A Fuzzy Tree System Based on Cuckoo Search Algorithm for Target Tracking in Wireless Sensor Network

Qing Xia(✉), Junjun Lin, Qiang Liu, and Supeng Leng

University of Electronic Science and Technology of China, Chengdu, China
{201822010510,201822010506}@std.uestc.edu.cn,
{liuqiang,spleng}@uestc.edu.cn

Abstract. Wireless Sensor Network (WSN) consists of sensors with small volume and limited power. These sensors can communicate with each other and fuse data to make different decisions. Target tracking is an important application in wireless sensor network. How to schedule nodes for tracking the moving target and how to improve the tracking accuracy are the problems that we face. In this paper, we introduce a fuzzy tree system in target tracking. The fuzzy tree system is composed of two layers, in which the first one is to decide which nodes to move and the second one is to decide the distance and angle. All the parameters are tuned by the Cuckoo Search algorithm (CS). We performed a large number of simulations in choosing different numbers of the moving nodes. The results of my experimental data show that the adaptive fuzzy system has a good effect on target tracking, and the Cuckoo Search algorithm outperforms the algorithms widely used now in tuning the parameters.

Keywords: Wireless Sensor Network · Cuckoo search algorithm · Target tracking · Fuzzy logic

1 Introduction

Based on the rapid development of Internet of things, WSN offers multiple applications in smart home, medical equipment and military field. Because of the sensing ability of WSN sensors communicating with each other and the powerful computing ability of artificial intelligence algorithm, it is widely used in various scientific fields to provide convenient services for people, and is extensive researched by contemporary scholars.

Target location and tracking is one of the typical application fields of wireless sensor networks. It mainly uses a group of sensor nodes to sense the target cooperatively, and processes the measurement information obtained, so as to obtain the dynamic process of the current state estimation of the target. Target location and tracking technology involves many fields, such as information fusion, signal processing, filtering and so on. It has been widely used in not only military and civil fields but also medical field. According to different scenarios, such as tracking accuracy, energy consumption, power

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consumption and so on, target tracking can be tracked by simultaneous interpreting of different sensors, from the perspective of target motion mode, target tracking can be divided into static target tracking and dynamic target tracking, each has its own advantages and disadvantages.

Genetic algorithm is a widely used optimization algorithm, but its calculation and modeling will bring a lot of time loss. Because of that, we use a new heuristic algorithm - Cuckoo Search algorithm to replace it, and experiment to see the effect of CS algorithm.

One of the algorithms I propose is a fuzzy tree system which has two layers in target tracking. The detailed chapters are as follows. Section 2 describes the adaptive fuzzy tree system. The heuristic algorithm named cuckoo search algorithm which is the lead algorithm I use is illustrated in Sect. 3. Then Sect. 4 provides the analyses and simulations. We summarize this paper and address future works in Sect. 5

2 Architecture of the Fuzzy Logic Tree System Used in Target Tracking

We randomly deploy n sensors $\{S_1, S_2, S3, \ldots, S_n\}$ in the area [3] with velocity $\{v_1, v_2, \ldots, v_n\}$, remaining battery power of sensors $\{b_1, b_2, \ldots, b_n\}$ and detection radius $\{r_1, r_2, \ldots, r_n\}$. The coordinate of sensor i is (x_i, y_i) where i is from 1 to n. $\{S_d\}$ represents the sensor nodes that has detected the moving target like UAVs or vehicles, $\{S_r\}$ represents the remaining sensor nodes.

When the sensors detect the arrival of the target, the first layer we use in the fuzzy logic tree system is to select *m* moving sensors from $\{S_r\}$ to track the target. We use $\{S_d\}$ to calculate the size of the perception radius R, where the center of the circle is E_t. According to the state of the current sensor node and the distance difference from the center of the sensing circle di. We use the fuzzy tree system to select the best m mobile node $\{S_c\}$ from $\{S_r\}$to track, which is based on the energy consumption and the remaining battery power to get a high tracking index.

Fuzzy logic does not have absolute 0 and 1 values like computer language. It is closer to human thinking. We often say "it's a little hot today." so what exactly does "a little" mean? To what extent? In fuzzy logic, we can get a good expression. According to membership function, fuzzy logic can divide its hot degree into cold, hot and extremely hot. In this paper, fuzzy logic can be used to evaluate the performance of mobile nodes.

