An improved deployment algorithm for wireless sensor networks based on Particle Swarm Optimization

DING Shuxin

Beijing Institute of Technology

2013-07-01

Outline

- INTRODUCTION
- PROBLEM FORMATION
- PROPOSED ALGORITHM
- SIMULATION RESULTS
- CONCLUSION & FUTURE WORK

INTRODUCTION

- Wireless Sensor Networks (WSNs)
  - Some sensors: small in size, low in power and cost
  - Short distance communication
  - Communicating without wires
- Some applications of WSNs
  - District/Environment monitoring
    - Measure the environment conditions to forecast disasters and to give early warnings before the occurrences
    - Deployed in places which are hard to reach(volcanic area monitoring)

Challenges of WSNs

- Sensors deployment optimization is an important issue
  - Limited communicating range and lifetime
- Make full use of limited detecting resources
  - Sensors should be placed within certain range

Sensors deployment

- Given conditions
  - Limited number of sensors with limited detecting range
  - Given region of interest(ROI)
- Possible objectives of deployment
  - Maximum coverage
  - Minimum overlap coverage

- In this paper, just consider maximum coverage

Coverage Problem

- Coverage rate evaluate the performance of the WSNs deployment
  - The positions of the sensors determines the coverage rate
- Detecting probability

probability function of i^{th} sensor $s_i(x_i,y_i)$ for point $P(x,y)$

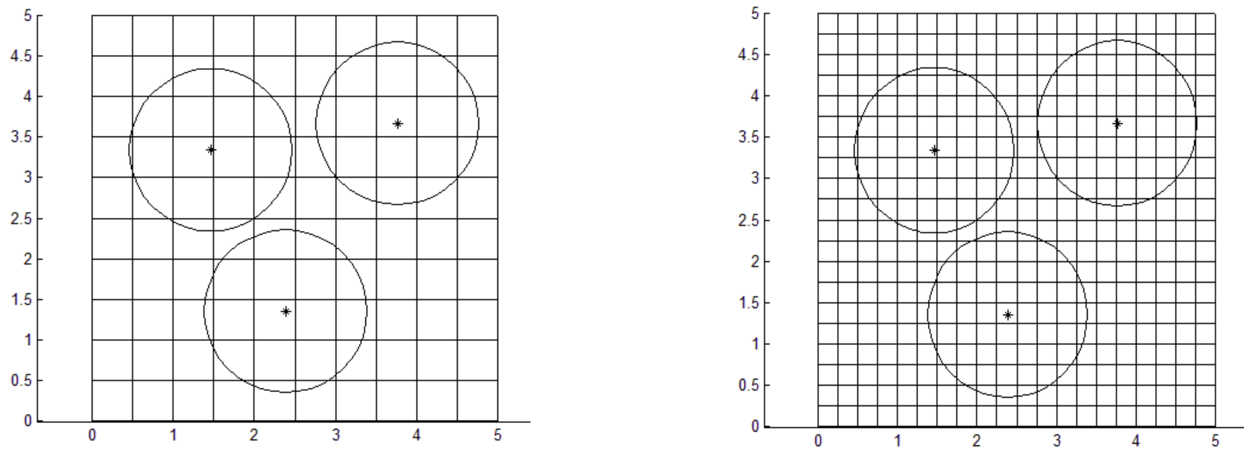
$$c_{x,y}(s_i) = \begin{cases} 0 & \text{if } r_i < d \\ 1 & \text{if } r_i \geq d \end{cases}$$

$$d = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

probability function of n sensors for point $P(x,y)$

$$c_{x,y}\left(\sum_{i=1}^{n} s_i\right) = 1 - \prod_{i=1}^{n}\left(1 - c_{x,y}(s_i)\right)$$

- Grids are used to determine the coverage rate



(a) (b)

Fig.1 3 sensor nodes deployed in gridded ROI: (a) grid size: 0.5 × 0.5; (b) grid size: 0.25 × 0.25

The grid size should be chosen carefully which balances the calculation time and accuracy.

