Landmark-based Matching Algorithm for Cooperative Mapping by Autonomous Robots

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Motivation

Mobile robots need to get a lot better at living in human environments

- keep good track of where they are (localize)
- develop a representation of their surroundings (mapping)
- move purposefully and safely

Constraints and Goals

- Environments of interest are usually
  - Dynamic
  - Noisy

  … and might be semi-structured

- We want
  - Online processing
  - Robust, fault-tolerant behavior

Our Approach: Topological Mapping

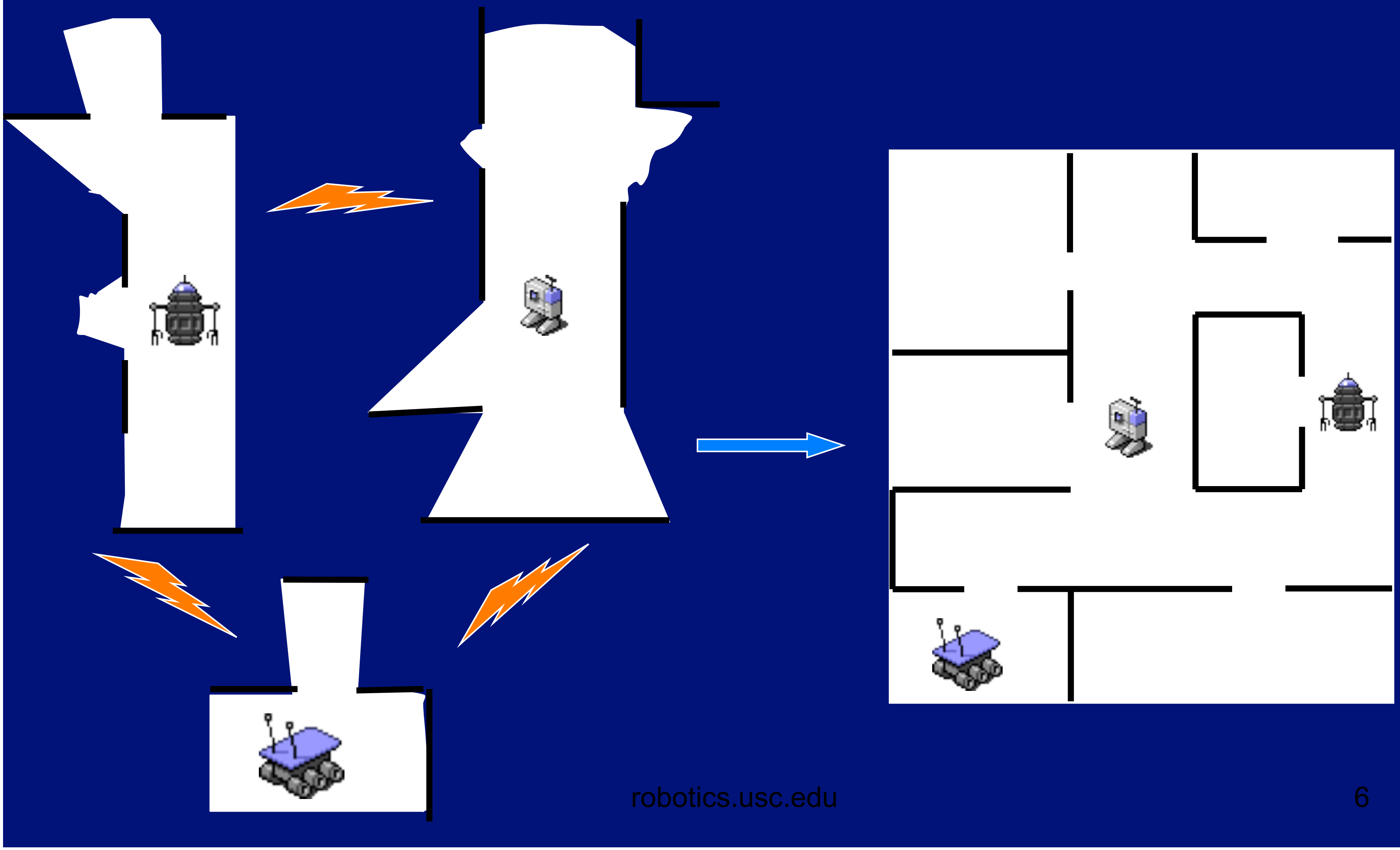
- Exploit presence of (known) features in the environment
- A map is a connected set of features

- Claims
  - Lightweight
  - Scalable
  - Distributed across multiple robots

Domain: Mapping the Interior of a Building

- Several robots (not localized in each others' coordinate systems) explore one floor of a building
- Each robot builds a topological map with rough metric support
- Maps are based on landmarks, which are detected using sonar range data, laser ranging and visual color cues
- Improved accuracy supported by reliable localization