This system will give each node score and select the best nodes to track the moving target.

3 Cuckoo Search Algorithm (CS)

The cuckoo search algorithm is a kind of bionic algorithm based on the breeding characteristics of cuckoo. Cuckoo is a very interesting creature, whose voice is beautiful and charming, but they can't build a nest, that is to say, they have to occupy the nest of other birds in order to reproduce, and put their eggs in the nest of other birds, but this method is risky, once they are found by the owner of the nest, they should abandon the nest and look for other nests, that is, to find other solutions. This is the source of CS algorithm. There are several strict rules for Cuckoo search algorithm:

(1) Assuming that each cuckoo can lay only one egg and distribute randomly in any nest, this rule shows that the initial solution is random;
(2) The well-built nest where the quality of egg is good will be passed on to the next generation. This is the process of seeking the optimal solution. That is to say we need to keep the good solution;
(3) If some eggs are unfortunately found by the nest owner, then we have to abandon this egg or find other nests. The probability of being found is P_a, that is to say, we can randomly discard the solution with this probability when finding the optimal solution, so that it will not lead to the local optimal situation. To extend this approach, the cuckoo search algorithm uses Levy flight. Levy flight is described by formula one, and it is also a way to avoid local optimization based on random walk:

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus Le'vy(\lambda) \tag{1}$$

where α represents the step size and ⊕ means the entry-wise multiplications. The step size follows the Levy distribution as follows:

$$Le'vy \sim u = t^{-\lambda}\ , (1 < \lambda \leq 3) \tag{2}$$

By using Levy flight and P_a, in this way, the optimal solution can be found more effectively. This is the special optimization method of cuckoo search algorithm.

4 Simulation Experiments and Performance Evaluation

Genetic algorithm is also a bionic algorithm, which was proposed in the late 1980s and is widely used nowadays. The process of genetic algorithm is to generate the population randomly at first, then judge the fitness of the individual according to the strategy, whether it meets the criteria of optimization. If it does, output the optimal solution finish this step. According to the fitness function we can select the parents, and individuals with high fitness are more likely to be selected. The parents' chromosomes are crossed according to certain methods to generate offspring, and then the offspring chromosomes are mutated. Finally, we get the optimal individual, which is the optimal solution we expect.

Compared with genetic algorithm, cuckoo search algorithm is more recent, and the mathematical formula is much simpler, so it does not need the complex operation of genetic algorithm, such as coding for make chromosome. To detect the performance of CS algorithm, we compare the performance of cuckoo search algorithm and genetic algorithm in mobile tracking in this article to see if cuckoo search algorithm has good application.

I used Matlab to simulate this experiment. Sensor nodes are distributed in areas of 100 in length and width and the node density is set to be 30%, 40%, 50% and 60%. Here, we chose the number of mobile nodes based on the density of the distribution of mobile nodes. The more the number of mobile nodes is, the batter the tracking accuracy will, but it will increase the energy loss of network and increase the burden of it. This shows how important it is to choose the right mobile node. In order to compare the performance

of CA and GA, in this section, we compare CS with GA from multiple perspectives. In this experiment, it is assumed that the target moves at a constant speed along a straight line at a speed of 10 m/s (Figs. 1 and 2).

