Departmental Seminar

Clustering Auto-calibration for Ultrasonic Positioning Systems

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Positioning Systems

Context Sensing:

- Provide a user with information relevant to their location.
- Location often combined with other contextual data, eg. compass heading.
- Different applications require different levels of accuracy.

Example Applications:

- In-car navigation system, tourist guide.
- Augmented reality – digital and physical combined.
- Electronic personal assistant.

Example Positioning Systems

Outdoor (wide area)

- Wide area, relatively low precision.
- eg. Global Positioning System (GPS).

Indoor

- Small-medium area (usually a room or building), higher precision.
- eg. UNC Hiball, InterSense Tracker.

User Centric

- Users track themselves using information supplied by building infrastructure.
- eg. MIT Cricket, Bristol Ultrasonic System.

Building Centric

- Infrastructure in the building tracks the location of one or more users.
- eg. Cambridge BAT.

All measure the location of the user relative to some known fixed point(s).

Accessible Positioning Systems

Cost of…

- Components
- Setup
- Size and weight
- Power consumption

Setup issues:

- Deployment in inaccessible environments
- Safety
- Time
- Personnel

The Auto-Calibration Problem

Unknowns:

- 4 positions of fixed nodes $\mathbf{F_{0...3}}$
- M positions of the mobile node $\mathbf{X_{0...M}}$

Knowns:

- Inter-node distances d_{ij} between fixed node $\mathbf{F_i}$ and mobile node position $\mathbf{X_j}$

Aim:

- Find the 4 unknown fixed node positions $\mathbf{F_{0...3}}$

Measuring Distances using Ultrasound

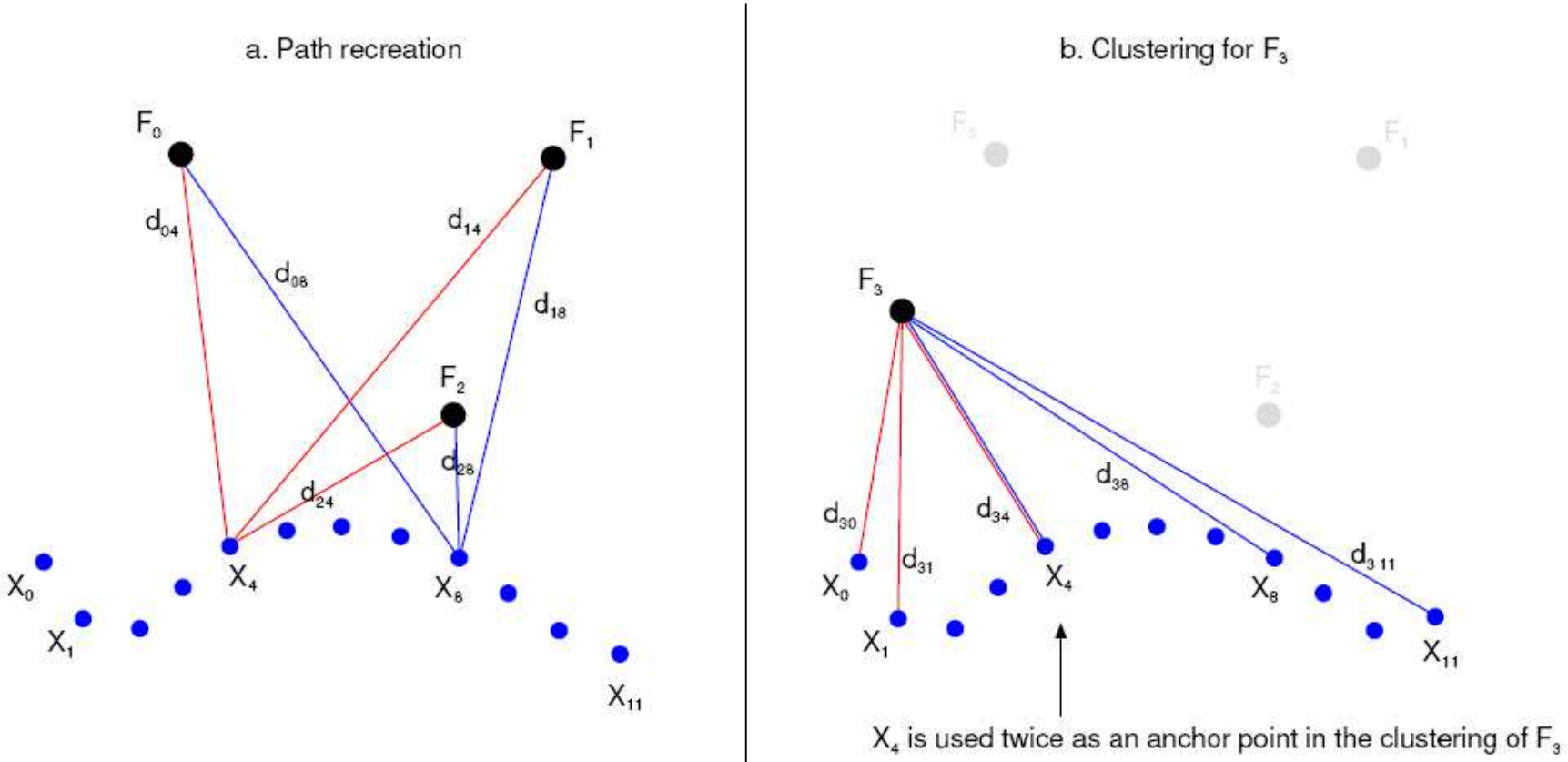
Active RF model:

- RF and ultrasound signals transmitted simultaneously

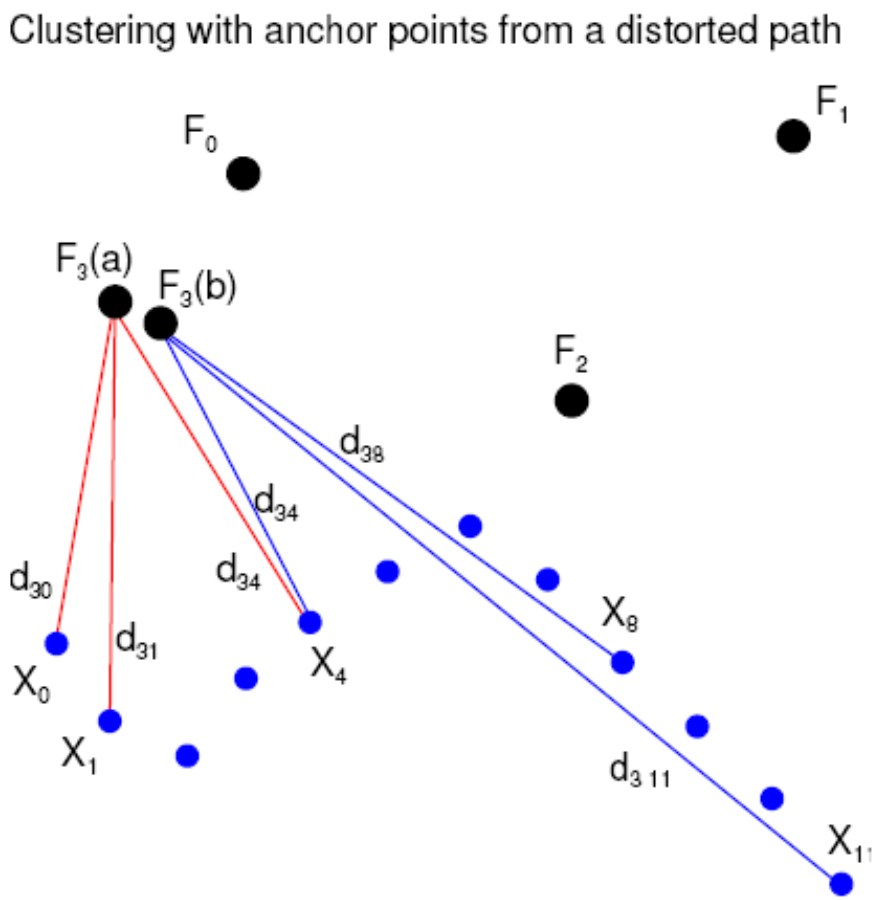
- RF signal received almost immediately
- Ultrasound signal received after an additional delay

