Localization Method for Wireless Sensor Networks Using Nero-Fuzzy

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Abstract – A wireless sensor network includes a series of nods, each of them containing some sensors which have a role in gathering data about the circuit in which they are distributed. Sensor networks enjoy variety of uses; that is why they are attracted by many countries. In a sensor network, few nods have already known their position which are called anchor node; other nods must calculate their position accordingly. In this essay, "received signal strength indicator" and "Nero-Fuzzy" are used in order to calculate unspecified-position nods' coordinate. Each unspecified-position node must know the position of some nearing anchor nodes. The more the nodes are, the more precise the coordinate is. In this essay, unspecified node's coordinate is estimated according to two or more anchor nodes using logic fuzzy. Since the range covered by sensor networks is broad, finding all anchor nodes is a time-consuming task and needs a lot of memory. Therefore, distance limit between anchor nodes and unspecified nodes is considered. The area around anchor nodes and unspecified nodes is divided reticulated, and then, the unspecified node's coordinate is estimated according to fuzzy logic rules. The estimated average error rate for 120 nodes using this method equals to 2% of radio range, which is minimal in comparison to APS algorithm.

Keywords: Sensor network, Anchor node, Ad-hoc localization system, Fuzzy logic

1. Introduction

Wireless sensor networks are distributed networks consisting of vast numbers of sensor nodes with limited capability. Being chip, wide implementation, and parallel-calculating ability are among numerous privileges of wireless sensor networks [1]. However, they suffer some limitations, such as limited communication and power, as well. In past, some sensors were wired to the processing unit, now the emphasis is on compact wireless nodes, though. Each node can cover a small part of the area; finally, all nodes' data is gathered together to demonstrate more precise details. Sensor networks are divided into different groups considering the way they are broadcasted [2]. Since the relation between the nodes is the main cause of using energy, all process must be done compactly, which means all process must be done locally as much as possible.

1.1 Applications of wireless sensor networks

Wireless sensor networks enjoy a variety of applications like martial, medical, security, agricultural, industrial, earthquake prediction, and routing [3]. Sensors can distinguish pests in farmlands, fire in vast forests, and the number of people and armored in an army.

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1.2 Features of wireless sensor networks

A: Substructure free

Sensor networks are usually distributed haphazardly by helicopter, airplane, rocket, or human; and their connection is wireless.

B: Dynamic changes

After being distributed in the circuit, nodes in wireless sensor networks must have the ability to configure themselves, and to rebuild themselves without human or robot interference when they are out of order. They must also have the ability to adapt themselves to the changes occurring in the connections; for instance, when the nods are compact, and when overlapping takes place among the nodes.

C: Using Energy

Sensor networks nodes are attached to no permanent power. They are merely attached to a limited power source which is used to connect nodes and to process. Connecting nodes need more energy than processing, so, by decreasing the connection between the nodes, the required energy declines. Connecting models of wireless sensor networks include: 1. "transferring data model" which explains the strategy to stimulate data sending, and 2. "data distribution protocol" which explains the strategy to distribute sensor data from the power source to synch nodes. Considering "transferring data model", wireless sensor networks are divided into 4 groups including:

- Alternative: Each sensor transfers its data constantly to transmitter
- Chromatic: Each sensor transfers its data when a predefined event takes place
- Answer-demanding: Each sensor transfers its data when it receives a clear demand from user
- Compound: Using the three mentioned methods when needed

2. Localization

Sensor nodes are randomly distributed among the circuit; so first, it is required for them to know their coordinate before gathering data [4]. Localization is really important because first, sending data from a node is of no value without its coordinate existence, and second, there are some routing algorithms which use nodes' coordinate to perform [5], [6].

In past, using GPS (Global Positioning System) directly was the solution; nowadays, however, it is not used to localize sensor nodes due to following reasons:

- GPS cannot be used in indoor places and full-planted areas
- Using GPS decrease battery duration because of numerous connections; this can cause the decline in network duration
- GPS dimensions and its antennas expand sensor nods which is in contrast with small light nods
- GPS equipment is expensive
- Measurement error in GPS is high

Therefore, various methods are offered so that the nodes can find their position at the lowest cost and without substructure.

2.1 Localization methods

There are three methods to calculate a node's position in a network: proximity (using nearby nodes' data), trilateration-triangulation (using geometric thesis), and sense analysis (analyze coordinate comparing pre-gathered data)[12].

2.1.1 Proximity

In this method, anchor nodes send their absolute coordinate by radio signals. Because these signals' range is short, nodes near to anchor nodes can approximately estimate their coordinate using some anchor nodes' data. Usually, the data sent is general [13].

