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An Energy Efficient Multi-Target Tracking in Wireless Sensor Networks Based on Polygon Tracking Method

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Abstract
Wireless sensor networks (WSN) have been considered as a promising system for area surveillance applications. As it moves through a sensor network target tracking has become an increasingly important application in Wireless Sensor Networks. Target detection deals with finding spatial coordinates of a moving object and tracking deals with finding the coordinates and being able to track its movements. Tracking mobile targets using sensor networks is a challenging task. Existing work mostly requires organizing groups of sensor nodes with measurements of a target's movements or accurate distance measurements from the nodes to the target, and predicting those movements. These are, however, often difficult to accurately achieve in practice, especially in the case of unpredictable environments, sensor faults, etc .In such cases the new tracking framework, called FaceTrack, suits best. FaceTracking employs the nodes of a spatial region surrounding a target, called a face. If a target is detected by a node after a time window, a target is detected by another node. It is assumed to be the same target or single object in FaceTracking method. But it achieves better tracking accuracy and energy efficiency for detecting and tracking single object. This paper proposes a new approach for multi target detection using FaceTracking or polygon tracking method. Simulations are carried out to underline the energy efficiency of the proposed method using NS2.

Keywords: *Multi-Target tracking, wireless sensor networks, accuracy, energy efficiency.*

1. Introduction

Wireless sensor networks (WSN) consist of thousands of tiny sensor nodes deployed in a physical environment for observation of an event of interest. The sensors must be able to monitor the event and report back to the sink. A sink sensor node has capability to communicate with outside world such as base station, laptop etc. Sensor nodes have been deployed to play significant roles in traffic control, battlefield, disaster relief operations, biodiversity mapping, and intruder tracking etc. in recent years. Wireless sensor networks make use of a centralized approach in the traditional target tracking methods. More messages are passed on towards the sink and will consume additional bandwidth, as the number of sensors rise in the network. Thus this approach is not fault tolerant as there is single point of failure and lacks scalability. More over sensing task is usually performed by one node at a time in traditional target tracking methods, and resulting in less accuracy and heavy computation burden on that node.

Wireless sensor networks are expected to bring the interaction between humans, environments, and machines to a new paradigm, so they have gained a lot of attention in both the public and the research communities. WSNs were originally developed for military purposes in battlefield surveillance;

however, the development of such networks has encouraged their use in health care, environmental, industries, and for different monitoring purposes like area monitoring, air quality monitoring, air pollution monitoring etc. or tracking targets of interest.

Detecting or tracking mobile targets using sensor networks is a challenging task because of the impacts factors such as sensing irregularity, environment noise etc. Due to extremely limited resource constrains for each sensor node, accurate large scale mobile target tracking still remains to be one of the challenging issues in the WSN community. According to the work in [1], a new tracking framework that detects the movements of a target using polygon (face) tracking is introduced called FaceTrack. It employs the nodes of a spatial region surrounding a target, called face. FaceTracking estimate the target moving towards another face, instead of predicting the target location separately in a face. The results in [1] shows that, FaceTrack has the ability to track a target with high accuracy and reduces the energy cost of WSNs.

The proposed system is indented for detecting multiple objects, called Multi-Target Tracking with high efficiency, reduced redundancy and energy cost. In order to achieve this a new system is developed and its effectiveness is checked using NS2 simulations based on the polygon tracking framework [1] called FaceTrack. Since this work is to detect multiple objects, it is tried to use only one sensor node to sense the target to reduce the redundancy of the sensed data.

2. Literature Survey

2.1 W. Zhang and G. Cao, "Dynamic Convoy Tree-Based Collaboration for Target Tracing in Sensor Networks," IEEE Trans. Wireless Comm., vol. 3, no. 5, Sept. 2004.