- Coverage rate

$$R = \frac{\sum_{j=1}^{n_p} c_{x_j,y_j}\left(\sum_{i=1}^{n} s_i\right)}{n_p}$$

detecting probability of n_p grid points

the number of grid points in the ROI

Objective: maximize the coverage rate

Particle Swarm Optimization

- Particle Swarm Optimization(PSO) is a algorithm based on the social behavior of a flock of birds.
- The particles are moving in the searching space according to their former speed, their experience and the experience of their neighbors around.
- Each particle represents a potential solution of the optimization.
- More particles, more accurate.
- A particle for n sensors can be represented as $(x_1,y_1,x_2,y_2,x_3,y_3,\ldots, x_n,y_n)$
  - 2n dimension: every 2 components represents a sensor’s position

Particle Swarm Optimization

- Evolution equation

$$v_{id}(t+1) = w \times v_{id}(t) + c_1 \times rand() \times (p_{ibest} - x_{id}) + c_2 \times rand() \times (p_{gbest} - x_{id})$$

$$x_{id}(t+1) = x_{id}(t) + v_{id}(t+1)$$

w: inertia factor(0.9-0.4) $v_{id}(t)$: former velocity

p_{ibest}: individual best position p_{gbest}: grobal best position

- Fitness function(coverage rate) evaluates the position quality of a particle, and p_{ibest} and p_{gbest} are replaced according to it.
- PSO stops after maximum iterations.
- Local optimal for a high-dimensional optimization
  - Some components move closer to the optimal position while others may move away from the optimal, while it gives a better solution for larger coverage rate. “two step forward, one step back”.

PROPOSED ALGORITHM

- D-PSO algorithm based on PSO
- Evolution equation

$$v_{id}(t+1) = c_0 \times randn() + c_1 \times rand() \times (p_{ibest} - x_{id}) + c_2 \times rand() \times (p_{gbest} - x_{id})$$

  - $randn()$ is a standard normal distributed function
  - c_0 is set according to the numbers of the sensors, the sensing range and the space size
- No former velocity but a disturbance
- The update formula of the position is the same with PSO

- Difference of the sensor position motion tendency between PSO and d-PSO

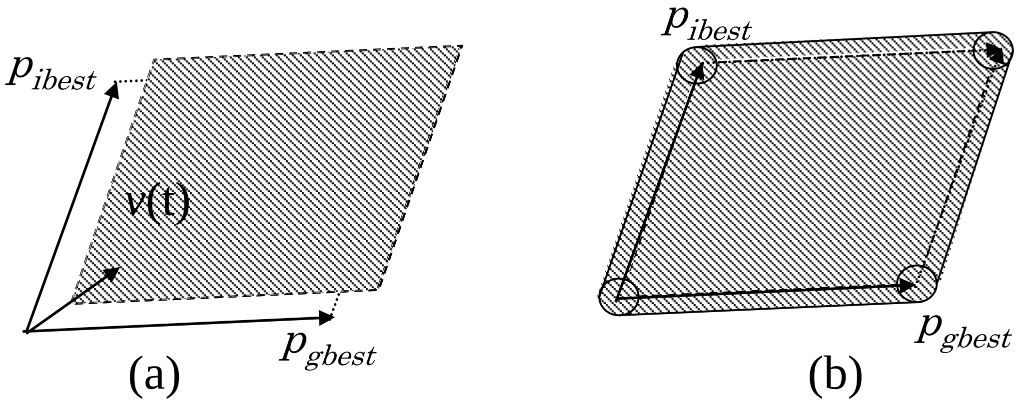


Fig.2 Searching space between PSO algorithm (a) and d-PSO algorithm (b)

- PSO only considers more about the direction of its velocity
- The shadow area in d-PSO contains the shadow area in PSO
- $c_0 \times randn()$ ranges from [-$3c_0$,$3c_0$] $\quad c_0 = \frac{cL}{nr}$
- c is a constant number(set as 1), ROI is a $L \times L$ square area, n is the number of the sensors, r is the detection range of one sensor.
- This factor plays an important role for particles to converge to the global optimized solution. If this factor is too big or too small, this algorithm will perform badly.

