Search, Navigate, and Actuate

Qualitative Navigation
Navigation

Critical ability for mobility

Challenging, because strong coupling with:

- Sensing, Planning, Acting
- Hardware / Software architectures
- Problem solving, computational efficiency
Mobility

• Where am I going? Mission planning
• What’s the best way there? Path planning
• Where have I been? Map making
• Where am I? Localization

How am I going to get there?

Behaviors
Path Planning

• *What’s the Best Way There?* depends on the representation of the world

• A robot’s world representation and how it is maintained over time is its *spatial memory*

• Two forms
  – *Route* (or qualitative / topology)
  – *Map* (or quantitative / metric)

• Map leads to Route, but not the other way
Route

Less general, but strong coupling with reactive layer

- Attention points
  *What features, landmarks to look for next*

- Distinction criteria
  *What features are good to recognize places:*
  - *Have I ever seen it before?*
  - *What has changed since the last time?*
Landmarks

- A *landmark* is one or more perceptually distinctive features of interest on an object or locale of interest.
- *Natural landmark*: configuration of existing features that wasn’t put in the environment to aid with the robot’s navigation (i.e. MacDonalds on the corner).
- *Artificial landmark*: set of features added to the environment to support navigation (i.e. highway sign).
- Highly useful landmarks are those visible at points where one has to select from multiple directions: *gateways*.
Coupling of landmarks

*floor plan*

Nodes: landmarks, gateways, goals

Edges: navigable path

*relational graph*
early relational graphs

- Not coupled with how the robot would get there
- Navigation path: direction and distance
- Shaft encoder uncertainty accumulates
Two solutions

• Localization relative to the landmarks

• Navigation path specified as sensor based behaviors
Getting to a Distinctive Place: Neighborhoods

Use one behavior until the landmark is seen then swap to a landmark localization behavior
relational graphs with behaviors

Dead end

Follow-hall with Look-for-T

T-junction

Follow-hall with Look-for-door

Front door

Follow-hall with Look-for-T

Follow-hall with Look-for-Dead-End

Follow-hall with Look-for-T

Follow-hall with Look-for-door with Look-for-blue

Blue door
Discussion

• Advantages
  – Eliminates concern over navigational errors at each node
  – Robot can build up metric information over multiple trips, since error will average out

• Disadvantages
  – Features that are easy to recognize, are often too numerous to be unique
  – Indoors it is nearly impossible to find distinctive places
Class Exercise

- Create a relational graph for this floor
- Label each edge with the appropriate Local Control Strategy
- Label each node with the type of gateway: dead-end, junction, room
- Identify unique features of each node
Alternative for relational graphs

- **Associative method**
  - spatial memory is a series of remembered viewpoints, where each viewpoint is labeled with a location
  - good for retracing known paths
Associative Methods

• Create a behavior that converts sensor observations into direction to go to reach a particular landmark

• Assumption: location or landmark are:
  – Perceptual stable: views from nearby locations look similar
  – Perceptual distinguishable: views far away should look different
Visual Homing

- Partition image into coarse subsections (e.g., 16)
- Each section measured based on some attribute – e.g., edge density, dominant edge orientation, average intensity, etc.
- Resulting measurements yield image signature
- Image signature forms a pattern
- If robot nearby, should be able to determine direction of motion to localize itself relative to the location
- Visual homing: the use of image signatures to direct robot to specific location
Image Signatures

The world

Tessellated (like faceted-eyes)

Resulting signature
Direction of movement
QualNav

- Basic idea: localize robot relative to particular orientation region
- Orientation region:
  - multiple landmarks visible
  - Defined by landmark pair boundaries
  - Within an orientation region, all landmarks appear in same relationship
- Vehicle localizes with view-angles, distances not used
Example of orientation region

Topological representation as orientation regions:

Metric Map:
Entering new orientation region
Discussion

• **Advantages:**
  – Tight coupling of sensing to homing
  – Robot doesn’t need to explicitly recognize what a landmark is
  – Enables robots to build up maps as it explores

• **Disadvantages:**
  – require massive storage
  – Require landmarks that are widely visible
Conclusions

- Landmarks simplify the “where am I?” problem by providing orientation cues
- Gateways: special cases of landmarks that allow robot to change directions
- Distinctive places can be related to each other by local control strategies for traveling between them
- Image signatures can be used to directly couple perception with acting
Orientation Regions
Orientation Regions
Homework

• Read the following paper:

• In this paper five examples of bioinspired robotic navigation are given. Invent another example.

• Your personal answer (one paragraph, ~250 words)
Tuesday June 7, Blackboard