Most existing work on sensor networks concentrates on finding efficient ways to forward data from the information source to the data centers, and not much work has been done on collecting local data and generating the data report. This work studied this issue and proposed a new technique to detect and track a mobile target. The traditional target tracking methods for wireless sensor networks make use of a centralized approach. The centralized target tracking approaches are both time and energy consuming. To avoid this limitation tree-based tracking method is proposed. For that a dynamic convoy tree-based collaboration (DCTC), and formalize it as a multiple objective optimization problem which needs to find a convoy tree sequence with high tree coverage and low energy consumption. Several practical implementations such as the conservative scheme, prediction-based scheme for tree expansion and pruning and the sequential and the localized reconfiguration schemes for tree reconfiguration are proposed. Simulation results showed that the prediction-based scheme outperforms the conservative scheme, and it can achieve a relatively high coverage and low energy consumption close to the optimal solution. When the same tree expansion and pruning scheme is used, the localized reconfiguration performs better when the node density is high, and the trend is reversed when the node density is low.

2.2 M.Z.A. Bhuiyan, G. Wang, and J. Wu, "Target Tracking with Monitor and Backup Sensors in Wireless Sensor Networks," Proc. IEEE Int. Conf. Computer Comm. and Networks (ICCCN), pp. 1-6, 2009.

Target tracking with monitor and backup sensors (TTMB) in wireless sensor networks is proposed in this work. TTMB to increase the energy efficiency of the network and decrease the target capturing time while considering the effect of a target's variable velocity and direction. The approach is based on a face routing and prediction method. They uses a state transition strategy, a dynamic energy consumption model, and a moving target positioning model to reduce energy consumption by requiring only a minimum number of sensor nodes to participate in communication, transaction, and sensing for target tracking. Two sensor nodes, namely, 'Monitor' and 'Backup', are employed for target tracking for each period of time. For the whole time of target tracking, a linked list of monitor and backup sensors is formed. This approach can still survive, if either monitor or backup sensor fails. Monitor and backup method provide faster target capturing speed, and better energy efficiency. Due to its fault tolerance capability failure of one or a few nodes does not affect the operation of the network during target tracking. This work has provision for further improvements in some areas, such as finding a better technique for position estimation while considering error avoidance, investigating the issue of quality tracking vs. energy consumption of the entire network and effect of localization errors on face routing for target tracking.

2.3 O.Kaltiokallio,M.Bocca, and L.M. Eriksson, "Distributed RSSI Processing for Intrusion Detection in Indoor Environments," Proc. Ninth ACM/IEEE Int'l Conf. Information processing in Sensor Networks (IPSN), pp. 404-405, 2010.

Differently than in other previous works, this work describes a WSN for real-time intrusion detection and tracking by distributed processing of the RSSI signals, in which the nodes of the network transmit all the collected RSSI measurements to the sink node. In the proposed system a distributed algorithm enables the nodes to transmit only those alerts related to significant events. The data received at the sink node are then combined and processed in real time to produce accurate estimates of the current position of the intruder. A Kalman filter is applied to improve the tracking accuracy and smoothness in this work. Furthermore, other previous works rely on collecting measurements and training the system in static conditions (i.e. monitored area is vacant) before deployment, thus making it impossible to be used in emergency response scenarios. The approach presented in this work doesn't rely on training the system and is ready to be used once deployed. The distributed algorithm reduces the amount of packets the nodes have to transmit to the sink node, and consequently the nodes power consumption, extending the overall lifetime of the system. Power consumption is further reduced by means of a high accuracy time synchronization protocol, enabling TDMA communication among the nodes. Being time synchronized, the nodes can activate their radio only in correspondence with the scheduled transmissions.

2.4 Y. Wang, M. Vuran, and S. Goddard, "Analysis of Event Detection Delay in Wireless Sensor Networks," Proc. IEEE INFOCOM, pp. 1296-1304, 2011.

Emerging applications of wireless sensor networks require real-time event detection to be provided by the network. An analytical framework called spatio-temporal fluid model is developed to capture the delay characteristics of event detection in large-scale WSNs. Accordingly, the mean event detection delay and soft delay bounds for event detection is modelled in this work. Usually timely delivery of a certain number of packets is required to improve the event detection reliability. Traditional timing analyses of WSNs are, however, either focused on individual packets or traffic flows from individual nodes.

