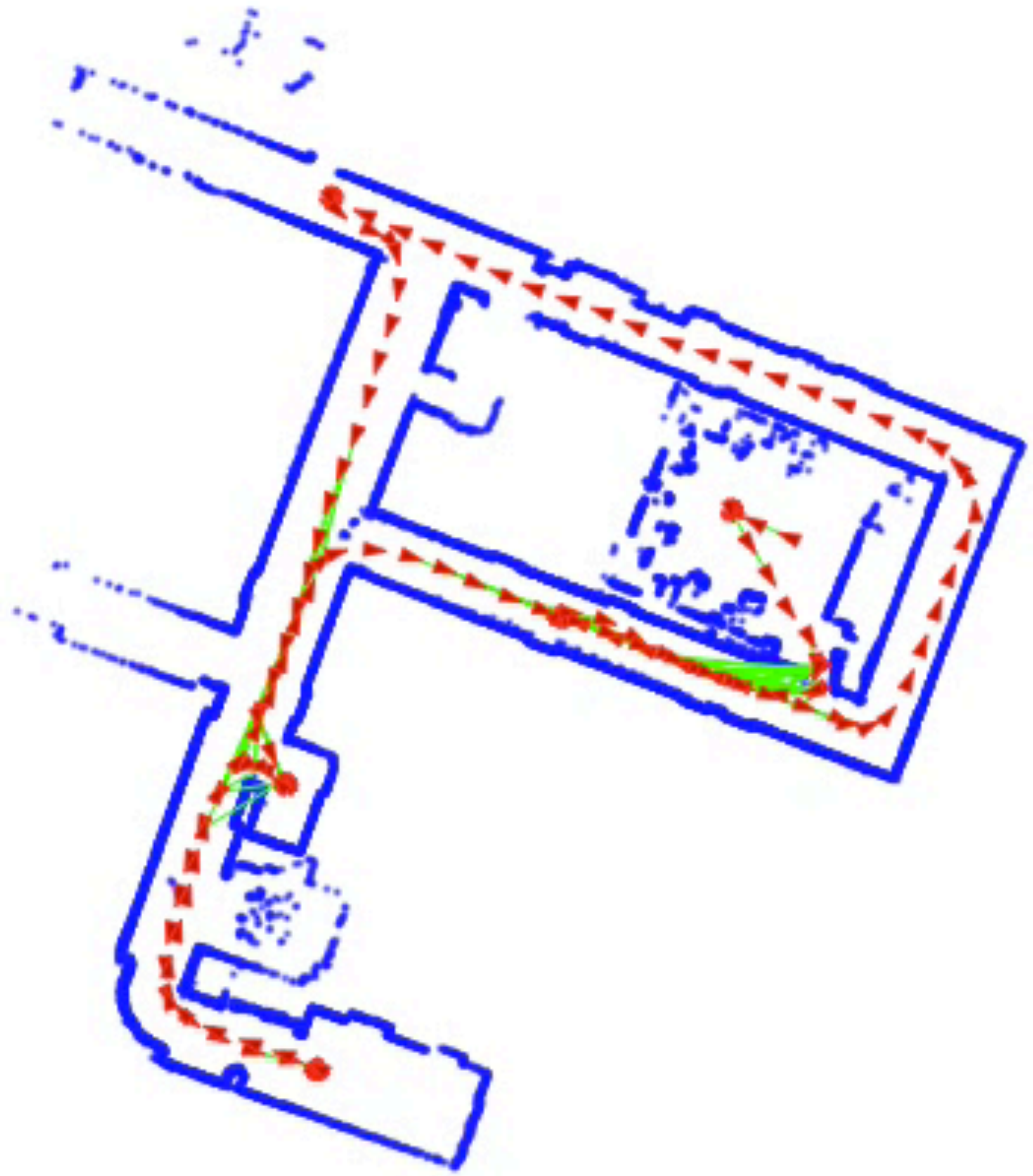


SLAM for Soar

Keegan R. Kinkade

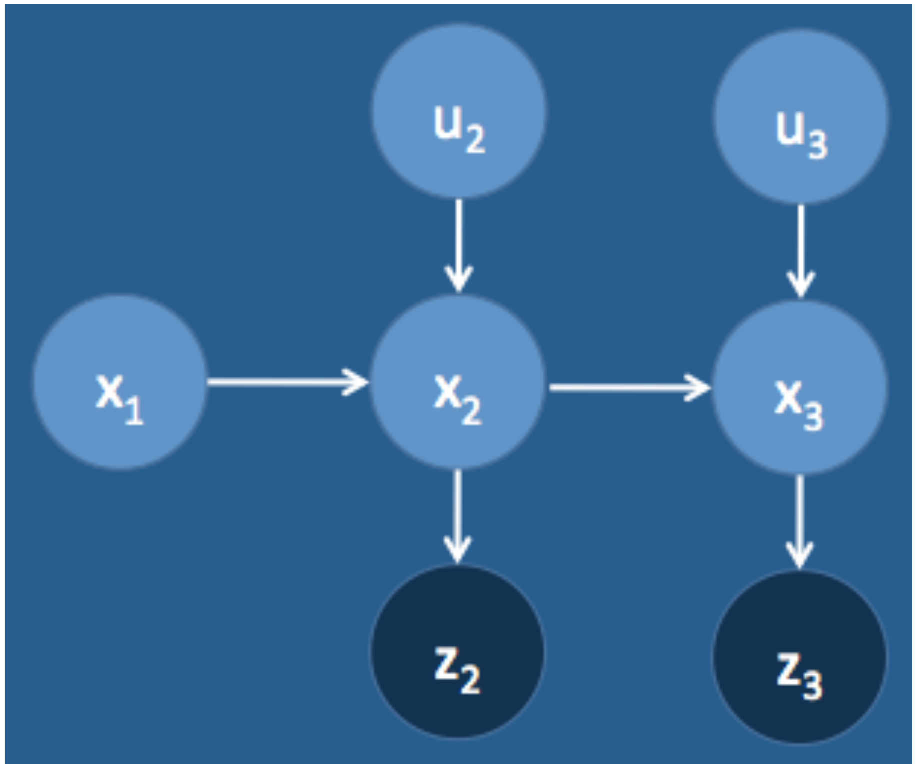
17 JUNE 2011

SLAM Theory / Code

- April Robotics Laboratory:
  - http://april.eecs.umich.edu/
- Presentation adapted from slides generously provided by Professor Edwin Olson
- Method similar to SLAM architecture used by Team Michigan in 2010 MAGIC Robotics Competition
- Radish: Robotics Data Set Repository
  - http://radish.sourceforge.net/

Simultaneous Localization and Mapping

- While robot is exploring unknown environment:
  - **GIVEN:** Robot's movement commands and observations of unknown environment
  - **ESTIMATE:** Map of features and robot's path through environment