- Difference of the sensor position motion tendency between PSO and d-PSO

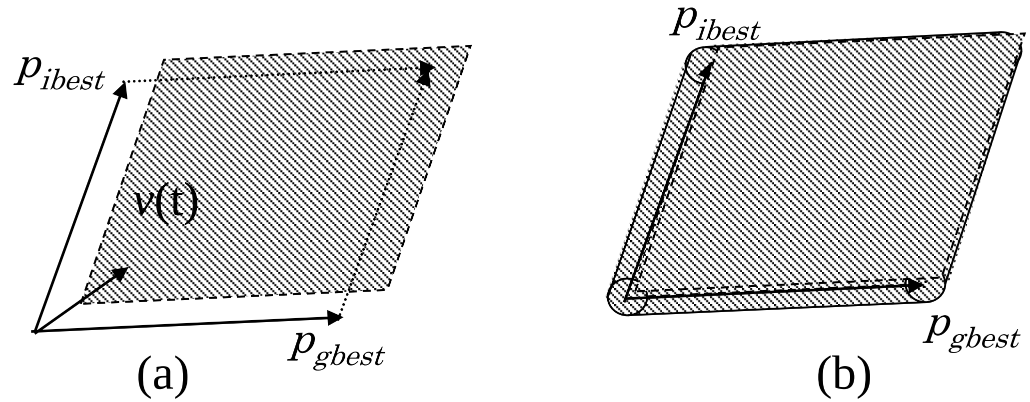
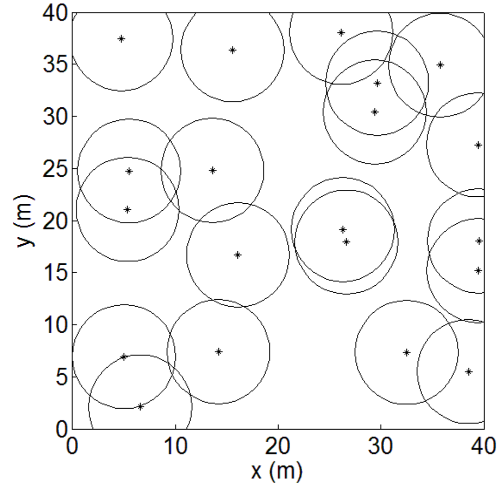


Fig.2 Searching space between PSO algorithm (a) and d-PSO algorithm (b)

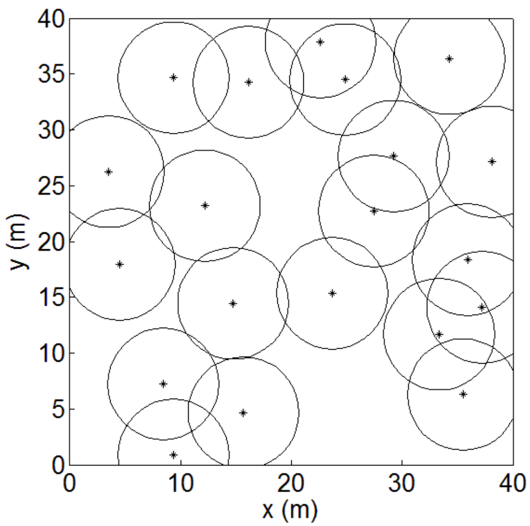
- PSO only considers more about the direction of its velocity
- The shadow area in d-PSO contains the shadow area in PSO
- $c_0 \times randn()$ ranges from [-$3c_0$,$3c_0$] $c_0 = \frac{cL}{nr}$
- c is a constant number(set as 1), ROI is a $L \times L$ square area, n is the number of the sensors, r is the detection range of one sensor.
- when $x_{id} = p_{ibest} = p_{gbest}$, PSO stops($v_{id} = 0$), while d-PSO with no velocity part, $v_{id} = c_0 \times randn()$, a $3c_0$ searching range as a circle
- Jump away from the optimal position for high dimensional optimization

SIMULATION RESULTS

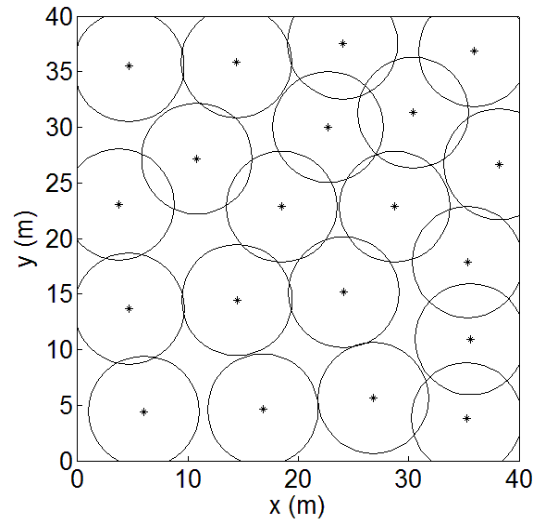
- Deployment performance between PSO and d-PSO
  - 20 sensors; 20 particles; c=0.75; c_1=c_2=1.4962;
  - *maximum iteration* = 600;
  - w=0.9 - 0.4 (linearly decreasing with t) for PSO;
  - ROI:40×40m^2; grid size: 1×1



