

Search, Navigate, and Actuate

Qualitative Navigation



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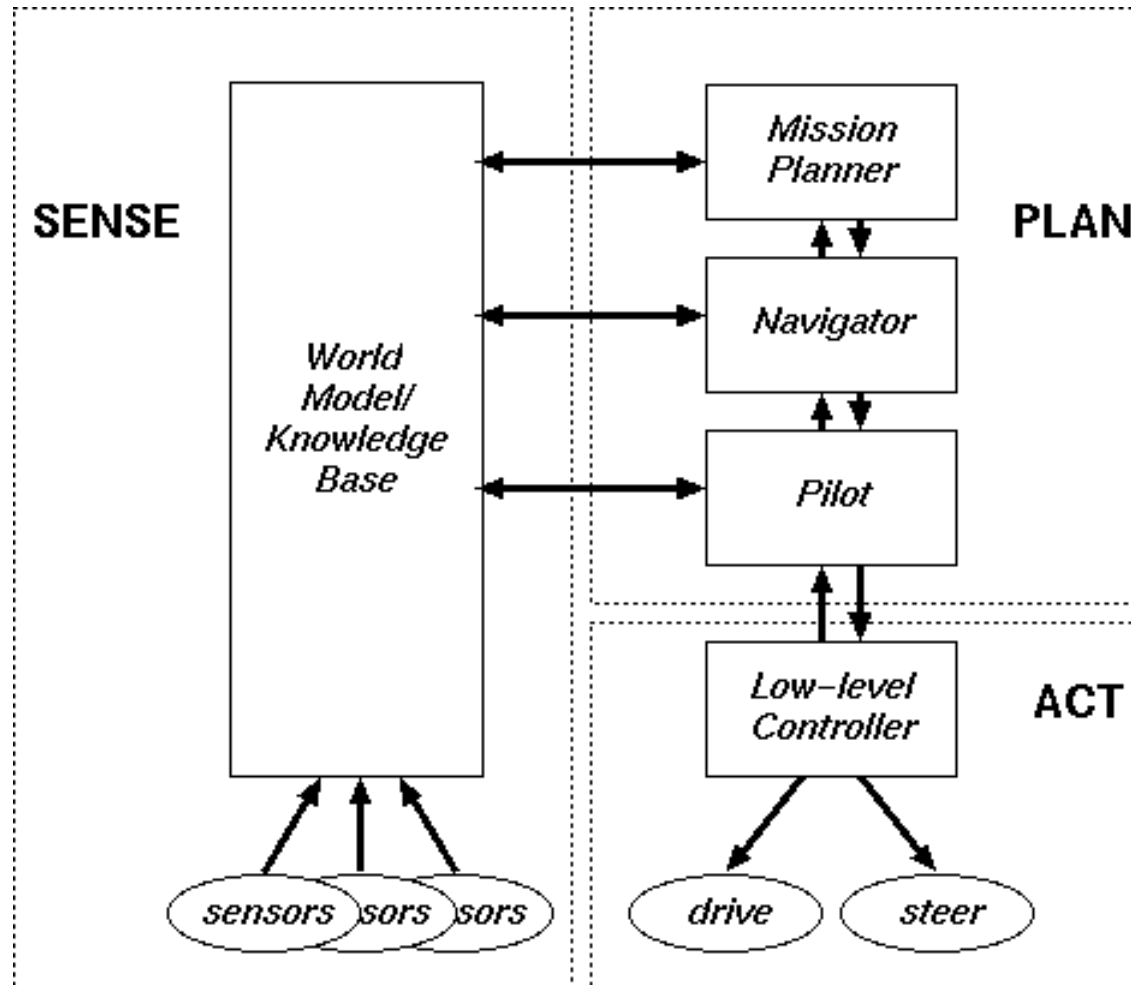
Navigation

