USP: A 3D Underwater Sensor Positioning Scheme

Amin Y. Teymorian, Wei Cheng, Liran Ma, and Xiuzhen Cheng

Motivation

- Sensor location information is desirable for many applications (e.g., environment monitoring)
- Common solutions to 3D localization such as GPS do not work well underwater
- Sparse deployments limit the availability of necessary numbers of anchors needed for other techniques (e.g., quadrilateration)

Contributions

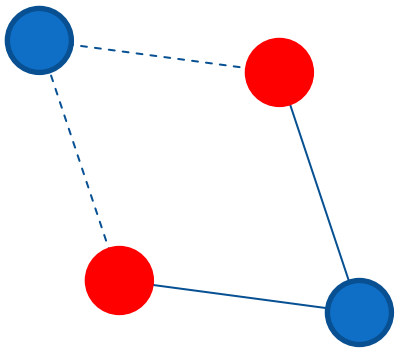
- Transform 3D underwater positioning problem into its 2D counterpart
  - Prove that a non-generative projection preserves network localizability
- Purely distributed localization scheme termed USP for underwater acoustic sensor networks
  - Improves localization capabilities over existing techniques, e.g., increases number of localized nodes

Background

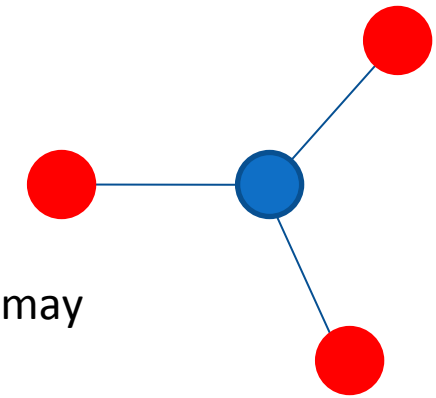
Localization Problem

- Determine a unique position for each node given
  - the locations of some nodes (``anchors'' or ``references'')
  - inter-node distances for some nodes
- In two dimensions, bilateration and trilateration techniques can be used to efficiently localize . . .