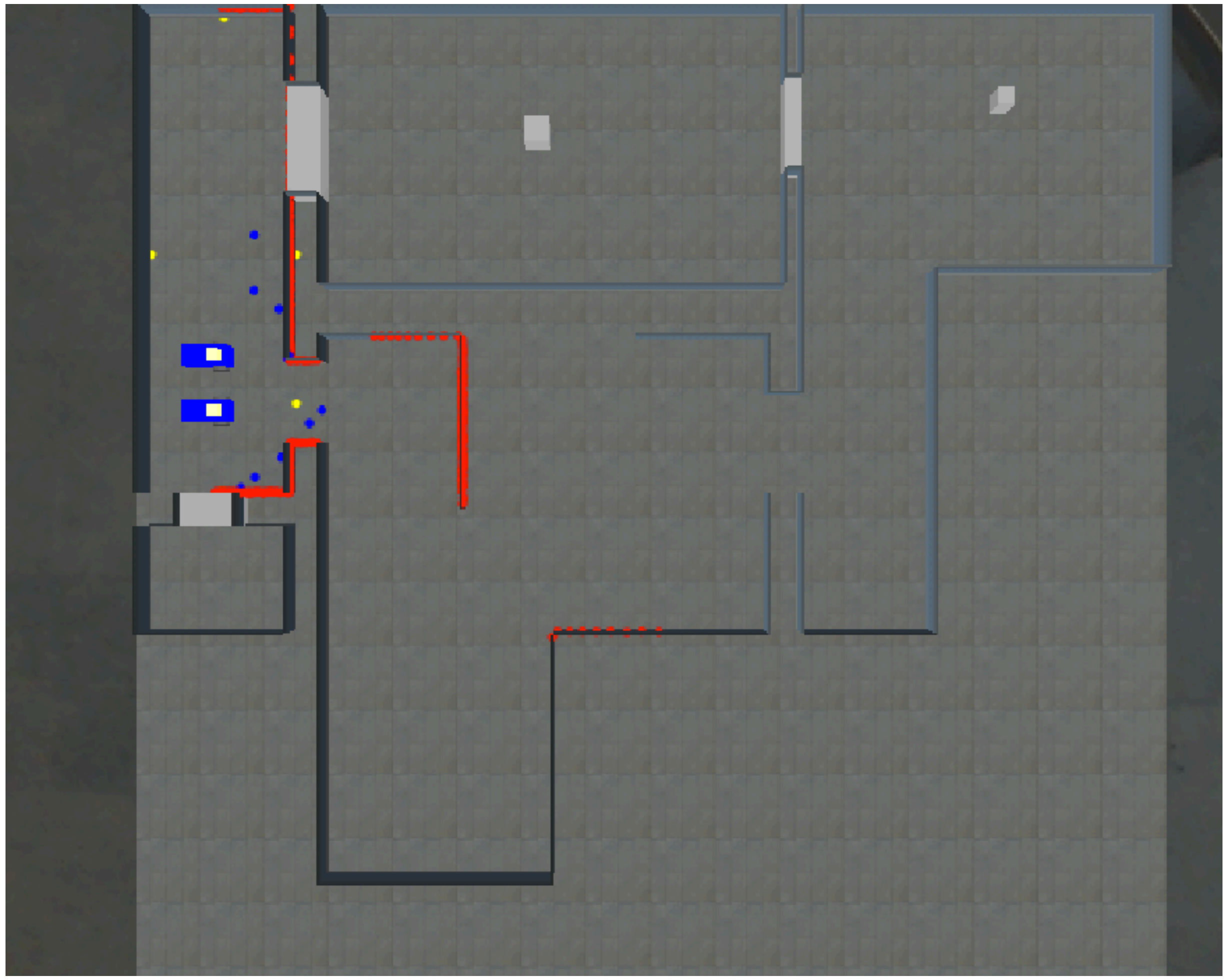


- Probabilistically motivated problem:
  - Errors within robot's movement and observations

$$p(s, f \mid u, z, d)$$

SLAM Motivation

- Soar Robot Project
  - Differentially driven robot utilizing LIDAR (**LI**ght **D**etection **A**nd **R**anging)
  - Encoders estimate robot's trajectory
- What additional machinery is required to place agent in world?



Input Link
^io.input-link

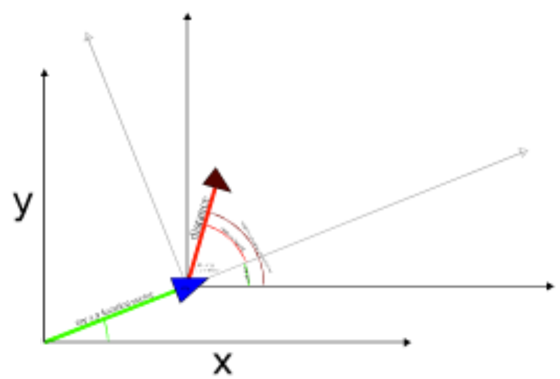
Objects

^object
- ^id
- ^visible
- ^x
- ^y
- ^distance
- ^… Arbitrary key-value properties

Examples:
- name: civ
- type: player

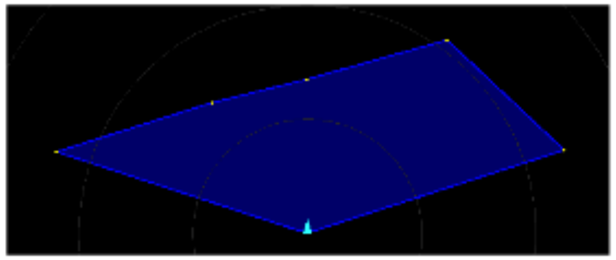
Waypoint System

^waypoints
- ^waypoint
  - ^id
  - ^x
  - ^y
  - ^distance
  - ^yaw
  - ^relative-bearing
  - ^abs-relative-bearing