Critical ability for mobility

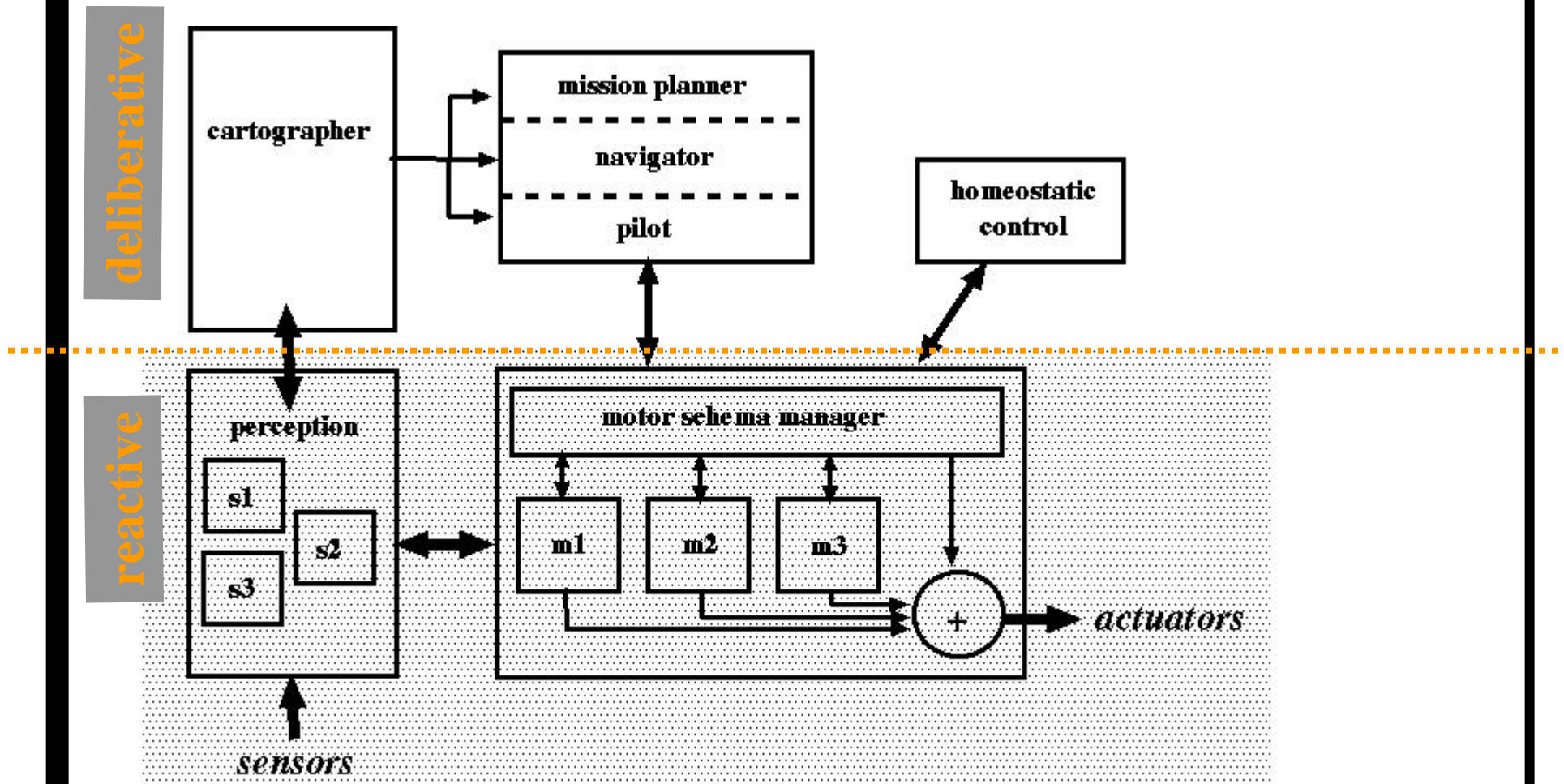
Challenging, because strong coupling with:

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

Hierarchical Paradigm



Hybrid Paradigm

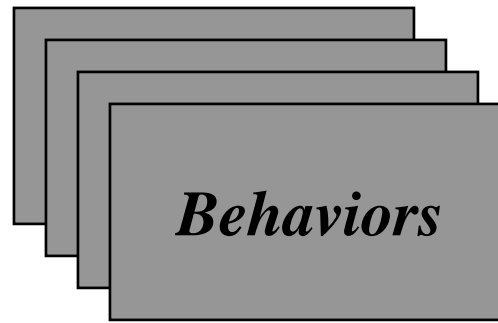


Mobility

- Where am I going? *Mission planning*
- What's the best way there? *Path planning*
- Where have I been? *Map making*
- Where am I? *Localization*

deliberative

How am I going to get there?