2-1-2. Trilateration-triangulation technique

Telecommunication between the nodes can distinguish their position comparatively; for instance, using the distance between two nodes (literation) or the shared angle of a node and an anchor node (angulation). Using these data, one can precisely say the absolute position of nodes [13].

2.1.2.1 Distance measurement techniques

- **Signal received energy:**

In this method, the distance is measured according to the difference between signal received energy and signal sending energy [2],[7],[8]. It is usually used for radio frequency, because it does not need side hardware, and also due to it's communicating low cost. However, if it is indirectly broadcasted, there will be error in calculating distance [2].

There are three models of broadcasting:

1. Outdoor area model
2. Double-linear reflexive model
3. Shadow model

In the first two models, communication area is supposed as an ideal circle, and received energy is calculated as a function of distance. Shadow model converts the ideal-circle model into a statistical model. It means if the nodes are in the range, they can relate by time possibility [9].Waste energy factor (a) is calculated by following equation in shadow model.

$$\frac{\Pr(d0)}{\Pr(d1)} = \left(\frac{d1}{d0}\right)^{a} \quad (1)$$

d0: distance of a fixed point

Pr(d0): received energy of the fixed point

d1: distance of the new point

Pr(d1): received energy from the new point

a amount is different in different areas shown in the table1.

Table1 Amount of A

A	*Area*	
2	Open area	Outdoor area
2.7 – 5	Jungle	
1.6 – 1.8	Without obstacle	Indoor area
4 – 6	With obstacle	

Received energy knows the specified distance of d0 and Pr(d0), estimates the received energy in d1, and shows it by

Pr(d1).

- **Time of arriving (TOA)**

In this method, distance is calculated by sent time and sent speed (figure 1). (d=v.t) Sender and receiver must be synchronic; otherwise, calculated distance would be wrong [10].

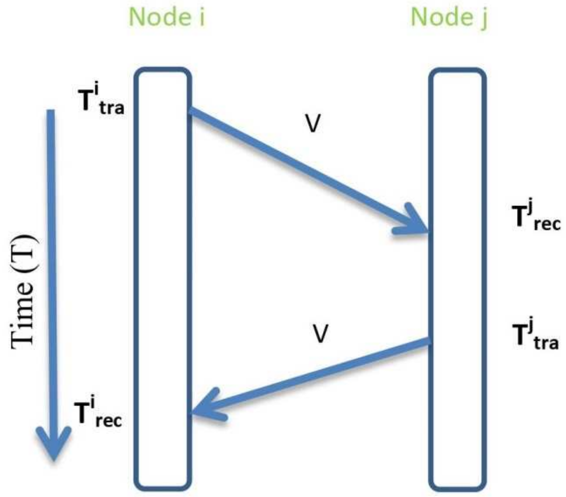

Figure1 Calculate the distance in the ToA method

$$d_{ij} := 2^{-1}\left[\left(T^i_{rec} - T^i_{tra}\right) - \left(T^j_{tra} - T^j_{rec}\right)\right]\cdot V \quad (2)$$

*V is m*edia release speed in the environment. Moreover, special factors including obstacles can also affect it since broadcasting speed performs differently according to the area.

- **Difference of time of arriving (TDOA)**

In this method, two signals with different broadcasting speed are used to measure the distance. The first signal is faster than the second signal. The distance is calculated by the difference in two signals arriving [7] (figure 2).

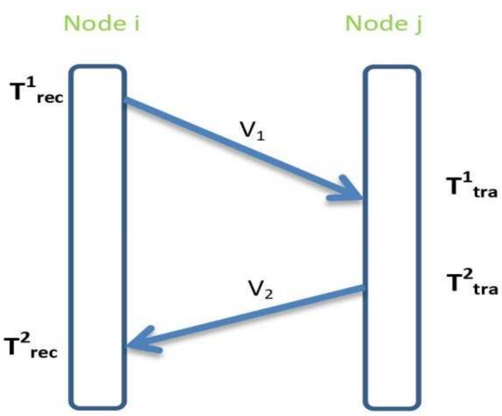

Figure2 Calculate the distance in the TdoA method

V1 is First media release speed in the environment
V2 is Second media release speed in the environment

$$d_{ij} := 2^{-1}\left[\left(T^2_{rec} - T^1_{rec}\right) - \left(T^2_{tra} - T^1_{tra}\right)\right]\cdot\left(V^1 V^2\right)\cdot\left(V^1 - V^2\right)^{-1} \quad (3)$$

The main problem in this method is using two senders and two receivers; however, it is as precise as 2cm-error [3].