Lidar

^lidar
- ^range
  - ^id
  - ^distance
  - ^relative-bearing



About The Robot

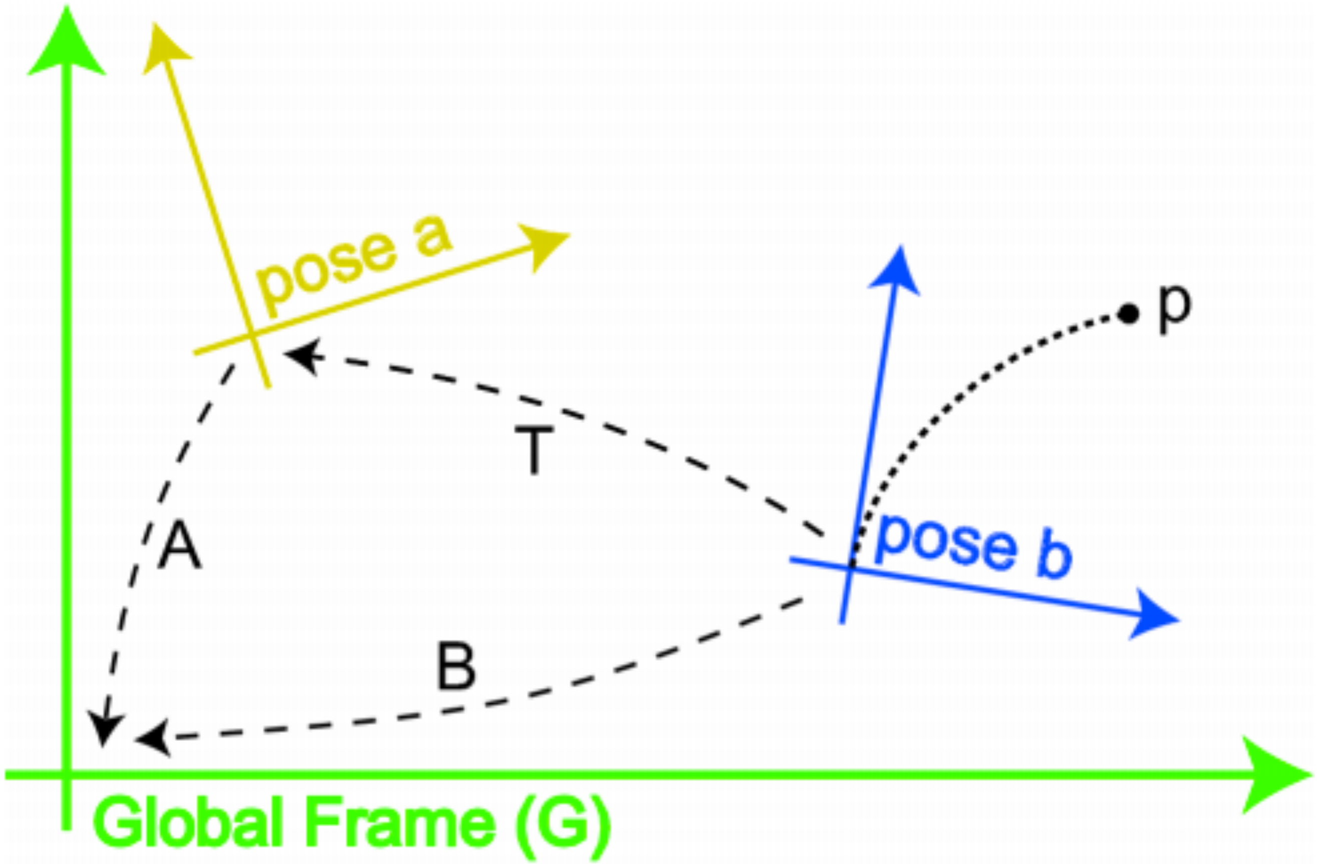
^self
- ^name
- ^area
- ^headlight
- ^battery
- ^pose
  - ^x
  - ^x-velocity
  - ^y
  - ^y-velocity
  - ^yaw
  - ^yaw-velocity

Current Focus

Pose / Feature Graphs

- Poses and Features represented as 'Nodes'
- Connected by 'Edges' composed of Rigid Body Transformations
- Additional observations create an overdetermined system
- Feature p in Global Frame:

$$
\begin{aligned}
p' &= Ap \\
&= ABp