reactive

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:

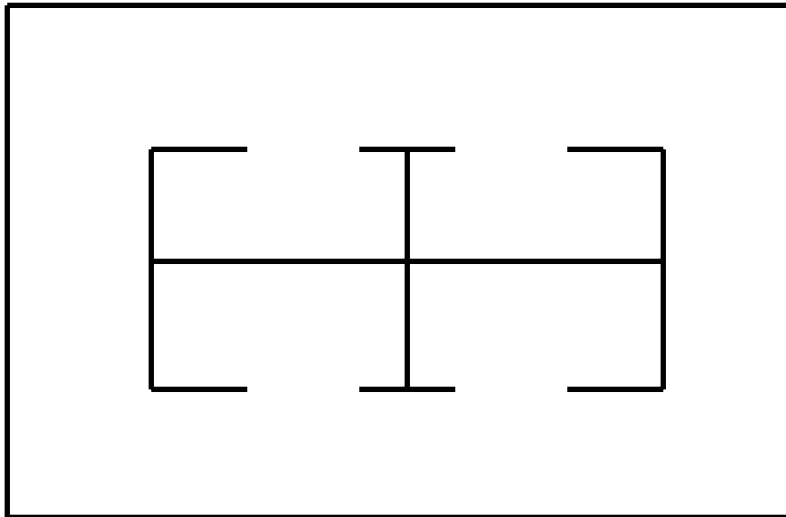
- *Have I ever seen it before?*
- *What has changed since the last time?*

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 which way to go: *gateways*