Localization Techniques



Bilateration techniques may *finitely localize* a node



Trilateration techniques may *uniquely localize a node*

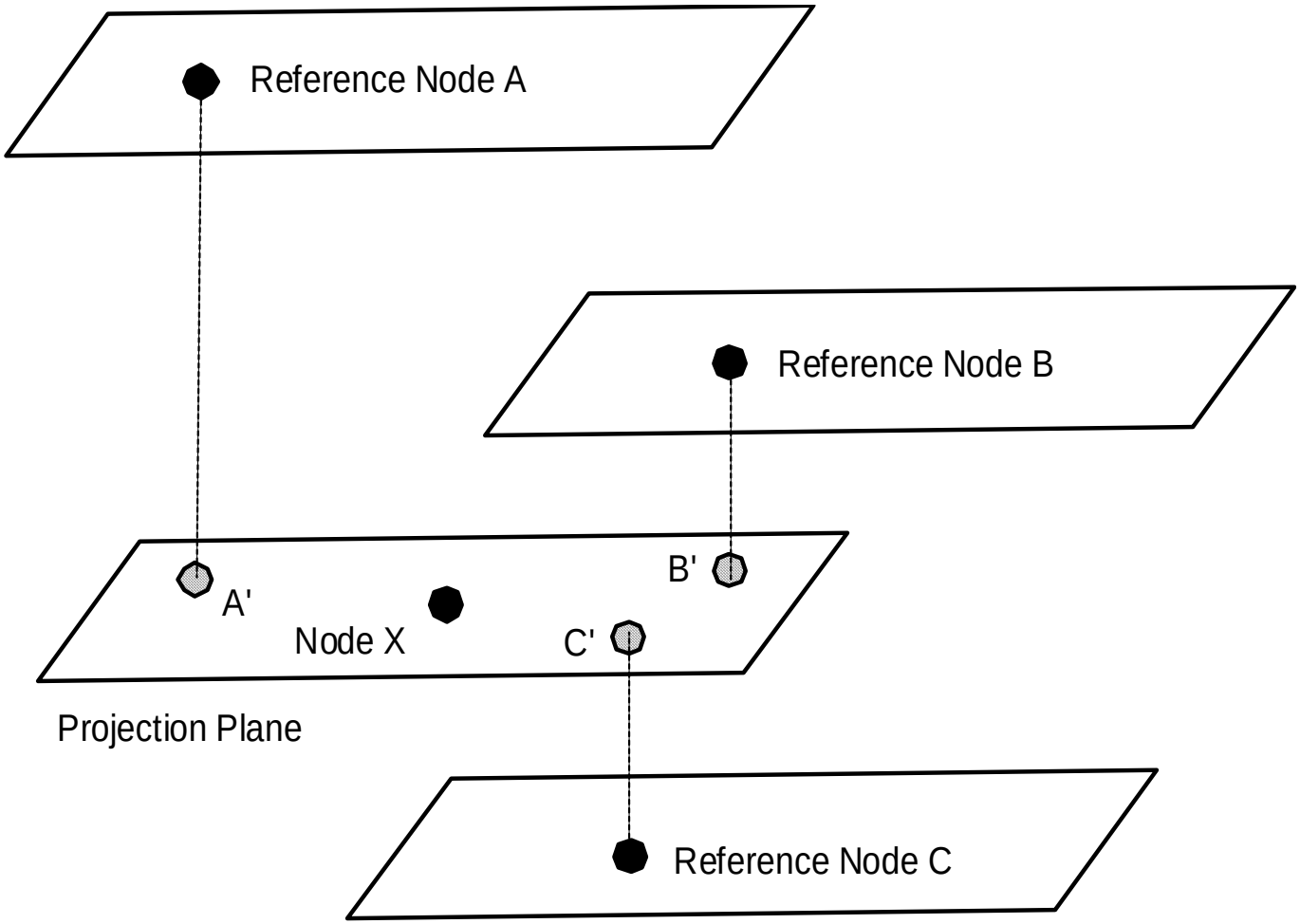
- It has been shown that bilateration methods can uniquely localize some nodes that trilateration methods cannot.
- USP employs this technique . . .

USP Design

Overview

- Employ sensor depth information to project reference nodes to the plane containing the to-be-localized sensor
- Apply elegant two dimensional localization techniques such as bilateration (and trilateration) to better localize nodes in sparse deployments
- Iteratively and efficiently propagate updated location information throughout the network

Projection Technique



USP – Phase 1 (Broadcast)

- Each sensor makes a local broadcast of any new position information that is has
  - If an anchor, available when 1st deployed, or
  - After an update from a computation or reduction operation
- Each sensor also records any new position information received from neighbors