- Distance = Delay x Speed of sound

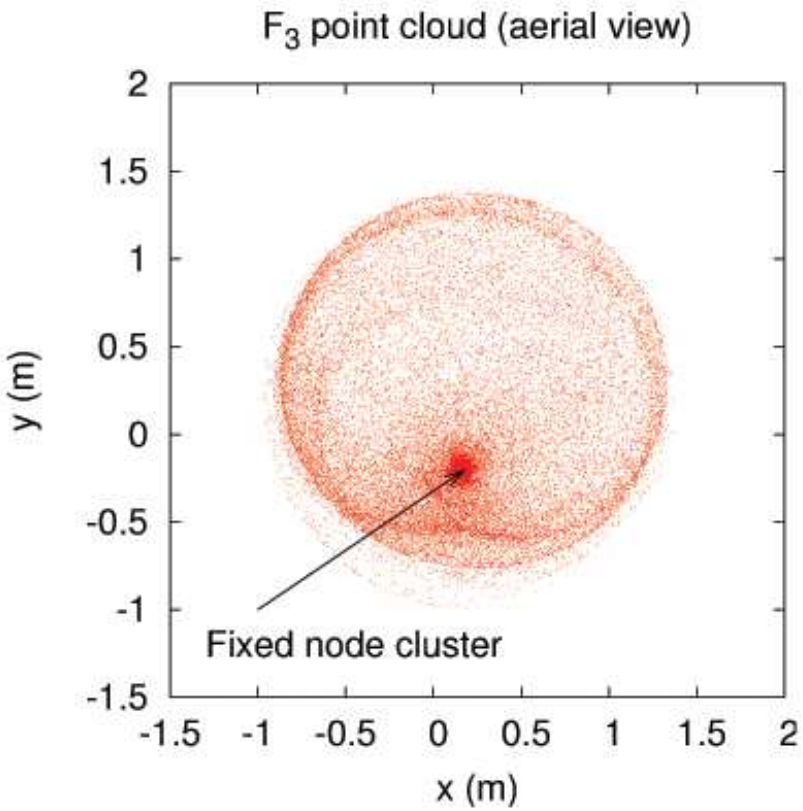
Recreating Mobile Path and F_3 Cluster

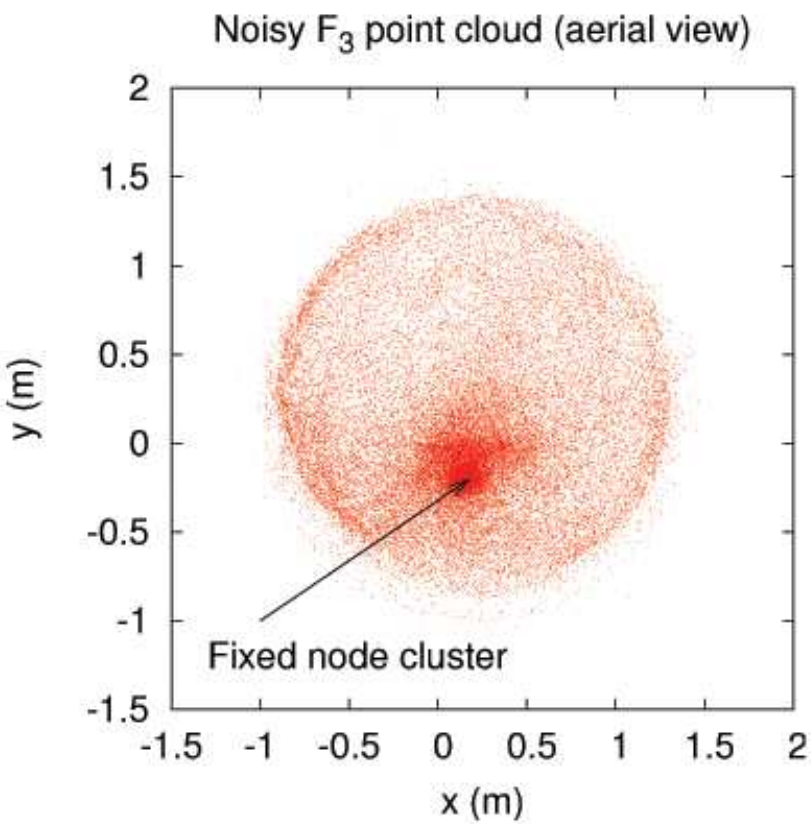


Recreating Mobile Path and F_3 Cluster



Clustering for $\mathbf{F_3}$ – Clean vs. Noisy





Seeding the Fixed Nodes

- Limit using the triangle inequality:

$$|\mathbf{F}_b - \mathbf{F}_a| \leq |\mathbf{X}_i - \mathbf{F}_a| + |\mathbf{X}_i - \mathbf{F}_b| \qquad (a \neq b)$$

