Robust Distributed Network Localization with Noisy Range Measurements

IN4181 Wireless Sensor Networks - Localization

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Spatial Information

How:

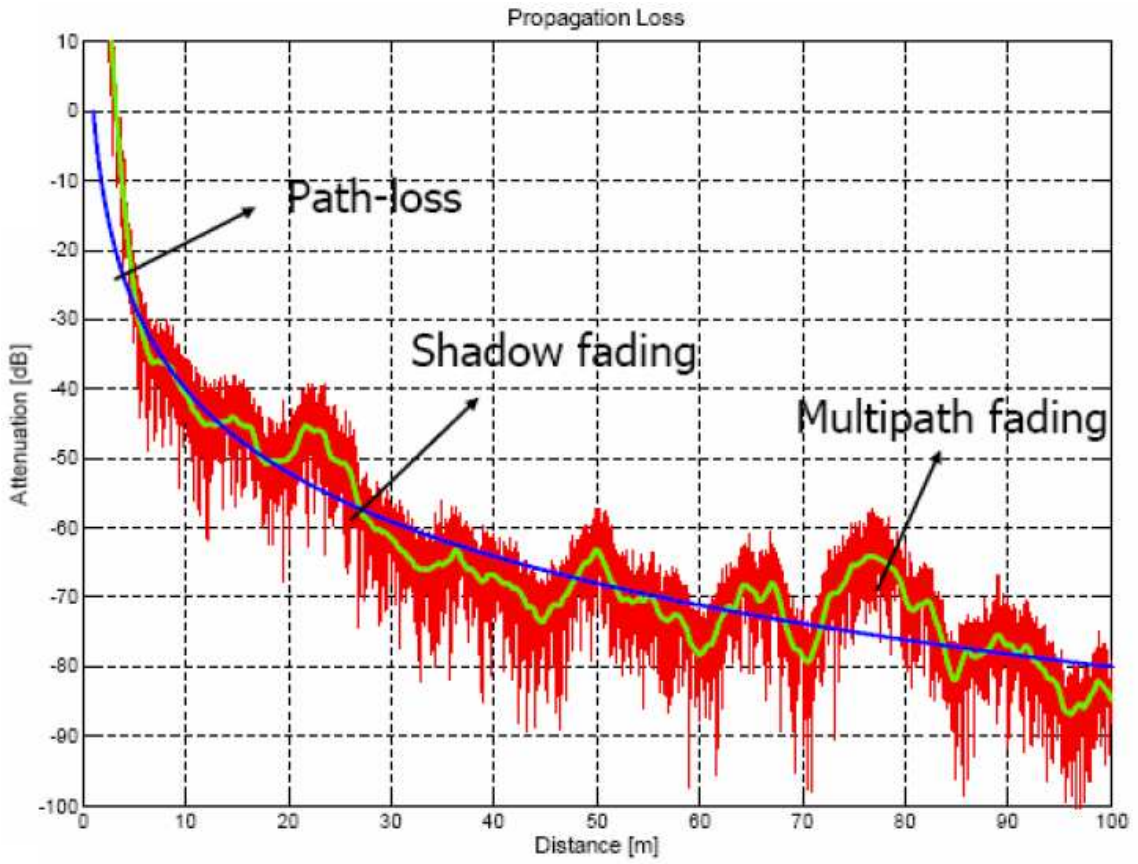
- GPS

Spatial Information

How:

- GPS
- Measure Distance between Nodes (range)

