International Conference on Science, Technology, Engineering & Management
[ICON-STEM'15]
Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Face Tracking Surveillance System using wireless sensor network

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ABSTRACT

The main application of wireless sensor networks (WSNs) is Target tracking. Almost all work 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 their movements. These are very difficult to accurately measure in practice, especially in the case of unpredictable environments and sensor faults, etc. In this paper, we propose Face Track, which employs the nodes of a spatial region surrounding a particular target, called a face. We estimate the target's movement toward another face instead of predicting the target location separately in a face. We introduce an edge detection algorithm to prepare a node for the target's movement, which greatly helps tracking the target in a timely fashion and recovering from special cases, e.g., sensor fault, loss of tracking. We also develop an optimal selection algorithm to select which sensors of faces to query and to forward the tracking data. Simulation results, show that Face Track achieves better tracking accuracy and energy efficiency than earlier works.

INTRODUCTION

Wireless Sensor Networks (WSNs*)* is widely used in both the public and the research communities because they can bring the interaction between humans, environments, and machines to a new pattern. Wireless Sensor Networks were originally developed for military purposes in surveillance of combat zones; however, the development of these networks has encouraged their use in medicine, industries, and for surveillance of objects.

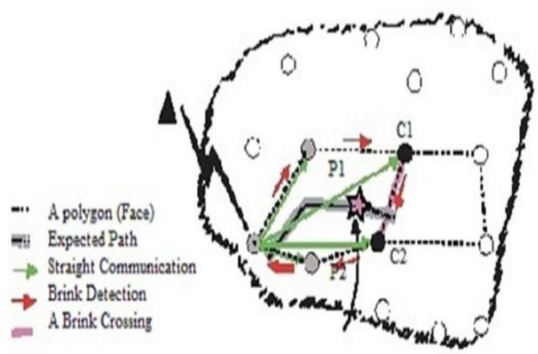

Fig 1.Vehicle being tracked in a polygon shaped area

The above figure shows a typical scenario of a vehicle. Sensor nodes are informed when the vehicle under surveillance is found in the network, while some nodes detect the vehicle and send a message to the nodes based on the vehicle's expected moving path, to make the nodes ready for tracking. Thus, the nodes in the vehicle's moving path can prepare in advance and remain active in front of the object as it moves. To be energy efficient and to track the vehicle accurately, only the nodes close to the path can be used in tracking and providing continuous coverage.

Regardless of various types of targets, there are three common procedures involved in existing solutions of target tracking system. The sensor nodes should be localized with minimum errors as possible, and a distance measurement from the nodes to a target, or a measurement of the target's movements is crucial; 2) nodes should be organized into groups (e.g.,clusters) to track a moving target; 3) primary sensors generally report the target's movement to a central sink (the sink is a resource-rich node that gathers information from the primary)[3]. Regarding the above procedures, if we want to work with scenarios like that of above picture, achieving high accuracy of tracking together with energy efficiency in Wireless sensor networks is a challenging problem, due to several difficulties like,

- Organizing groups of nodes with accurate measurements of a target's movements is difficult, as WSNs are dense/sparse, unattended, untethered, and deployed in usually unpredictable environments.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

- Obtaining accurate target localization is impossible in a real operation field, even when different kinds of noises/disturbances are added during detection.

- Maintaining operations of nodes in a timely fashion is difficult, i.e., turning their services off most of the time, and enabling only a group of nodes to be functional in the target's moving path.

- Loss of tracking or node failure is often possible, since WSNs are prone to fault or failure. Research about target tracking can be roughly divided into three categories: 1) tree-based schemes; 2) cluster-based schemes; and 3) prediction-based schemes. We propose FaceTrack, a framework to detect movements of a target using face tracking in a Wireless Sensor Networks, which does not fall into existing categories and is, to the best of our knowledge, the first of its kind. The concept of Face Track is inspired by computational geometry, geographic routing, and face routing. Face Track mitigates the discussed difficulties, when satisfying our objectives like achieving tracking ability with high accuracy and reducing the energy cost of Wireless Sensor Networks.

Benefits: Some benefits of Face Track, which help us reach our objectives are listed below.

1. When an event of sensor fault occurs, or there is an event of loss of tracking, FaceTrack mitigates such events without making changes to the whole network.