- By substitution:

$$|\mathbf{F}_b - \mathbf{F}_a| \leq \text{argmin}_i \, (d_{ia} + d_{ib}) \qquad (a \neq b)$$

Clustering Auto-Calibration Overview

1. Seed fixed nodes $\mathbf{F_0}$, $\mathbf{F_1}$, $\mathbf{F_2}$.
2. Trilaterate using measured distances to recreate mobile node path.
3. Trilaterate using mobile node path to recreate fixed node $\mathbf{F_3}$. Repeat multiple times to generate a cloud of points.
4. Measure cloud of points generated at step 3.
5. Move $\mathbf{F_0}$, $\mathbf{F_1}$, $\mathbf{F_2}$ and repeat from step 3 until the cloud of points reaches minimal size.
6. Use the centre of the point cloud as the solution for $\mathbf{F_3}$.

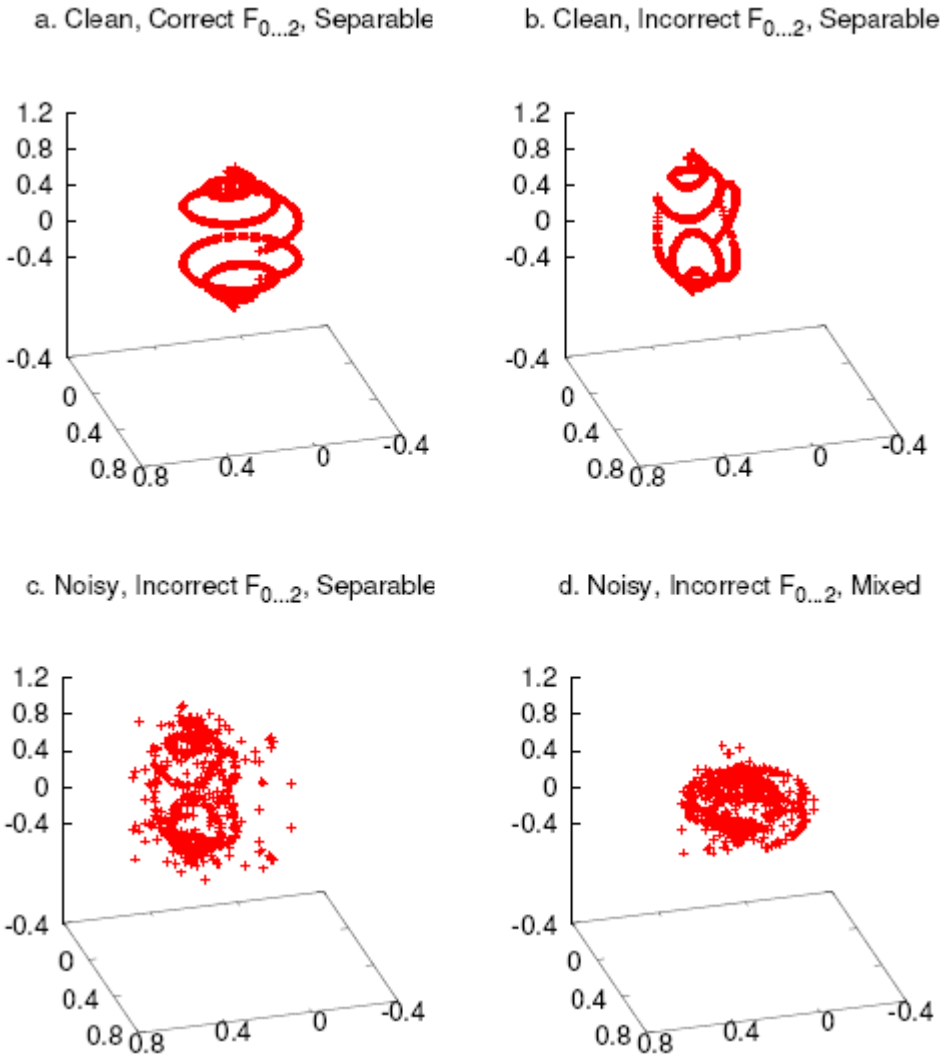
Path Classification

Need for classification:

- Must in fact consider dual trilateration solutions

Problems:

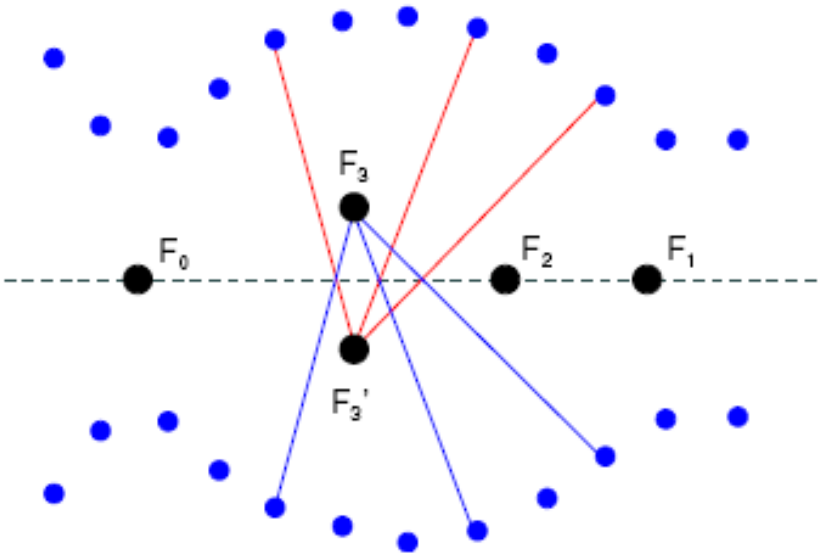
- Noise and errors
- Overlapping path solutions
- Can give rise to mis-trilaterations



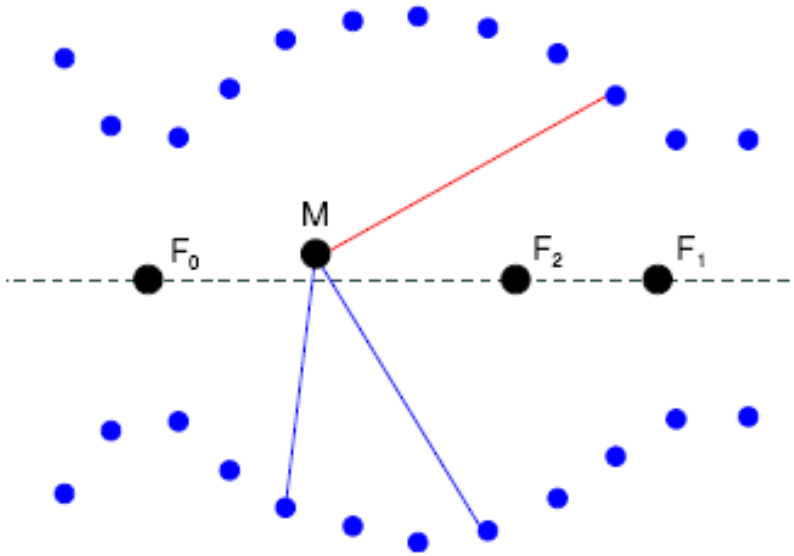
Mis-Trilaterations

- Without correct path classification, it is possible to *mis-trilaterate* geometrically nonsensical points

a. Correct trilaterations F_3 and F_3' (side view of 3D)