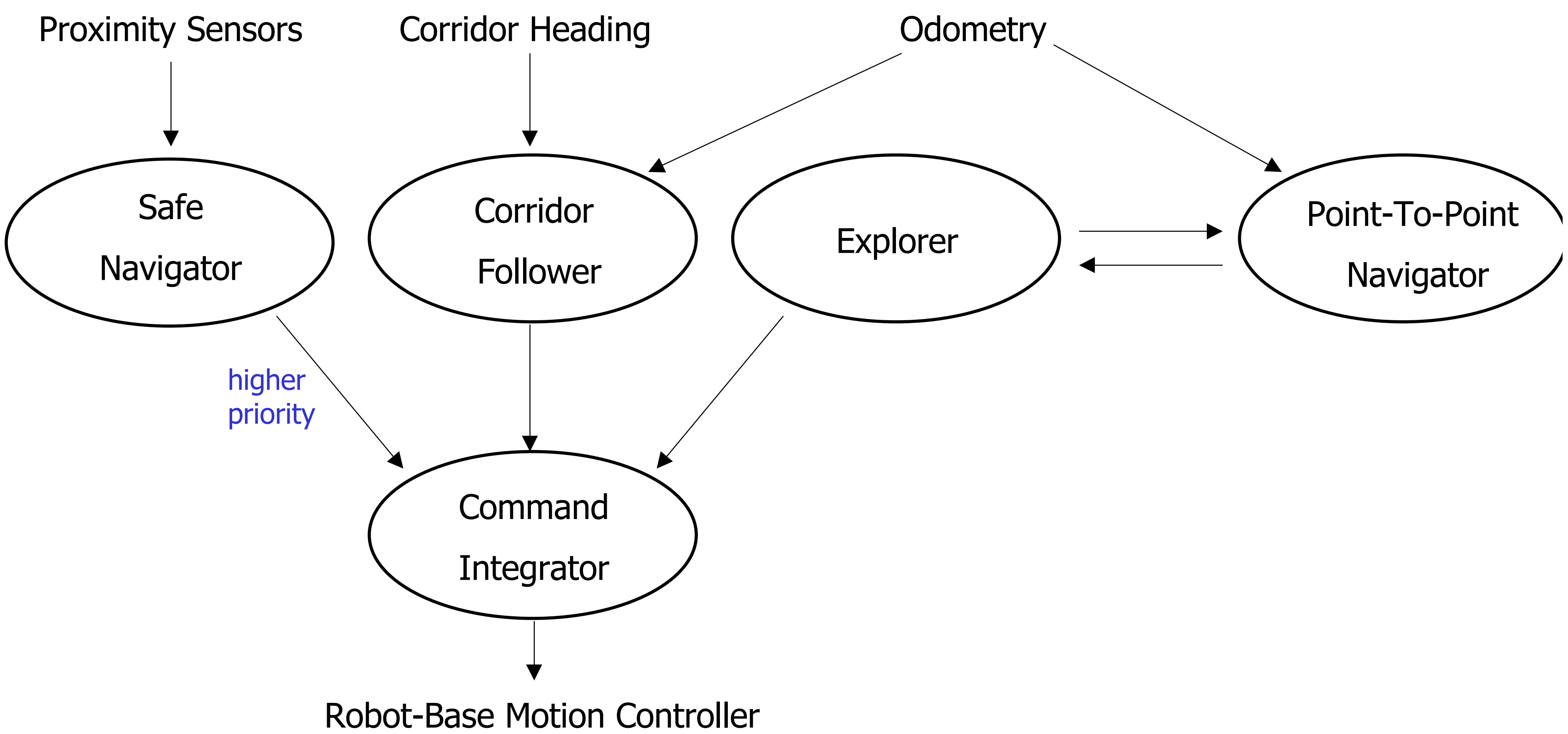
Multi-robot Mapping



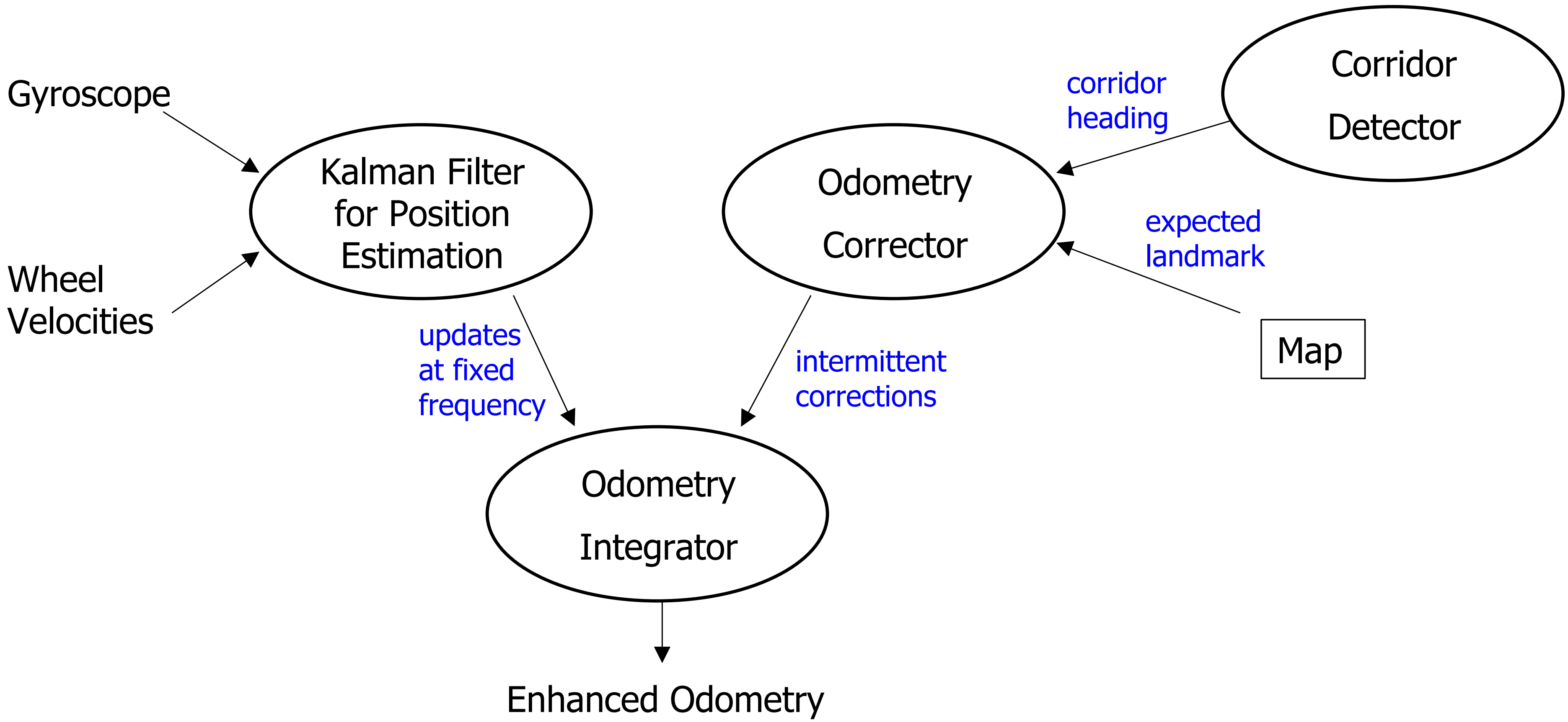
Mapping Algorithm: Outline

- Individual robots detect features
- Individual robots create topological maps with rough metric support
  - Each map is a planar graph
- Match algorithm finds best match topology using heuristic pruning