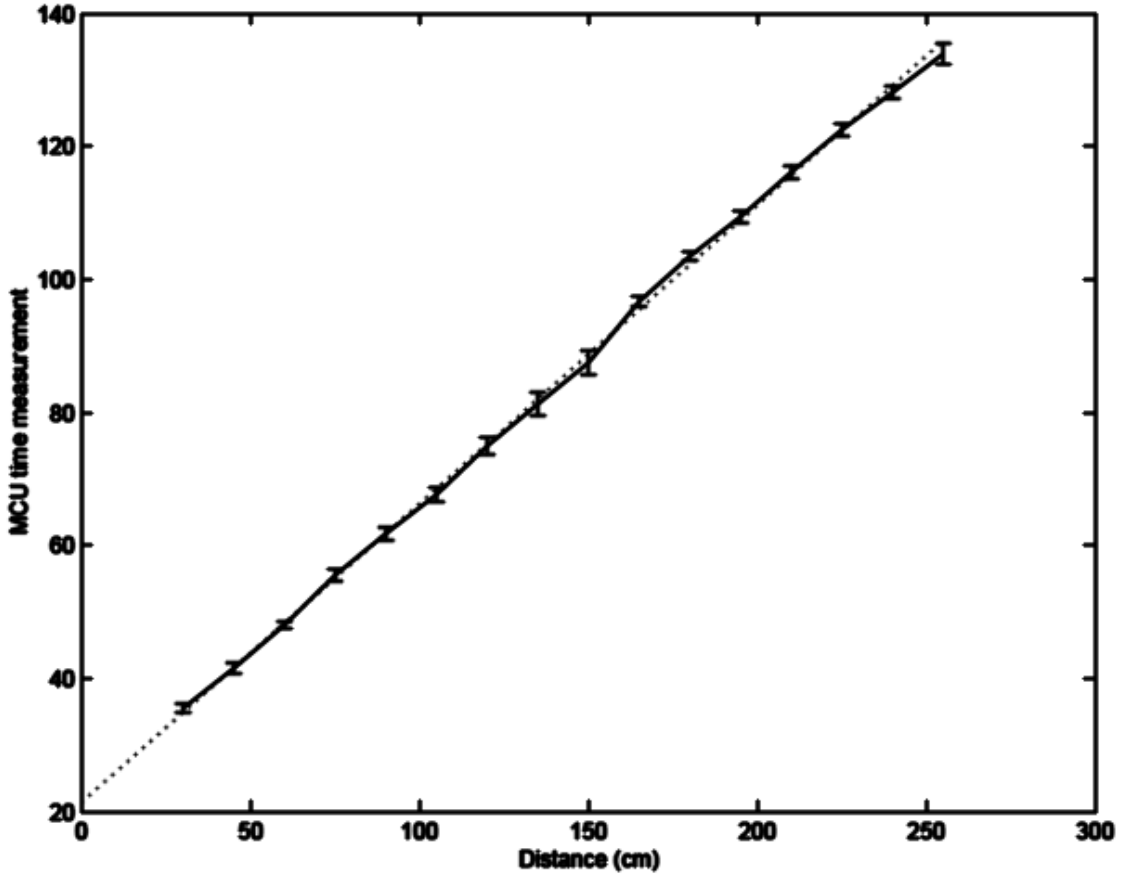
Distance Measurements



[G. Janssen, ET4358]

EM

Distance Measurements



Ultrasonic

The Proposed Algorithm

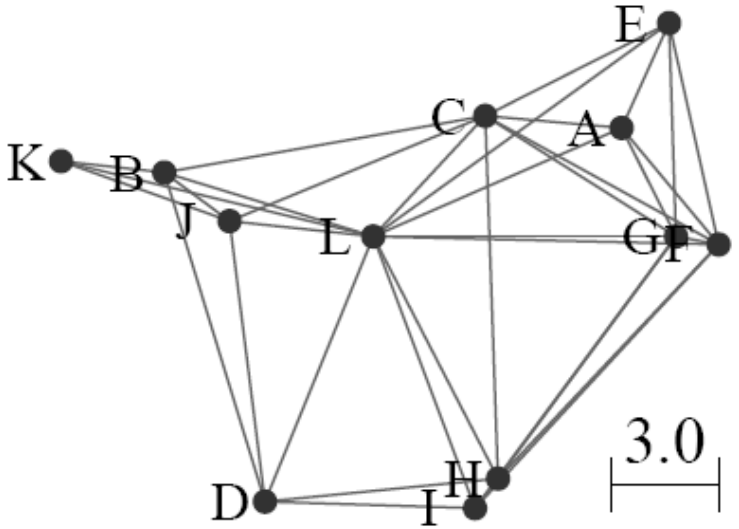
- Distributed, Linear-Time
- Noise Aware
- Rather No Localization than Wrong Localization
- 2D Graph Realization Problem

Graphs

- The Graph Realization Problem = Finding Eucledian Position of Vertices. NP-Hard.
- Rigid Graphs: Finite Number of Realizations.
- However...