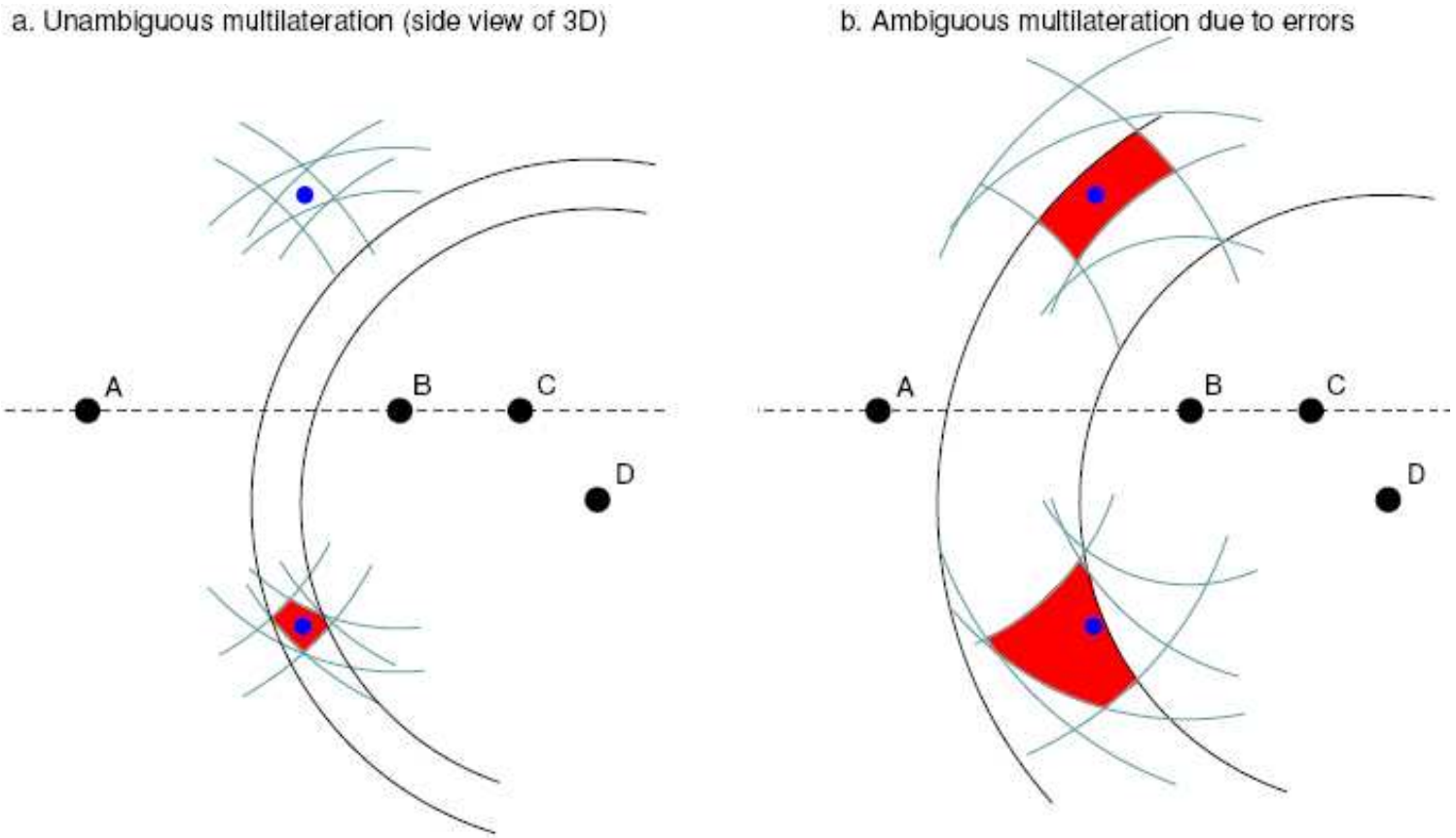


b. Mis-trilateration M (side view of 3D)



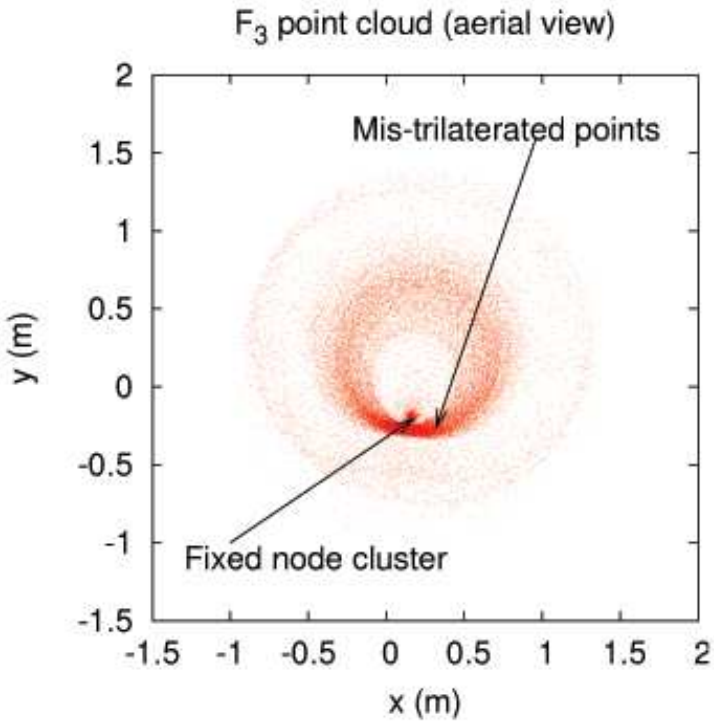
Why Not Multilateration?