2. The presence of the target are locally detected by nodes and decide whether to continue tracking tasks, i.e., they do not need to communicate with the sink frequently. However, the sink is informed by the couple of nodes if target enters the surveillance area or not.

3. Nodes do not predict or maintain the target's movement history completely, but keeps only the most recently reported information and time instance.

4. If the number of active nodes is large, the tracking accuracy is very higher, but the energy cost is higher too. Face Track relies on accumulated detection from a selected node that is in the polygons.

The four main contributions of this paper are:

- We used Face Track framework to detect the movements of a target using polygon structure face tracking, which does not rely on any other topology.

- We used a brink detection algorithm that enables the Wireless Sensor Networks to be aware of a target entering the polygon a bit earlier, and to work in a timely fashion.

- We used an optimal selection algorithm to select couple nodes on the target's moving path to reduce the number of active sensors.

- We found the performance of Face Track extensively through simulations and compare with existing methods. The results show that Face Track has the ability to track a target with high accuracy and reduces the energy cost of Wireless Sensor Networks.

Preliminaries and model: In this section, we are going to briefly discuss about Face Track. Then, we briefly discuss the preliminaries and introduce the system models.

A. Objectives: The main aim of this paper is to design Face Track to achieve a real-time tracking through detecting the movement of a target using face tracking. To measure the performance of Face Track, two of the important metrics areas are as follows: 1) tracking accuracy: To decrease tracking errors found (TEF) by nodes that are involved in tracking and increasing tracking ability rate (TAR), i.e., the high degree of successful tracking; 2) energy cost and energy- efficiency of the WSN.

B. Assumptions and Notations: Some of basic assumptions of Face Track are as follows:

- The mobile target (event) that is of interest is sensed and optionally observed by a Wireless Sensor Network, such as tracking an enemy vehicle, an intruder, or a moving wild animal. We consider a single target, i.e., a car is being tracked in the Wireless Sensor Network with a maximum off/on-road speed of around 10 m/s.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

- Sensors are considered to be homogeneous. The sink is considered to be a user, where all the sensors are controlled.
- All nodes are synchronized and they follow a state transition policy to be active or inactive.
- The Wireless Sensor Networks is assumed to have some fault or damaged nodes. It is randomly set after initialization of the network.
- If a target is detected by a node after a time window, and then if a target is detected by another node. It is assumed to be the same target. This assumption is made because the target does not carry any form of classification, nor can any different target be distinguished.

The various notations used in this paper are explained below:

Table.1.Mathematical Notation

Symbol	Description	Symbol	Description
P_c	Active Polygon	D	Brink length
P_f	Future Polygon	C_v	Localization error covariance
P_i	Number of neighbouring Polygons in a node	d_{ik}	Distance between two sensor nodes
P_N	Number of sensor nodes in the polygon	d_{ij}	Distance between a sensor node and a target
N_N	Number of neighbouring nodes in the polygon	r_s	Sensing range
O_N	The optimal number of sensor nodes	r_c	Communication range
C_N	Couple nodes	T	Given time window of the whole period

C. Network Model: We consider a WSN is G= (V,N) composed of a set V of N nodes and a set E of edges in a 2D planar field, and the nodes are able to tune their range up to radio range rc. Let N(u)={v||(u,v)|≤rc} be the set of neighbor node u, and there is a sink or user in the WSN that requires information about a target. Consequently, all u to V and v to V together define a unit disk graph (UDG), which has an edge (u,v) if, and only if, the Euclidean distance ||(u<v)||≤1. To track the target route, extracting planar graphs is needed to guarantee the information delivery before the target arrives at a region. Related neighborhood graph is an example algorithm that creates a planar graph. The main idea is that two nodes, u and v, from a planar graph, are in each other's communication range, if there is no neighbor, w, called a witness, within their common area that is closer to either u or v. We can obtain a connected planar subgraph G'=(V,E') that maintains connectivity with very fewer edges. The planar subgraph contains one or more closed polygons. Such a polygon contains more than three nodes. A polygonal region is a topological concept that can be defined abstractly, without use of exact coordinates.