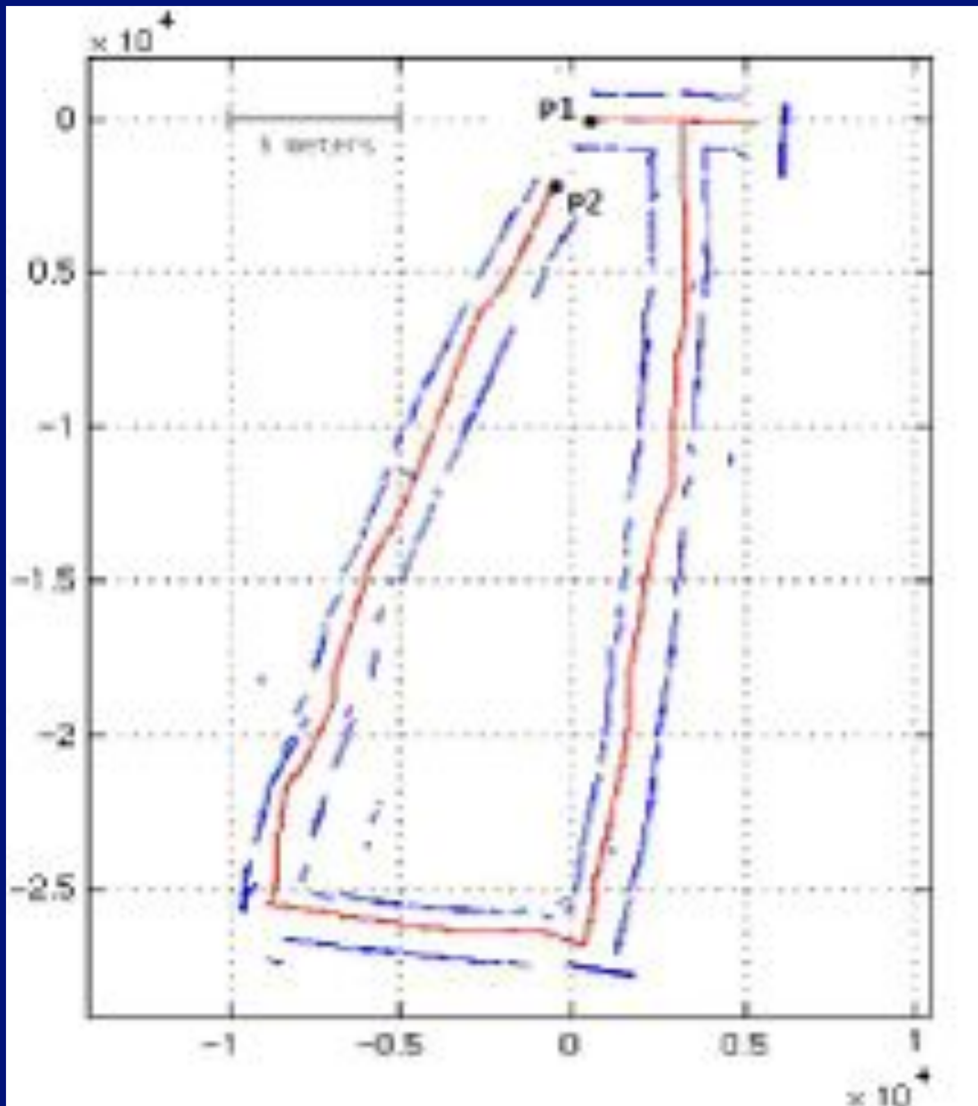
Behavior-based Navigation

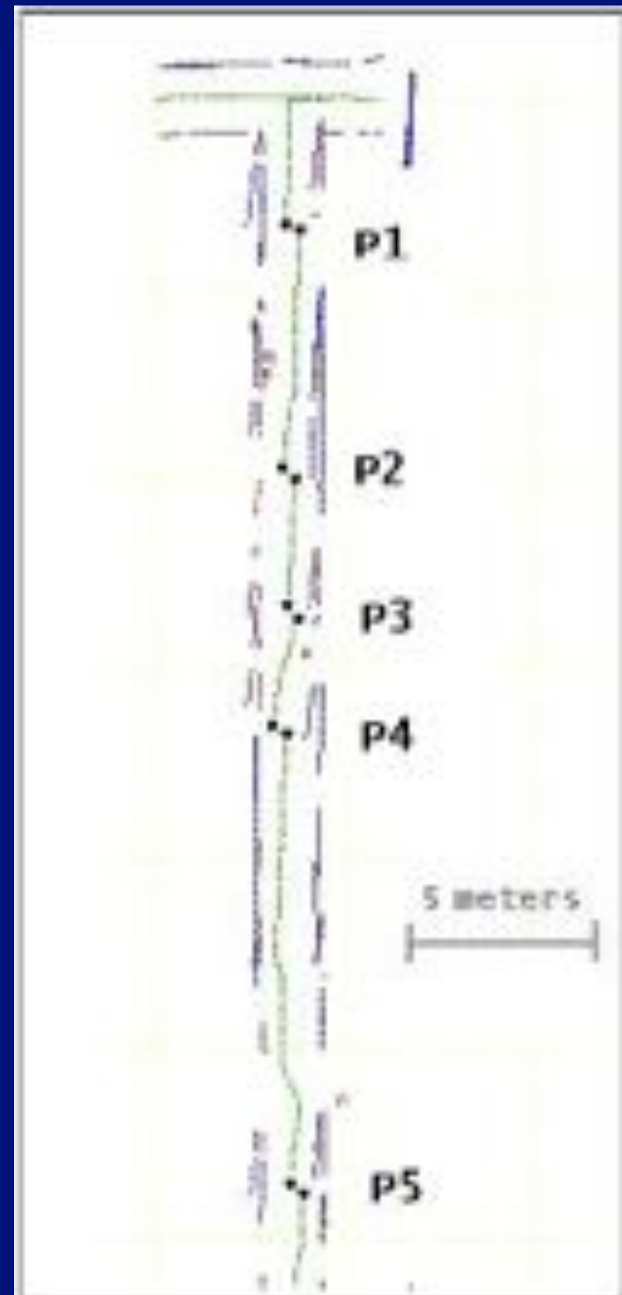


Position Tracking

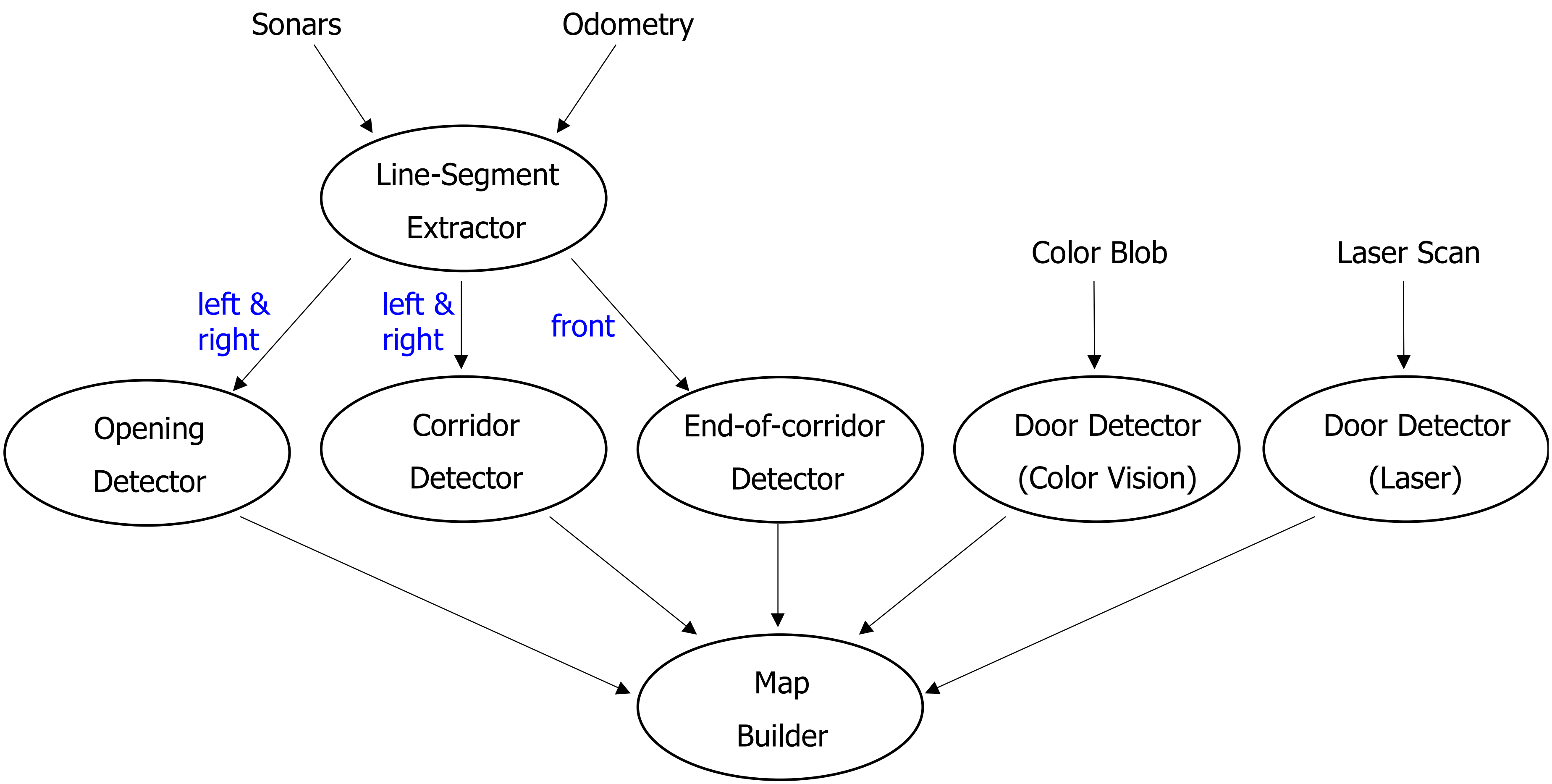


Correcting Odometry





Landmark Detection and Mapping



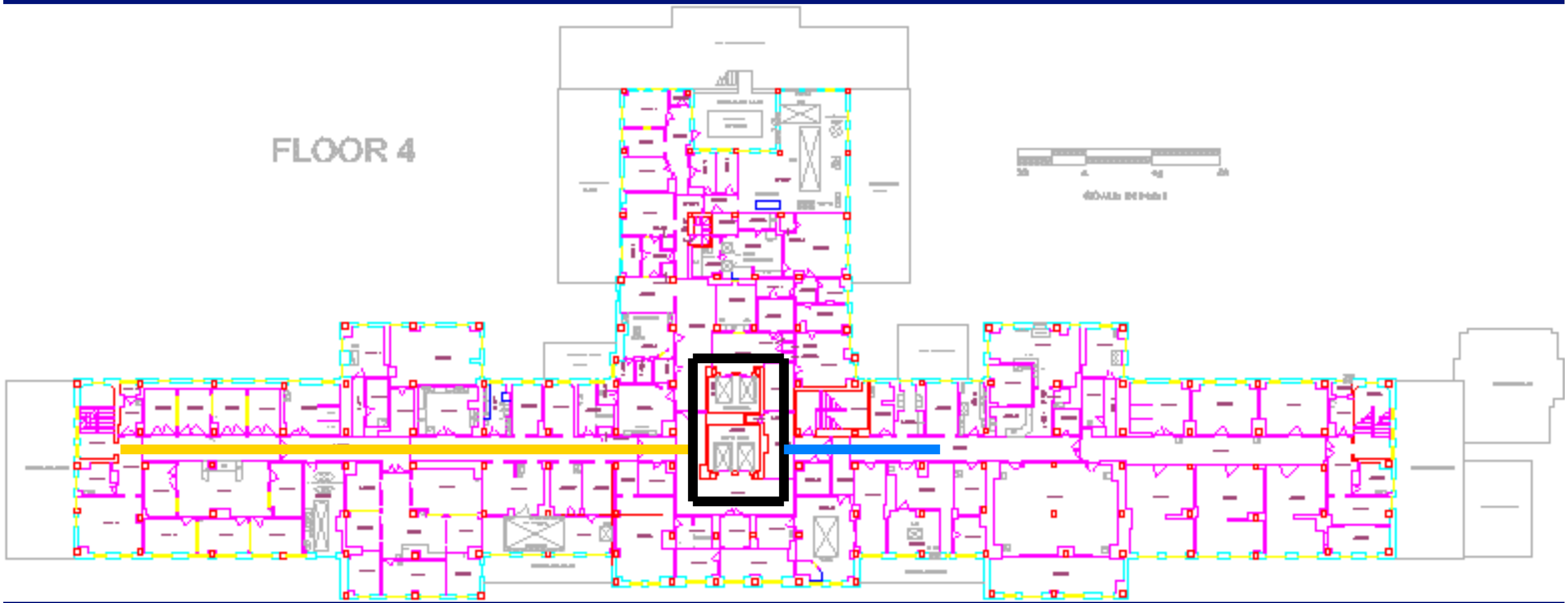
