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# Underwater Acoustic Sensor Networks Deployment Using Improved Self-Organize Map Algorithm

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**Abstract:** *The traditional Self-Organize Map* (*SOM*) *method is used for the arrangement of seabed nodes in this paper. If the distance between the nodes and the events is long, these nodes cannot be victory nodes and they will be abandoned, because they cannot move to the direction of events, and as a result they are not being fully utilized and are destroying the balance of energy consumption in the network. Aiming at this problem, this paper proposes an improved self-organize map algorithm with the introduction of the probability-selection mechanism in Gibbs sampling to select victory nodes, thus optimizing the selection strategy for victory nodes. The simulation results show that the Improved Self-Organize Map* (*ISOM*) *algorithm can balance the energy consumption in the network and prolong the network lifetime. Compared with the traditional self-organize map algorithm, the adopting of the improved self-organize map algorithm can make the event driven coverage rate increase about 3%.*

**Keywords:** *SOM, deployment, UW-ASNs, Gibbs sampling.*

## 1. Introduction

With the further research and application of wireless sensors, the scope of their application becomes wider and wider. Applying wireless sensor networks [1-3] under water (Underwater Acoustic Wireless Sensor Networks) has attracted greater attention of the researchers [4, 5].

The deployment strategy is a basic problem in underwater sensor networks. The deployment strategy of underwater sensor networks determines three key factors, including the energy consumption of nodes, the communication capacity and the network reliability. In 2006 Pompili et al. [6, 7] did a research about the three dimensional arrangement of the underwater sensor nodes at first, proposing the Bottom-Grid algorithm which was based for the arrangement of triangle grid nodes underwater to reach the goal of seamless coverage in the monitoring area with fewest nodes, forming a three-dimensional node arranging scheme by adjusting the depth of the node. But the Bottom-Grid algorithm is a centralized one, the adjustment of the node position needs the basis of the global information which is difficult to achieve and the research emphasis is mainly on one-seamless coverage which is unable to meet the needs of application in many cases. In 2007, aiming at different perceptual demands in the monitoring region, Aitsaadi et al. [8] put forward the Differentiated Deployment Algorithm (DDA), using the mesh line representation, arranged the sensor nodes unevenly and realized different coverage in the monitoring area. Aiming at the irregular region, DDA arranges the underwater sensor nodes more practically according to different coverage needs, and it can match well the coverage requirements with the coverage of the arranged nodes. Nevertheless, it is difficult to achieve this in reality because the algorithm is a centralized one which only suits for a static monitoring goal. About a dynamic monitoring goal there is no research, and the algorithm only suits for water quality monitoring in closed environment. In 2008 Pashko et al. [9] transferred the problem of arranging nodes to the problem of linear programming and found a solution based on the prediction of the danger point underwater, using the rules approximation method to achieve the coverage of the danger points underwater. This method is a comprehensive research with better properties of the coverage, but it does not pay any special attention to the danger regions with high-visit probability. In 2009 Akkaya and Newell [10], basing on the above work proposed a self-deployment algorithm, further reducing the repetitive coverage between neighbor nodes, and improved the coverage rate of the monitoring area. The self-deployment algorithm is a distributed one, simple and easy to be realized with better properties of the coverage and the connectivity. But the pros and cons of the algorithm are directly related to the initial distribution of the nodes underwater. So, it is difficult to guarantee the validity of the algorithm and it also does not adapt to the application of multiple coverage needs. In 2010 Golen et al. [11] estimated the probability of sub-regional events underwater by solving the minimax game matrix and accordingly calculated the number of nodes in each sub-region needing to allocate nodes. This method associates the node arrangement with the probability estimates of the events efficiently, which is more targeted. But this method focuses more on the probability estimates of the events (centralization) and the number of nodes assigned to each part without any detailed information about the nodes arrangement.

These existing methods cannot fully meet the need of the application demands of underwater sensor networks, due to three problems.

1) Most of the methods are centralized optimization methods, which are difficult to be achieved by the distribution of nodes.

2) They mainly aim at determined event nodes. For uncertain events under open water environments and dynamic changing events due to the external factor of ocean currents, it is difficult to adjust the node deployment to ensure monitoring quality.

3) There has not been yet a performance evaluation metric of the sensor nodes arrangement underwater driven by events.

Aiming at the above problems, this paper studies the sensor nodes arrangement method with uneven coverage needs in the three dimensional space under the water and designs a distributed underwater sensor node arrangement algorithm based on the improved self-organize map [12, 13]. This paper proposes an algorithm combining Self-Organize Map (SOM) algorithm with the sensor networks and puts forward a performance evaluation metric of the sensor nodes arrangement underwater driven by events. Unlike the previous work, this algorithm is distributed, open, and self-adaptive, which measures the advantages and disadvantages of the distribution based on the performance evaluation index of the sensor nodes arrangement underwater driven by events. At the same time this algorithm considers better equilibrium of all nodes, so that it improves the selection mechanism optimization of victory nodes.

