Control Algorithms for Directional Sensor Networks ,"[J]. Journal of Software, vol.22 (10),　pp.2317-2334, 2011.

[20]Meng Fan-zhi, Wang Huan- zhao, He Hui, "Connected Coverage Protocol Using Cooperative Sensing Model for Wireless Sensor Networks ,"[J]. Acta Electronica Sinica, vol.4(39),pp.772-779,2011