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Robust Sound Source Localization Via Bat Algorithm Using a Wireless Sensor Network

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Abstract

This paper studies and proposes a method of using sensors to locate sound sources through wireless sensor networks(WSN). Sound source localization is applied in many fields, such as military, transportation, rescue and so on. In this paper, the sensor receives the sound energy emitted by the unknown sound source, uses the the received signal strength indication(RSSI) method, introduces Gaussian white noise, and creates a fitness function. The fitness function is optimized by the bat algorithm to obtain a minimum fitness value. The optimal solution is the sound source position. Applying the above theory, through Matlab simulation, the feasibility, accuracy and robustness of the method are evaluated. A small-scale simulation experiment was conducted to verify the actual value of the method.

Keywords

Wireless Sensor Network; RSSI; The Bat Algorithm; Gaussian Noise.

1. Introduction

Sound source localization is a technology to find the location of sound source in space. Sound source location technology is widely used in industry, military and civil fields.For example, by locating the abnormal sound of industrial products, we can find the fault point and unqualified in industry;the sound source technology will be used to judge the accuracy of the shell strike in the military field; in traffic law enforcement, locating the illegal vehicles whistling in the forbidden area to capture and enforce the law.

In this paper, wireless sensors are used to measure the sound source. The traditional method of sound source location is microphone array. The WSN layout is more simple and arbitrary, and can be arranged in large quantities with higher accuracy. The arrangement of wireless sensors can be in the form of aircraft throwing or drones, which is convenient and quick In choosing WSN ranging method, this paper chooses RSSI received signal strength to calculate the distance between the measuring point and the sound source. In [2], Several methods are compared.Compared with other ranging methods, such as TOA to measure the propagation time between two units, RSSI method needs less hardware and is convenient and fast.

But RSSI also has some shortcomings, [2] analyzes the principle of various wireless sensor network positioning technology, and then through the analysis of RSSI positioning algorithm, it is concluded that the ranging algorithm is easily affected by other environmental factors.

In [4], The expression of sound energy ranging in ideal state and the expression of noise pollution in real situation are given. On this basis, this paper proposes a contaminated Gaussian noise model to represent a more realistic environment. In the real environment, there may be outliers due to sensor failure, which will destroy the Gaussian noise model.We can make fitness function by expression.

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The bat algorithm is used to find the maximum value of fitness function.Bat algorithm is a new swarm intelligence optimization algorithm inspired by bat's foraging behavior using ultrasonic echo location. This paper introduces the basic principle of bat algorithm, and analyzes the influencing factors of performance in [3]. According to the above methods, this paper makes simulation through matlab. Through the above steps and simulation, we randomly distribute some wireless sensors in an area and have a sound source point. Through RSSI, we set up the deployment of sensors and build an acoustic energy model in a noisy environment,each wireless sensor receives an energy value for the sound emitted by the sound source point, and compares the position of the wireless sensor with The energy value is written into the fitness function, and then through the optimization of the bat algorithm, the location of the sound source point is found.

In the case of the feasibility of the simulation experiment, do a small-scale simulation experiment. We choose a relatively quiet laboratory, delimit a range, randomly place wireless sensors, and use a continuous buzzer as a sound source in one location. The wireless sensor measures the position and the voltage value of the received sound, and performs the above calculation to measure the sound source position. The measured sound source position is compared with the real sound source position to judge the practicability of the method.

2. Fitness function model

2.1 Wsn settings

We set a wsn, the number of its sensors $(Sen_i\,; i \le SenNum)$ can be set, each sensor can measure the size of sound energy and can transmit data, we randomly deploy the wsn in a square area, and emit a higher energy in an unknown location For sound, each sensor will obtain the real sound energy value, and calculate the approximate distance between the sensor and the sound source through the RSSI method.

2.2 Sound energy observation model with Gaussian noise

RSSI (Received Signal Strength Indication) is an indication of the received signal strength. The distance between the signal point and the receiving point is measured by the received signal strength, and the distance between the units and the propagation factor are calculated according to the formula. Compared to TOA (time of arrival), the time required to propagate between different network units, TDOA (Time Difference of Arrival) is different frequency signals have different transmission speeds, and the time it takes to transmit the same distance is different, which is calculated by this time difference, AOA (angle of arrival), its own axis is relative to its In terms of methods such as the angle between the received signals, TOA and TDOA have higher system time synchronization, complex calculation distance, and larger errors. AOA requires an antenna array to measure the angle and requires higher hardware. RSSI hardware requirements are not high, and the calculation is simple and fast.