(a) initial random placement 65.97%



(b) PSO algorithm 74.30%



(c) d-PSO algorithm 84.95%

d-PSO presents a better deployment solution than PSO

- PSO converges faster than d-PSO
- d-PSO seems to find better solution there are a large number of iterations
- disturbance always allows the particle to find better solutions

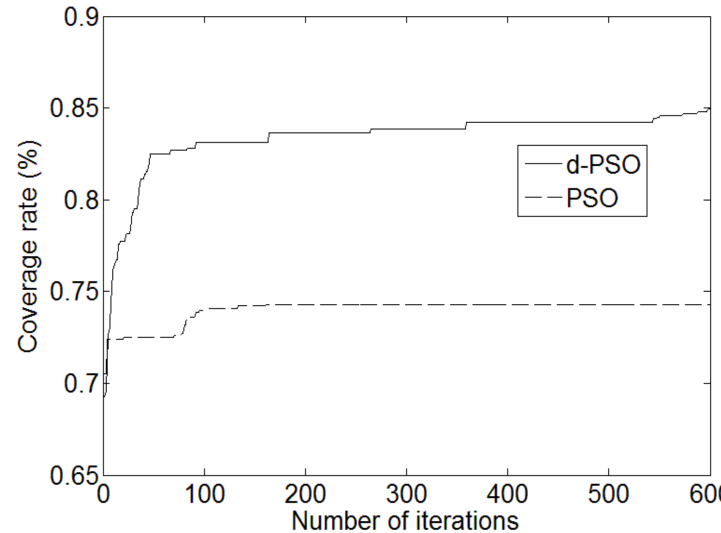


Fig.4 The coverage rate of PSO and d-PSO during the iterations.

- 50 independent experiments
- d-PSO seems to be better in effectiveness and robustness than PSO

Table 1. The average coverage rate, its standard deviation and execution time

Algorithm	PSO	d-PSO
Average coverage rate (%)	74.67	84.88
Standard Deviation (%)	2.04	1.08
Average execution time (s)	7.13	6.98

- Analysis of the particle numbers

- 50 independent experiments
- Particles: 1 to 40
- d-PSO algorithm has an acceptable solution when there are few particles
- PSO algorithm seems to be better when particle number is growing

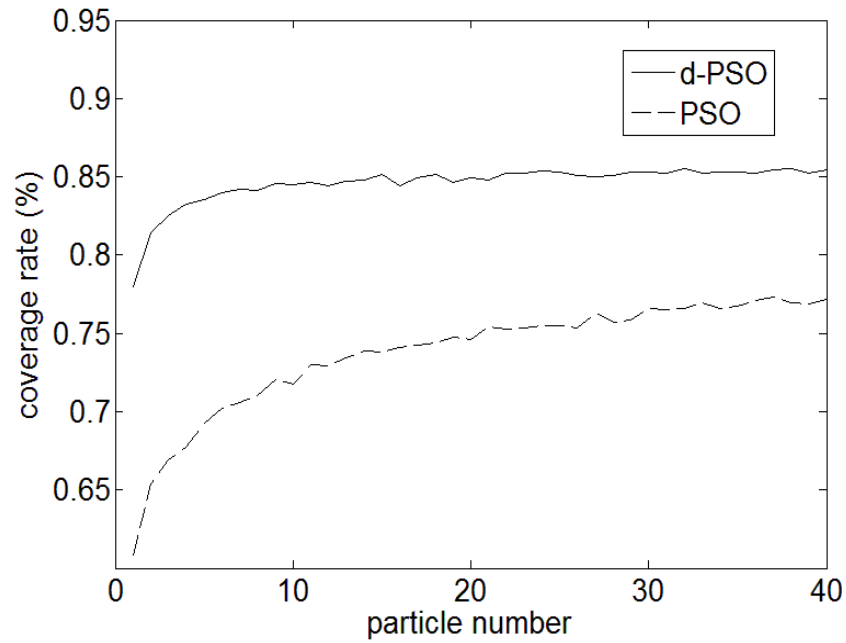


Fig.5 The coverage rate of PSO and d-PSO with different amount of particles

- The execution time will cut down with fewer particles using d-PSO, with acceptable solutions.

CONCLUSION & FUTURE WORK

- Conclusion
  - An improved deployment algorithm called d-PSO algorithm to solve the coverage problem of WSNs.
  - Better coverage rate; less particles to save time; better global searching ability than PSO.
- Future work
  - Study the convergence property of d-PSO and the factor of the disturbance.
  - More complicated description of ROI and sensors.

Thank you！