Distributed Measurement Model: Consider a target moving, e.g., a car, in a restricted area (R), and its movement is detected by a Wireless Sensor Network. The car may increase its speed or decrease its speed at any time. Let si to R be the location of the i^{th} node, and $L_i=\{s_i:1\leq i\leq N\}$.

We model the sensor measurement problem by using a standard estimation theory. In this framework, all sensors are acoustic, measuring only the amplitude of the sound signal. Let es(t) be the time-dependent average signal energy measurements over t, then a sensor can make the following measurement:

$$e_s(t) = S_i(t) + \mathcal{E}_i(t) \qquad (1)$$

where $S_i(t)$ is the signal and $\mathcal{E}_i(t)$is the noise energy, respectively. The background noise has a distribution with the mean, which is equal to σ^2_i, and the variance, which is equal to $2\sigma^2_i/M$. M can be larger, for example 40. In FaceTrack, the brink detection depends on the target's location. To estimate the brink, the location information is estimated with an adjustment

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115
on error covariance, c_v. We adjust the approximate target location information by using a covariance bound that is similar to the formulation of the Cramer-Rao lower bound (CRLB).

DESIGN OF FACETRACK

We first define how the polygons can be localized in Face Track. Then, we present our brink detection algorithm. At last, we introduce our optimal node selection algorithm and its features.

Localized Polygon: In order to describe the problem of detecting the movement of a target as an unauthorized target traversal problem through polygon tracking, we see an example of the generated polygons. We use polygons to describe the target's moving path. The polygon is not necessarily a convex, but it must not be self-overlapping. Let the number of nodes in a polygon be P_N = (v1, v2, . . . ,vp) where p ≥ 3. Suppose that the target is detected by some nodes somewhere in the WSN, and it is surrounded by the nodes in a polygon, e.g., P2. Then, P2 is called an active polygon (P_c), and nodes (e.g., v5) in P2 are active nodes. In the figure, P1 is a triangle, P2 is a pentagon, and P7 is a tetragon. Node v5 in P2 is aware of the following information: 1) its own information; 2) the information of its adjacent (or 1-hop) neighbors v4, v11, v7, and v6; 3) the information of its active neighboring nodes v6, v1, v3, and v4; 4) the information of the neighbors in P2, P3, P4, and P7 through direct communication or the 1-hop intermediate nodes after deployment. Thus, v5 stores information about four polygons that are adjacent to it in G–{fv5; v4; v17; v11}, {v5; v11; v19; v8; v7}, {v5; v7; v6}, and {v5; v6; v1; v3; v4}.

The target may move from Pc to any of the adjacent polygons, e.g., P7. The adjacent polygon is called a forward polygon (Pf). v5's adjacent neighbors that correspond to Pc, with respect to the target detection, are called immediate neighbors. Thus, node v5 can have only two immediate neighbors, v4 and v6, out of the four adjacent neighbors in G. Either v4 or v6 becomes active as the target crosses edge(v5, v4) or edge(v5,v6). Suppose the target travels toward polygon P7; it crosses edge (v5; v4), thus, we call v5 and v4 couple nodes (CNs). The process of selecting the couple nodes is described in a later section. All of v5's neighboring nodes in P2 are denoted by NNs. The working area of v5 covers all of the edges between the adjacent neighbors and itself. Thus, a node corresponds to a number of polygons (Pi) that depends on the number of edges or adjacent neighbors. The size of a polygon is defined by the number of edges surrounding the polygon. The average size of a polygon is$P \leq$ 2vi/(vi–ei+2), where vi and ei are the numbers of nodes and edges of the polygon, respectively. The relationship between nodes, edges, and polygons is given as Pi + vi - ei = 2, where Pi is the number of polygons corresponding to a node according to Euler's formula. This implies that Face Track has cells for a planarized Wireless Sensor Networks, with as many edges as possible. Some observations on underlying issues/advantages of this localized polygonal. We provide a representation, which elaborates two important concerns: 1) how does the system detect the target in a polygon in the beginning; 2) which polygon is the target moving toward.