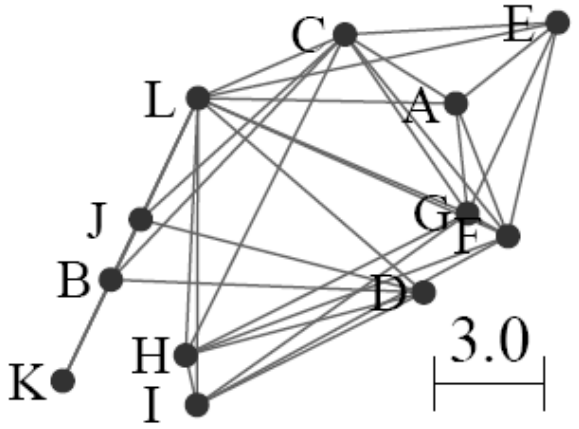
Graphs

(a) Ground truth



$\sigma_{err} = 0.37$

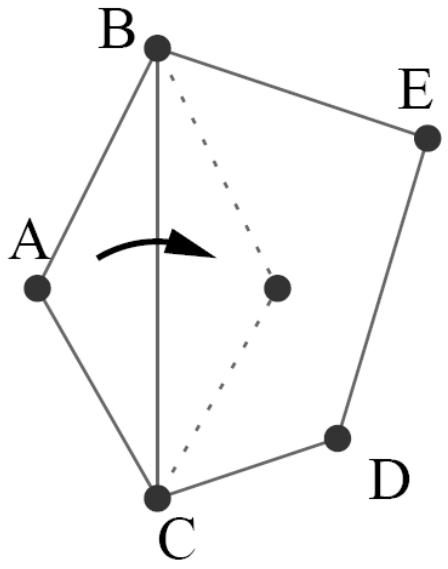
(b) Alternate realization



$\sigma_{err} = 0.34$

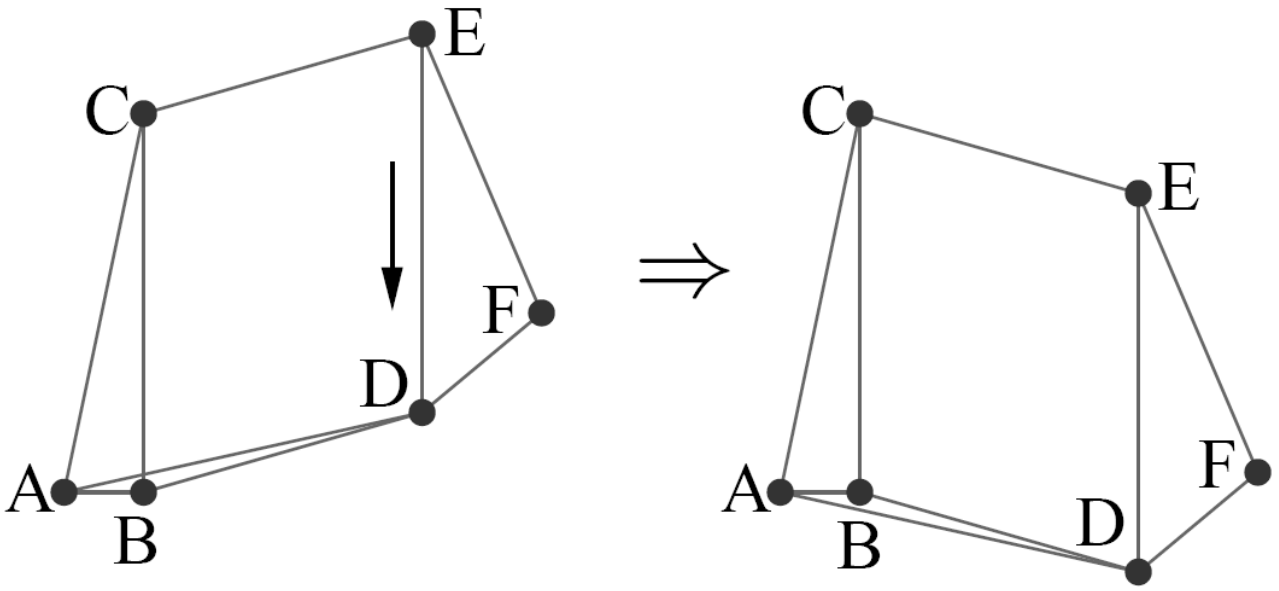
Better Error-metric can give Worse Results

