Laser Tracker Position Optimization

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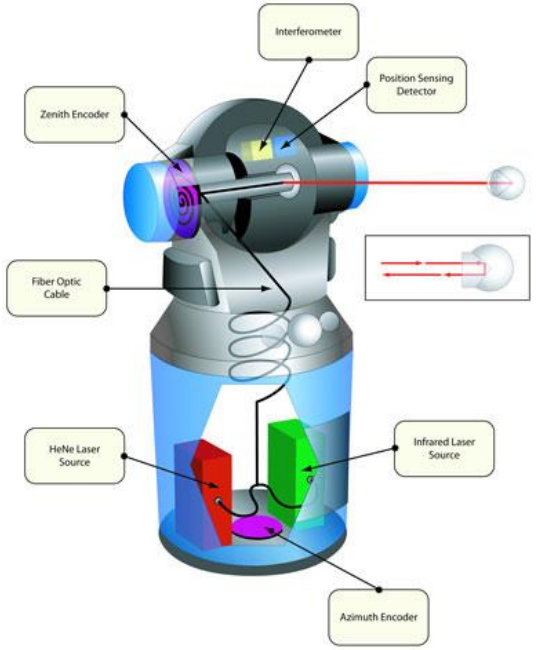
Laser Tracker

- Portable large volume coordinate measuring instrument
- Range 30-50m
- Accuracy 20-200µm

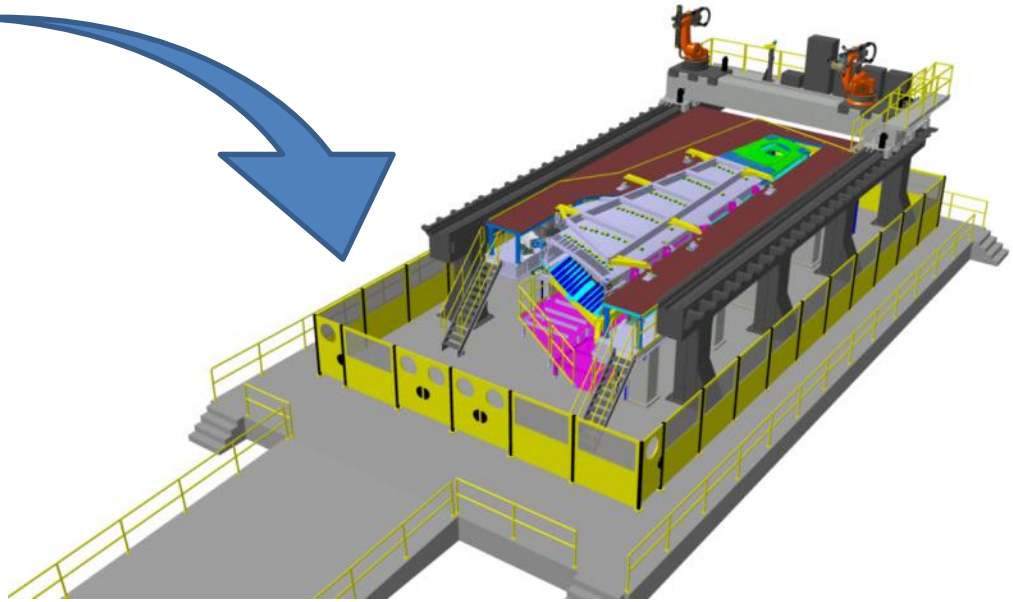


FARO Laser Tracker

The Problem

- Where should I place my tracker/tracker stations?

?

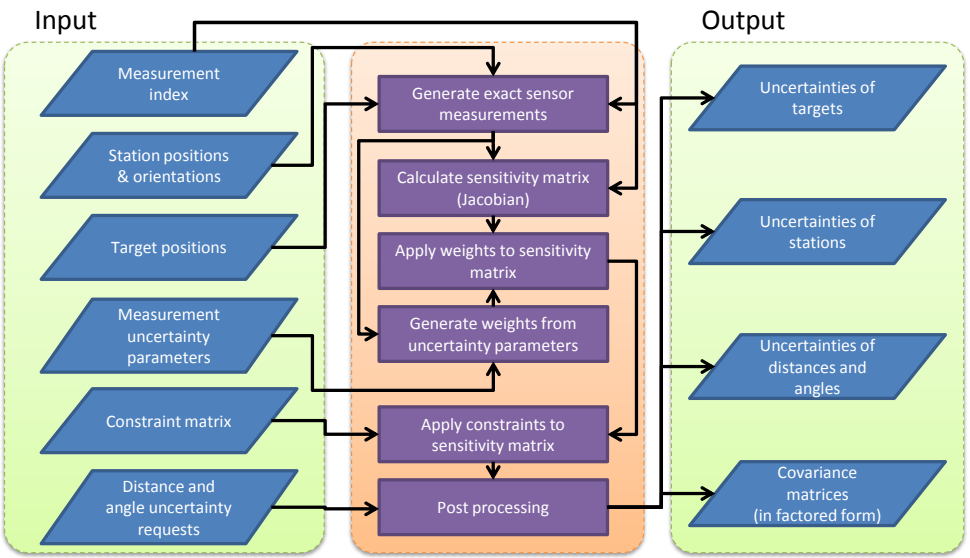


Overview of features

- Based on NPL (Alistair Forbes) multi-station tracker code
- Pattern search, GA, PSO, or hybrid optimization
- Features:
  - 1 – N trackers
  - 1 – N targets (must be > 3 for > 2 trackers)
  - Objective function weighting for points, distances and angles
  - Constraints for tracker positions
  - Constraint for minimum measurement distance
  - GPU accelerated Line-of-sight check with CAD

The NPL Laser Tracker Model

- Specialized version of the NPL generic model
- Inputs:
  - Measurement Index
  - Target & station positions
  - Tracker uncertainty parameters
  - Constraint matrix
  - Distance and angle requests
- Outputs:
  - Uncertainty of targets and stations
  - Covariance matrix
  - Uncertainty of distances and angles