The traditional self-organize map method is used for seabed nodes arrangement. That is to say, according to the distance between the event and the node, it chooses the nearest node as a victory node for the event and makes the victory node move to the event. Each event has a victory node, eventually making all the nodes move to the event in order to cover the events. But if the distance between some nodes and events is far, these nodes cannot be victory nodes and they can be abandoned not moving to the direction of the event, so that those nodes have not been fully utilized.

Aiming at this problem, the paper introduces the probability-selection mechanism in Gibbs sampling which is adopted for selection of victory nodes. The closer the distance between the node and the event is, the greater possibility of the node to be chosen as a victory node is. The smaller the chances of the nodes to be selected as victory nodes before are, the greater the probabilities of nodes to be selected as victory nodes are this time. Although the probabilities of nodes far from the event to be selected as victory nodes are very small, they may also probably be victory nodes and move to the direction of the event after the nodes near events all become victory nodes. Thus, every node in the network is fully used to balance the network energy consumption and prolong the lifetime of the network.

The second part of this paper describes the researched network model. The third part proposes an improved self-organize map deployment algorithm and makes comparison with the traditional self-organize map deployment algorithm. The fourth part puts forward a performance evaluation metric of the sensor nodes arrangement and carries out simulation analysis about the improved self-organize map deployment algorithm. Finally, a conclusion is given.

# 2. Modeling of the node deployment in UW-ASNs

## 2.1. Description of the node deployment in UW-ASNs

In UW-ASNs, the task of nodes is to collect the events information. The nodes are usually arranged in the monitoring region underwater, through underwater nodes to cover the monitoring area to achieve the purpose of monitoring. The underwater sensor node arrangements can be divided into the seabed and ocean node arrangement. This paper only considers the seabed node arrangement, which can be attributed to node arrangement in a two-dimensional plane.

Assuming that the underwater sensor node set is $S=\{s_1,s_2,...,s_n\}$, and $n$ is the number of underwater sensor nodes. Any node $s_i$ underwater has the ability of **p**erception, **c**ommunication and mobility. $B_i=\left\langle r_i^{\rm p}, r_i^{\rm c}, l_i\right\rangle$, among them, $r_i^{\rm p}\geq 0$, $r_i^{\rm c}\geq 0$, $l_i\geq 0,\ 1\leq i\leq n,$ respectively describe the radius of perception, the radius of communication and the largest mobile step of $s_i$. All $s_i$ in the homogeneous network have the same attribution, namely $r_i^{\rm p}=r^{\rm p}$, $r_i^{\rm c}=r^{\rm c}$, $l_i=l,\ \ 1\leq i\leq n.$

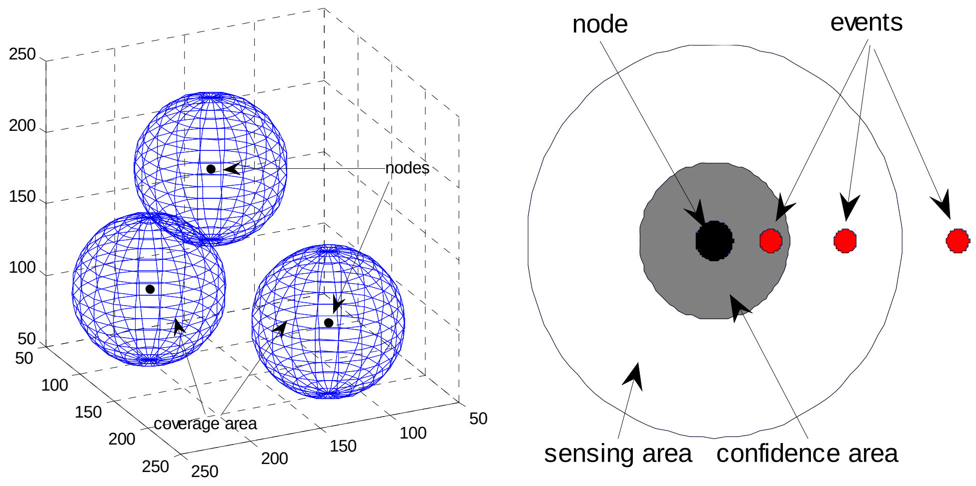
**Definition 1.** *Event*: Assume the monitoring region A. There the dynamic point which the user is interested in, is called an event. We assume an event set $E=\{e_1,e_2,...,e_m\}$, $e_i\in A$, $i = 1, 2,\ldots, m$.