Coupling of landmarks

floor plan

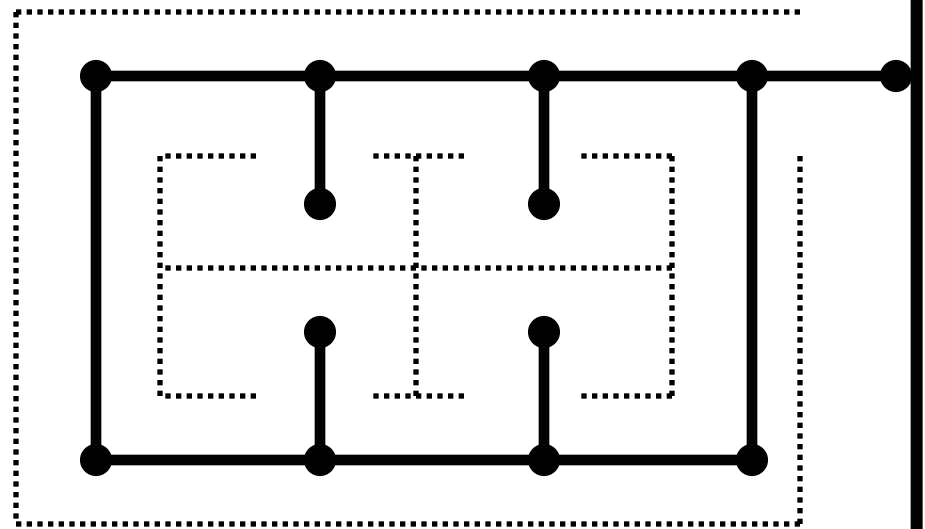


Nodes:
landmarks, gateways,
goals

Edges: navigable path

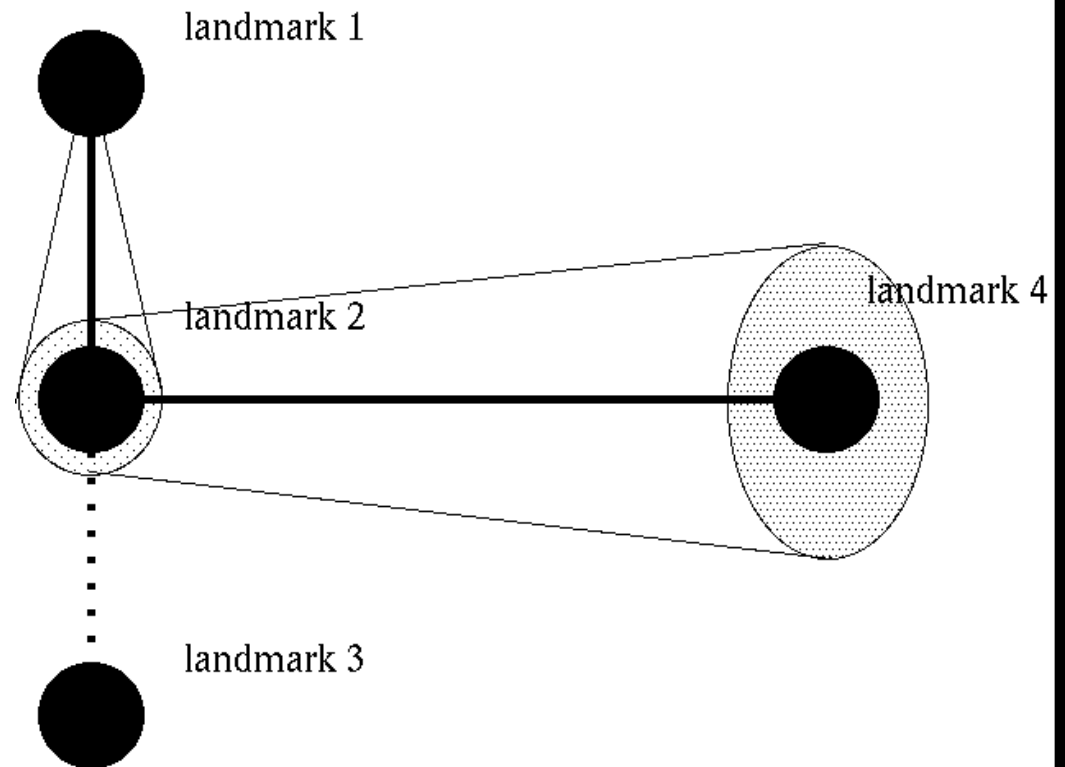


relational graph