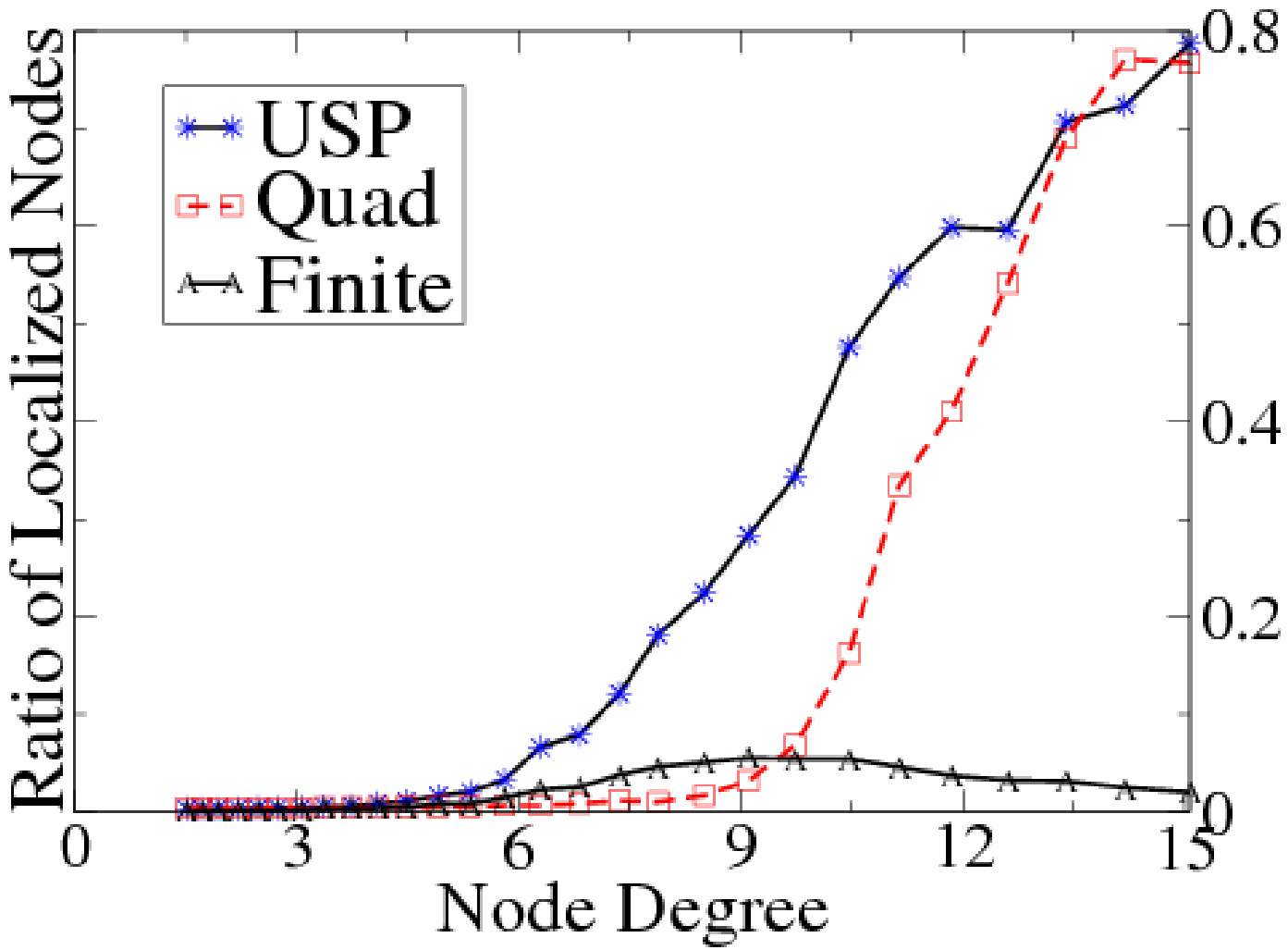
USP – Phase 2 (Compute)