Map Representation

- A map is an augmented planar graph
  - Nodes are landmarks
  - Links are metric connections

```
struct node{
  id
  type    // corner, junction, door
  x, y    // approx coordinates
  struct link[4]   // 4 possible
                   // directions
  visit_counter
  detection_counter
}
```

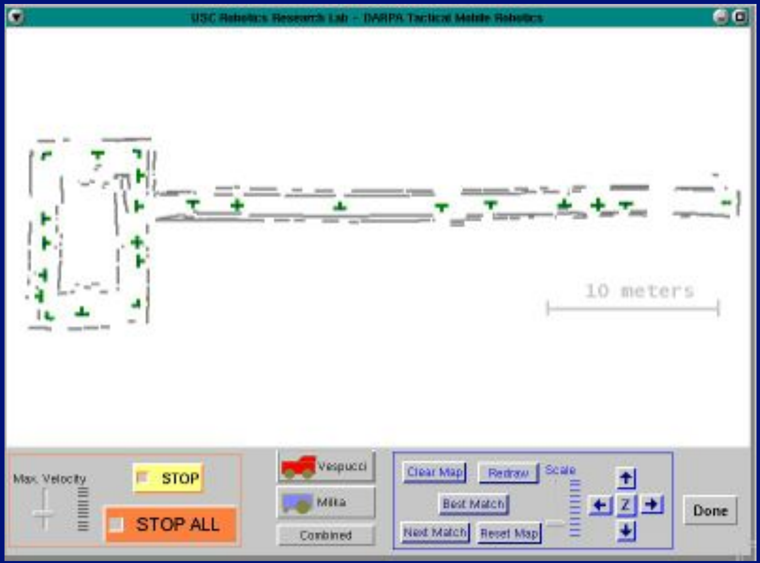
```
struct link{
  connected_to_id
  type            // open space, blocked
                  // door
  heading         // in local frame
  compass
  distance
  travel_counter
}
```