\end{aligned}
$$



$$
T = \begin{bmatrix} cos(\Delta\theta) & -sin(\Delta\theta) & \Delta x \\ sin(\Delta\theta) & cos(\Delta\theta) & \Delta y \\ 0 & 0 & 1 \end{bmatrix}
$$

Non-Linear SLAM

- Edge $\longrightarrow$ Observation: $z_i = f_i(x)$
- Observation Residual: $r_i = z_i - f_i(x)$
- Scale Residual by Observation Confidence:

$$\chi_i^2 = (z_i - f_i(x))^T \Sigma_i^{-1} (z_i - f_i(x))$$

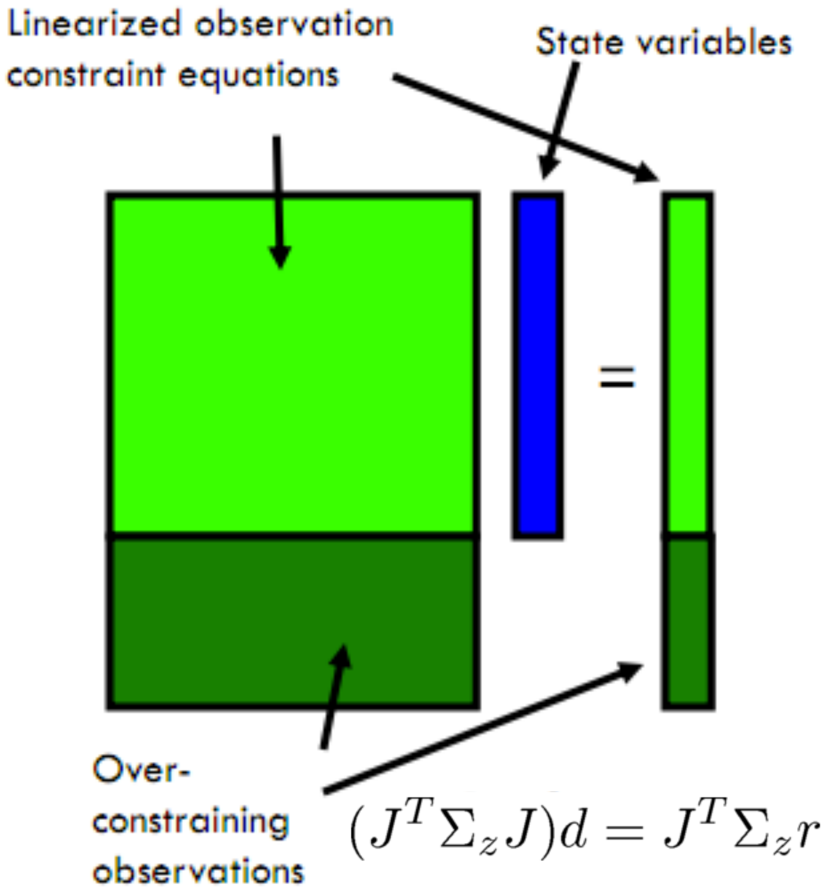
- Typical Observations != Linear
- Stack linearized observations using Jacobian:

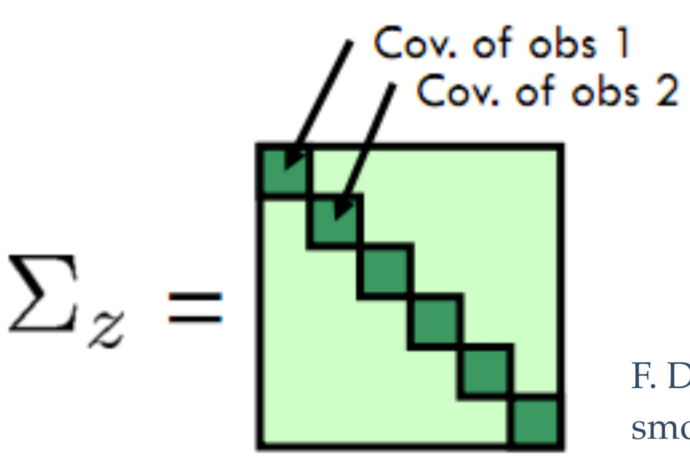
$$\chi^2 \approx (Jd - r)^T \Sigma^{-1} (Jd - r)$$, where

  - r is the observation residual
  - d is the linearization residual $(x - x_0)$

- Differentiate χ^2 with respect to d, solve for d which minimizes the χ^2 error

Square root SAM





- Naive Solution:

$$d = (J^T \Sigma_z^{-1} J)^{-1} J^T \Sigma_z^{-1} r$$

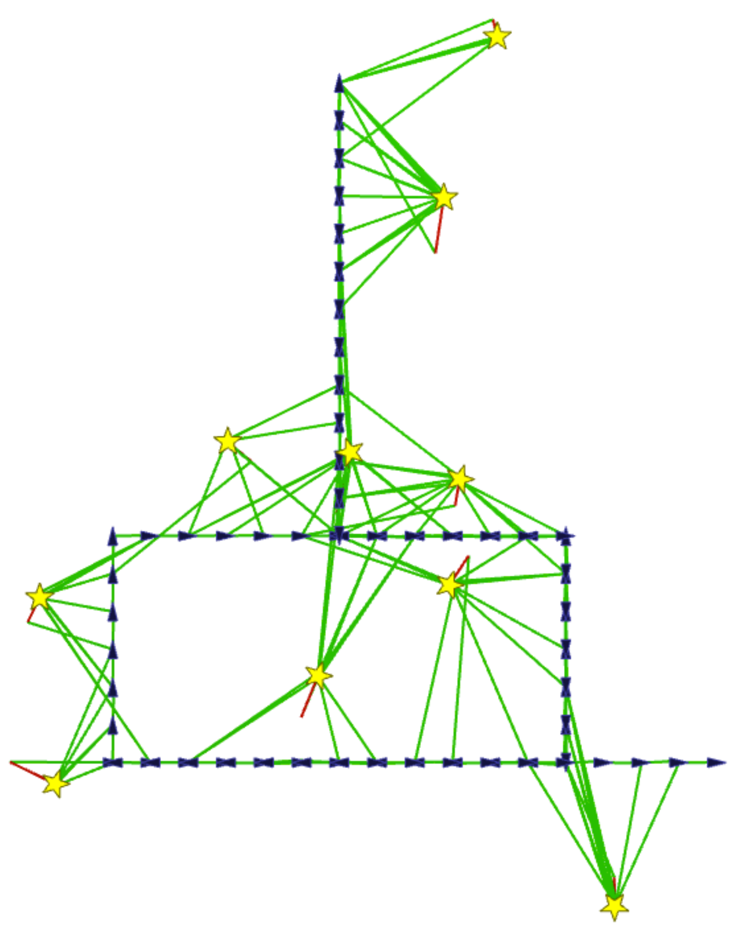
Information Matrix

- Typically impractical due to matrix inversion complexity ~ $O(N^3)$
  - Other SLAM methods attempt to approximate this
- Solution: Exploit sparsity within the information matrix
  - Reorder nodes to induce additional sparsity
  - Back solve using Cholesky decomposition