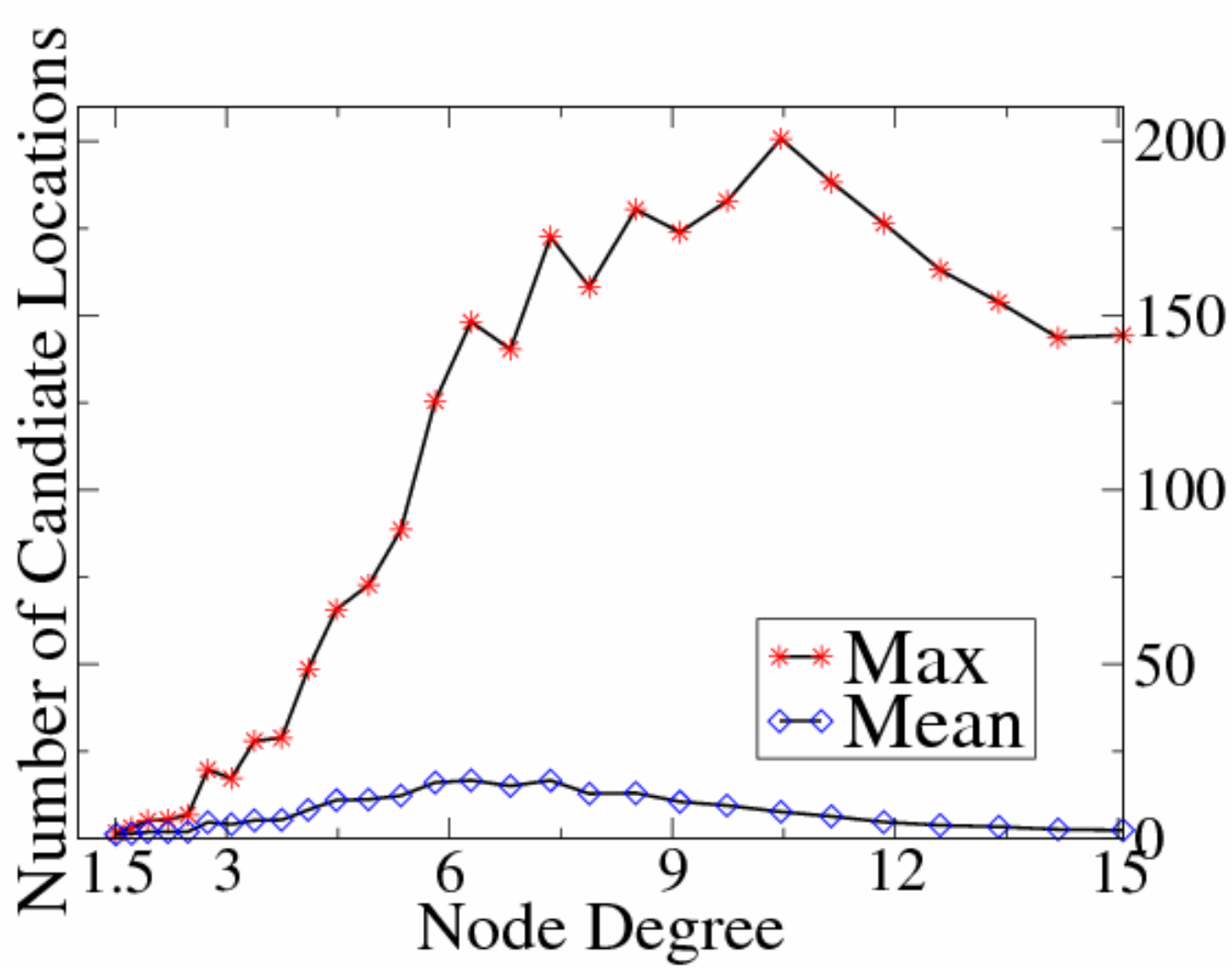
- After receiving neighbor information
- If a sensor has no previously computed position information, it attempts to compute its position after making a projection
- If position information is already available, it attempts to reduce its set of candidate positions