Brink Detection Algorithm: We introduce an edge detection algorithm, which is used to recreate another conceptual polygon, which is a critical region formed by generating an edge, called a brink, to the active polygon, Pc. As the brink is generated on the boundary of Pc, the polygonal region problem turns into a critical region problem. In the algorithm, our objective is to detect the brink, while the target is moving to a brink between CNs that confirms that the target is leaving Pc and moving to Pf, which could allow for tracking the target in a timely fashion. After the detection of the target and the reconstruction of Pc around the target, this algorithm is applied during the target movement from Pc to Pf. In the algorithm, the edges of Pc are mapped by the brinks. As the target moves to a brink, the target is focused on a spot, called a follow spot. In the follow spot, a brink between CNs can be similar to an automatic door. Often found at supermarket entrances and exits, an automatic door will swing open when it senses that a person is approaching the door. The door has a sensor pad in front to detect the presence of a person about to walk through the doorway. Therefore, the door can be called an entrance door or entrance brink. When a person accesses the entrance sensing area, the door opens; however, if the person does not pass through the door and waits in front, the door is closed automatically after a period of time. Hence, in the case that the waiting period occurs in the algorithm, the CNs do not need to broadcast the message to Pf. Suppose that the person/target passes toward the door/brink from Pc to Pf. As the target moves toward a brink of Pc, the follow spot is divided into the following three-phase detection spots. By using the three-phase detection, each brink in Pf has to be identified during the target's crossing over. To estimate the phases, we consider the brink to be mapped over the X-axis. Let D be the length of the brink, and let i and k be the couple nodes, respectively. We assume that D αd_{ik} and $\frac{D}{2} \leq r_s$. D is achieved from (-D/2) to (D/2). D ≤ $2r_s$ is a length of both square and rectangular spots. Hence, A = D^2 is for the total square spot, and A = D^2 X D is for the total rectangular spot. Suppose that the target is in the square phase. When it touches the rectangular phase, a joint-message is broadcast to Pf. When the target passes the crossing phase, Pf becomes the new Pc. All of the brinks in the previous Pc are removed, and the previous Pc becomes inactive and remains as a neighboring polygon. Variability of different parameters of the brink, i.e., 1) brink length, 2) local mean length, and 3) local standard deviation, allow the CNs to identify the brink more easily.

Movement detection by polygon tracking: In this section, we provide an overview of target detection through the polygon tracking process. We also discuss the fault tolerance in the Wireless Sensor Networks during tracking.

Overview of the Polygon Tracking Process: There are five steps in the framework. The Step 1 is about the system initialization, including initial polygon construction in the plane. A node has all of the corresponding polygons information after the Wireless Sensor Networks planarization. Initially, all nodes in the Wireless Sensor Network are in a low-power mode and wake up at a predefined period to carry out the sensing for a short time. We presume that a sensor node has three different states of operation, namely, active (when a node is in a vigilant manner and participates in tracking the target), awakening (when a node awakes for a short period of time), and inactive (when a node is in a sleeping state).