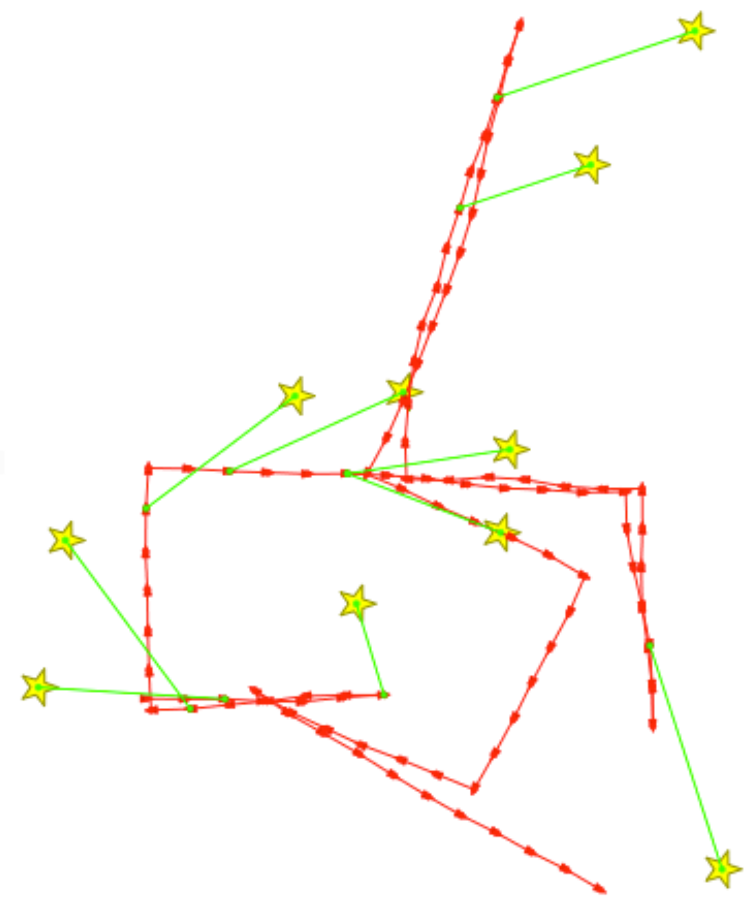
F. Dellaert and M. Kaess. Square root SAM: Simultaneous localization and mapping via square root information smoothing. International Journal of Robotics Research, 25(12):1181–1203, December 2006

