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Sensor Selection Wireless Multimedia Sensor Network using Gravitational Search Algorithm

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Abstract

A wireless sensor network consists hundreds or thousands of sensors with limited computing power and memory, which give the information from the environment and then analyze and process the data and also send the sensed data to other nodes or basic stations. In these networks, sensing nodes have with a limited battery to provide the energy. Since in these networks, energy is considered as a challenging problem, we decided to propose a new algorithm based on the gravitational search algorithm to prolong the network lifetime and achieve maximum coverage of target area. Performance of the proposed algorithm is evaluated through simulations and compared to GA algorithm. Experimental results show that the proposed algorithm has more appropriate sensor selection to compared algorithm. In fact, total coverage increased by 2 percentage and we have 5 percentages more alive sensors in network when reached to coverage threshold.

Keywords: Gravitational Search Algorithm, Sensor Selection, Surveillance, Wireless Multimedia Sensor Network

1. Introduction

The Wireless Sensor Networks (WSNs) represent a blooming technology where they can probe and collect environmental information. In that way, rapid advances in CMOS technology have enabled the development of cheap and low-power camera modules[1]. These cameras could be combined with low power radios to create multimedia sensor networks that will provide more suitable solutions for many applications like video surveillance and environmental monitoring[2]. So, Network lifetime and coverage maximization is two fundamental problems in WMSN. These problems has tightly related together. In other words, more coverage of target area increases energy usage for each sensor[3].

In comparison to traditional WSN, a number of WMSN characteristics are different including Field of view, bandwidth requirement, multimedia data processing, sensor coverage and collision in transmitting data. Therefore, new design of existing WSN techniques and protocols are required in field of environmental monitoring that they should address discussed issues (i.e. sensor coverage and energy consumption)[4,5].

In this paper, we proposed an approach for sensor selection in WMSN based on gravitational search algorithm, in order to decrease number of active sensors for acceptable coverage of target area; and consequently, to prolong network life time. In Figure 1, the feasible coverage of a camera-equipped sensor is shown. According to Figure 1, each sensor has unique coverage area which depends on its initial orientation and location; and, sends their orientation and location to base station. Besides orientation and location, the remaining energy of each sensor would be periodically sent to the base station.

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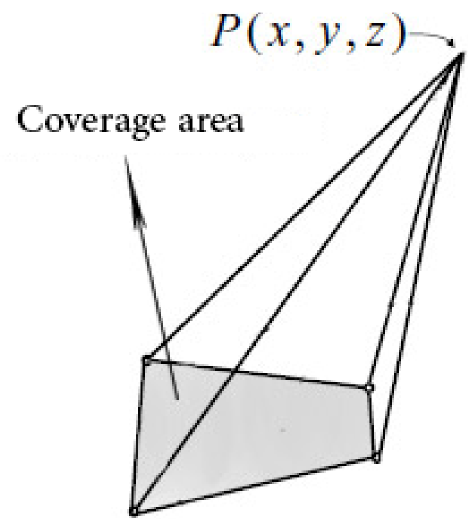

Figure 1. A sensor node.

Therefore, the base station could make decent choice to gain desired coverage[6,7].

Gravitational Search Algorithm (GSA) is one of trending heuristic approach for solving NP-Complete problems[8,9]. Earlier researches show that GSA suggests appreciates solution for many problems like grid systems and job scheduling.

Gravitational Search Algorithm is one of the newest stochastic population-based meta-heuristics that has been inspired by Newtonian laws of gravity and motion. In the basic model of the GSA which originally has been designed to solve continuous optimization problem, a set of agents, called masses, are introduced in the n dimensional search space of problem to find the optimum solution by simulation of Newtonian laws of gravity and motion[10,11].

The problems related with the selection of sensors in a wireless multimedia sensor network have been previously investigated. In particular, Dagher et al.[12] investigate the problem of the optimal allocation to each node of a part of a scene that has to be transmitted back to the base station, so that the lifetime of the sensors is prolonged. While they look at 2D coverage, we extend this problem to coverage over a 3D space.