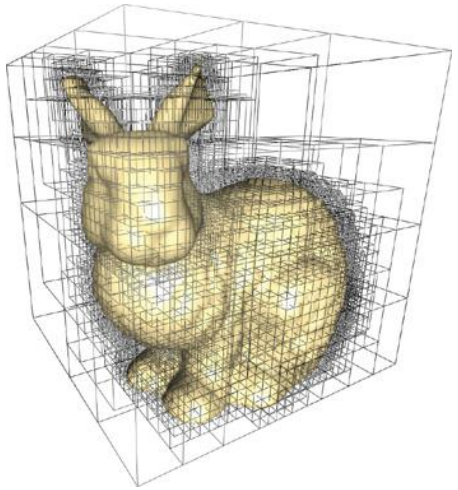


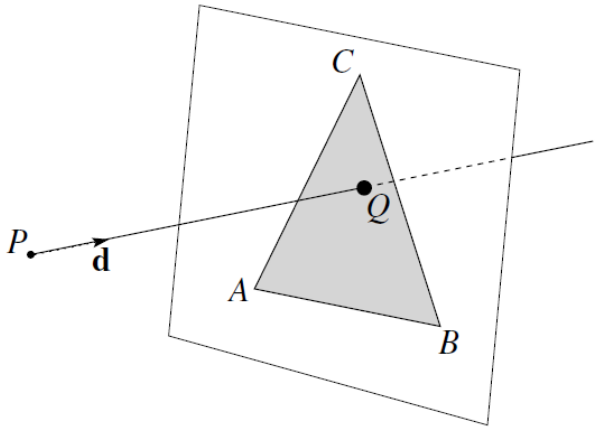
8 Parameter tracker model

$\sigma_{D,A}$, $\sigma_{D,R}$, $\sigma_{A,A}$, $\sigma_{A,R}$, $\sigma_{E,A}$, $\sigma_{E,R}$, σ_L, σ_M

Line-of-sight checking

- Efficient Octree collision detection
- intersection test
- Direct import of .stl files exported from CAD (Catia, etc.)





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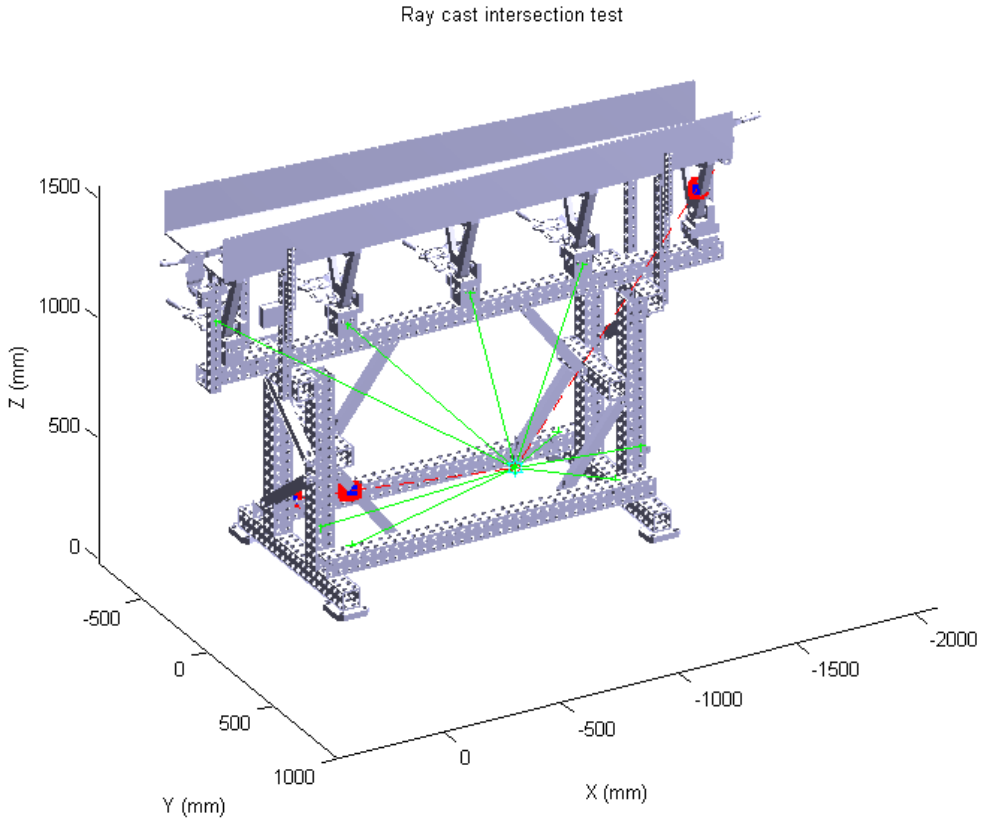
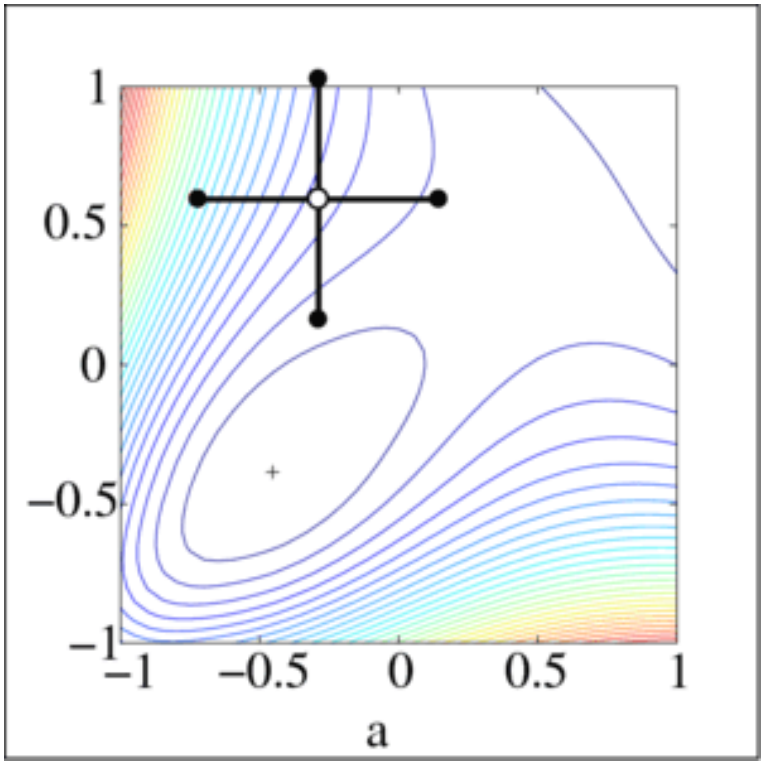