- **Ad-hoc RF (Radio Frequency) Base:**

Many of today's sensor systems use this method because of cheapness, low-used energy, and adaptation [2], [8]. Each node calculates its position as the centroid of anchor nodes.

Xest=(Xi1+…+Xik)/K ,Yest=(Yi1+…+Yik)/K (4)

2.1.3 Sense analysis

Since this method needs too much memory in order to save previous data to analyze current position, it is hardly used in wireless sensor networks [11].

Generally, localization algorithms can be divided into two groups:

1. anchor-node related[13][15]
2. anchor-node frees [7][14].

In anchor-node related algorithm, unspecified-position nodes can calculate their position using tridimensional, multidimensional, and multi-sequential dimensional [9] techniques.

Since calculating the coordinates of unspecified-position nodes are related to anchor nodes, the precise number of anchor nodes isof high significance. If their number is low, the number of nodes needing calculation of their position will highly increase; this leads to high use of energy among the nodes. On the other hand, if the number of anchor nodes increase too much, there will be interference between them.

The number of nodes in a specified area is called network compactness. It is calculated by this equation:

$$\mu(p)=\frac{N\pi r^2}{A} \quad (5)$$

in which N is the number of nodes, R is the radio range, and A is the area which nodes are distributed in.

3. Suggested method, similarization, and result analysis

Nodes' received energy is calculated by following equation [6].

$$prex=\frac{p}{4\pi r^2} * \lambda^2 G \qquad (6)$$

G: receiver antenna gin,

ƛ: wave length,

P0: sending energy,

r: communication range

As mentioned before, multi-dimensional algorithms such as APS suffer from some problems including high energy usage. So, calculating coordinate using Euclidean method is impossible; hence, another method is offered in which the relation between nodes decrease which leads to the decline of energy usage. This method is called anchor-node related which performs localization in two phases.

In the first phase, some proper anchor nodes are chosen. The number of chosen anchor nodes can be 2, 3, 4, or more. The more the chosen anchor nodes are, the more precise coordinate of unspecified node is estimated. In this method, distance limitation up to 10m is chosen; for, the more the distance is, the more the error rate is using RSSI method which leads to a high-error rate calculation.

In the second Phase, chosen anchor nodes signal their coordinate to unspecified nodes. Then the unspecified nodes divide the area reticulated, using received coordinate, in a way that anchor nodes and the unspecified nodes situate in that area. This area can be divided into 2*2, 3*3, 4*4, 5*5, or more parts (figure 3).

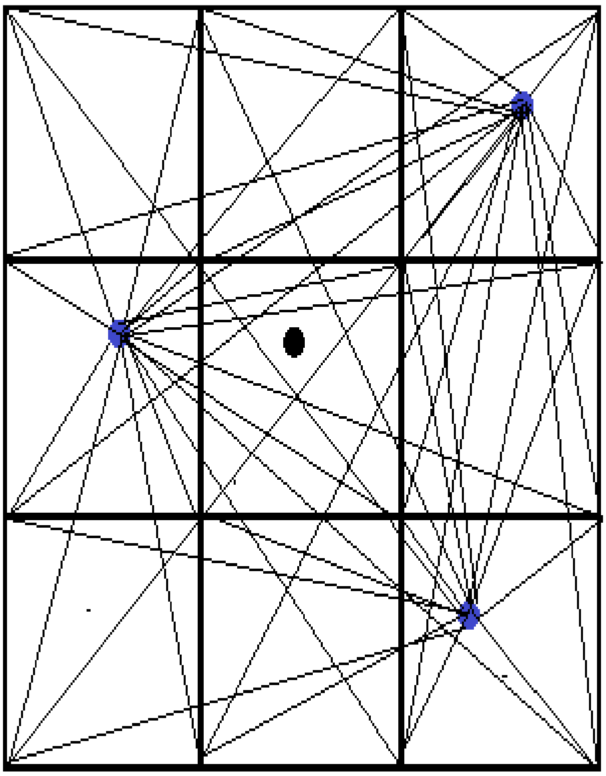

Figure 3 Dividing area consisting unspecified-coordinate node and chosen anchor nodes

Blue nodes: chosen anchor nodes
Black nodes: unspecified node

Like the first phase, the more parts involved, the more precise the estimated coordinate is Afterwards, unspecified node calculates its anchor nodes distance with all points in the reticulated area using this equation

{Xest,Yest, Zest}=(Xi1+…+Xik)/K, (Yi1+…+Yik)/K, (Zi1+…+Zik)/K) (7)

and save it in a data base.

Now, unspecified node calculate its distance with chosen anchor nodes; and, according to logic fuzzy, search for the lines near to this distance in the data base. Then, it locates a membership factor for each member using a made membership function, and estimate its location including x, y, and z (figure 4).