Suppose that in the square where sensors are deployed above, at kth time, there is a sound source emitting sound at location $\tau(k)$ and a sound signal with a constant energy level S, at the i the sensor, The expression is as follows:

$$y_i(k) = f\big(x_i, \theta(k)\big) + e_i \tag{1}$$

$$f\big(x_i, \theta(k)\big) = \frac{g_i S}{\|Sen_i - \tau(k)\|^2} \tag{2}$$

$f\big(x_i, \theta(k)\big)$ is the received sound energy without noise interference, $y_i(k)$ is the sound energy in a noisy environment, g_i is the sensor gain, e_i is assumed to be Gaussian noise and conforms to a normal distribution $N(\mu_i, \sigma_i^2)$, and its standard deviation σ_i and mean μ_i can be used as a sample reference in [4]. $\|*\|$ is straight-line distance. $\theta(k) = \{S, \tau_x(k), \tau_y(k)\}$ is the unknown variable.

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3. Bat algorithm

The swarm intelligence optimization algorithm is based on the nature, especially the behavior of animals. There are particle swarm algorithm, ant colony algorithm and so on. Bat algorithm is also one of them. Bat algorithm is an algorithm inspired by the process of bat catching prey. In comparison, the bat algorithm converges quickly and has fewer parameters to adjust, so choose the bat algorithm to optimize and find the optimal value of the sound source.

The steps of the bat algorithm are as follows:

(1) Population initialization, set the number of bats, the number of iterations, the volume attenuation coefficient, the search frequency coefficient, and the loudness.

(2) Randomly distribute the bat positions, calculate the fitness value of the bat position, and find the current optimal value.

(3) Update the speed, position and frequency of the bat, the following is the update formula:

$$v_i^t = v_i^{t-1} + (x_i - x_{best}) * f_i \quad (3)$$

$$x_i^t = x_i^{t-1} + v_i^t \quad (4)$$

$$f_i = f_{min} + (f_{max} - f_{min}) * \beta \quad (5)$$

Generate random number rand, compare with r_i, if $rand > r_i$, randomly perturb the current optimal position, and then generate a new solution.

$$x_i^t = x_{best} - 1 + 2 * rand \quad (6)$$

Generate another random number rand and compare it with A_i. If $rand < A_i$ and the adaptability of the new position is better than the old position, the new position is accepted and the loudness and frequency are updated.

$$A_i^{t+1} = \partial A_i^t \quad (7)$$

$$r_i^{t+1} = R_0[1 - exp(-\gamma t)] \quad (8)$$

If the fitness of the new position is better than the optimal position, the optimal position will be replaced.

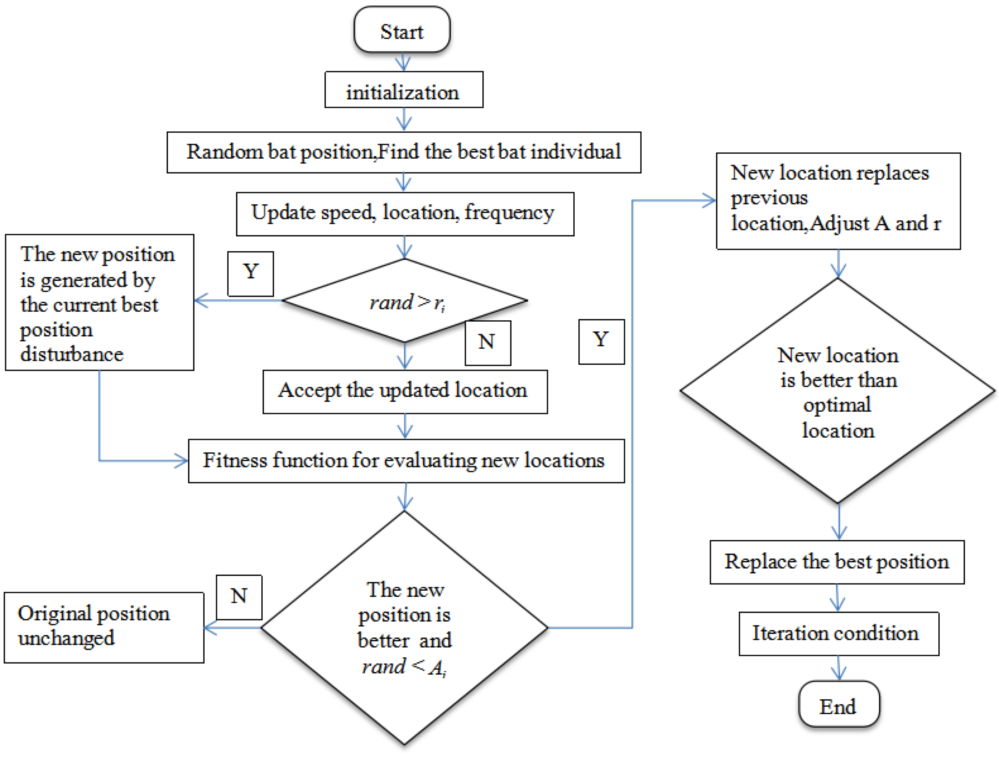

Figure 1. Bat algorithm flow

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Before reaching the maximum number of iterations, repeat the above steps, after reaching the maximum number of iterations, output the optimal position and best fitness.