early relational graphs

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



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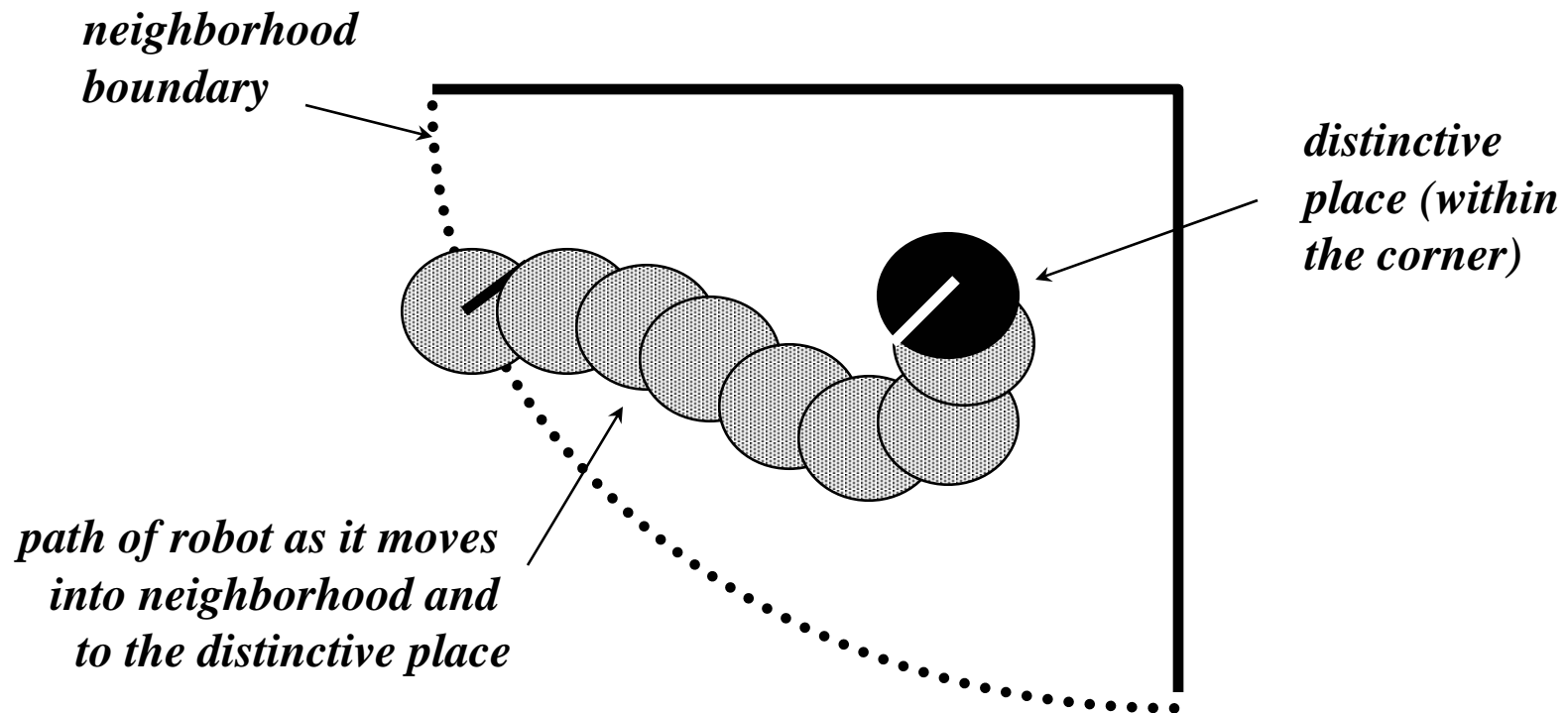
Two solutions