2.5 Z. Zhong, T. Zhu, D. Wang, and T. He, "Tracking with Unreliable Node Sequence," Proc. IEEE INFOCOM, pp. 1215-1223, 2009.

Because of the impacts of factors such as sensing irregularity, environment noise etc., tracking mobile targets using sensor networks is a challenging task. In this work a robust tracking framework using node sequences is proposed. It is an ordered list extracted from unreliable sensor readings. Instead of estimating each position point separately in a movement trace, they converted the original tracking problem to the problem of finding the shortest path in a graph, which is equivalent to optimal matching of a series of node sequences. Multidimensional smoothing is developed to enhance tracking accuracy in addition to the basic design. This work introduces multi-dimensional smoothing in the modality domain, time domain, and space domain, working together to contribute to the accuracy and generality of the whole system design. Time domain smoothing over continuous detection results is commonly used for filtering out random noise in many systems. Practical system deployment related issues are discussed in this work, and the design is evaluated with both simulation and a system implementation using Pioneer *III* Robot and MICAz sensor nodes. Tracking with node sequences provides a useful layer of abstraction, making the design framework generic and compatible with different physical sensing modalities.

2.6 Guojun Wang, Md Zakirul Alam Bhuiyan, Jiannong Cao,and Jie Wu, "Detecting Movements of a Target Using Face Tracking in Wireless Sensor Networks" IEEE Transactions on Parallel and Distributed Systems, vol. 25, no. 4, April 2014.

Target Tracking has become an increasingly important application in Wireless Sensor Networks (WSNs). In WSNs target tracking were originally developed for military purposes in battlefield surveillance. The main functionality of a surveillance wireless sensor network is to track an unauthorized target in a field. To determine how to perceive the target in a wireless sensor network efficiently, is the existing challenge. In this work a unique idea for detecting movements of a target using polygon tracking called FaceTrack is proposed. The proposed method does not adopt any prediction method. That means it do not predict or assume the future movement locations of the moving objects. Wang et al also formulated an optimal selection algorithm to select couple nodes on the target's moving path to keep the number of active sensors to a minimum. The applicability and benefits of FaceTrack is validated in this paper by implementing a proof-of-concept system of the Imote2 sensor platform using the TinyOS. The evaluation results of the proposed tracking framework demonstrated that it can estimate a target's positioning area, achieve tracking ability with high accuracy, and reduce the energy cost of WSNs.

3. Proposed System

The proposed system is indented for multi-target detection in wireless sensor network. In this work is mainly focused to extent the energy efficiency and tracking accuracy of target tracking in wireless sensor networks to track multiple objects. For this work, it is tried to develop a system based on three techniques such as Polygon Tracking along with edge detection algorithm and optimum selection technique [1]. This work is also tried to reduce the redundancy of the sensed data by reducing the number of active sensor nodes used to sense the target. The first step is the system initialization, including topology formation, data gathering and initial polygon construction in the plane shown in Figure 1. A node has all of the corresponding polygon's information after the network planarization. Initially, all nodes in the WSN are in a low-power mode [6] and wake up at a predefined period to carry out the sensing for a short time. Sensor node has three different states of operation, namely, active, awakening, and inactive [1]. These three states can be called as sensor state transitions. Consider that a sensor should be kept awake so long as its participation is needed for a given task. The second step is meant for target detection and creation of the active local environment. Finally target tracking method called FaceTrack will enhance and apply to detect multiple objects.