This is the main flowchart of the bat algorithm. The data obtained by RSSI is brought into the algorithm. The evaluation is the size of the fitness function. The smaller the value is the better.

4. Simulation results and analysis

Based on the above description of wireless sensor networks, sensors and bat algorithms, combined with wireless sensors, a mathematical model of RSSI for wireless sensor sound source positioning is given. On this basis, the bat algorithm will be further applied to the mathematical theory of model positioning. analysis. We perform matlab simulation on the sound source localization method to verify the feasibility and theoretical accuracy of the method. The following are the steps for matlab simulation.

4.1 Parameter settings

The simulation experiment area is a square area of 8000*8000. In this area, 300 wireless sensors are arranged to form a wireless sensor network. Set fitness function, add Gaussian noise model, S is the value of received RSSI. The number of bats is set to 300, the number of iterations is 200, the volume attenuation coefficient is set to 0.98, the search frequency coefficient is set to 0.9, and the individual frequency is between 0 and 1.

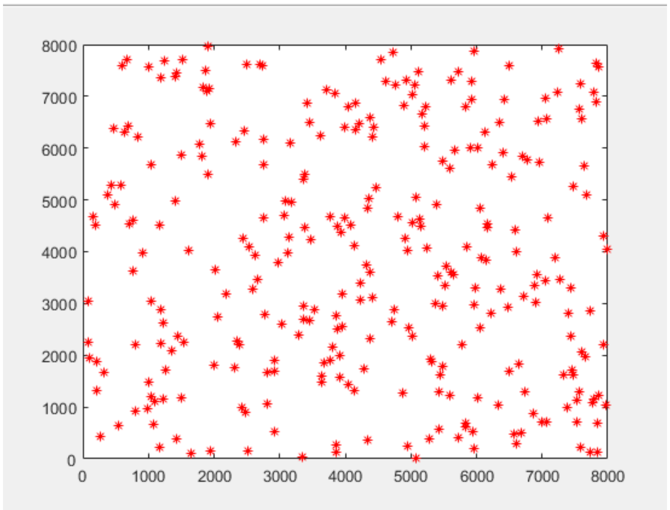

Figure 2. Bat initialization

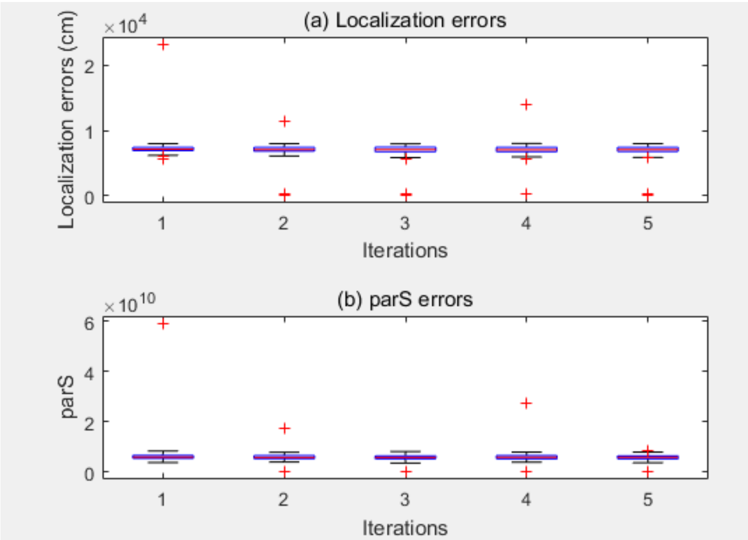

Figure 3. Simulation results

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4.2 Simulation results

Through the above settings of the first generation bats, the fitness function is created, Gaussian white noise is introduced, and the real situation is simulated. Through a large number of simulations in matlab, we can see that the sound source position found is very close to the real sound source position, see Fig 3.

5. Simulation experiment in real environment

5.1 Sensor layout

From the success of the above MATLAB simulation results, we can see the feasibility and effectiveness of the method. On this basis, we do a simulation experiment on the method to verify the feasibility of the method in practice.

We choose a relatively quiet place indoors, choose a 2m*3.5m test site, use matlab to randomly arrange 10 wireless sensors in the site, use the buzzer as the continuous sound source, choose the arduino as the motherboard, and use the DFRobot sound sensor to accept the sound voltage value is connected to the router through the adapter board, and the received data is sent to the computer.