Graphs



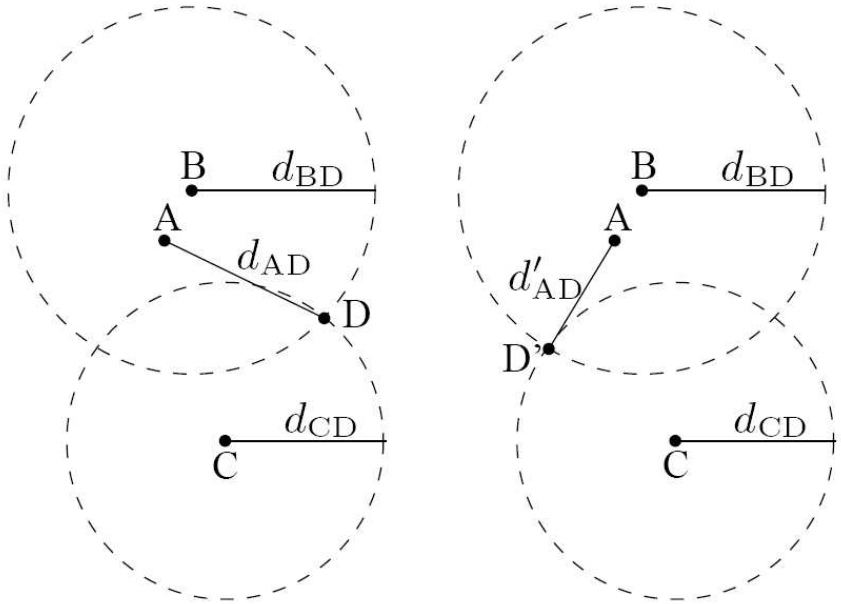
Flip Ambiguity

Graphs



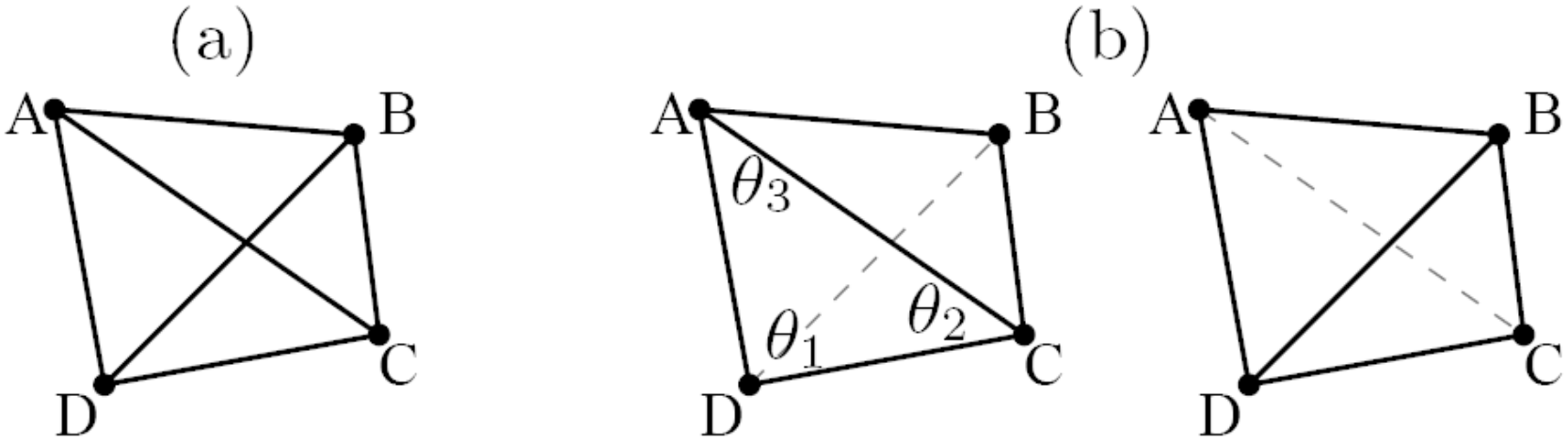
Flex Ambiguity

Graphs



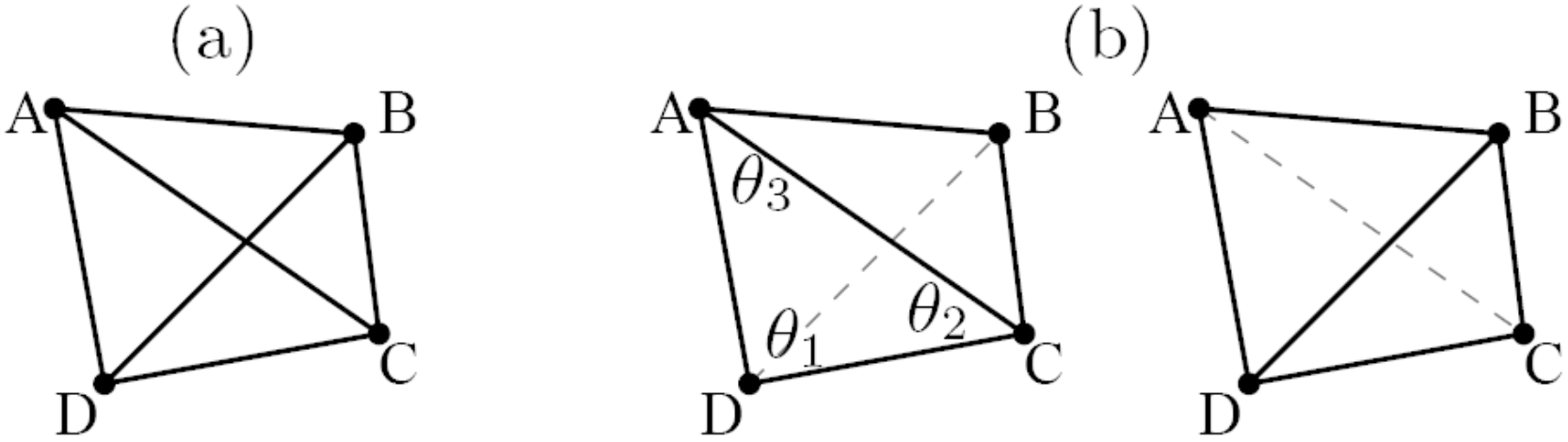
Flip Ambiguity Result

The Robust Quadrilateral (Quad)



Globally rigid: unique positions, up to rotation, translation and reflection

