Multi-Target tracking using Ant-Colony Optimization for Static Sensor Networks

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Abstract

Sensor Networks are mainly used for target tracking. They have many real world utilities such as environment monitoring, target tracking in military applications, studying wild life, and soon. Many researchers were carried out on the mobility nature of the devices in network and the limitations of nodes in terms of energy, storage and processing power. Recently Mourad et al. proposed a target tracking method based on ant colony optimization. The problem of multi-target tracking was considered now which was not considered before. The method estimates present position of the target and predict the immediate future position of the target. Then the method determines the positions for sensor nodes in order to track the targets accurately. It uses Ant Colony Optimization for obtaining shortest path for Static Sensor Nodes. This paper deals with Static Sensor Network further it can extended to Mobile Sensor Network. The empirical results revealed that the prototype is effective and can be incorporated and used in real world applications.

Keywords: Ant Colony Optimization, Position Estimation, Static Sensor Networks, Target Tracking

1. INTRODUCTION

Sensing is an important aspect in modern computer applications. In some kind of military applications, it is important to sense the surroundings in order to monitor the areas where people cannot monitor manually. Static Sensor Network is a network which comprises a set of nodes with capabilities for sensing, processing and communication [1], [2].

The sensor nodes are resource constraint. For this reason it important to reduce the energy consumption of the nodes. When energy is optimally consumed the lifetime of the network is improved. The sensor networks are of two types. They are Static Sensor Network and Mobile Sensor Network. The Static Sensor Networks guarantee complete coverage of network which will be useful for finding the targets.

The Environment monitoring and military applications are the main applications of Sensor Networks [3], [4] besides target tracking. Security and surveillance are two most important requirements of military domain. The sensing problem is considered with static nodes in [5], [6] where the target tracking is done using clustering and particle filtering techniques are used respectively.

When Static sensor networks are used it can be treated as an advantage in target tracking, since it covers the entire network. In this case managing mobility [7] is another problem which has to be addressed. The researches such as [8], [9] and [10] focused on controlling the sensor nodes. In such kind of nodes which are part of Static Sensor Networks, it is essential to estimate the present location of target and also the sensor nodes. As the target moves, it is important to estimate the next location of target and also let the sensor nodes to be placed accordingly in a controlled fashion.

2. RELATED WORK

Recently Mourad et al. [11] proposed a novel method for tracking single object using ant colony optimization [12], [13]. They used mobile sensor nodes. An exclusive method for target tracking in controlled mobility sensor networks was applied. Having a moving target at each time step, the technique consists of estimating the current position of the target and then predicting its following position using a second-order prediction model. A repositioning of sensors is then performed in order to optimize the target localization for the following time step. The position of sensor node is obtained using an ant colony optimization algorithm. While the replacement phase uses a meta-heuristic-based approach, estimation and prediction phases uses interval analysis where target positions are boxes including the real value.

In order to conserve energy the controlled mobility is proposed. By using controlled mobility, one can control the sensor to which course it should move. Using this method, sensor is confined to a particular course and so the single target tracking is only achievable. If there are multiple targets arriving then controlled mobility will have a limitation of
confining a node to a particular area. As the targets are randomly arriving and moving, the static sensor networks are proposed as they are distributed all over the network.

As the sensors are energy constraint so the above methods proposed by Mourad et al. [11] can be efficiently utilized until the energy of a sensor is existing. If the sensor has continuous mobility it will be losing the energy continuously. So in this paper a method is proposed to conserve the energy of sensor and also extend the work for multi-target tracking which previously did only for single target tracking.

The alternative approach is having the four methods and the steps are represented as follows and can be well explained in the Fig. 1. The schematic view of the proposed approach is as presented in Fig. 1.

![Diagram](image)

**Fig.1.** Illustrates the phases of the proposed method

The rest of this paper is structured as follows. Section 3 presents target position estimation. Section 4 provides information about finding targets next step position. Section 5 describes the static sensor location process. Section 6 presents experimental results while section 7 concludes the paper.

### 3. Target Position Estimation

It is important to find the coordinates of the moving target object in order to estimate its position in each time step. After finding the current position, then its next step position has to be predicted in order to track it accurately. In order to find the position of the target one has to get whether the target is active or passive. If the target is active then it will always be communicating with the sensors within the network [11]. If the target is passive and non-cooperating then the sensors will be contacted with the fusion center every time. If the target is found then connection from the target to the sensor node indicated by the time which it is arrived

### 4. Prediction of Target’s Next Step Position

After finding the recent position of the target, it is essential to predict where the targets accurate position after the previous detection. Let \( y(1), \ldots, y(t) \) are the available estimates with respect to the positions of target. Then a \( k^{th} \) order prediction is made as follows where \( f \) is the prediction function.

\[
\hat{y}(t + 1) = f(y(t), \ldots, y(t - k))
\]

The second order prediction model used in this paper. As per model, the prediction is made as follows.

\[
\hat{y}(t + 1) = y(t) + \Delta t . v(t) + \frac{\Delta^2 t}{2} . a(t)
\]

The final prediction model is formulated as follows after considering instantaneous velocity and instantaneous acceleration at given time \( t \).

\[
[y](t + 1) = [y](t) + \Delta t . [v](t) + \frac{\Delta^2 t}{2} . [a](t)
\]

### 5. Sensor Location

The purpose of this method is to compute the optimal location to which the sensor has to be placed. As the sensor nodes are energy constrained the accuracy of static nodes is important. All sensor nodes are located in such a way that there is no uncovered area. Afterwards new locations are to be assigned to the sensor nodes so as to place them accordingly. The optimization of the target node mobility is obtained by using Ant Colony Optimization as presented below.

```plaintext
procedure ACO_MetaHeuristic
    while(not_termination)
        generateSolutions()
        daemonActions()
        pheromoneUpdate()
    end while
end procedure

Ant Colony Optimization Algorithm(excerpt from [15])
```
As shown above, the algorithm takes sensors coordinates and available positions as input and computes the new coordinates for target nodes.

6. EXPERIMENTAL RESULTS
To demonstrate the proof of concept a custom simulator was built in Java programming language. The prototype is built in an environment consisting of a PC with 2GB RAM and Core 2 Dual processor running in Windows XP. Net Beans IDE is used for rapid prototype development. The experimental results are recorded and compared with the existing approach.

As can be seen in Fig. 2, experiments are made with different number of sensors as shown in horizontal axis. The vertical axis represents error. The error value is more in the existing method while it is less in the proposed method.

Fig. 2. Number of Sensor vs Error

As can be seen in Fig. 3, experiments are made with different number of sensors as shown in horizontal axis. The vertical axis represents boxing areas. The boxing area value is more in the existing method while it is less in the proposed method.

Fig. 3. Number of sensors vs. Boxing Areas

As can be seen in Fig. 4, experiments are made with different number of sensors as shown in horizontal axis. The vertical axis represents computational time. The computation time value is more in the existing method while it is less in the proposed method.

Fig. 4. Number of Sensors vs Computational Time

7. CONCLUSION
In this paper an enhanced method was proposed for multi-target tracking. The Static Sensor Nodes are used to optimize the target tracking. The method performs the evaluation of recent position of target and its next position as well. The Static Sensor Nodes are being used to distribute them over the entire network uniformly. To estimate the optimal position of the sensor node, ant colony optimization is used. Thus the location of sensor node is essential. The proposed method in this paper focuses on implementing the method which is distributed in nature. It also incorporates mechanisms for multi-
target tracking. A custom simulator was built to demonstrate the proof of concept. The empirical results reveal that the proposed application is able to demonstrate multi-target tracking in Static Sensor Networks.

REFERENCES