**Definition 2.** *The coverage and k-coverage*: In the monitoring region A, $\forall e_i\in A$, if the distance between the underwater sensor $s_j$ and the event $e_i$ is less than or equals to $r_j^{\rm p}$, that is $d(e_i,s_j)\leq r_j^{\rm p}$, then $e_i$ is covered by the underwater sensor node $s_j$. Thereinto $d(e_i,s_j)$ is the Euclidean distance between the underwater sensor $s_j$ and the event $e_i$. $k$-coverage: if for $\forall e_i\in A\ \ \exists\, s_1,s_2,...,s_k\in S$, $e$ is covered by $s_1,s_2,...,s_k$, then $e_i$ is covered by $k$.

For the binary cover model if the event is in the range of perception, the probability that the event is detected is 1, otherwise it is 0:

$$c(e_i,s_j)=\begin{cases}1 & \text{if } d(e_i,s_j)\leq r(s_j),\\ 0 & \text{otherwise.}\end{cases} \tag{1}$$

For the seabed node deployment we assume that all underwater nodes can implement the whole direction monitoring of the surrounding, and its coverage is a circular region $D=\pi(r^{\rm p})^2$ with the node as a center of the circle and the radius as $r^{\rm p}$, which is the perception model based on a round. The nodes can efficiently detect the information within the coverage area.



(a) (b)

Fig. 1. The sensing range of nodes in 3D mode (a); probability model of nodes (b)

For the ocean sensor node deployment we assume that all sensor nodes can implement the three-dimensional omnidirectional monitoring of the surrounding. Its coverage is the spherical region $\Omega = 4\pi(r^{\mathrm{p}})^3/3$ with the node as center of the sphere and the radius as $r^{\mathrm{p}}$, which is the perception model based on a sphere, and active nodes can efficienty detect the information within the coverage area, as shown in Fig. 1a.

For the probability coverage model shown in Fig. 1b, the perceived probability of the nodes in the perception range is shown by the next formula (2). In the confidence circle (in the unit distance with nodes), the perceived probability of events is 1, and when the event is between the confidence circle and the perception circle, the perceived probability of the events will decrease with the increase of the distance between the events and the nodes, when the event is out of the perception circle, the event cannot be perceived by the sensor nodes:

$$(2) \qquad c(e_i, s_j) = \begin{cases} 1 & \text{if } d(e_i, s_j) \le 1, \\ \dfrac{\alpha}{d(e, s_i)^{\beta}} & \text{if } 1 \le d(e_i, s_j) \le r(s_j), \\ 0 & \text{if } d(e_i, s_j) \le r(s_j), \end{cases}$$

where $\alpha$ is a related parameter of the underwater sensor technology and $\beta$ is a parameter of the propagation properties. This paper uses a binary coverage model. The underwater node arrangement problem is to arrange the sensor nodes in the monitoring region A underwater to make the node distribution density and the event distribution density tend to be uniform, and make the nodes cover events as much as possible at the same time. That is to say, the region with more events must be arranged with more sensor nodes, and the region with less events is only arranged with less sensor nodes. We balance the perception task in the underwater sensor network and the energy consumption of the perception events, prolong the network survival time and solve more complex problems. We have defined the communication radius $r_c$ between the nodes in the former section. If the distance between the two active nodes is less than or equal to $r_c$, the two nodes can communicate with each other reliably.

**Definition 3.** *Connectivity*: We assume that $G(s, B), \quad s \in S,$ is the underwater communication graph of nodes. If $\forall\, s_i \quad s_j, i, j \in \{1, 2, ..., n\}$ the edges between $s_i$ and $s_j$, are described as $\langle s_i\ s_j\rangle$. $\langle s_i\ s_j \rangle \in B$ and if $d(s_i, s_j) \le r^{\mathrm{c}}$, the communication graph $G(s, B)$ is connected.

In the two-dimensional sensor network model underwater, similar to terrestrial wireless sensor networks, the nodes cluster as clusters, and the cluster heads collect the information within the clusters, and then the cluster heads transfer the information to the base station. In the 3D model for sensor networks underwater, unlike terrestrial wireless sensor networks, it is in the three-dimensional space. Its perception range of nodes is a sphere without the concept of clusters and the nodes are equal in status with the same function, that is to say, the connectivity between the nodes is established on the basis of the communication.

### 2.2. The fluid model

The underwater environment is complex, with the effect of underwater objects caused by the fact of a flow or a vortex, etc. So the following part would introduce a mobile model for the underwater environment: River mobile model.