Optimization: Problem Formulation

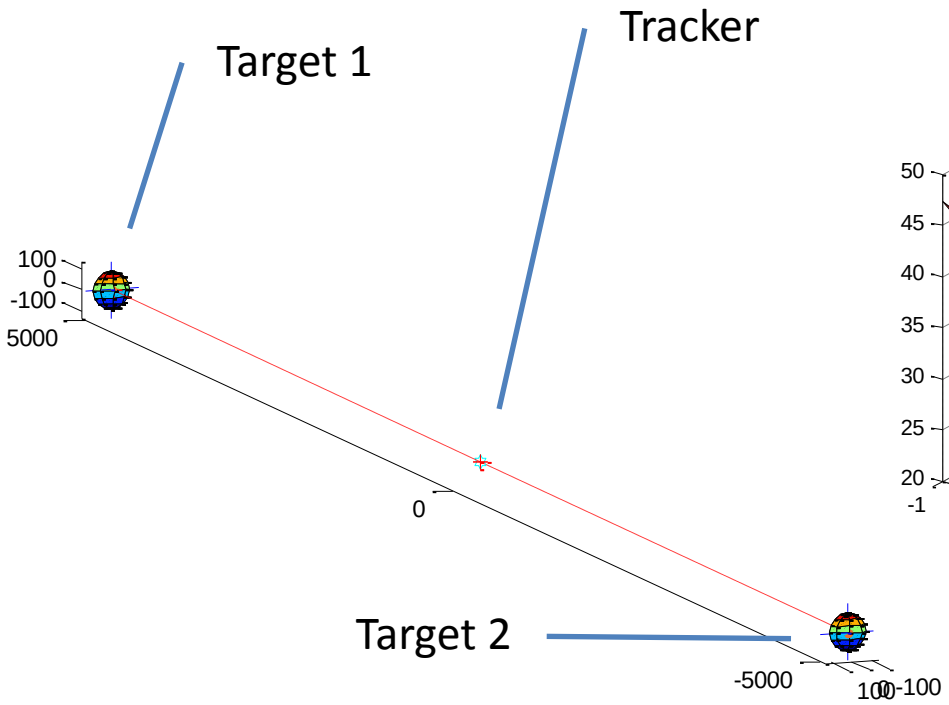
- Objective: minimize either
  - Sum of total of target uncertainties
  - Uncertainties of selected targets, distances and angles
  - Or a weighted sum of the above
- Subjected to:
  - Line of sight constraints
  - Minimum measurement distance constraints
  - Tracker or tracker station position bounds
- By varying:
  - Tracker or tracker station positions

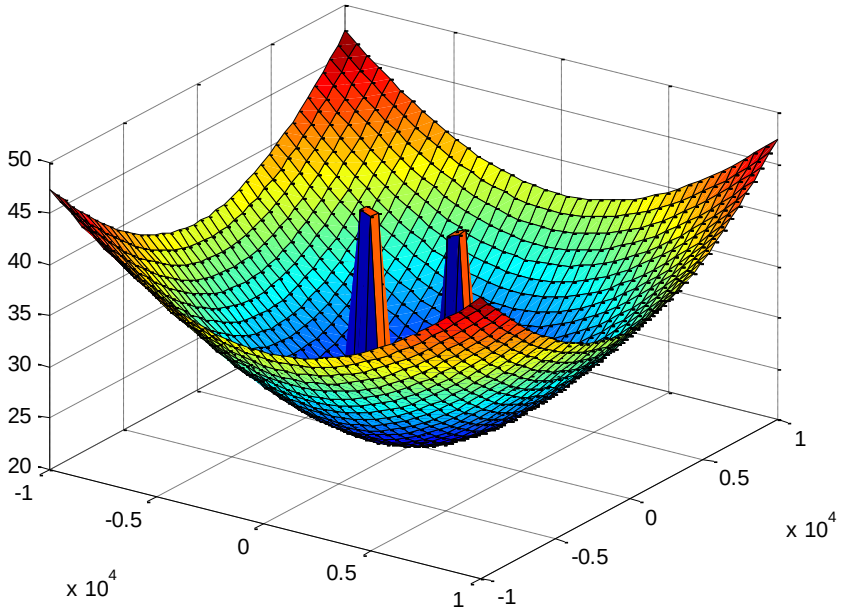
Optimization: Pattern Search

- The objective function is first evaluated at the starting position
- Positions in the cardinal directions are also evaluated
- Re-centre pattern on lowest value, expand pattern size
- If current position is lowest, contract size
- Stop when pattern size is below limit