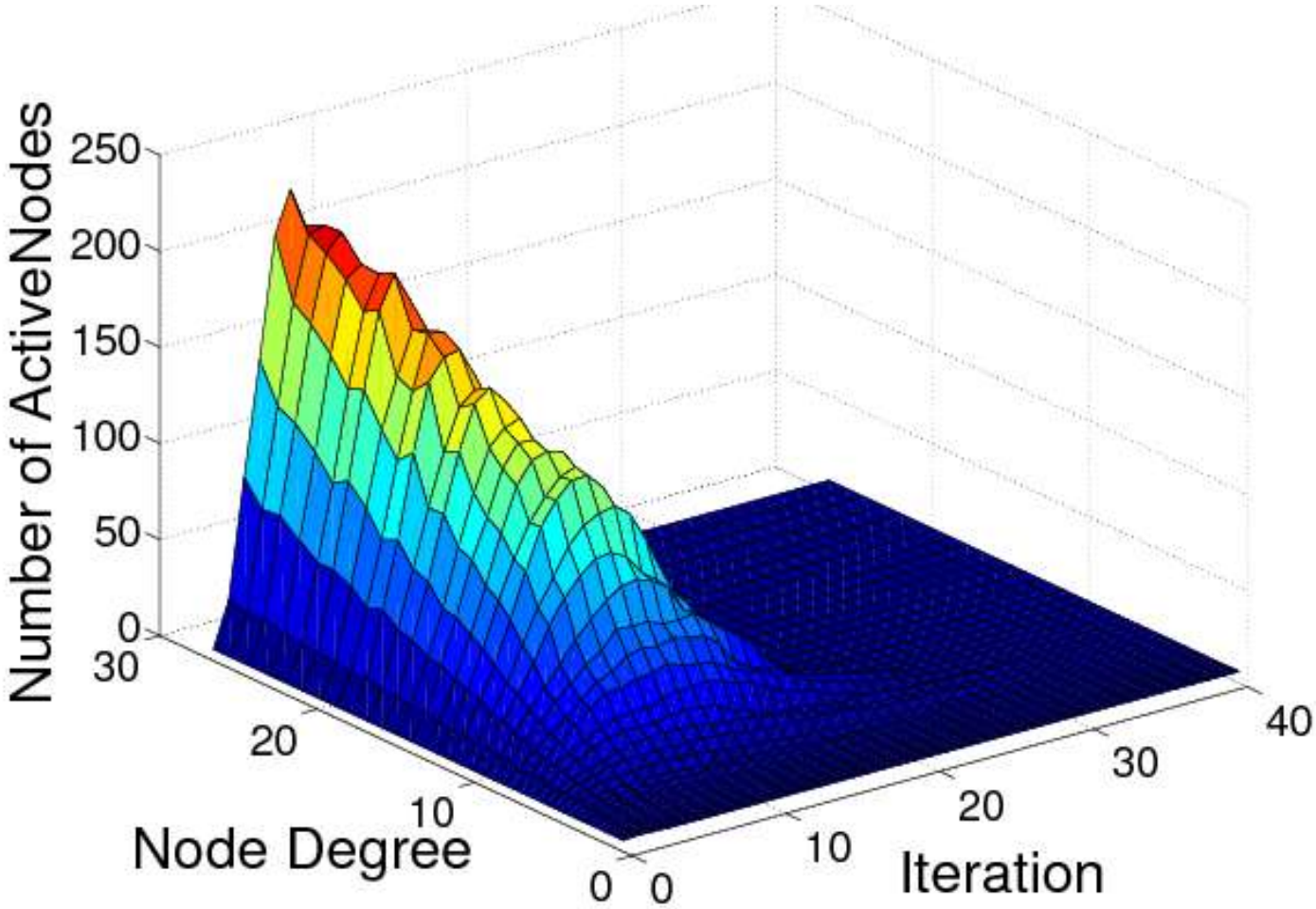
Analysis

- Theorem 1: A non-degenerative projection preserves the localizability of the network, i.e., a node is uniquely (finitely) localizable in the network if and only if it is uniquely (finitely) localizable in the projection plane

- Theorem 2: USP can localize all nodes localized by a bilateration method


Ratio of Localized Nodes
Node Degree
USP
Quad
Finite
0
3
6
9
12
15
0
0.2
0.4
0.6
0.8


Number of Candiate Locations
200
150
100
50
0
1.5
3
6
9
12
15
Node Degree
Max
Mean


Number of ActiveNodes
250
200
150
100
50
0
30
20
10
0
Node Degree
0
10
20
30
40
Iteration