McCurdy et al.[13] describe the system that uses video streams from mobile nodes in order to obtain visual information from a monitored area. The primary constraint of such a system is the incomplete coverage provided by the head-mounted cameras attached to staff, since they cannot monitor every part of the space over time. Our work differs from the work presented in [14] in several aspects. First, we assume that all cameras in the system are static after deployment, thereby providing fixed coverage of the monitored area. Also, we are more concerned with the energy constraints of such a system, which influences the selection of the "best" cameras to provide the desired coverage and increase the network lifetime.

Distributed power management of camera nodes based on coordinated node wake-ups is applied by Zamora and Marculescu[14] to lower the energy usage of cameras. Their proposed policy assumes that each camera node is awake for a while, after which the camera node decides whether it should take the low-power state based on the states of its neighboring nodes.

2. Problem Formulation

In this paper, we assume that WMSN is employed for environmental monitoring. In fact, the network includes a number of sensors which are randomly implemented in a particular height from target area. Therefore, acceptable coverage is most important factor for a valid sensor selection[15].

As it is discussed earlier, each sensor has random location and its orientation could be determined by three angles X, Y, Z. Hence, each sensor knows own orientation and sends it to the base station which should select some sensors based on these orientations and sensors' coverage. Finding optimal number of sensor for adequate coverage is an NP-Complete problem, so it is more appropriate to use heuristic techniques[16].

Each sensor has a specific value of initial energy and could be activated for a while. Due to capturing image and transmitting data to base station, sensor consume own energy and after a while remaining energy of this sensor would be finished. At this time, sensor is dead and desired coverage is not accessible. Thus, we should select other subset of sensors with better coverage and more remaining energy.

In WMSNs, two cameras can capture similar area of environment. The coverage area of these cameras could overlaps which make excessive redundancy due to large visual data size[17]. In other words, it's possible to have same coverage with a number of different sensors' subsets. But, the deference of these subsets is energy consumption and its impact on network life time[18].

Maximum possible coverage which can be achieved by any subset of camera sensors is equal to initial total coverage of all sensors. After time t, achieving to initial total coverage is not possible due to energy consumption of sensors and reduction number of alive ones. Hence, total coverage of all alive sensors after t is less than initial total coverage and this value would reduce with time. If maximum possible coverage had been desired then all of sensors would be active which would cause so fast resources decreasing. In this situation, we define A as degradation coefficient for performing trade-off between network lifetime and total coverage area. In fact, our proposed algorithm could have more suitable choices of sensor subsets and matter on make network alive with a little less coverage area.

3. Proposed Algorithm

Surveillance by WMSN needs capturing image from area and transmitting these images to base station. The first step of surveillance is randomly distributing a certain number of cameras over the target area. After that, base station will knows each sensor's orientation and location by calibration phase. When a camera sensor node transmits its captured image, the base station knows exactly which part of target area are specific sensors. Hence, coverage percentage of each sensor could be known by base station in this phase and it could select a number of sensors for maximum possible coverage. In this paper, novel algorithm is proposed for sensor selection based on gravitational search algorithm.

In sensor selection phase, if certain constraint defined by problem is satisfied, captured images transmit should be transmitted to the base station by appreciate routing algorithm. In this paper, we employ MAODV [19] for finding routes between sensors and the base station. After a while, some sensors fail due to capturing and transmitting data, so the base station has to select new subset of sensors. In the following subsection, proposed sensor selection algorithm is described in details.

3.1 Proposed Algorithm Based on GSA

As shown in Figure 2, to solve the problem of optimal sensor selection for environmental monitoring, at first sensors will be selected randomly and placed within an array till adequate coverage reached. at this time, a solution has created for problem and the suitability of solution determined as CU. Candidate solution will be created from current solution based on sensors value and problem constraints. CA will be determined as candidate solution suitability and in comparison with CU, if CA was greater, algorithm consider candidate solution for next executions and if CU was greater, algorithm does not consider candidate solution and make new solution based on current one. Then, algorithm parameters like F, V and m will be updated and this loop will repeat until the algorithm reach to end point. The algorithm is completed in following two conditions: All velocity vectors goes zero, or the number of algorithm iterations reaches its maximum.