The Robust Quadrilateral (Quad)



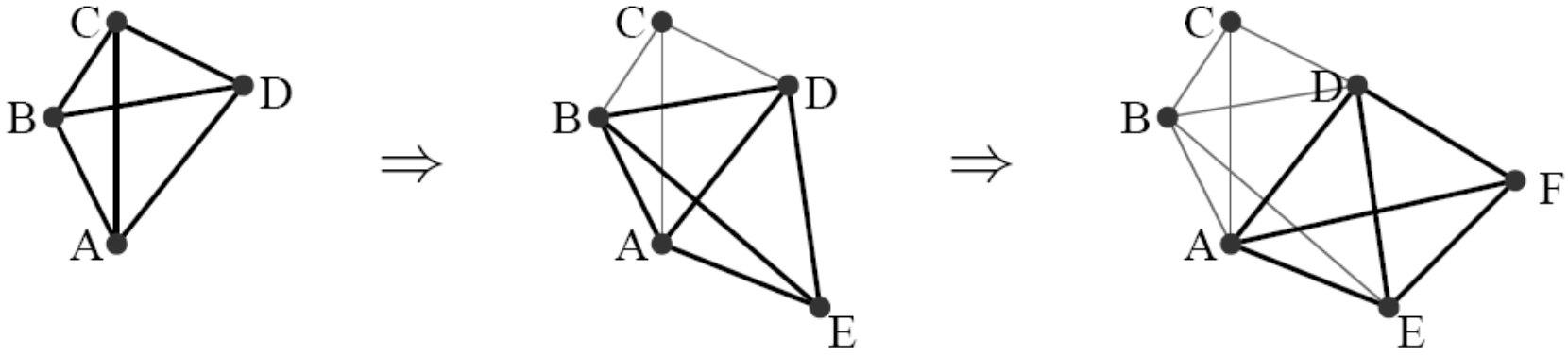
$b \sin^2 \theta > d_{min}$, where

b = |shortest side|, θ = smallest $\angle$, d_{min}= treshold based on noise.

Phases of the Algorithm

Phase I - Cluster Localization

- For each node, find neighbours, find robust quads, trilaterate positions.