- Localization relative to the landmarks



- Navigation path specified as sensor based behaviors

Getting to a Distinctive Place: *Neighborhoods*

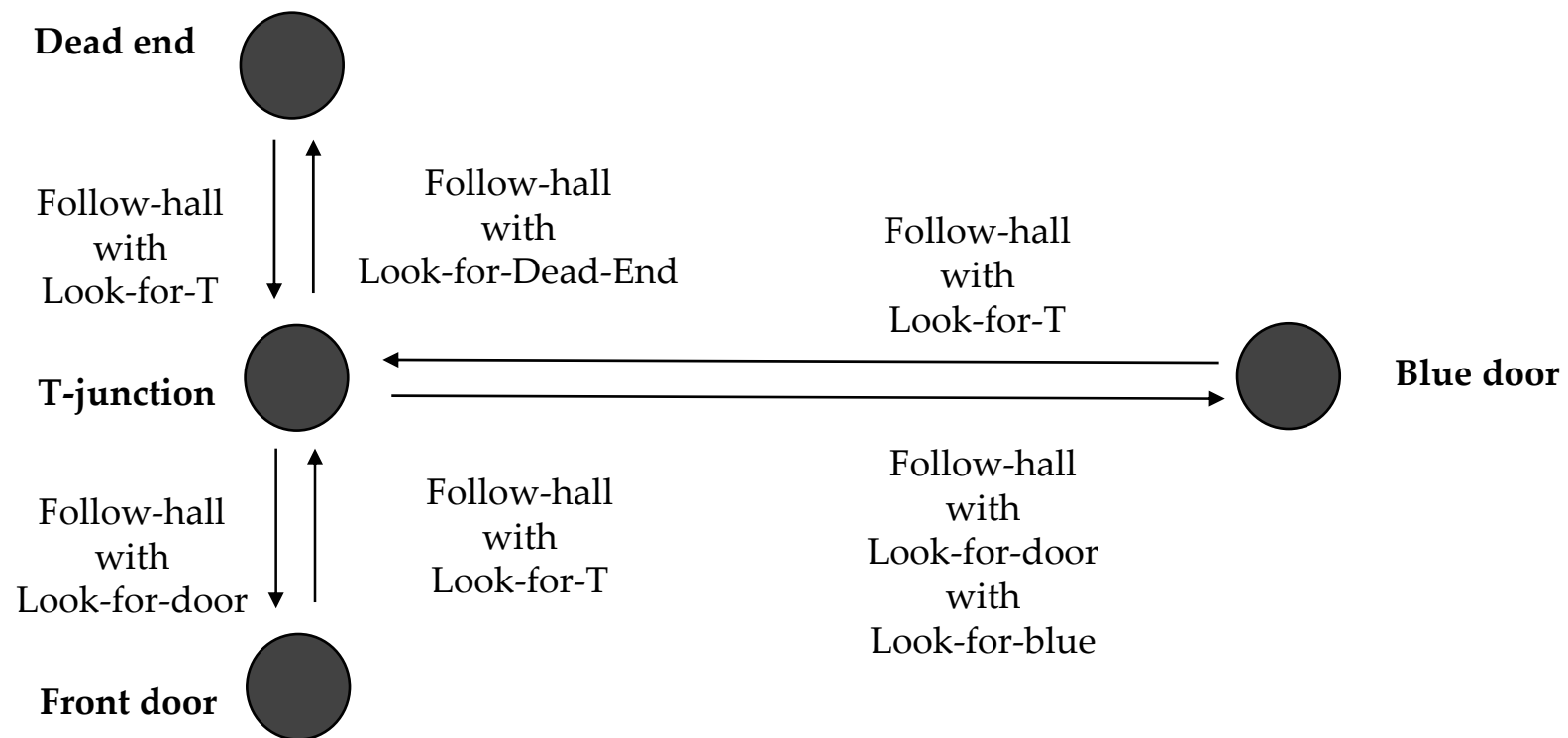


***Use one behavior until the landmark is seen
then swap to a landmark localization behavior***



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relational graphs with behaviors



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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



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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



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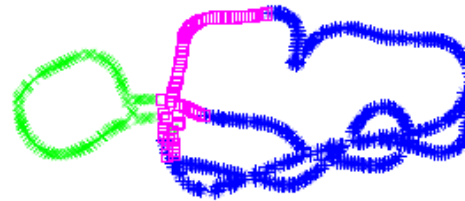
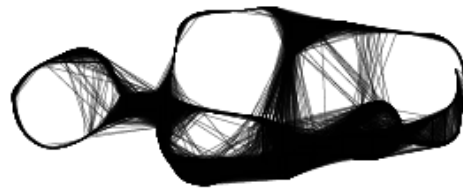
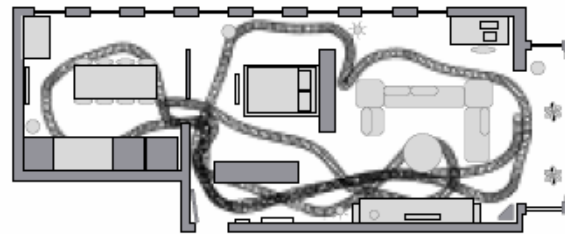
Associative Methods

- 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



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Cogniron project



- Pair-wise similarities between the images are computed using local features extracted from the images and geometric constraints

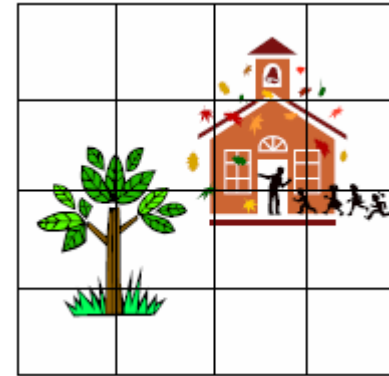
Visual Homing

- 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

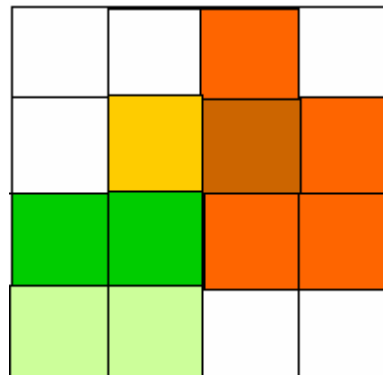
Image Signatures



The world



Tessellated (like faceted-eyes)