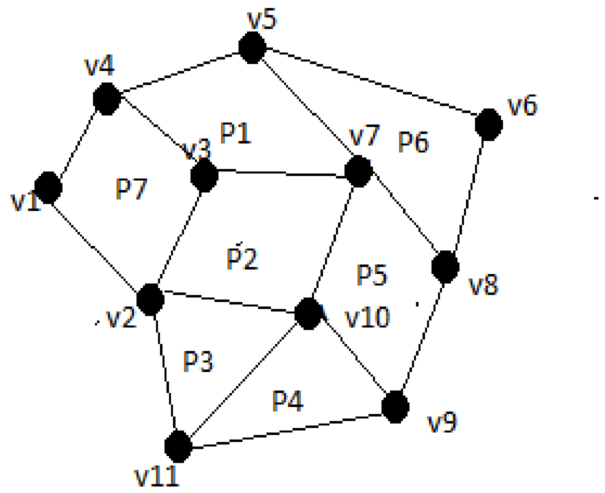

Figure 1: Sensor network demonstrating polygonal shaped regions

In a situation, if a target is detected by a node after a time window, a target is detected by another node, it is assumed to be the same target in the existing polygon tracking method. The target does not carry any form of classification. For multi target tracking method each target carry an identification mark for distinguish them.

4. Target tracking through polygon tracking

Polygon tracking method is a new tracking method for target tracking in wireless sensor networks developed by Guojun Wang et.al. Polygon tracking can also called as FaceTrack , which has the ability to track a target with high accuracy and reduces the energy cost of WSNs. The frame work for tracking multiple objects in wireless sensor network is shown in Figure 2.

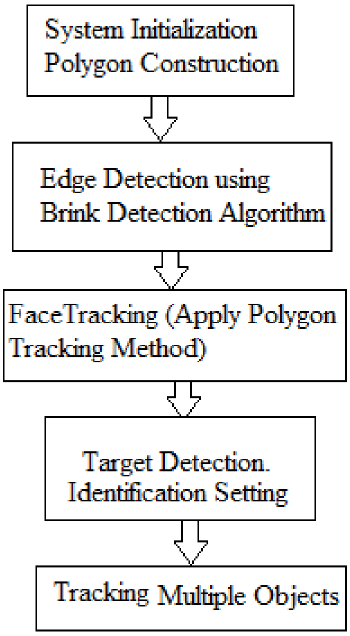

Figure 2: Enhanced polygon based framework for multi target detection

5. Simulation Results

An interesting observation on energy consumption for Multi Target tracking can be seen in Figure 3. Figure shows the performance of the new framework in terms of energy consumption versus time. Total energy consumption gradually reduces during tracking with polygon tracking. The unnecessary energy consumption is reduced by reducing the number of active sensors to a minimum.

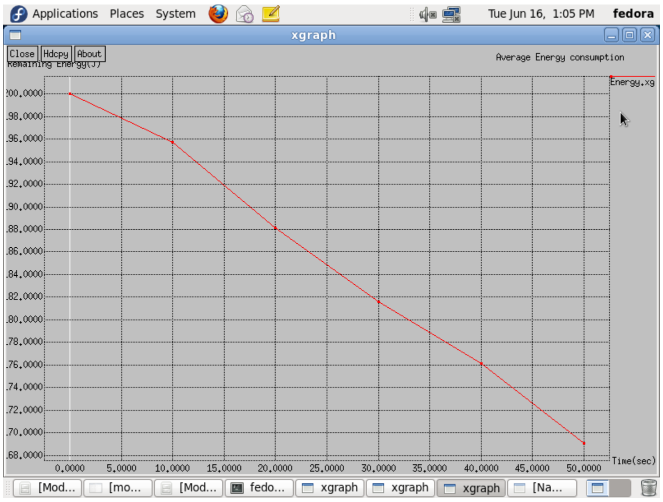

Figure 3: Experimental multi target tracking performance in terms of energy consumption.

6. Conclusion

Today, Multi-Target tracking has found applications in areas, including, surveillance, intelligence, oceanography, autonomous vehicles and robotics, space applications, biomedical research, remote sensing etc. Tracking multiple unauthorized targets in wireless sensor network is a challenging task. We proposed an idea to achieve an energy efficient tracking of multiple objects in wireless sensor networks with the help of Polygon tracking method. Each target is distinguished with the help of the identification mark assigned to them.

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Author Profile

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