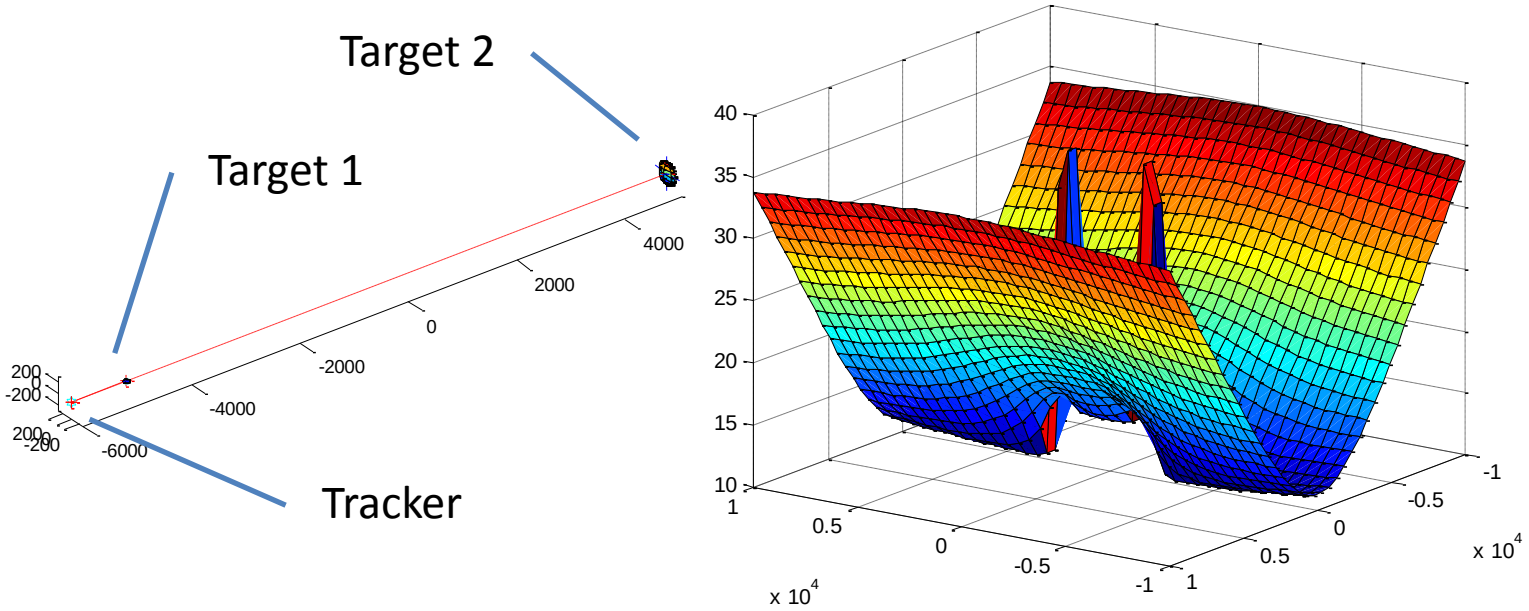


Example Solution for 1 LT 2 Targets

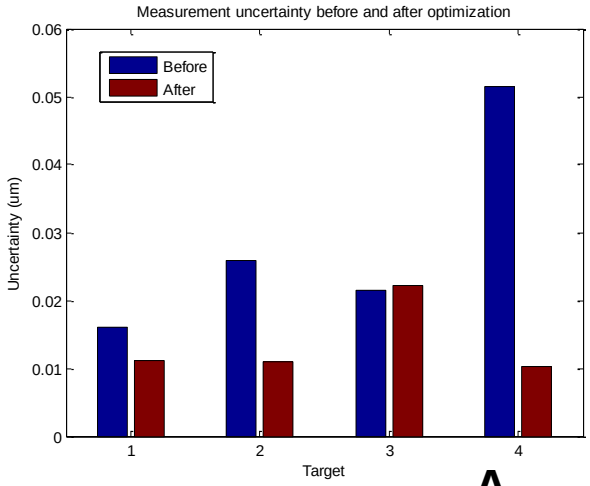




Solution for 1 LT 2 Targets

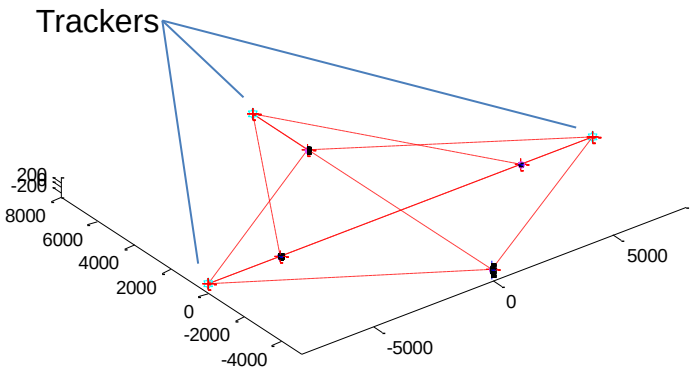


Example Solution 3 LT 4 Targets

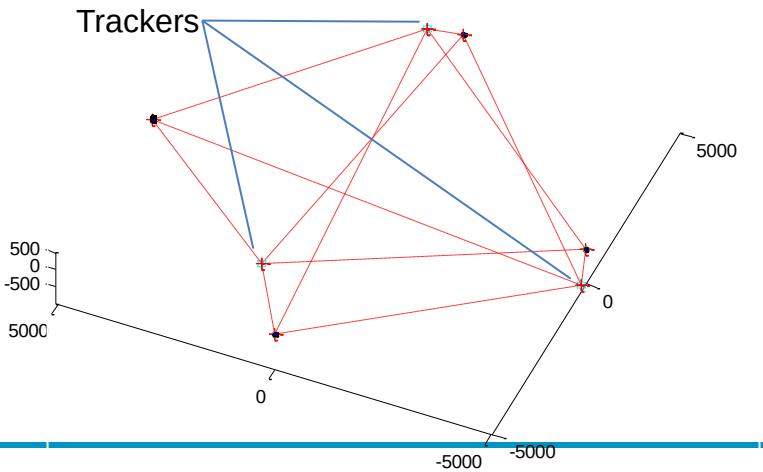


- Vertical position diversity