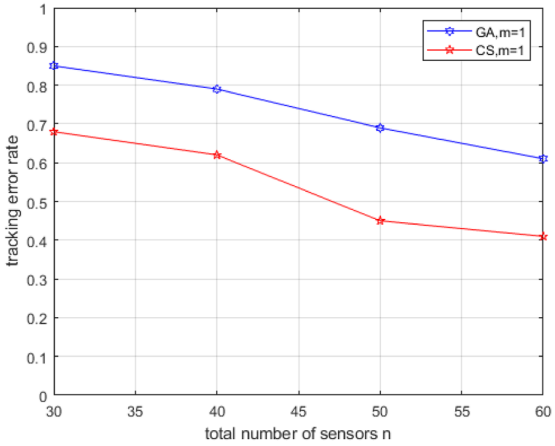

Fig. 1. When m = 1, the tracking error of different n

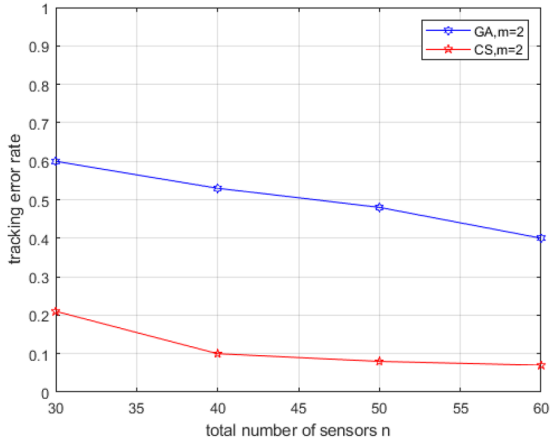

Fig. 2. When m = 2, the tracking error of different n

From the pictures above, we can see that the CS is much better than GA in reducing the target error rate, and when n = 60, m = 2, the tracking effect is very good and the calculation cost is less. Next, we have a comparison between CS and GA on the loss rate of the target (Figs. 3 and 4).

Compared with the GA algorithm, CS algorithm can reduce the target loss rate, but the effect is not obvious. When the deployed sensor is increased to 60, the effect of the two algorithms is similar. But in terms of running time, CS takes less computing time

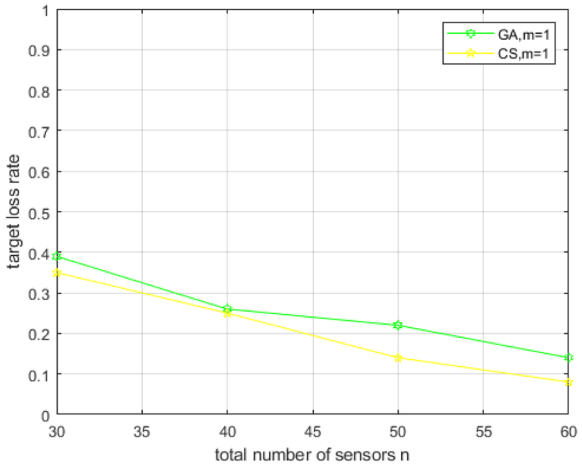

Fig. 3. When m = 1, the target loss rate of two algorithms

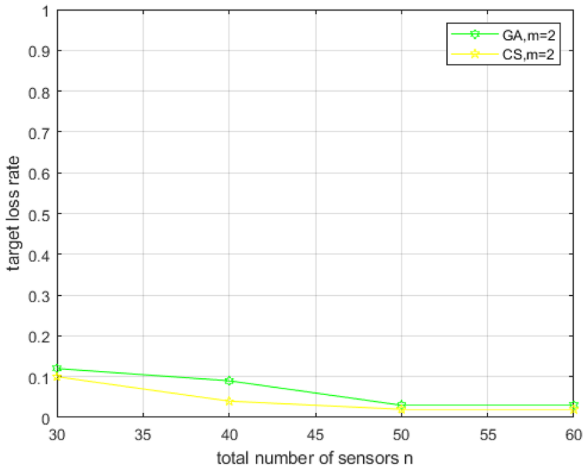

Fig. 4. When m = 2, the target loss rate of two algorithms

than GA, which we can see in Fig. 5. Time consuming is a very important measurement for network. From this point of view, CS has more advantages than GA.

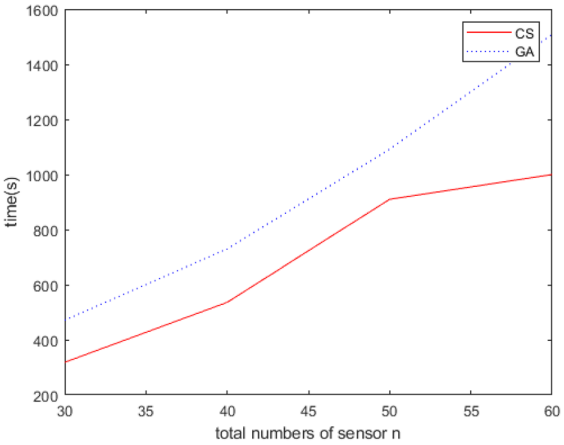

Fig. 5. The comparison of time consuming between CS and GA

5 Conclusions

This paper introduces the application of cuckoo search algorithm and fuzzy logic tree system in mobile tracking algorithm. The experimental data shows that cuckoo search algorithm is better than genetic algorithm in reducing error of location, time efficiency, computational complexity, tracking accuracy, etc., which also gives me the experimental basis to expand the application of cuckoo search algorithm in mobile sensor networks.

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