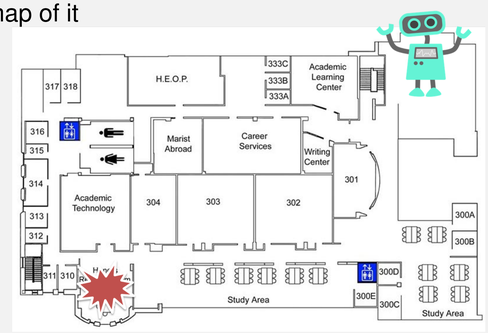
Focused Information Gathering With An Application In SLAM

Beipeng Mu, Matthew C. Graham, Jonathan P. How

Massachusetts Institute of Technology

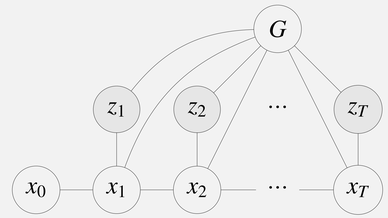
Simultaneously Localization and Mapping (SLAM)

- **Problem:** navigate through an environment and build a map of it
- **Sensor capabilities and constraints**
  - **RGB-D** RGB camera and depth camera to gain perception of the environment
  - **Odometry** – measure incremental position change
  - **Landmarks** – anchor poses and detect loops
  - **Computation** – resource limited so can only process fixed number of frames
- **Challenge**:
  - Position estimate drifts over long duration runs
  - Scalability (collect ~10G data over 2min)
  - Must be selective in the images that are processed



How to Solve Focused Information Gathering Problem?

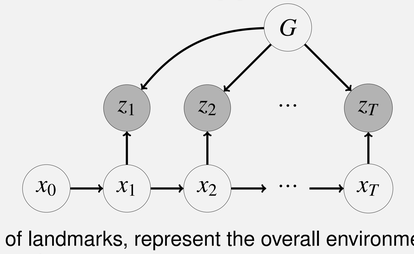
- Transform to Gaussian Markov graphical model
  - Connectivity = information matrix;
  - efficient inference;
  - uncertainty decoupled from realization
- Greedy select measurement to maximize information in focused hidden variables:
  1) initial A_0 with a random small set to guarantee robustness
  2) $z_i = \text{argmax}_{z_i} f(S|A_{i-1}, z_i)$
  3) $A_i = \{A_i, z_i\}$
- **Proposition**[2]: If graph is a tree, then cost function is sub-modular, so greedy selection gives a bounded approximation to the optimal solution.
  - Empirical studies show greedy selection still works much better than unfocused approach on cyclic graphs



Undirected Graphical Model for SLAM

Graph Model and Focused Information Gathering

- Graphical model for SLAM[1]



  - G: set of landmarks, represent the overall environment
  - z_t: perception measurement at t
  - x_t: camera pose at time t
  - shaded variables are observable
- Observations:
  - G is static, but $|x_t|_1^T$ grows with time
  - The fast growth of measurement set $|z_t|$ makes graph-based SLAM solver for long time dataset intractable
  - Typically only care about (subset of) the whole map
- **Information gathering**

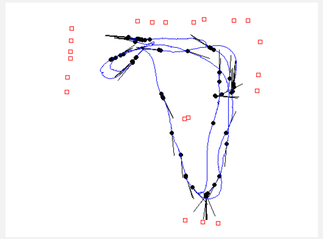
$$\max_{A \subset Z_T} \quad f(S|A)$$
$$\text{s.t.} \quad c(\mathcal{A}) \leq \beta \qquad (1)$$

  - S: set of hidden variables that are important
  - $\mathcal{A}$: selected measurements to process
  - $f()$ function to quantify informativeness
  - $c()$: resource measure; β resource constraint
  - Note that this is a **focused information gathering problem**

Initial Experimental Results

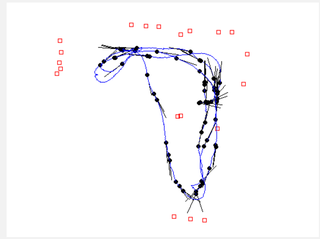
ground truth

- Trajectory truth from motion-capture system



focused selection

- Trajectory and landmark locations are well reconstructed

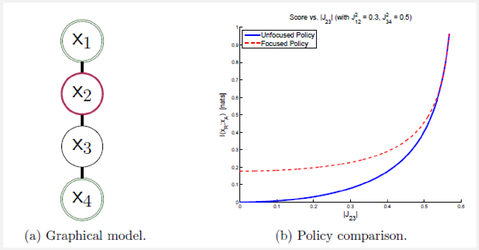


down-sampled (XX- every nth image? -XX)

- Landmark locations on the left are distorted

Does Focused Information Gathering Help?[2]

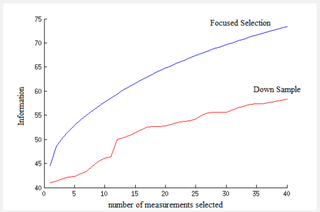
- **Issue**: implications of having a focused information gathering problem?
- **Example:**
  - Focused set: $\{x_2\}$
  - nuisance $\{x_3\}$
  - Observable set $\{x_1, x_4\}$
  - Resource constraint: only one measurement can be selected
- **Result**: unfocused variable selection can lead to arbitrary bad selection compared to focused approach



(a) Graphical model. (b) Policy comparison.

Summary

- Information gathered



- Images processed

	# images
full dataset	2500
down-sample	40
focused selection	40

- **Summary**: Focused information gathering enables SLAM to select and process the most important images
- **Future work**
  - Use image features: relax assumption on known landmarks
  - On-line information evaluation
  - Robustness to light condition, distance, continuity of data, and outliers
- **Reference**

[1] H. Kretzschmar, C. Stachniss, and G. Grisetti. Efficient information-theoretic graph pruning for graph-based slam with laser range finders. In *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on*, pages 865–871, Sept 2011.

[2] Daniel S. Levine. *Focused Active Inference.* PhD thesis, Massachusetts Institute of Technology, Department of Aeronautics and Astronautics, Cambridge MA, August 2014.

Dept. of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA 02139

This research is supported in part by Army Research Office MURI grant number W911NF-11-1-0391.