Phases of the Algorithm

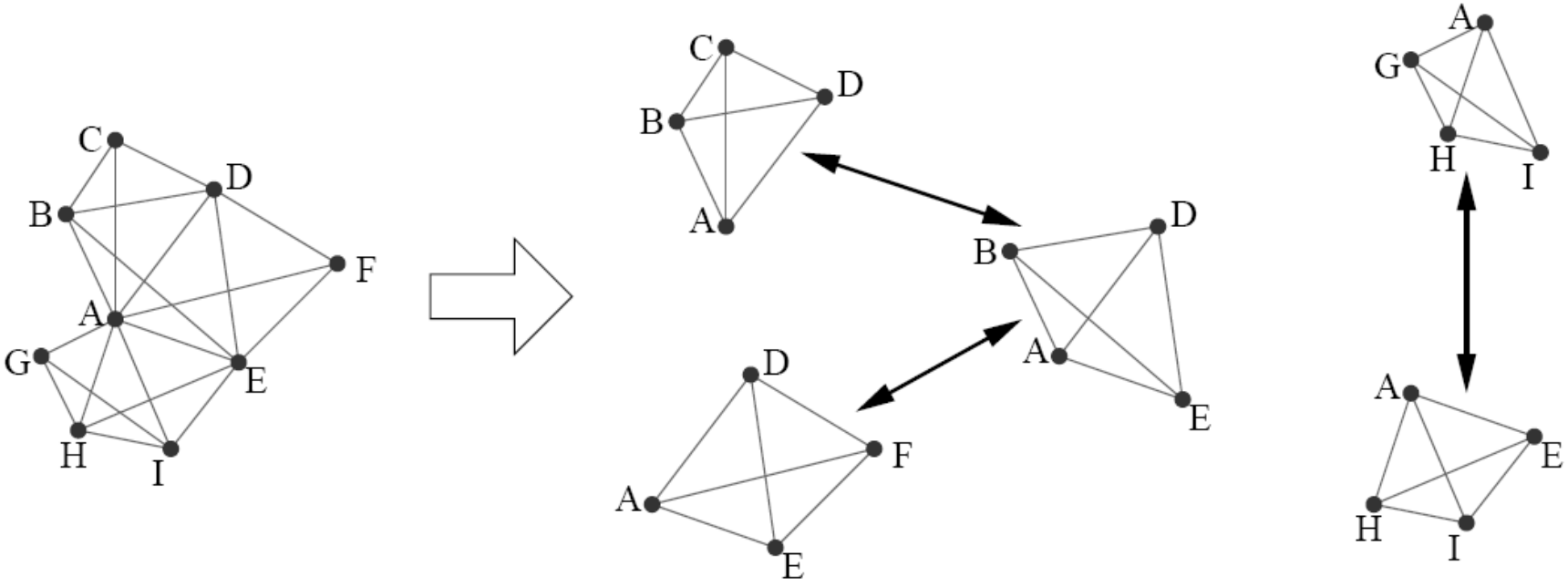
Phase II - Cluster Optimization (Optional)

- Per cluster, refine positions using numerical optimization (spring relaxation, Newton-Raphson) because of error accum.

