Wireless sensor localization techniques

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Abstract

Intelligent wireless sensing devices are becoming ubiquitous and are being applied in many applications ranging from environmental monitoring to animal tracking and numerous other applications. The devices themselves are usually small and inexpensive. They typically have limited computing resources and limited wireless range. These devices are often assembled into vast networks that communicate between the devices, or nodes, and perhaps a central location. Often in order for these systems to function, the nodes need to know their location within the network and/or a central location needs to know their location within the network. The work we’ve been conducting involves investigating algorithms that perform localization of wireless sensor nodes using only connectivity information, also referred to as range free localization. These algorithms allow the sensor nodes to reduce hardware complexity and power requirements. We’ve been evaluating the effectiveness of several these connectivity based algorithms with respect to location accuracy.

Range or Angle Based Approaches

- Uses signal travel time to measure distance between nodes
- Requires time synchronization between nodes
- By measuring the distance between three or more nodes and using the known position of three or more nodes, triangulation is used to calculate the position of a fourth node.
- Requires hardware to make Angle of Arrival (AoA) measurements

Global Positioning System

- The Global Positioning System is mature, inexpensive and ubiquitous
- Requires hardware to make ToF measurements

Range Free Approaches

- Uses directional antennas to measure the angle of arrival of a signal
- By measuring three or more angles and using the known position of three or more nodes, triangulation is used to calculate the position of a fourth node
- Requires hardware to make Angle of Arrival (AoA) measurements

Multidimensional Scaling (MDS)

- Uses signal travel time to measure distance between nodes
- Requires time synchronization between nodes
- By measuring the distance between three or more nodes and using the known position of three or more nodes, triangulation is used to calculate the position of a fourth node
- Requires hardware to make Angle of Arrival (AoA) measurements

Early Methods and New Algorithms

- Received Signal Strength Indicator (RSSI): RSSI has been proposed as alternative to ToF for making distance measurements.
- Power of a signal decreases at 1/d².
- RSSI is not an accurate indicator of distance: Environmental factors, such as the presence of a wall and other obstructions affect the received signal strength.
- Transmissions from other devices also interfere with RSSI.
- RSSI is incorporated into all wireless transceivers and is readily available with no additional hardware

A Microsoft C# language application was developed to investigate each of these algorithms. The application allows the investigator to create a random graph of any size with any number of nodes. It uses a Hammersley sequence to generate a quasi-random distribution of nodes. The application also allows the investigator to specify the ratio range of a node. This is used to determine the connectivity graph of the network. A graph can be saved and restored for use in later tests. This research project is using this tool to investigate the effectiveness of the four connectivity based approaches. Each of these approaches has strengths and weaknesses. Utilizing what we will have learned, we will attempt to design an algorithm that utilizes the identified strengths of these approaches, creating a hybrid.

Until low energy state achieved.

End Monte Carlo

Perform Re-sampling

Identify Witnesses

End Compute Delaunay Complex

Identify Voronoi Cells for Landmarks

End Compute Voronoi Diagram

Identify Landmarks

End Main

Identify Landmarks

Compute Voronoi Diagram

Begin

End Monte Carlo

Perform Re-sampling

Identify Witnesses

End Compute Delaunay Complex

Construct Delaunay Edges

End Compute Delaunay Complex

Begin Main

Identify Landmarks

Compute Voronoi Diagram

Tri-lateral Remaining Nodes

End Main

Monte Carlo

Choose N samples from the initial distribution of the system

Perform Sampling

Choose N samples from the distribution

Compute the weight of each sample

Normalize the weights

Perform Re-sampling

End Monte Carlo

A Monte Carlo approach is a class of algorithms that depend on generating random sampling of data to compute a result.

The approach is a particle filtering approach. This research focused on mobile networks.

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Perform Sampling

Choose N samples from the distribution

Compute the weight of each sample

Normalize the weights

Perform Re-sampling

End Monte Carlo

The technique is summarized in the follow pseudo code:

Compute MDS-MAP

Begin

Using an all pairs shortest path algorithm, estimate the distance between each pair of the possible nodes

Using these distance, use MDS to the estimated distances to a coordinate system

Using any known nodes, normalize the positions

End Compute MDS-MAP

The characteristic of this approach is that:

Uses connectivity information to derive the location of nodes in a network

By measuring nodes of a network as physical elements, such as weights and springs. The nodes are modeled as having forces applied to them.

The original work was from a VLSI technique called Force Directed Placement.

The algorithms can be some of the most flexible algorithms for simple undirected graphs.

The Fruchterman-Reingold algorithm defines an attractive force function and repulsive force function. The attractive force function is used for adjacent nodes and the repulsive force function is used for non-adjacent nodes. Vertices in the graph are moved repeatedly until a low energy state is achieved.

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Using these distance, use MDS to the estimated distances to a coordinate system

Using any known nodes, normalize the positions

End Compute MDS-MAP

The algorithms are used in wireless sensor networks to determine the location of nodes. They are particularly valuable in networks where the nodes cannot be positioned accurately. The algorithms have been shown to be effective in a variety of different network environments. The algorithms are also useful in situations where the nodes are mobile. In these situations, the algorithms can be used to track the movement of the nodes over time.

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