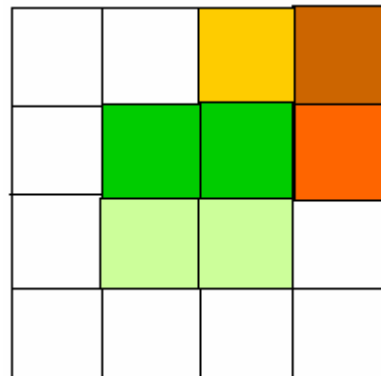


Resulting signature



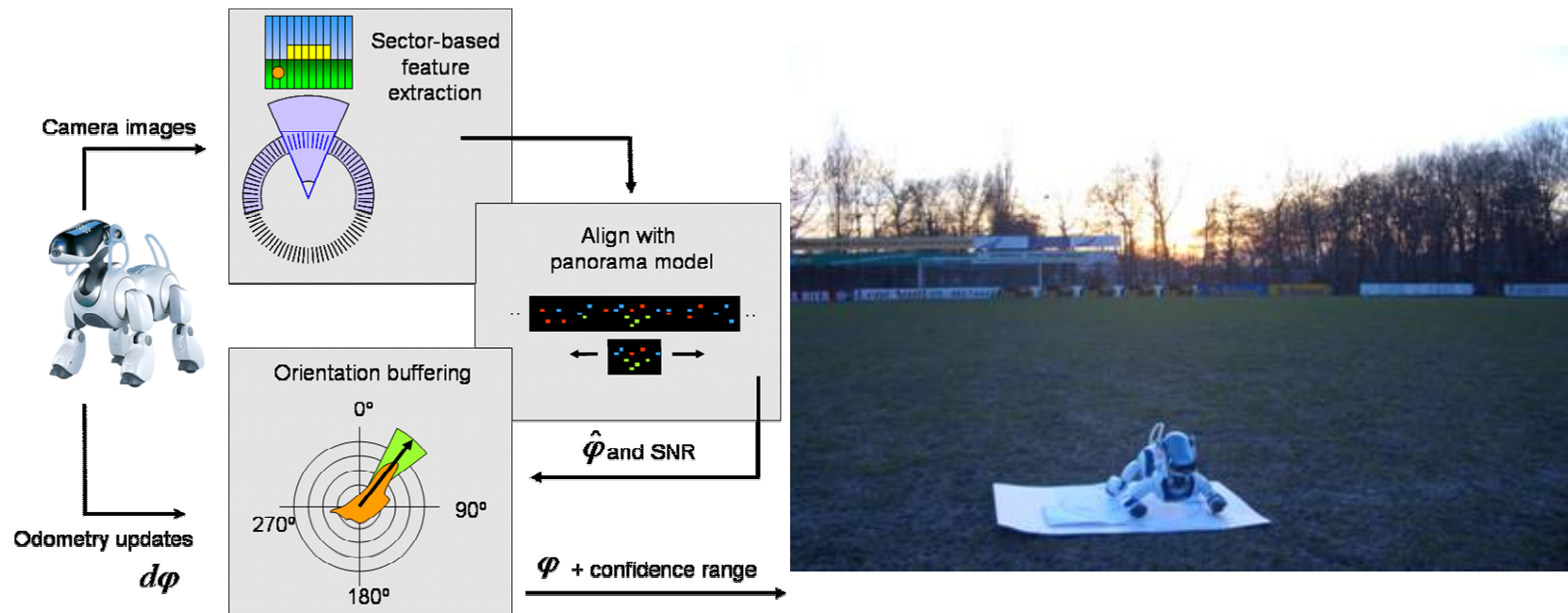
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Direction of movement