Phases of the Algorithm

Phase III - Cluster Transformation

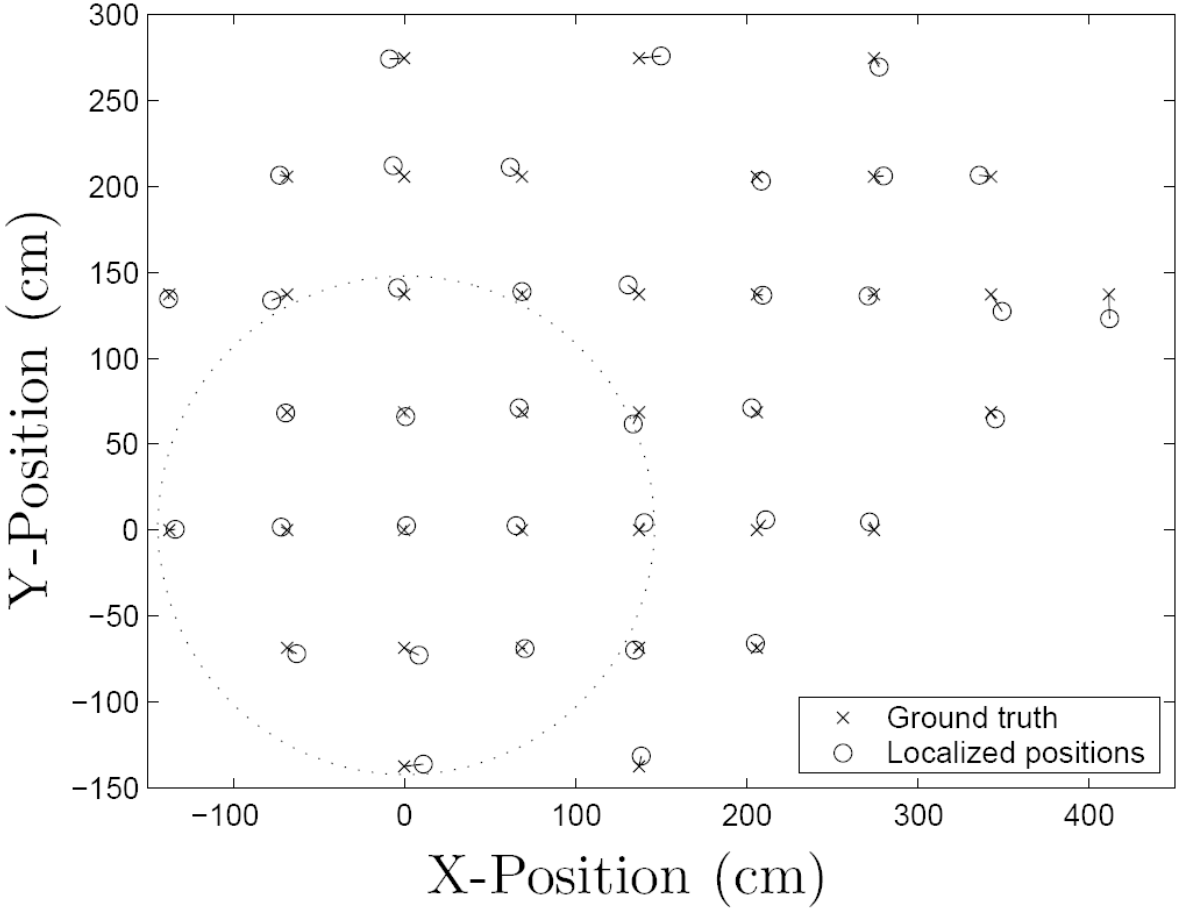
- Connect clusters using *robust triangles*.



Results - Metrics

- $\sigma_p^2 =$Mean-square error in Eucledian 2D space
- $\sigma_d^2 =$Mean-square error in distance measurement
- $\bar{R} =$Cluster success rate, average percentage of localized nodes per cluster.
- $\tilde{R} =$Largest forest size / # nodes. forest = not localized with respect to other graph

