Tour Planning for UAV Data Mules in Border Wireless Multimedia Sensor Networks

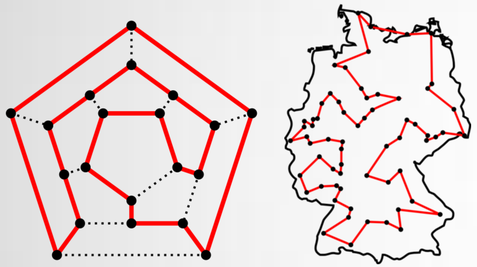
Abstract

In recent years, research has been done to show mobile sinks could be beneficial to Wireless Sensor Networks (WSNs) contrary to previous beliefs. These mobile sinks would be especially helpful in Wireless Multimedia Sensor Networks (WMSNs), which have higher data volume and can have tighter delivery constraints. Border monitoring networks are prime examples of WMSNs, wherein multimedia sensors are used to detect entities attempting to cross a secured border. In a network of this kind, power consumption is a major concern because of the increased amount of data. One way to reduce the power consumption is to reduce the amount of multi-hop forwarding required to collect the data at the base station. To do this, a mobile sink, or data mule, can be sent out to recover high-fidelity multimedia data and then return to the base station. In order to maximize these savings, the data mule should find the best path to collect all of the data. The path-planning problem has been modeled as a variant of the Traveling Salesman Problem (TSP), but existing solutions to TSP variants require ideal vehicles capable of arbitrary turning. The possibly large coverage area involved in border monitoring will require a fast vehicle, such as an Unmanned Aerial Vehicle (UAV), which introduces a constraint and complicates the TSP. We propose the Convex Hull heuristic to solve the path-planning problem for a UAV operating as the data mule of a Border Wireless Multimedia Sensor Network. Furthermore, to satisfy the curvature constraint we model the path as a series of shortest-length R-Geodesics

Traveling Salesman Problem

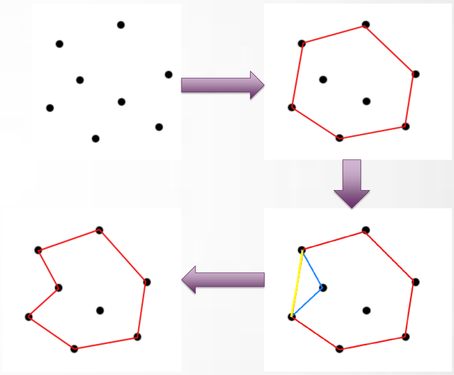
The TSP is a classic NP Hard optimization problem in which, given a graph, one attempts to find a Hamiltonian cycle (tour that visits each vertex exactly once) of minimum cost. Cost is usually Euclidean distance.

Since the decision version of the TSP is NP-Complete, heuristics must be used to find a “good” solution in a reasonable amount of time.



Convex Hull Insertion Heuristic

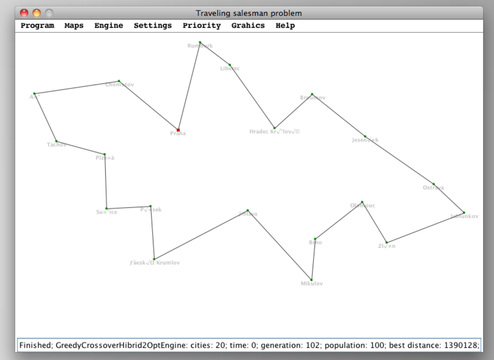
Also known as the “Shrink Wrap” method, this heuristic constructs an initial tour by finding the convex hull for a given set of nodes. Then, for each node not yet in the tour, the algorithm finds the place to insert that node that adds the least distance to the tour and creates a list containing the best insertion for each node. Finally, the algorithm takes that list and uses a secondary metric to decide which insertion is the “best of the best” and performs that insertion. The secondary metric can be anything, including least distance, ratio, or, for our application, smallest angle. The smallest angle metric should help keep tours smooth and easier for a UAV to follow.



Genetic Algorithms

Commonly used in search and optimization problems, genetic algorithms are a type of heuristic that allow a solution to evolve from a population of randomly generated candidate solutions.

We compare a number of genetic algorithms for solving TSP and use them as a basis for comparison with other heuristics



Data Mules

Data Mules are special mobile sink nodes in a network intended to increase network lifetime by reducing the amount of multi-hop communication. They can also help alleviate congestion due to bottlenecking and even out the heterogeneous power consumption distribution experienced by nodes closest to the sink.

R - Geodesics

Given an initial point u and terminal point v and velocity vectors, U and V respectively, the curve of minimal length with radius of curvature everywhere greater than R is called an R-geodesic. The path described by an R-geodesic is either a Circle-Line-Circle (CLC) path or Circle-Circle-Circle (CCC) path.

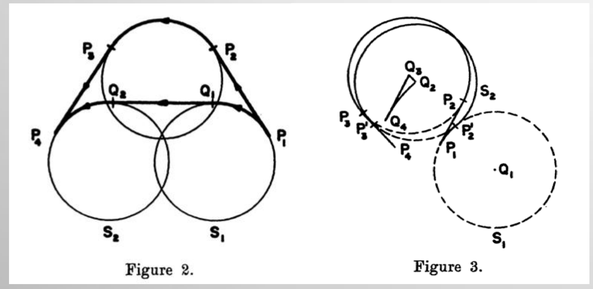
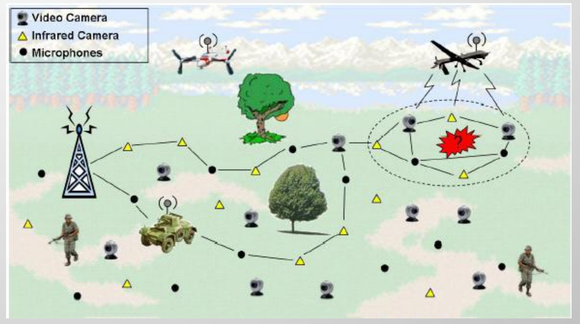


Figure 2. Figure 3.

Dubins, L. E. (1957). "On Curves of Minimal Length with a Constraint on Average Curvature, and with Prescribed Initial and Terminal Positions and Tangents." American Journal of Mathematics **79(3): 497-516.**

Wireless Multimedia Sensor Networks

Wireless Multimedia Sensor Networks are sensor networks with the added capability of capturing multimedia data, such as video or audio. This is a new field that gives a more refined view of the sensed area and will give a more complete picture as to what is happening.



Border Monitoring

Border Monitoring can work in a variety of applications, from monitoring country borders to security for a residence or corporation. These networks are characterized by their elongated shape. They can be made of sensors with video, audio, or data capability in order to sense unauthorized movement across some border.

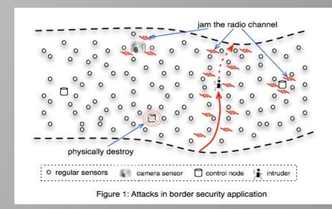


Figure 1: Attacks in border security application

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