Square root SAM Demo

Ground Truth

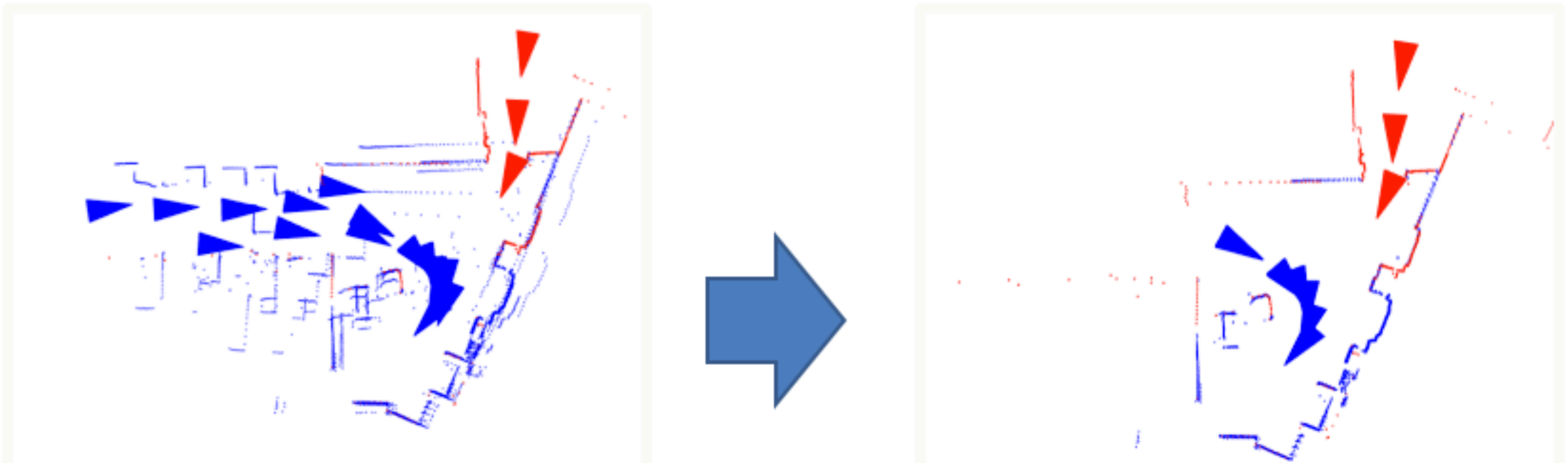


Open Loop



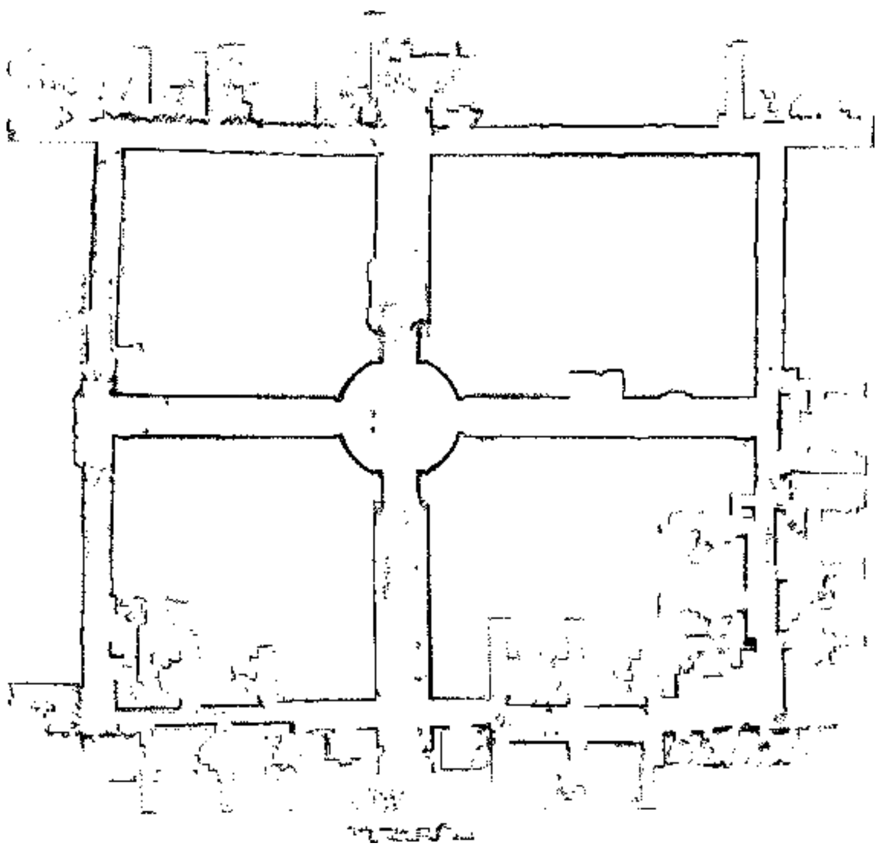
Loop Closure

- Using LIDAR to close the loop:
    - Determine if robot is in the location of a previous pose
    - Attempt to create RBT between two poses using their corresponding LIDAR scans
        - Resolution Scan Matching algorithm to align points of individual scans