By [14], for incompressible liquid, the two-dimensional flow is described by the stream function Ψ, and a stream function generally contains two velocity fields $\mathbf{u} \equiv (u, v)$ with different directions, which can be expressed as follows:

$$u = -\frac{\partial \Psi}{\partial y}, \quad v = \frac{\partial \Psi}{\partial x}, \tag{3}$$

where $u$ is generally the velocity field with eastward direction, and $v$ is generally the velocity field with northward direction. With a mobile flow the race of Lagrange method can be described as follows by Hamilton differential equation:

$$\dot{x} = -\partial_x \Psi(x, y, t), \quad \dot{y} = -\partial_x \Psi(x, y, t). \tag{4}$$

This paper adopts the following water jet model:

$$\Psi(x, y, t) = -\tanh\left[\frac{y - B(t)\sin(k(x - ct))}{\sqrt{1 + k^2 B^2(t)\cos^2(k(x - ct))}}\right], \tag{5}$$

where $B(t) = A + \varepsilon\cos(\omega t)$, the model contains a transmission network of the flow and strong chaos; $k$ represents the number of bends per unit length; $c$ represents the phase velocity; the time correlation function $B$ modulates the width of the curve; $A$ represents the average bending width; $\varepsilon$ represents the amplitude of the modulation, and $\omega$ represents the frequency of the modulation. For example: $A = 1.2$, $c = 0.12$, $k = 2\pi/7.5$, $\omega = 0.4$, $\varepsilon = 0.3$, 42 event nodes initially form a linear uneven distribution in the area underwater. After the effects of water flows, by (5) we obtain the simulation results as shown in Fig. 2 which shows the events movement with flows. At different time, the location of the event changes, namely, the dynamic events.

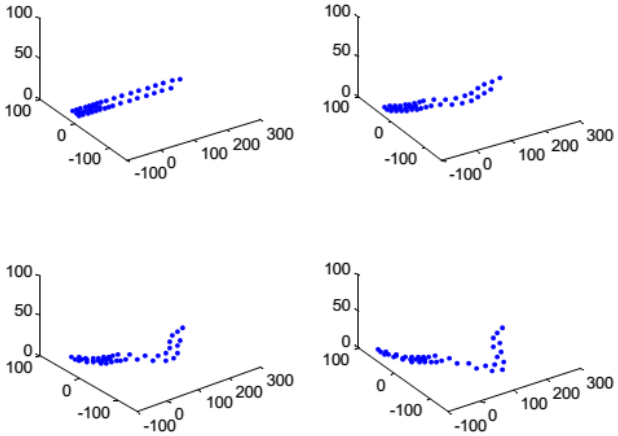


Fig. 2. Events move with the water flow

## 3. The improved self-organize map algorithm

Self-Organize Map (SOM) algorithm is a kind of unsupervised clustering algorithms, which classify the target by a certain method. Section 3.1 will introduce the basic self-organize map algorithm. Section 3.2 will put forward the undersea sensor node deployment based on the Improved Self-Organize Map (ISOM) algorithm.

### 3.1. The basic self-organize map algorithm

The self-organize map algorithm is an unsupervised clustering method and its basic idea is: the network obtains response opportunities of input models by the competition between neurons. Ultimately, only one neuron becomes the winner and it adjusts the related connection weights with the winner neuron accordingly, which makes easier to win in the later competition. The final competition winner shows the classification of this input pattern [15].

The clustering operation is achieved by calculating the differences (and similarities) between all input vectors $a_i$, $i = 1, 2, \ldots, n$, and each weight vector $w_j$, $j = 1, 2, \ldots, n$, which combines the input vectors with the neuron $j$ in the self-organize map. The criterion used in common is the Euclidean distance:

$$e_{ij} = \sqrt{\sum_k \left[ a_{ik} - w_{jk} \right]^2}, \tag{6}$$

where $k$ denotes $k$-th component of the vector. After the calculation, by comparison, when $e$ is small, it becomes the winner neuron, and the output is “1”, otherwise, the output is “0”. The update of the weight is calculated by the difference of the current input vector $a_i$ and the current weight $w_j$ $(n)$, as shown in Fig. 3. Here, $n$ denotes the number of iterations. The winning neuron weight is calculated as follows:

(7) $$w_j(n+1) = w_j^*(n) + \alpha\left[a_i - w_j^*(n)\right].$$

For the other neuron weights

(8) $$w_j(n+1) = w_j(n).$$

Thereinto, the asterisk denotes the winner neuron; $\alpha$ represents the learning rate, $0 < \alpha < 1$.