- Before: 30µm
- After: <15µm

A



B



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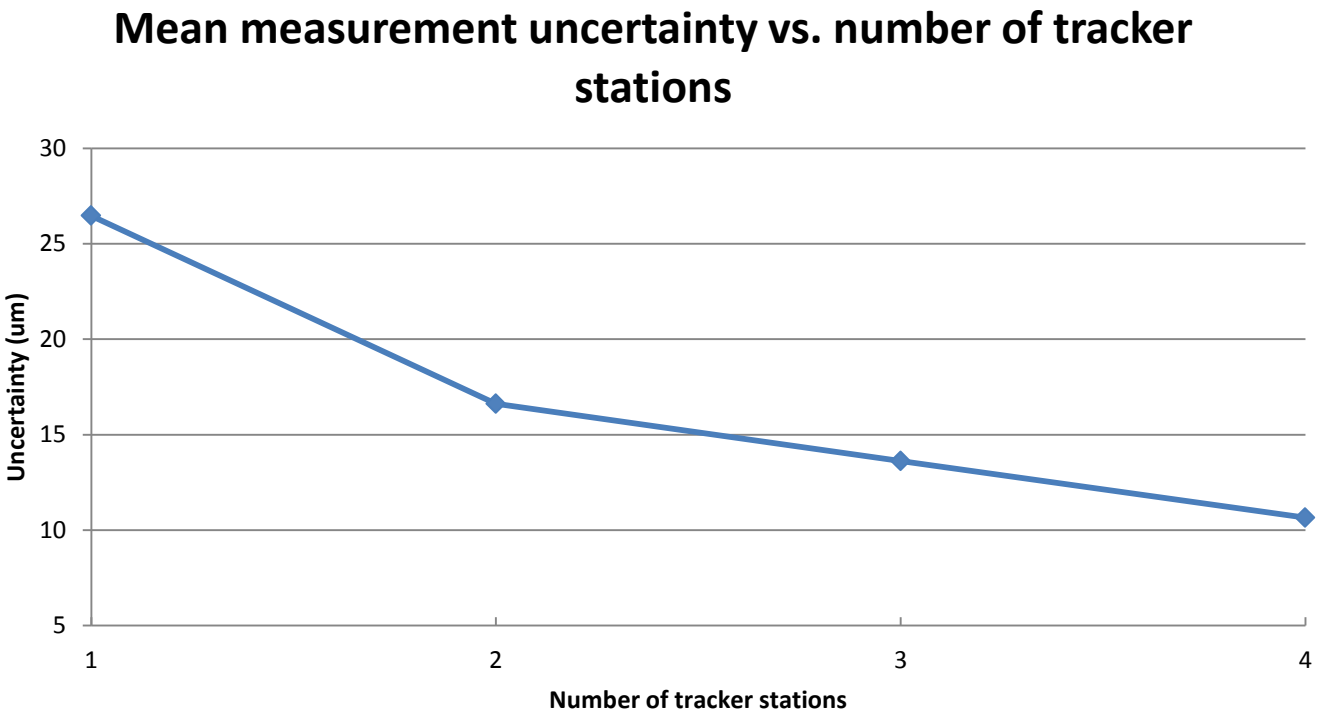
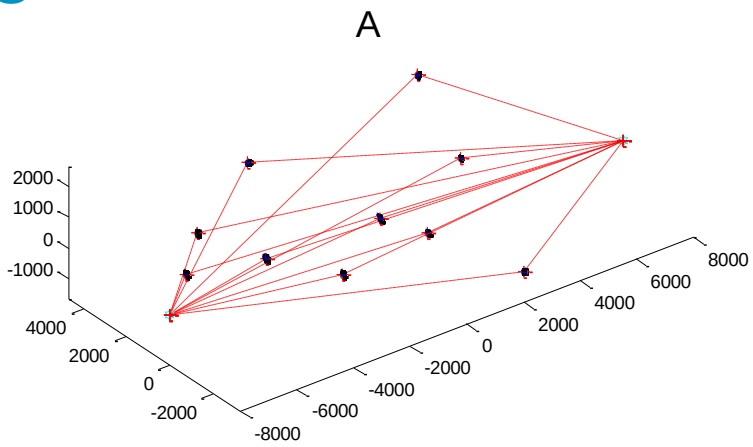
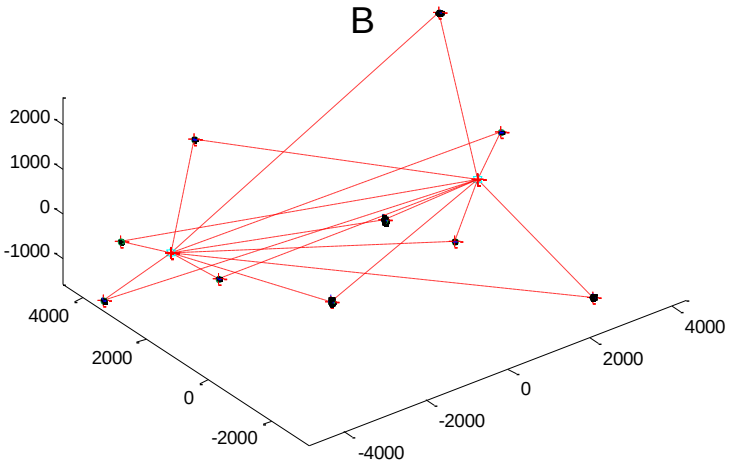
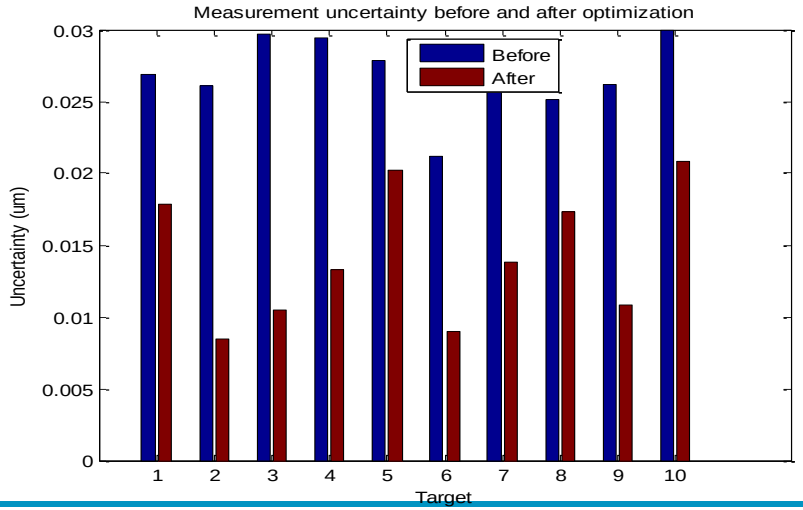
How many tracker stations do I need?