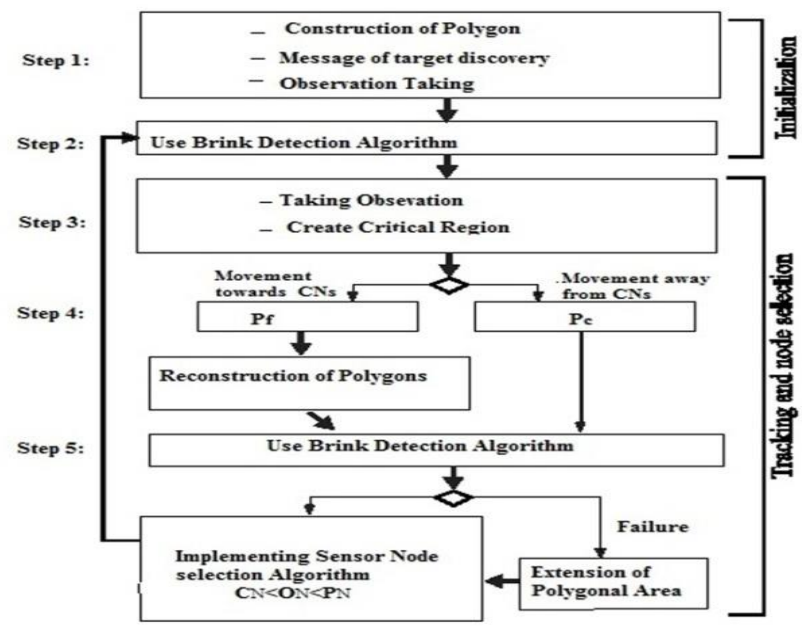

Fig.2.Illustration of Polygon based tracking framework

We consider that a sensor should be kept awake as long as its participation is needed for ongoing task. In the beginning, when a target is detected by some nodes, the nodes communicate to all of its adjacent neighbors with their detection information, and reconstruct the polygon. Once the target is surrounded by the perimeter of a polygon, it becomes Pc. Whenever the CNs are selected by the optimal selection algorithm, the detection probability p' or p'', confirms that the target is about to cross the rectangular phase and then the crossing phase. A joint-request message is sent to Pf at the moment the target touches the rectangular phase, saying that the target is approaching. All NNs in Pf receive the request, change their state to an awakening, and then start sensing. When the target crosses the brink, another joint-request message is sent to the nodes in Pf, saying that the target is crossing the brink. After the target crosses over the brink (i.e., it is now in the new Pc), another message is sent to the NNs in the previous Pc. After receiving the message, all NNs, except the previous CNs, return to the inactive state. The target may move in any way toward any brink. When the target speed is lower or the target moves away, it does not influence the tracking. We think of the target's faster speed. When it is faster, the movements may be abrupt. The CNs keep sensing continuously until the target leaves/enters the square phase. The CNs use the difference in distance dij between two consecutive sensing results. The results are measured by reducing CRLB covariance to obtain fewer errors in three-phase detection. Since the target travels across the square phase, and then the rectangular phase, dij decreases accordingly. The CNs are aware of it. If the target leaves the square phase for the same Pc, the CNs send a message instantly to the NNs in Pc. The NNs remain active and are ready to receive the message. If they receive the message, shortly there-after, they start sensing further. The next procedures go on in the aforementioned way. However, if any rectangular phase is not generated, there is no Pf selected.

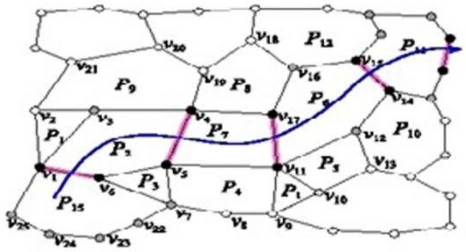

Fig.3.Detecting Target's movement through Polygons

According to the framework, the above diagrams illustrates the target movement detection through the polygons. The target is initially detected by sensors v1 and v6 in the polygon P15, and the rest of the corresponding nodes in P15 are in the vigilant manner, and the rest of the nodes in the sensor network are in the inactive state when the target is in the target travels through the polygons. The tracking of the polygons represents the target tracks. A tracking sequence can be P15, P2, P7, P6, P11, and so on.

Fault tolerance: Generally, the Wireless Sensor Network planarization does not have any fault tolerance support. Thus, initially constructed polygons may not be preserved during tracking. While the target is moving to Pf , if a node cannot execute itself (i.e., it is out of service because of an internal error such as battery depletion, failing to detect itself, or missing from its location) or there is a link failure due to inter-node wireless channel fluctuations, tracking can be interrupted. These result in the event of loss of tracking. There are several ways that we mitigate these situations: by using the outside area of Pc, by extending the polygon area coverage, or merging two or more polygons into one single polygon.

CONCLUSION

The main functionality of a surveillance wireless sensor network is to track an unauthorized target in a field. The challenge is to determine how to perceive the target in a Wireless Sensor Networks efficiently. We proposed a unique idea to achieve a Wireless Sensor Network system for detecting movements of a target using polygon (face) tracking that does not adopt any prediction method. The proposed tracking frame work can estimate a target's positioning area, achieve tracking ability with high accuracy, and reduce the energy cost of WSNs. From the framework, two facts can be highlighted emphatically: 1) the target is always detected inside a polygon by means of brink detection, and 2) it is robust to sensor node failures and target localization errors. Two interesting problems, which we are currently investigating, are as follows: 1) the performance of variable brink lengths of the polygon versus adjustable transmission power levels in a Wireless Sensor Network for target detection and its energy cost in it; 2) the impact of the target's dynamic movements, brink detection, and real-time polygon forwarding in target tracking.

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