Topological Map Merging for Distributed Mapping

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Problem

- Distributed mapping and exploration
- Lots of robots, no central "authority"
- Unknown environment
- Unknown initial locations
- Unknown relative positions

Lots of sub-problems

- What kinds of maps to build (metric, topological, etc.)
- How often should robots exchange data, and how
- How to distribute processing
- How to maintain a "global" view

Querying a distributed map

- Who has what parts of a map?
- Planning using a distributed map
- What if we can't talk to some robots?
- What if we don't even know what parts of a map are available and what aren't?

Topological maps

- Feature-based
- Graph representation
  - nodes are features, edges are paths between them
- A lot less data to send around than a metric map
- Can build these while we're building metric maps

First problem to tackle

- Topological map-merging
- Given two topological maps created by different robots, how can we merge them accurately?
- Once we can do this, the two robots will:
  - have a common frame of reference
  - know who to query for more detailed data about areas they themselves don't know much about

How to think about this

- Graph isomorphism: given two graphs $G_1 = (V_1, E_1), G_2 = (V_2, E_2)$, find all mappings $f : V_1 \rightarrow V_2$ such that G_1 and G_2 are identical
  - in other words, decide whether the two graphs are the same!
- In particular, we care about "maximum subgraph isomorphism" — finding the largest common subgraphs in two graphs
- Lots of different versions of these problems make different assumptions

Our assumptions

- Labeled nodes (e.g. "door", "corner", etc.)
- Some metric data
  - (x, y) of nodes
  - metric information about edges
- Perhaps we can assume common ordering of edges incident to a node

Another issue: error

- E.g. in metric data, especially in edge information, relative positions of nodes, etc.

- Another qualification: "error tolerant" maximum subgraph isomorphism

  – subgraph isomorphism that is resilient to errors in our metric data

Other work in this area

- Choset and Nagatani: Topological simultaneous mapping and localization (use graph matching to perform localization)

- Tomatis: Use a global topological model to connect local metric maps
  - almost exactly what we want to do, but in the context of single-robot mapping

- Computer vision: lots of people have done work on error tolerant isomorphism
  - e.g. retinal scanning, fingerprint matching, etc.

What we need to do next

- Dig through more work that has been done in this area, and understand it/decide how to use it
- Justify using topological map merging for distributed mapping
- Pen/paper algorithm fun!
- Try it (with our new robots?)