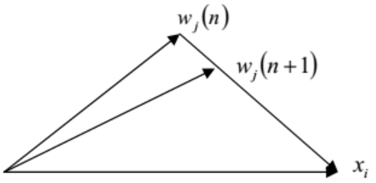


Fig. 3. The adjustment of the victory node position

### 3.2. The design of the node deployment algorithm based on ISOM

We assume that the target region is a static two-dimensional area, not affected by the water flow and others. Based on the principle of Section 3.1, the node will eventually move towards the direction of the event. The cores of the algorithm are: at first, the event makes a judgment about its nearest node which is selected to be its own victory node. Then the victory node of the event moves to this event. A node can be a victory node of multiple events, while an event only has one victory node, i.e., each event has attraction to the other event, and eventually all nodes will tend to the event completing the task of the event coverage. The preliminary test results are shown in Fig. 4 where the dots represent the events; the small green triangles represent the nodes' initial positions; the small red squares represent the positions of the node after the basic SOM algorithm arrangement. After the initialization, some nodes are in the event area, and some are out of the event area. Through SOM algorithm there are more nodes entering the event area to monitor targets.

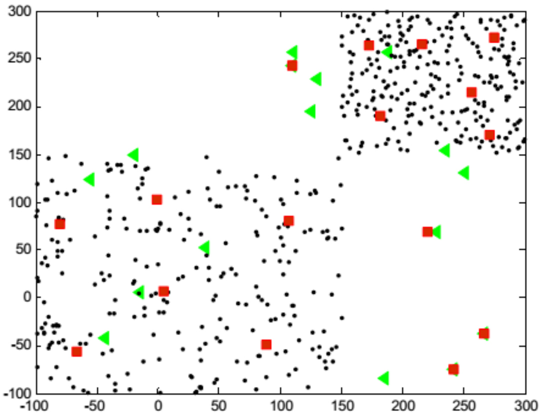


Fig. 4. The event-driven node deployment of the basic SOM

Although the node arrangement driven by events based on the self-organize map can make the node move to the event with the purpose to monitor the target region better, it can be seen from Fig. 4.

(1) When some nodes are very close to events, others far away, the victory nodes of all events may be just nodes in the close region. The nodes in the close region move to events, while the nodes far away do not become victory nodes so as to be abandoned. Those nodes do not participate in monitoring the target area so that they are not fully utilized.

(2) In high density areas of the event, failing to deploy more nodes easily leads to the earlier death of the regional nodes with many events and networks paralysis. So, this paper puts forward the improved algorithm to overcome the above shortcomings.

The reason investigated is mainly the victory nodes selection strategy. Because the nodes, close to the event definitely become victory nodes, and the ones far from the events definitely do not become victory nodes and they are abandoned easily. Some nodes probably become victory nodes of many events, while others probably become victory nodes for less events. This makes it difficult to arrange more nodes in the high density event areas.

This paper commences from the selection strategy of the victory nodes to improve the self-organize map algorithm so that the nodes far from events may also become victory nodes, not abandoned. At the same time, more nodes are arranged in the high density event areas. Each node is fully utilized to balance the energy consumption in the network and to prolong the network survival time.

Gibbs sampling algorithm [16-18] is a special kind of Markoff Monte Carlo algorithm, whose most significant characteristics are to structure the Markov chain of the algorithm by the method of constructing the conditional distribution sequence along a series of complementary directions. Then calculate all kinds of choice probabilities through structuring the energy function; choose the next state according to the different probabilities. Inspired by Gibbs sampling probability selection, this paper adopts the probability choice method to select victory nodes of every event. The probabilities of nodes closer to the event to be victory nodes, are greater. The fewer the time of the node to be a victory node is, the higher the probability of the node to be selected as a victory node is. The selection probability of the victory node is shown by equation given bellow. We assume that the time of $i$-th node to be selected as a victory node is $N_i'$. The closest distance between the $i$-th node and the event is $d_{\min}(i)$, and $N$ is the total number of sensor nodes. Adopting the probability selection strategy of the victory nodes, we calculate the probability of each node becoming a victory node for every event:

$$(9)\qquad p(i)=\frac{e^{-\beta N_i' d_{\min}(i)}}{\sum_{m=1}^{N} e^{-\beta N_m' d_{\min}(m)}},$$

where $\beta$ is a constant, which is mainly used for amplifying the difference between every state. According to the difference between various states, we adjust the selection of parameter $\beta$. If the difference between each state is smaller, then the value of $\beta$ is bigger, and vice versa. On the contrary, it is smaller. The closer the distance between the node and the event is, the greater the probability of the node becoming a victory node is. The smaller the time of the node being the victory node is, the greater the probability of the node becoming a victory node is. In this way we can guarantee all nodes participate in the monitoring of target areas with full usage of each node. At the same time, high density areas can attract more nodes to ensure that the arranged node density matches the event density.