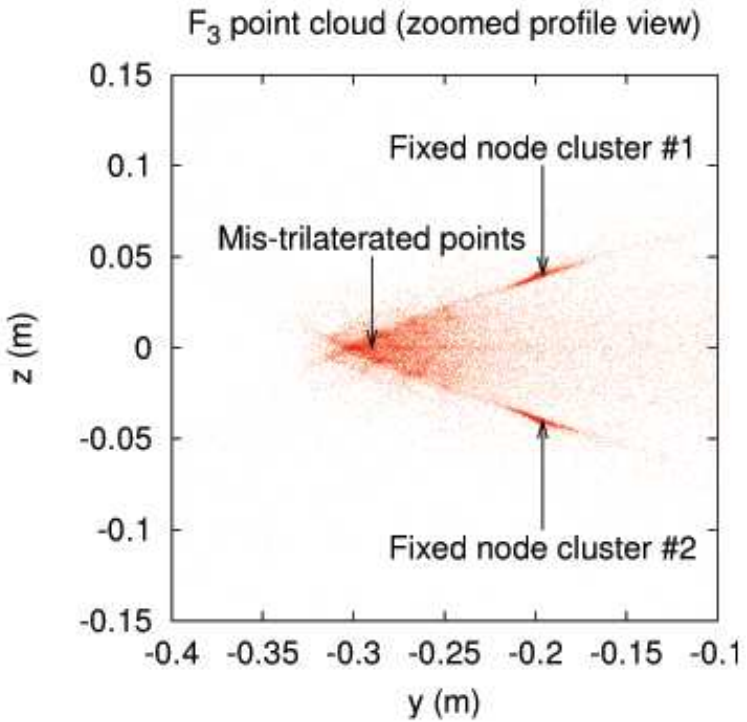
- Works poorly in the presence of noise



Clustering for $\mathbf{F_3}$ – Mis-Trilaterations

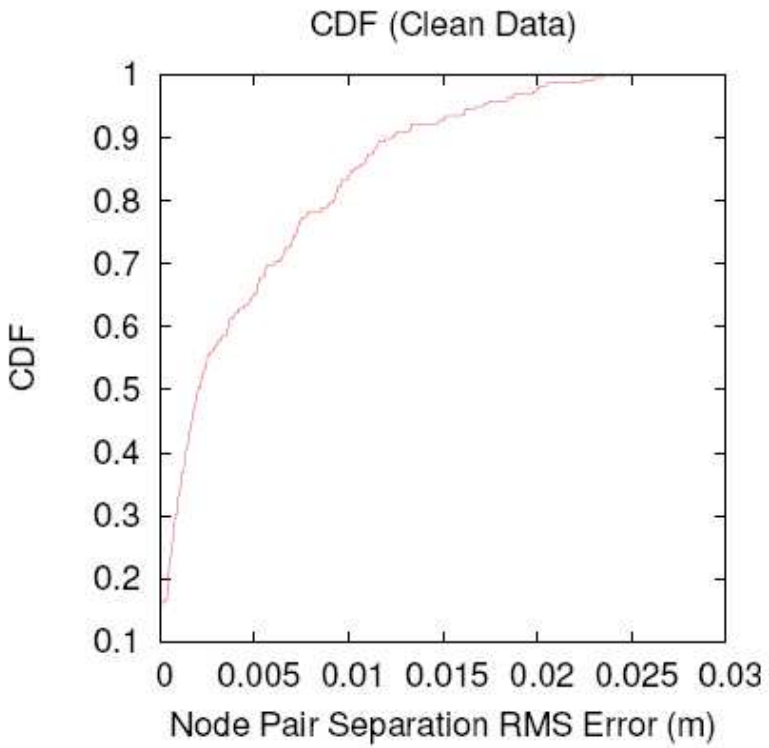
- Mis-trilaterated points may obscure the true cluster representing $\mathbf{F_3}$