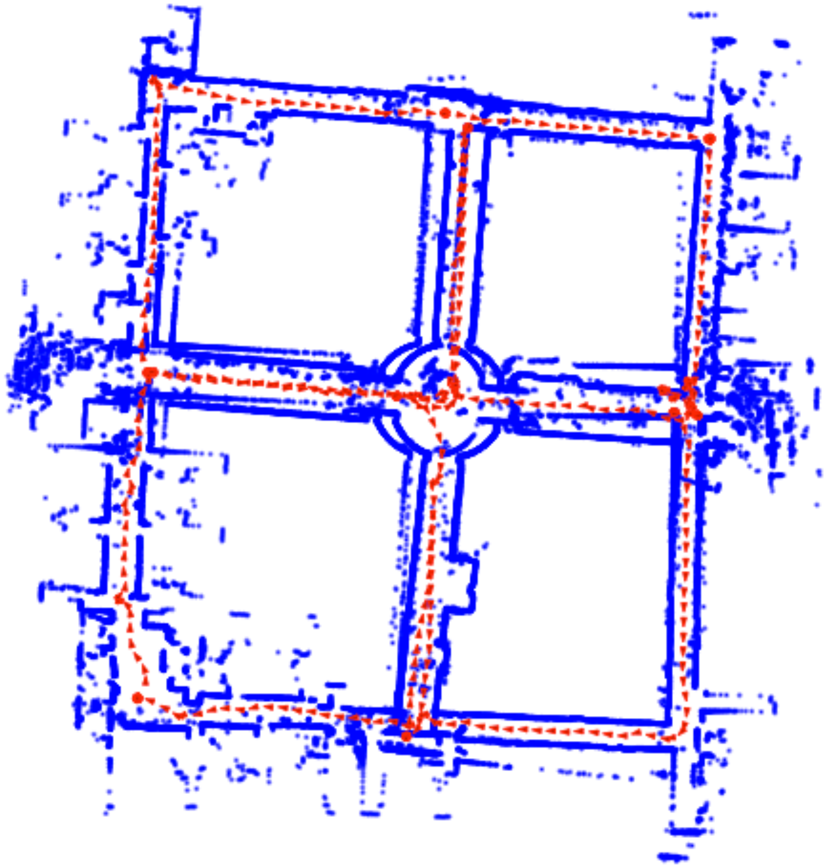


Full System Demo

Ground Truth

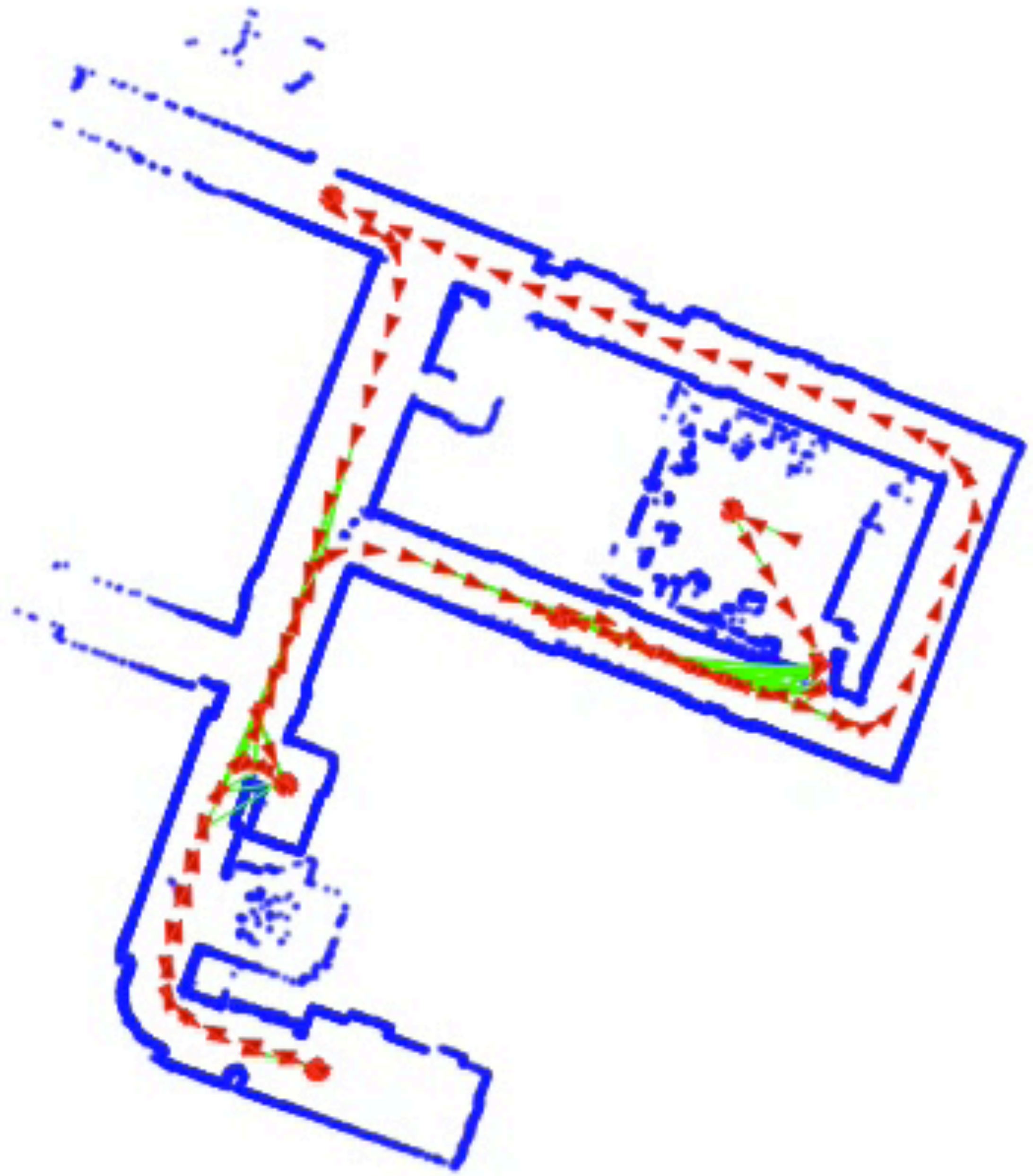


Open Loop



Evaluation

- Nuggets
  - Robust system capable of handling multiple environments
  - Architecture supports the tracking of additional information
  - System is sufficient to handle a minimal sensor suite
- Coal
  - Requires fine tuning of parameters depending upon sensors
  - Have not implemented full system on robot / simulation
  - Still requires additional algorithms to provide information to input link



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