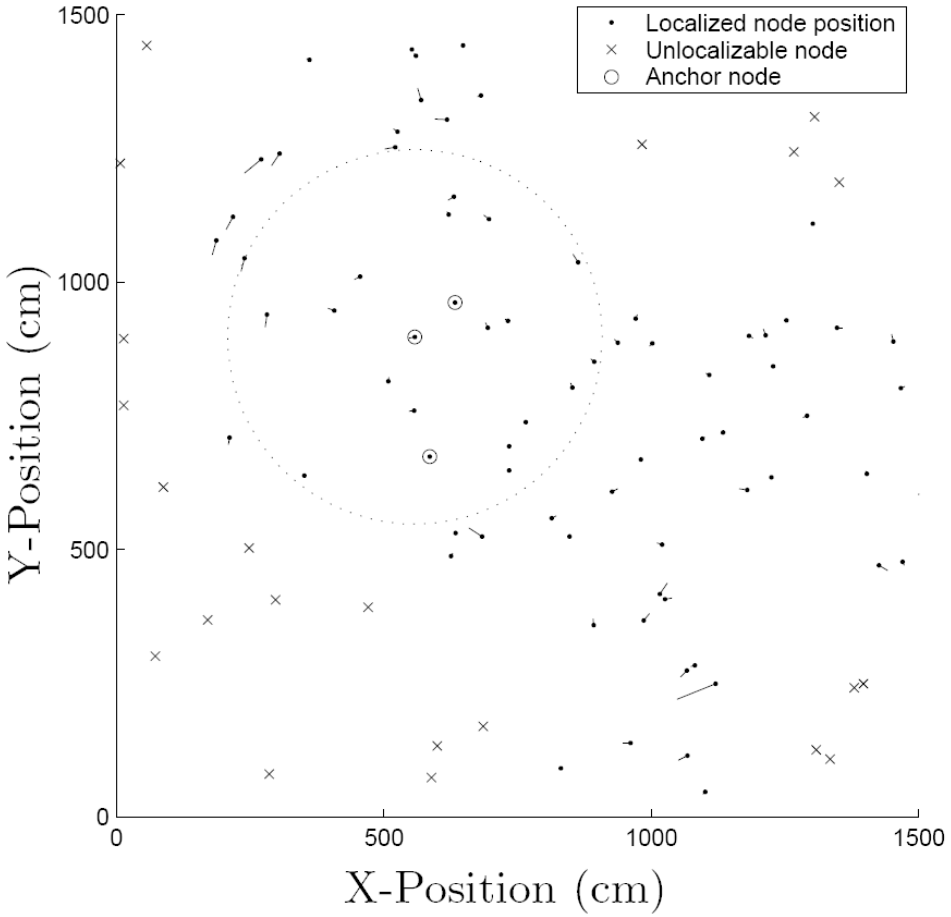
Results - Hardware Deployment



Results - Hardware Deployment

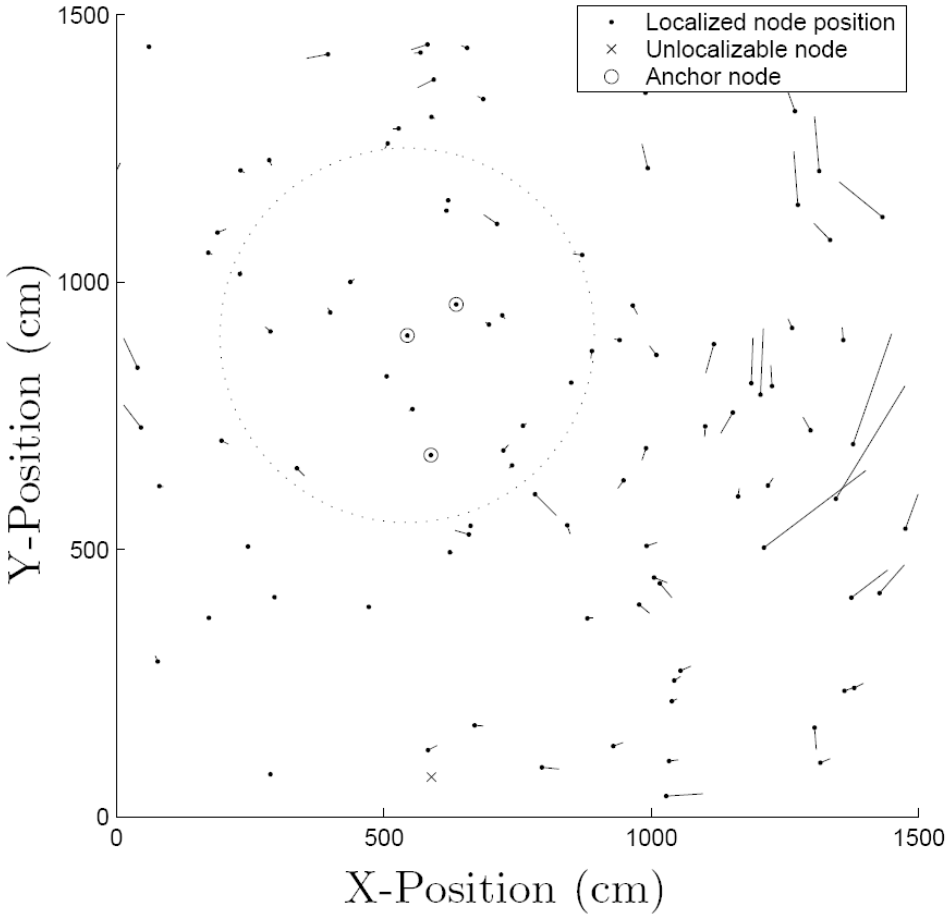
- Error in distance (σ_d): 4.38cm
- Error in position (σ_p): 6.82cm
- Cluster succes rate ($\bar{R}$): 0.97
- Largest forest ($\tilde{R}$): 0.95

Results - Simulation



robust quads

Results - Simulation



no robus quads

Results - Simulation

metric	Our algorithm			w/o robust quads
σ_d	**1.0 cm**	**3.0 cm**	**5.0 cm**	**5.0 cm**
σ_p	4.43 cm	14.39 cm	16.22 cm	54.87 cm
$\bar{R}$	0.91	0.85	0.79	0.95
$\tilde{R}$	0.93	0.87	0.75	0.99

Conclusion

- Works with noise;
- Errors can be bound;
- Robust quads reduce errors.

Questions?