Example Solution for 2 LT 10 Arbitrary Targets

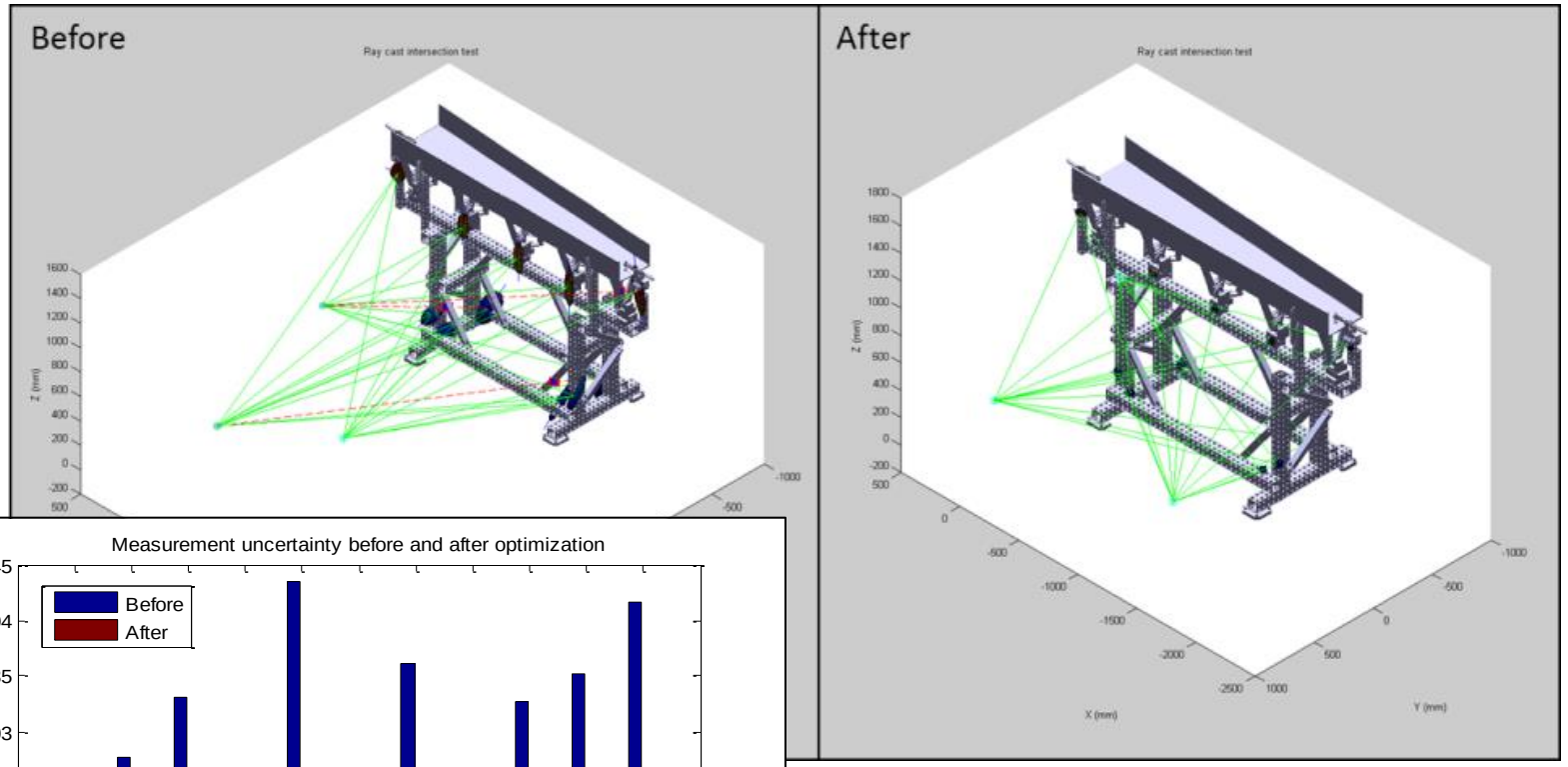


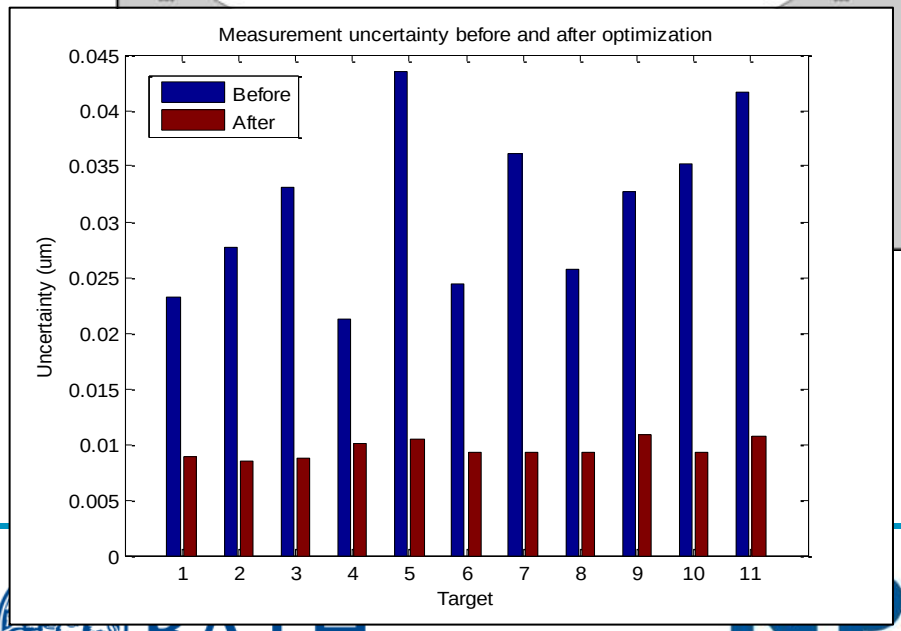




- Tracker closer to targets
- Ray angles close to 90 degrees

Example Solution 3 LT 11 Targets, LOS





- 59 iterations
- Computation time: 4 min 30 s
- Before: 32.5µm
- After: 8.4µm

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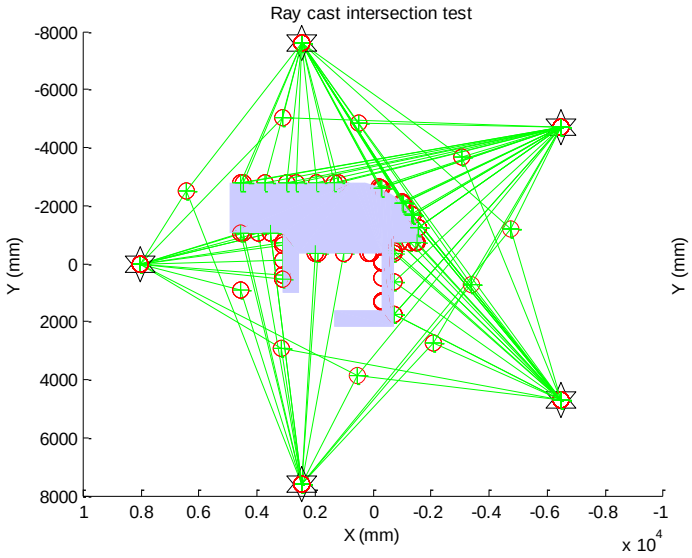
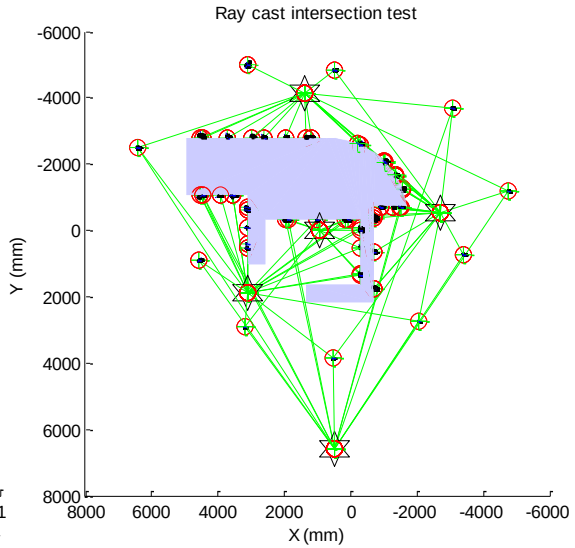
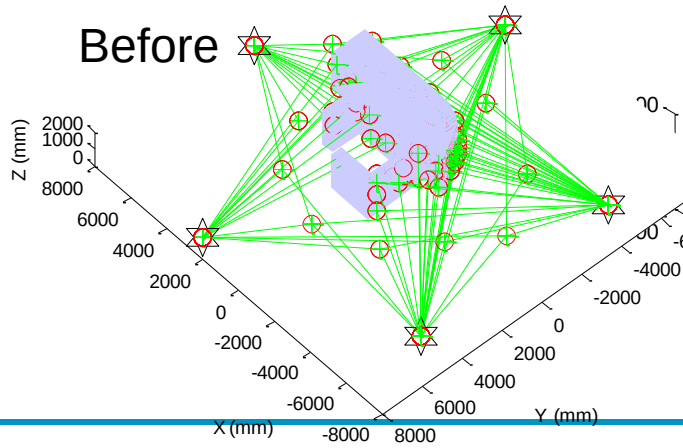
Example Solution 5 LT 60 Targets, LOS