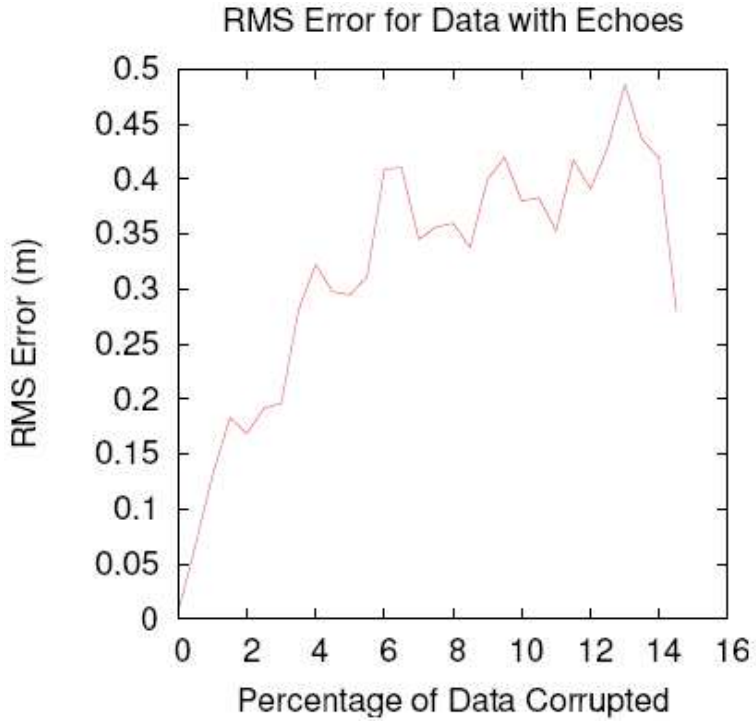


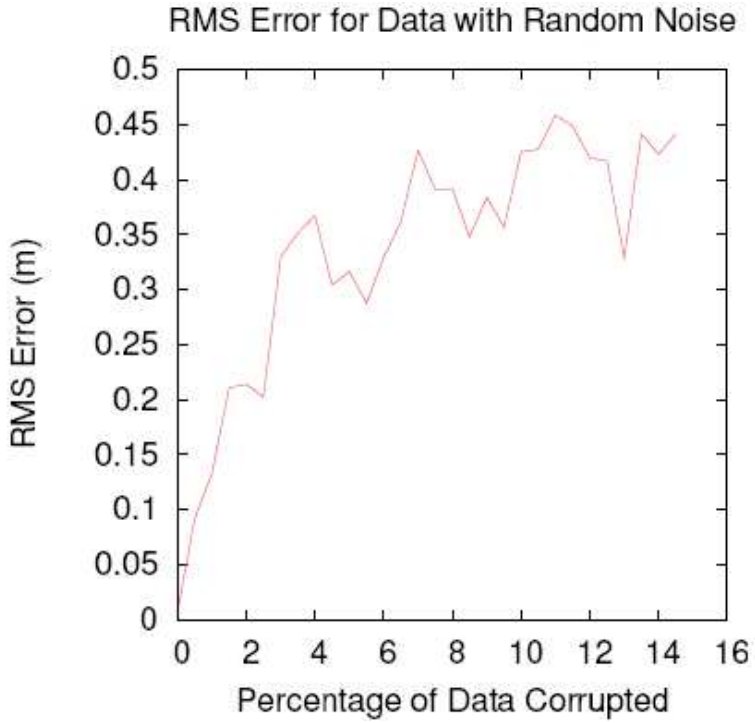
Performance (Clean Data)

- RMS error of 1.7cm for 95% of solutions, compared with actual fixed node spacings of up to 2m



Performance (Noisy Data)





- Future work: Improved clustering may reduce the effects of noisy data

Questions