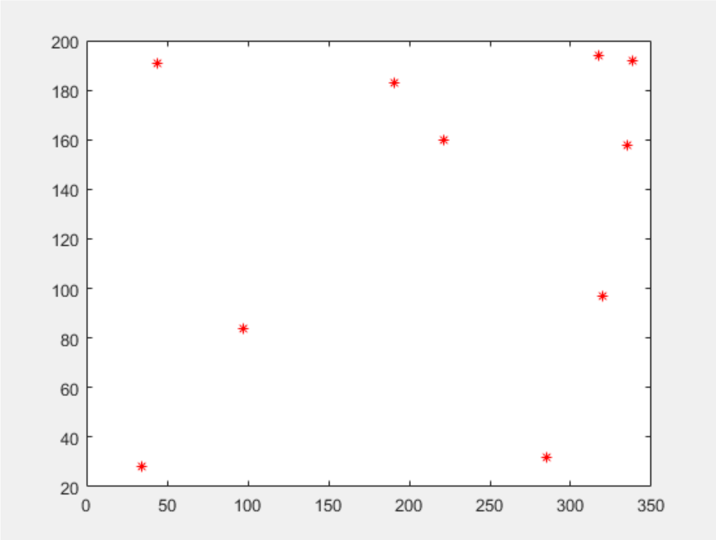

Figure 4. Sensor placement

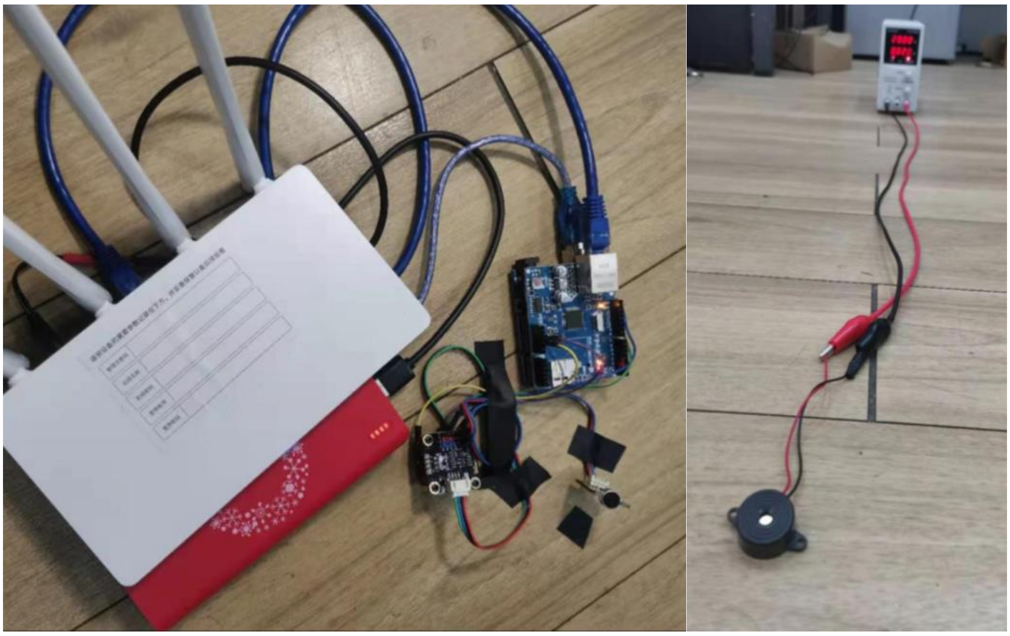

Figure 5. Simulation experiment device

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5.2 Real experiment

The following is the physical picture of the wireless sensor. The arduino is connected to the analog-to-digital converter and the router through the adapter board, and the power bank is used to power the arduino and the router. The analog-to-digital converter uses the DFRobot I2C ADS1115 16-bit AD converter, and then connect it Sound sensor. The buzzer is placed at 100*100 as the sound source and connected to a stable voltage source for power supply.

Through the above arrangement, the sound voltage values received at 10 network nodes are as follows, but for one group, the buzzer voltage is stable at 5V, and the maximum voltage received by the sensor is 6143mv. See Table 1.

Table 1. Data from the experiment

x	y	5V
28	34	28
32	285	409
84	97	5049
97	320	198
158	335	1507
160	221	3649
183	191	1325
191	44	48
192	338	14
194	317	17

Through the data obtained above, substituting into matlab for calculation, using the bat algorithm, the difference between the sound source point and the real sound source point is about 4.1539cm, and the effectiveness and practicability of the method can be seen.

6. Conclusion

The study of sound source localization is now a hot topic, with broad application prospects and far-reaching research significance. With the development of communication technology in recent years, wireless sensor networks have developed with the continuous development of communication, wireless networks, sensors and other technologies in recent years. This paper uses wireless sensor network to localize the sound source, and proposes a model suitable for target sound source localization based on the RSSI model. The bat algorithm is innovatively used in the target sound source localization of wireless sensors. From the above computer simulation and real environment simulation experiment, we can see the feasibility and practicability of the method.

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