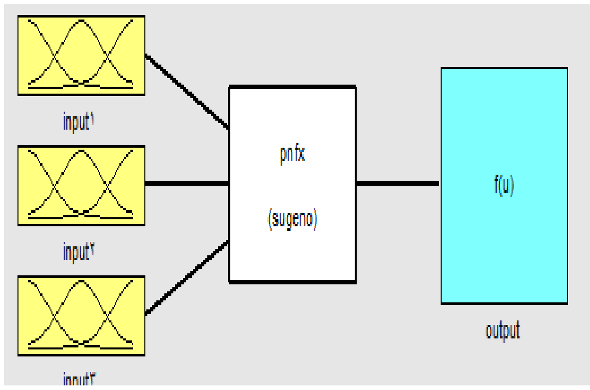

Figure 4 Estimated location includes x or y or z

In this research, a sensor network including 120 nodes, 20 of which are anchor nodes, is distributed in a 100*100 area supposing each node in its anchor node's range. The result is shown in Figure 5 and table 2.

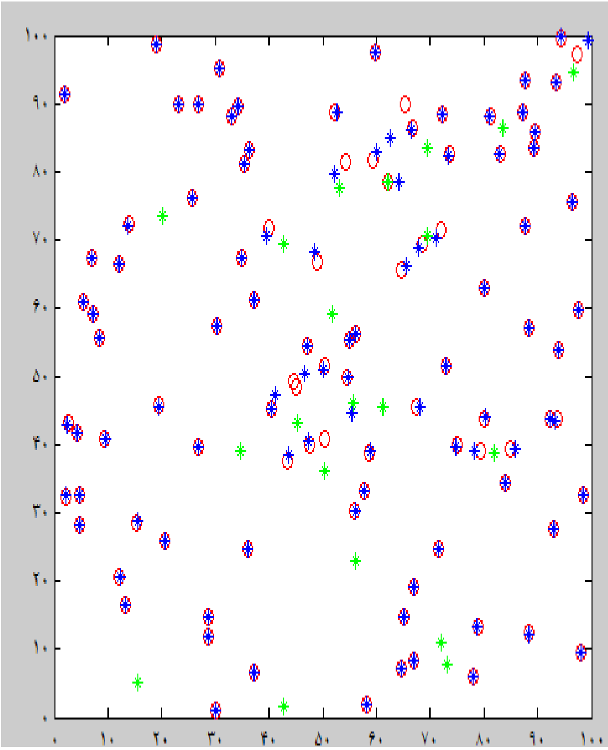

Figure5 Network Of 120 Nods Contain 20 Anchor nodes and 100 unspecified node

Green : anchor nodes
Blue : actual coordinates
Red : estimated coordinate

Table 2 Average measurement error by meter

	Chosen method	*Number of chosen anchor nodes*	*Approximate node error (m)*
1	Memdany	2	1.0272
2	Memdany	3	0.9083
3	Memdany	4	0.8745
4	Memdany	5	0.7535
5	Memdany	2	0.9736
6	Sogno	3	0.2371
7	Sogno	4	0.2318
8	Sogno	5	0.2279
9	Sogno	6	0.2173

As it is shown, the more the anchor nodes are, the less error rate is, but more complicated calculations are.

In this assumption, a node may be found in the edge of the network which is not in the direct range of anchor nodes. Therefore, the algorithm is converted in a way that each node which estimated its coordinate can play the role as an anchor node for other nodes. This algorithm is called multi-dimensional. We expected that error of each node is distributed through entire network; however, as it is shown in table 3, average error in the network decreased minimally.

Table 3 Average measurement error by meter using multi-dimensional method

	Chosen method	*Number of chosen anchor nodes*	*Approximate node error (m)*
	Sogno/multi-dimensional	3	0.2313

It is seen that average error obtained by all offered methods is less than the average error in APS algorithm which is almost 50% of the receiver's radio range [3]. Also, the nodes distributed in the edges of the network and have less access to anchor nodes can estimate their coordinate more easily.

4. Conclusion

Using logic fuzzy in wireless sensor networks decreases the connection between the sensor nodes, which is a highly effective factor in saving energy. It is also a great help to increase the localization speed [7]. If anchor nodes can be chosen in a way that the unspecified nodes situate in their area, the resulted reticulated area will be smaller, and calculation amount will be less as well as the estimated error in each node. As a future work, presented research can be continued and completed from different angles, including following:

• Select anchor nodes with an unspecified node between them so that the algorithm can teach the network a smaller area.
• Use mechanisms with higher accuracy and speed.
• Perform all operations in a fuzzy method to computational operations with less complexity.

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