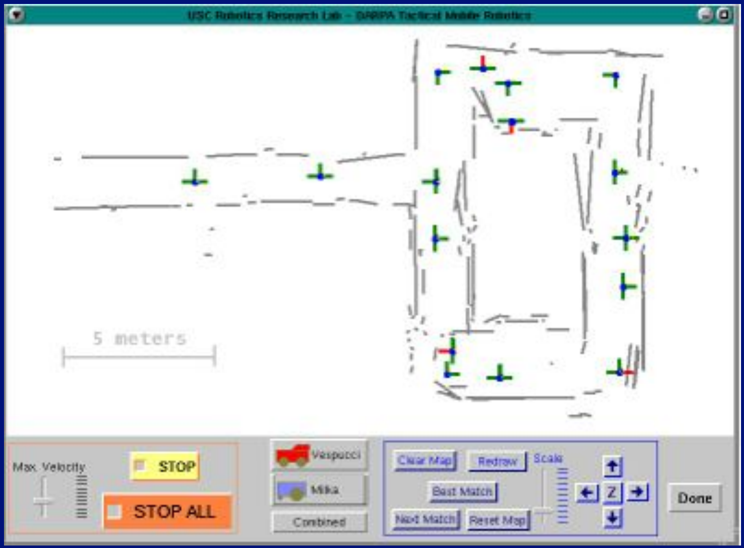
Experimental Example



Robot 1
Robot 2
Both

Experimental Example: Individual Maps



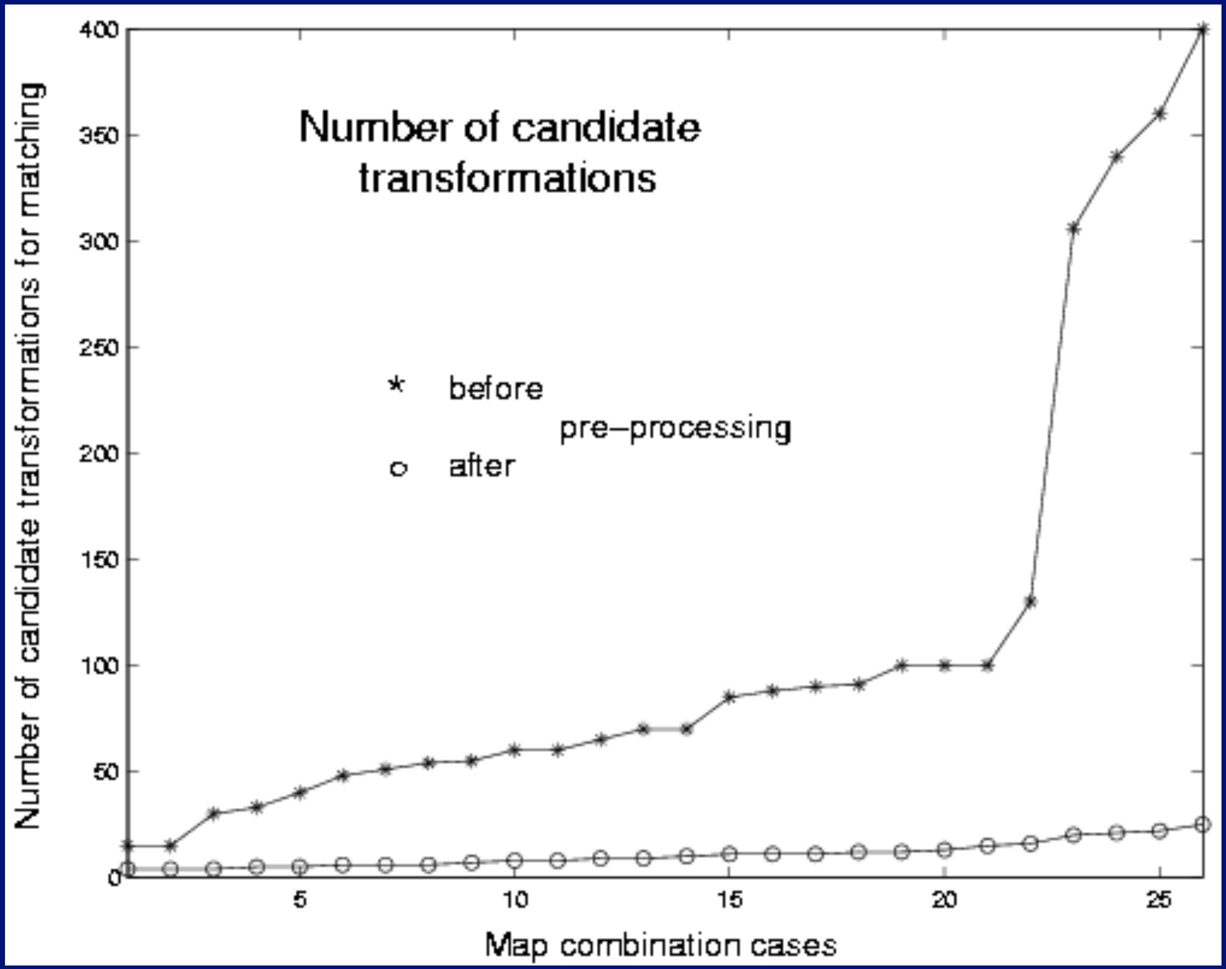


Experimental Results: Combining Maps

- Consider two maps with *n* and *m* nodes respectively
  - Pair landmarks of same type attribute (e.g. corners with corners)
  - Consider only landmarks that describe spatial features (e.g. corners and junctions)