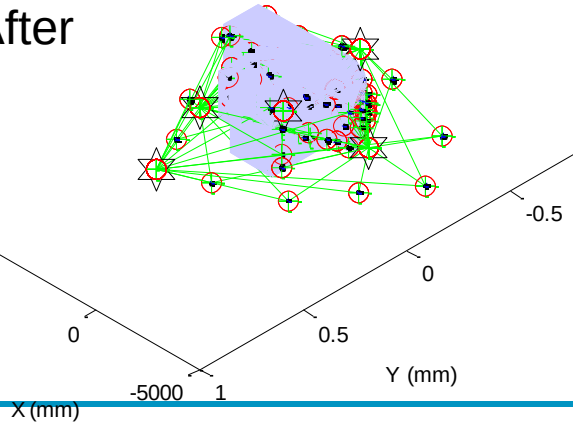


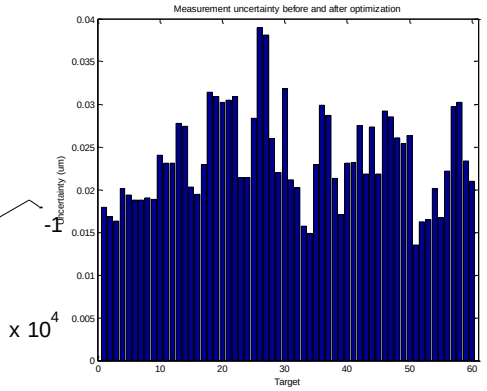
- GA initial search
- 56 iterations
- Computation time: 45 min
- Before: 8 targets missing
- After: all targets measured, 25.1µm

Before



After





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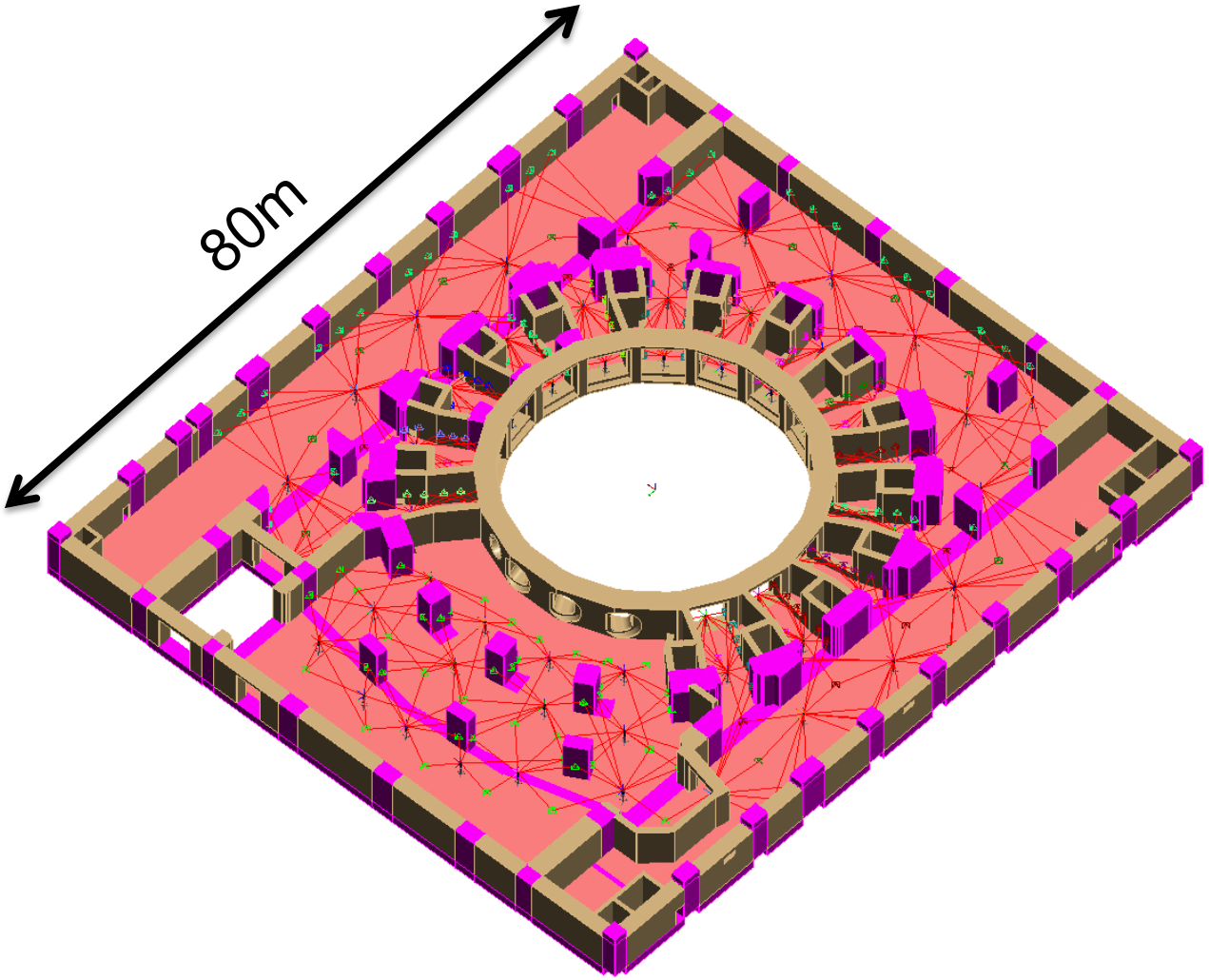
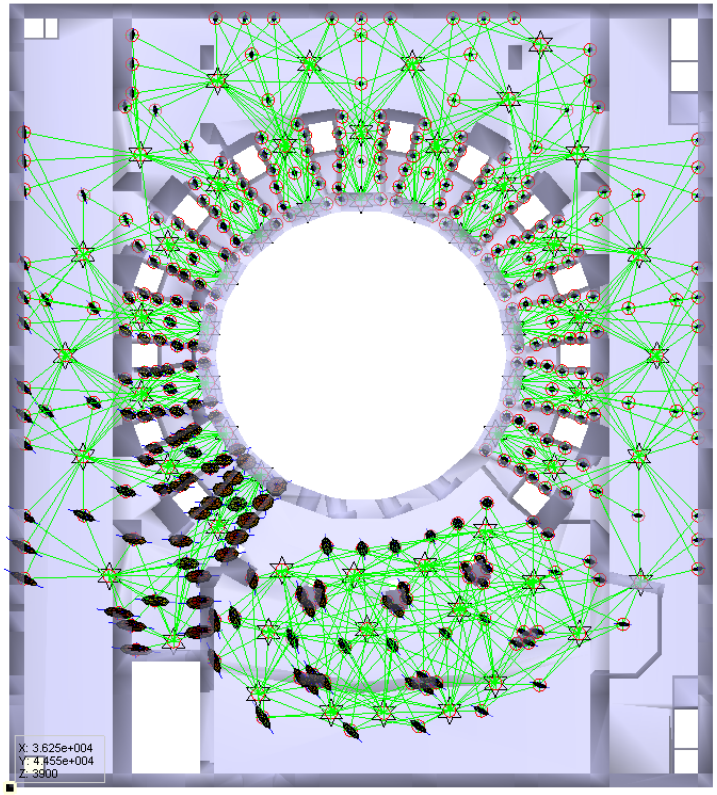
Example Solution: ITER Gallery