## 4. Simulation and analysis

### 4.1. The performance evaluation index of the node deployment

According to the modeling and analysis of the underwater sensor network node arrangement as above shown, this section proposes a new performance evaluation index of the underwater sensor node arrangement – cover efficiency, which can well evaluate the performance of underwater sensor network node deployment.

The following section will describe the problem of underwater sensor node in a binary coverage model. The coverage degree of the event $e_i$ is defined as

$$D(e_i) = \sum_{s_k \in S} I(d(e_i, s_k) \le r_k^{\mathbf{p}}). \tag{10}$$

In the formula, $I$ is an indicator function. When the conditions are satisfied, it equals to 1, otherwise 0.

**Definition 4.** *Relatively efficient coverage*: A node arrangement scheme is given; the relatively efficient coverage degree of event $e$ is defined as

$$C_A(e_i) = \frac{D(e_i)}{\sum_{e_u \in E} D(e_u) \left[ 1 + \sum_{e_v \in E, e_i \ne e_v} I(d(e_i, e_v) \le r^{\mathbf{p}}) \right]}, \tag{11}$$

where $d(e_i, e_v)$ is the Euclidean distance between the event $e_i$ and event $e_v$, so that $\sum_{e_v \in E, e_i \ne e_v} I(d(e_i, e_v) \le r^{\mathbf{p}})$ is the neighbor event number of the event $e_i$.

The problem of underwater node arrangement is to arrange the sensor nodes in the monitoring area A under the water, which makes sure that the relatively efficient coverage degree $s$ of all events are equal, so that the node density and the event distribution density tend to be consistent (the area with many events contains more nodes, and the area with a few events contains fewer nodes). Meanwhile, we make more nodes cover the event.

The following section introduces the information entropy to evaluate the equilibrium of the relatively efficient coverage of the event. We structure the conditions of a complete set as follows:

$$C'_A(e_i) = \frac{C_A(e_i)}{\sum_{e_p \in E} C_A(e_p)}. \tag{12}$$

The covering entropy of an event set is defined by

$$H_A(E) = -\sum_{e_i \in E} C'_A(e_i) \log C'_A(e_i), \tag{13}$$

which describes the equilibrium of the relatively efficient coverage for events appropriately.

The covering efficiency of an event set is defined as

$$\eta(E) = \alpha \frac{H_A(E)}{\log m} + \beta \frac{\hat{n}}{n}. \tag{14}$$

In (14), α, β∈[0, 1], and α+β=1; $\hat{n}$ is the total number of nodes of the coverage events.

Obviously, when $C'_A(e_i) = 1/m$, $i$ = 1, 2, …, $m$, the covering entropy $H_A(E)$ reaches the maximum value $\log_m$. Meanwhile, if all nodes cover the events, that is $\hat{n} = n$, then $\eta$ ($E$)=1 reaches the maximum value. Above all, the problem of the underwater node arrangement is to reach the maximum of $\eta(E)$ by arranging the sensor nodes in the monitoring area A underwater.

The section below will illustrate that $\eta(E)$ can describe the coverage quality driven by events, as the performance evaluation index of the sensor node arrangement.

In a two-dimensional space, the number of the events and the relatively effective coverage $C'_A(e_i)$ of the round area $D = \pi(r^{\mathrm{p}})^2$ with event $e$ as the center and $rs$ as the radius reflect the relative relationship between the node density and the event density in region D. When the relative relationship between the node density and the event density in region A are close to or the same, we can achieve the match between the node density and the event density. That is to say, when $C'_A(e_i)$ is equal, the covering entropy $H_A(E)$ reaches the maximum. At the same time, when the nodes cover events as much as possible, the cover efficiency $\eta(E)$ can reach its maximum. It is also applicable in a three-dimensional space.

### 4.2. Simulation experiment settings and result analysis

This paper uses Matlab to carry on the simulation of the underwater node arrangement. The experiment in this paper spreads randomly event nodes with $L$ type uniform, linear non-uniform, block random non-uniform, circular non-uniform distribution in the 400×400 region. There are 16 sensor nodes with the sensor perception radius of 50. The initial positions of the nodes are randomly spread in the area. The experimental results are obtained for 150 iterations.

From Figs 5a-d, respectively the simulation results with $L$ type uniform, linear non-uniform, block random non-uniform and circular non-uniform distribution for events are shown. In Fig. 5, the black spots are events; the small green triangles are initial sensor positions; the red squares are the results of the basic self-organize map method, and the blue squares are the results of the improved self-organize map method.