Reduces the number of candidate transformations to approx. 20% of *nm*

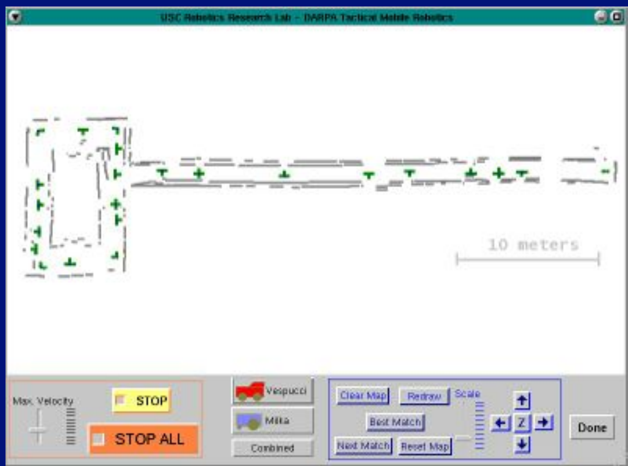
Scaling: Number of Candidate Transforms

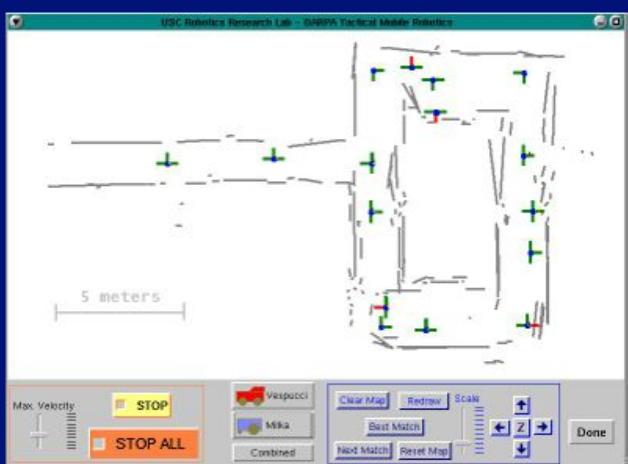


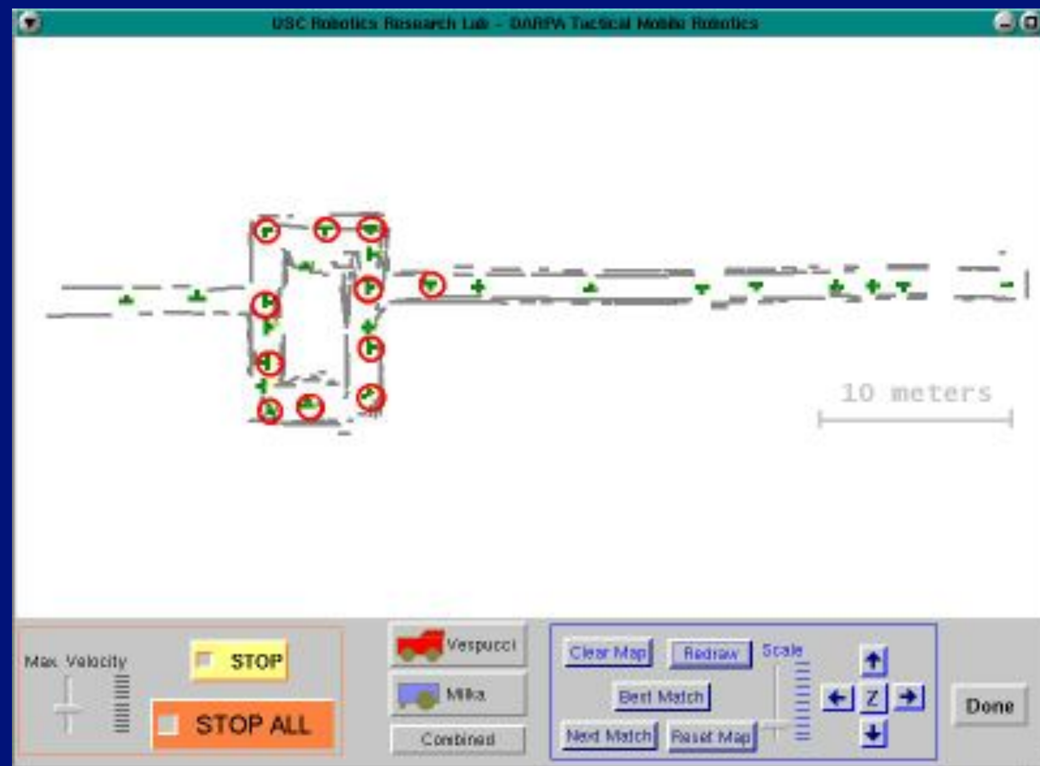
Final Map Matching

- Check for mismatch in absolute heading value
- Compute translation and rotation transformation for each remaining pair of candidate matches
- The transformation that yields the highest number of overlapping landmarks is the best match

Results of Match Algorithm







Map Overlay on Floorplan

Conclusions

- A lightweight, distributed approach to mapping based on topology matching
- Experimental evidence suggests that the approach scales well to many robots
- Does not require co-localized initial conditions or even a shared coordinate system
- Well suited to heterogeneous robot teams

Future Work

- Augment topological nodes with multi-criteria confidence levels
- Simultaneous tracking and mapping
- Improved user-interface for recalling and re-displaying images registered to map

- http://robotics.usc.edu/~embedded

- Tools:
  - ARENA multirobot simulator
    - http://robot.usc.edu/arena
  - Golem robot server
    - http://fnord.usc.edu/golem

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