GSA Sensor Selection at z^th time step
In: Sensors and Monitoring Area
Out: Selected Sensors as BestSolution

```
Begin
If C(L_z) < C(L_0)
    Exit
If C(L_z) < C(L_0)

MaxC = 0, IVL = MaxV, cnt = ITER;
While MaxC < C(L_z)
  Begin
    InitialSolution ← A random Sensor
    If  MaxC < C(InitialSolution)
        MaxC = C(InitialSolution)
End
BestSolution = CandidateSolution;
For i = 1 to L_z
Velocity_i = Random No. from 1 to IVL
calculate CU
while (All Velocity > 0) and (cnt < ITER)
  Begin
  calculate solutions adjacent to the InitialSolution
      as CandidateSolution
  calculate CA
  If CA>CU
      BestSolution = CandidateSolution;
  Calculate F;
  Update V_(z+1), m_z, Value_z For L = {L_0, ... , L_z};
  cnt+ = 1;
  End
 Return BestSolution
```

Figure 2. Pseudo code of proposed algorithm.

3.2 Algorithm Parameters

Gravitational search algorithm parameters described as follows:

In time t, gravitational force between current solution and candidate solution is[20–22]:

$$F = \frac{G_{(t)}\left(CU - CA\right)}{R^2}$$

Where CU, CA, R and $G_{(t)}$ are value of current solution, value of candidate solution, distance between sensors and gravitational constant in time t.

Gravitational constant G, will be decreased by algorithm execution time. It make deeper search for algorithm and maybe cause better performance. If assume T is number of:

$$G_{(t)} = G_{(0)}\left(1 - \frac{t}{T}\right)$$

Agent acceleration will be calculated by low of motion. Afterwards, next velocity of an agent is determined as its current velocity added to its acceleration.

$$a_i(t) = \frac{F(t)}{m_i(t)}$$

$$V_i(t+1) = V_i(t) + a_i(t)$$

Mass of each agent equals to sensor value in WMSN. In proposed algorithm, value of each sensor is relative to remaining energy of each sensor, sensor coverage and overlap.

$$Value_s = E_s + C_s - O_s$$

In that order, mass of each agent defined as follows:

$$m_i(t) = \frac{Value_s(t) - Worst(t)}{Best(t) - Worst(t)}$$

Which best (t) and worst (t) are most value and less value of sensors in time *t*.

4. Experimental Result

MATLAB 2011 is used for evaluating performance of proposed algorithm. For a valid comparison, dataset used by Hooshmand[14] is considered. To do this, 120 sensor network with coverage more than 1 percentage of target area randomly distributed over a 100m*100m area. Initial energy of sensors is between 1000 and 1300. Value of simulation parameters shows in table 1.

Comparison of the results of proposed algorithm and GA algorithm is presented in Figures 3–6.

Number of live sensors, number of selected sensors, total coverage and overlap, defined by $\frac{OV(S_i)}{C(S_i)} * 100$ are 4 factors that are used for our comparisons.

Table 1. Simulation parameters

Parameter	Value	Parameter	Value
E_{max}	1300	E_{min}	1000
L_0	120	δ	0.95
L_y	100	L_x	100
r	25	γ	0.5

Due to most sensors are alive before 500th time step, algorithms have produced full coverage. After that, it's common to see reduction in coverage. We assume that coverage percentage below 50% is not appreciated and network will fail after that time step. Figure 3 and 4 show that proposed algorithm has more coverage in comparison with GA while it makes more alive sensors in network.