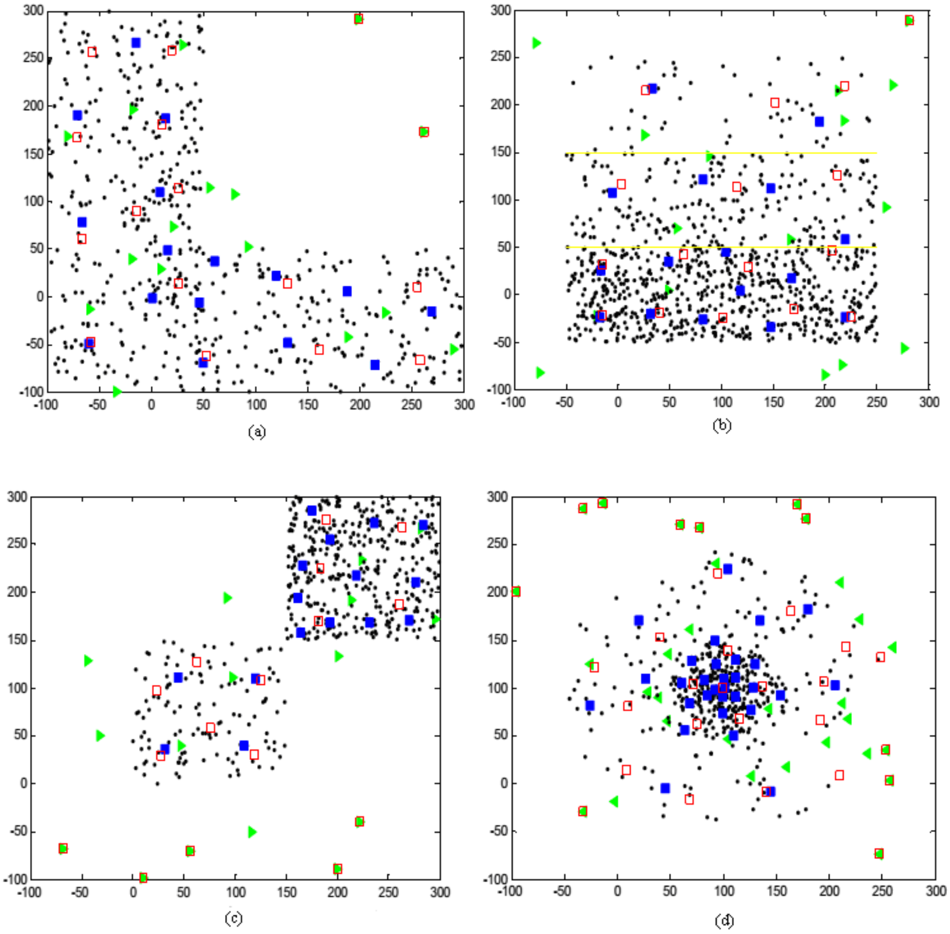


Fig. 5. The distribution simulation of underwater node events:
the *L* type uniform distribution (a); the linear non-uniform distribution (b); the block random non-uniform distribution (c); the circular non-uniform distribution (d)

This paper takes the event block non-uniform distribution as an example to compare with the basic SOM method. The following section is the analysis in two aspects.