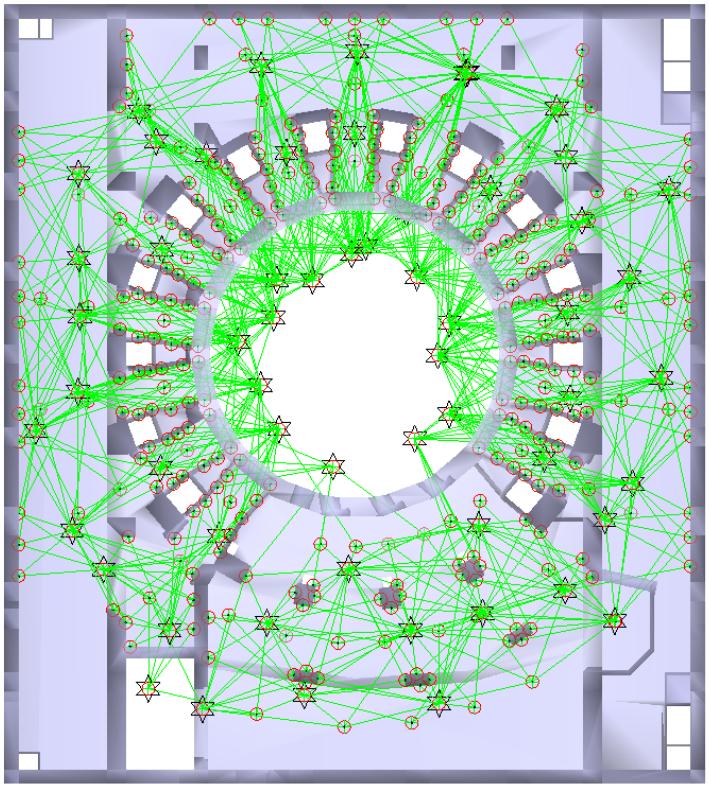
- 58 Trackers
- 308 Targets
- Courtesy of David Wilson (ITER)

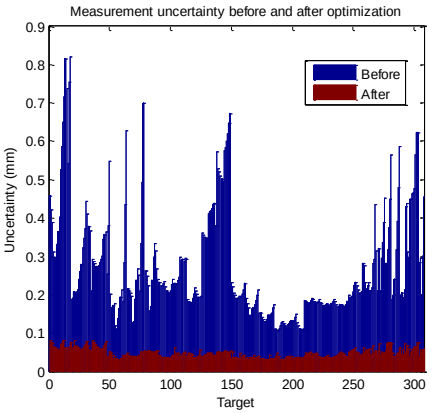
Example Solution: ITER Gallery

Before



After





- GA initial search
- Computation time: 3 Days
- Before: 273µm
- After: 48µm

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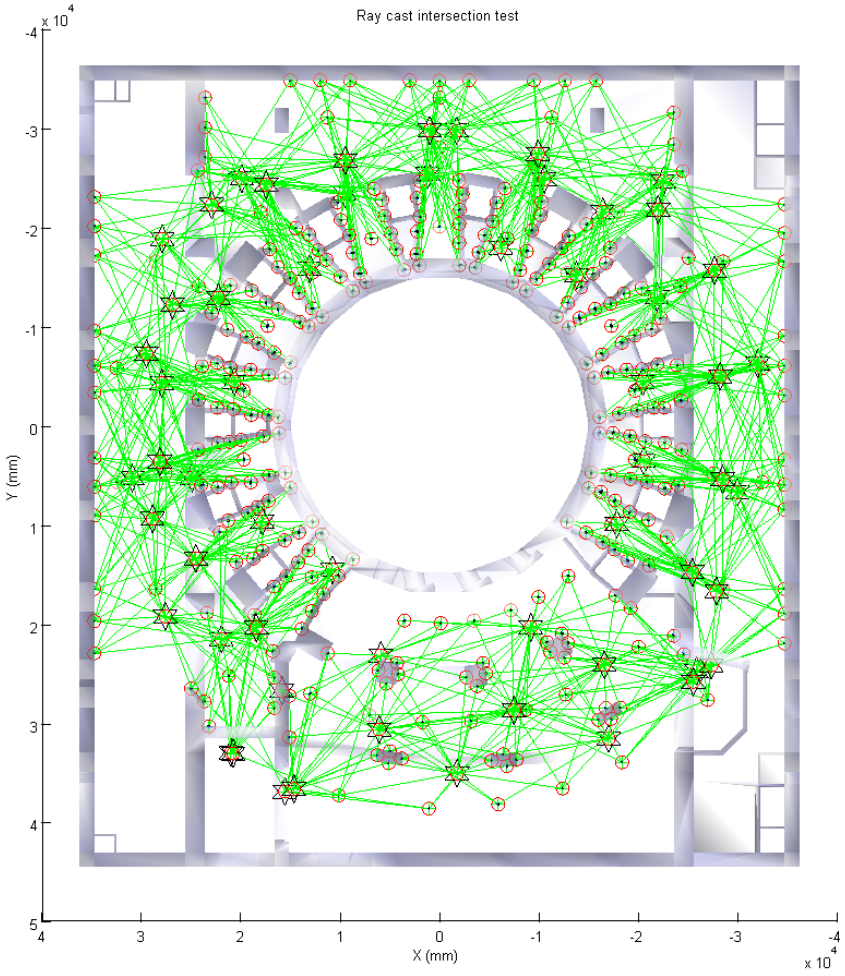
Example Solution: ITER Gallery



With central pit constraint:

- Before: 273µm
- After: 55µm

Summery

- Laser tracker position optimization code based on the NPL laser tracker model
  - Laser tracker model
  - Line-of-Sight Check
  - Optimization
- Optimized networks can very significantly reduce measurement uncertainties
  - Use cheaper and less accurate instruments
  - Reduce measurement stations and time
  - Plan complex measurements

Future Work

- Improve user interface
- Increase performance
- Industrial case study
- Benchmark against SA
- Use 3D scan instead of CAD
- Extend model
  - Theodolites
  - Laser radar
  - iGPS
  - Multilateration
  - Photogrammetry