Figure 5 present selected sensors in each time step of WMSN application. Overlap is one of important factor

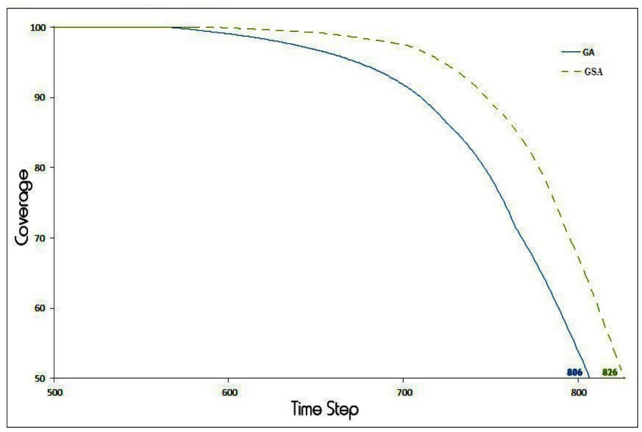

Figure 3. Total coverage of sensors.

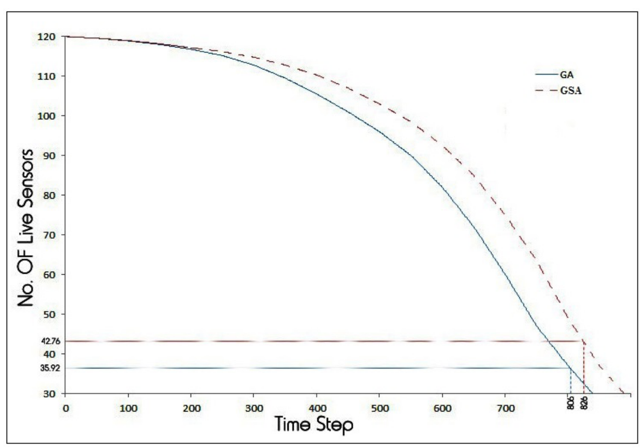

Figure 4. Live sensors.

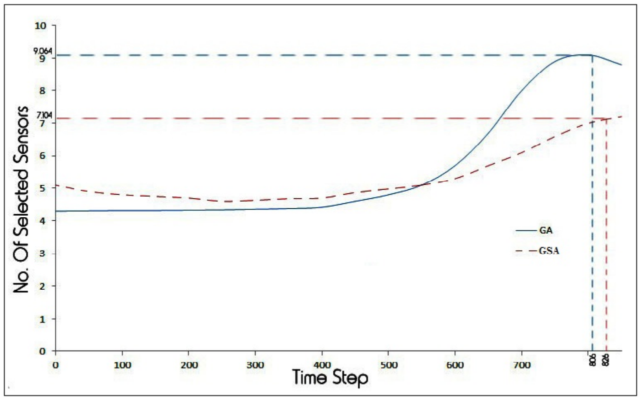

Figure 5. Selected sensors.

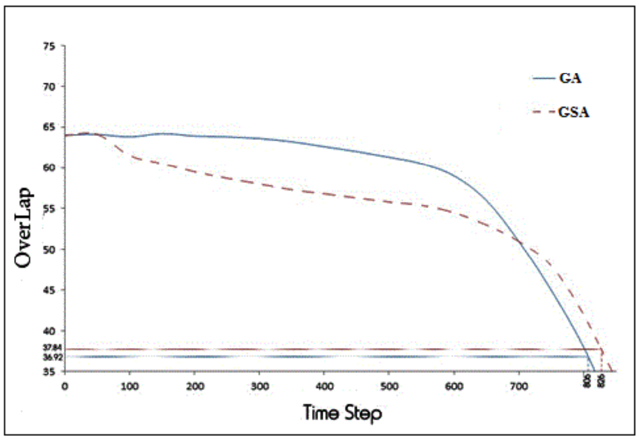

Figure 6. Overlap in network.

in proposed sensor selection method, so algorithm chooses more sensors in some time steps. Figure 6 shows overlap percentage of sensors that we can see less overlap in most time steps of proposed algorithm execution time.

5. Conclusion

Performance of our proposed algorithm has evaluated by simulation performed in MATLAB. The algorithm has better performance in comparison to GA algorithm. In fact, total coverage increased by 2 percentage and we have 5 percentages more alive sensors in network when reached to coverage threshold.

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