### 4.2.1. The event-driven coverage rate

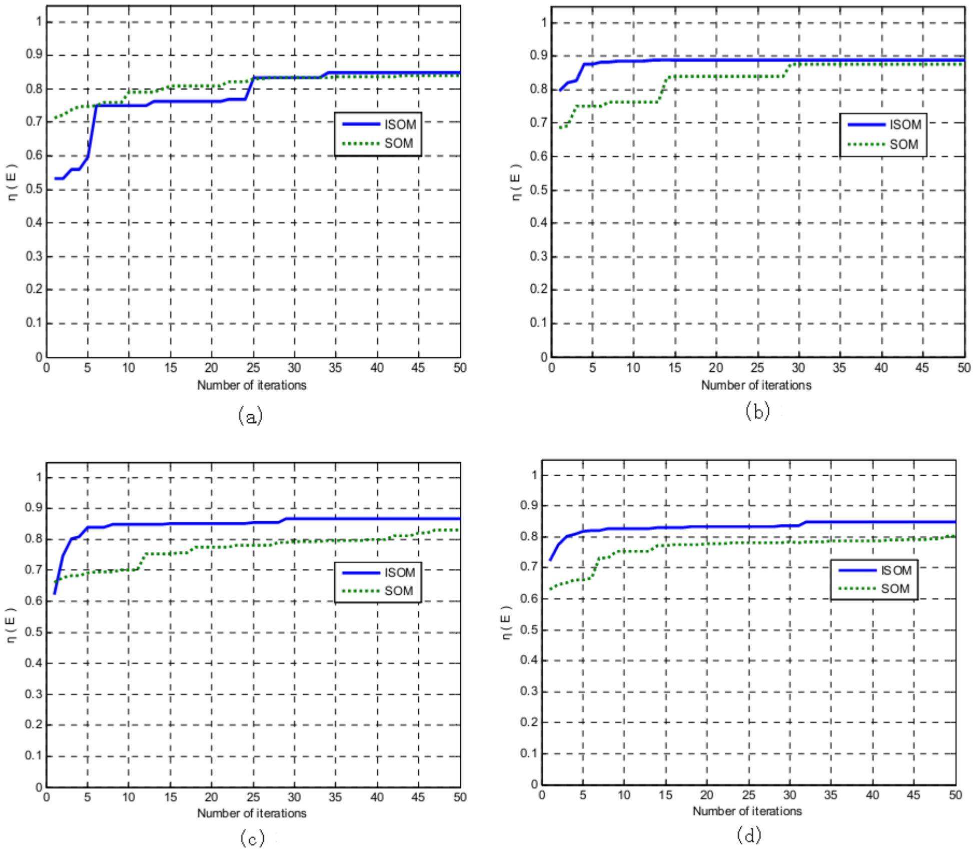
The coverage rate is to arrange the nodes driven by events, which is called the event-driven coverage rate. The event-driven coverage rate is the basic optimization index for the node arrangement, but it cannot evaluate the disadvantages and advantages of the index for balancing the node arrangements of non-uniform perception needs. So, this paper only takes the event block non-uniform distribution as an example, and lists two kinds of statistical data comparison of the event-driven coverage rate, as shown in Table 1 respectively. From the table we can see that under the condition of the event block non-uniform distribution, the event-driven coverage rate based on ISOM method is better than that based on SOM method.

Table 1. The comparison of the event-driven coverage rate with the block non-uniform

| Method | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| SOM | 86.4% | 87.1% | 85.3% | 89.9% | 83.6% | 88.7% | 85.5% | 82.8% | 84.4% | 86.2% |
| ISOM | 92.5% | 93.8% | 89.2% | 91.6% | 90.9% | 92.7% | 91.4% | 90.9% | 91.5% | 92.1% |

### 4.2.2. The covering efficiency of an event set

In the events with *L* type uniform, linear non-uniform, block non-uniform, circular non-uniform distribution, the evolution processes of the covering efficiency are shown in Fig. 6. From Figs 6a-d we can see that no matter what shape distribution is presented, the covering efficiency is always good and the convergence is very fast, which shows that in a few iterations, the nodes can well cover events and they will realize the match between the node density and the event density.



(a)

(b)

(c)

(d)

Fig. 6. The coverage efficiency comparison with different types of distribution: the *L* type distribution (a); the linear distribution (b); the block distribution (c); the circular distribution (d)

It is shown in the simulation results that the properties, based on ISOM method, such as the event-driven coverage rate, covering efficiency of the event set and the convergence speed, are all better than those, based on SOM method. The improved SOM method inherits the merits of the former one; overcomes the disadvantages, and makes full use of the selection strategy of victory nodes. It is possible for all nodes to be selected as victory nodes. This method has certain effects in the network. In addition, to improve SOM method by consideration of the node time being selected as a victory node and the distance between events and nodes, could overcome the case of existing abandoned nodes in the basic SOM method. This realizes the arranged node density in the region with the event different probability to match the probability of events, which makes the nodes fully utilized and the perception tasks balanced. Moreover, the network lifetime is prolonged, and more complicated problems are solved.

## 5. Conclusion

This paper adopts the self-organize map method for seabed node arrangement, namely that according to the distance between the node and the event, we choose the nearest node as the victory node of the event and make the victory node move to the event. Because each event has a victory node, all nodes are eventually made to move towards events until they cover the events. But if some nodes are far from events, then these nodes cannot be victory nodes. They cannot move to the direction of events, so they are abandoned without full usage.

Aiming at this problem, this paper introduces the probability selection mechanism of Gibbs sampling which the selection of the victory nodes uses. The closer the distance between the node and the event is, the greater the possibility of the node being selected as a victory node is. The smaller the chance of the node being selected as a victory node before is, the greater the possibility of the node being selected as the victory node is this time. Although the possibilities for the nodes far from events to be victory nodes are small, they can also be victory nodes and move to the events direction, after the nodes near the events become victory nodes. Thus, each node in the network is fully used to balance the network energy consumption, prolong the lifetime of the network and solve more complicated problems. Finally, through comparisons of multiple experiments, we validate the rationality and validity of the algorithm.

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