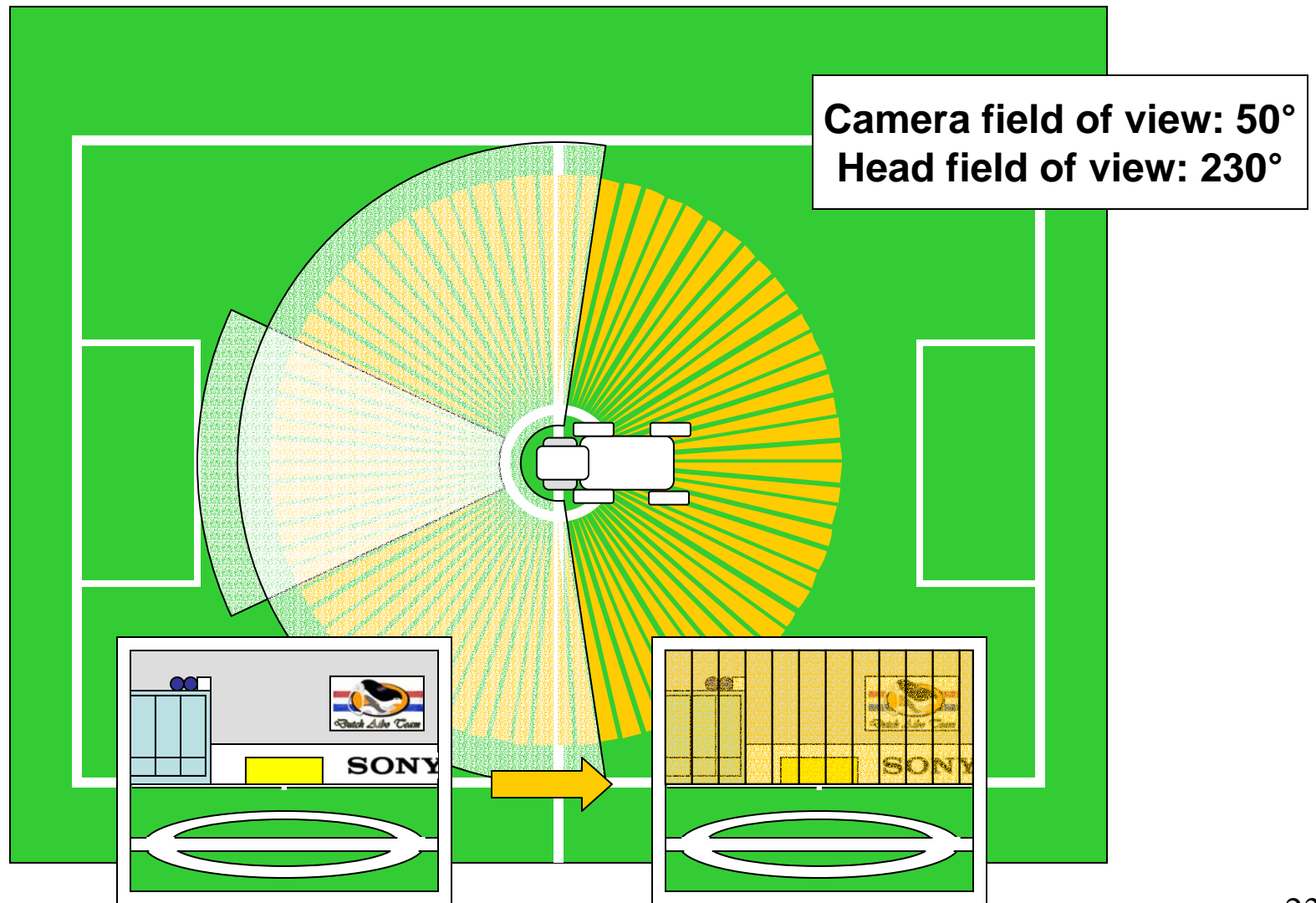
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Visual Compass



- Segmentation of surroundings in 80 sectors

Sector-based feature extraction



Demo Video

Visual Homing

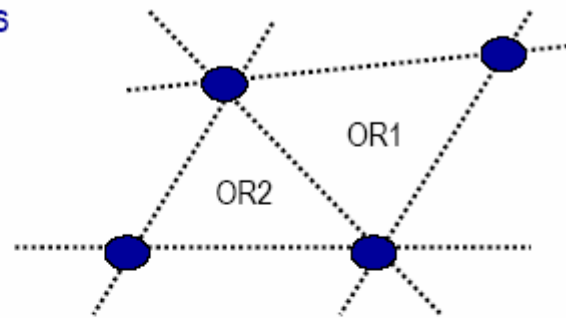


QualNav

- 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:

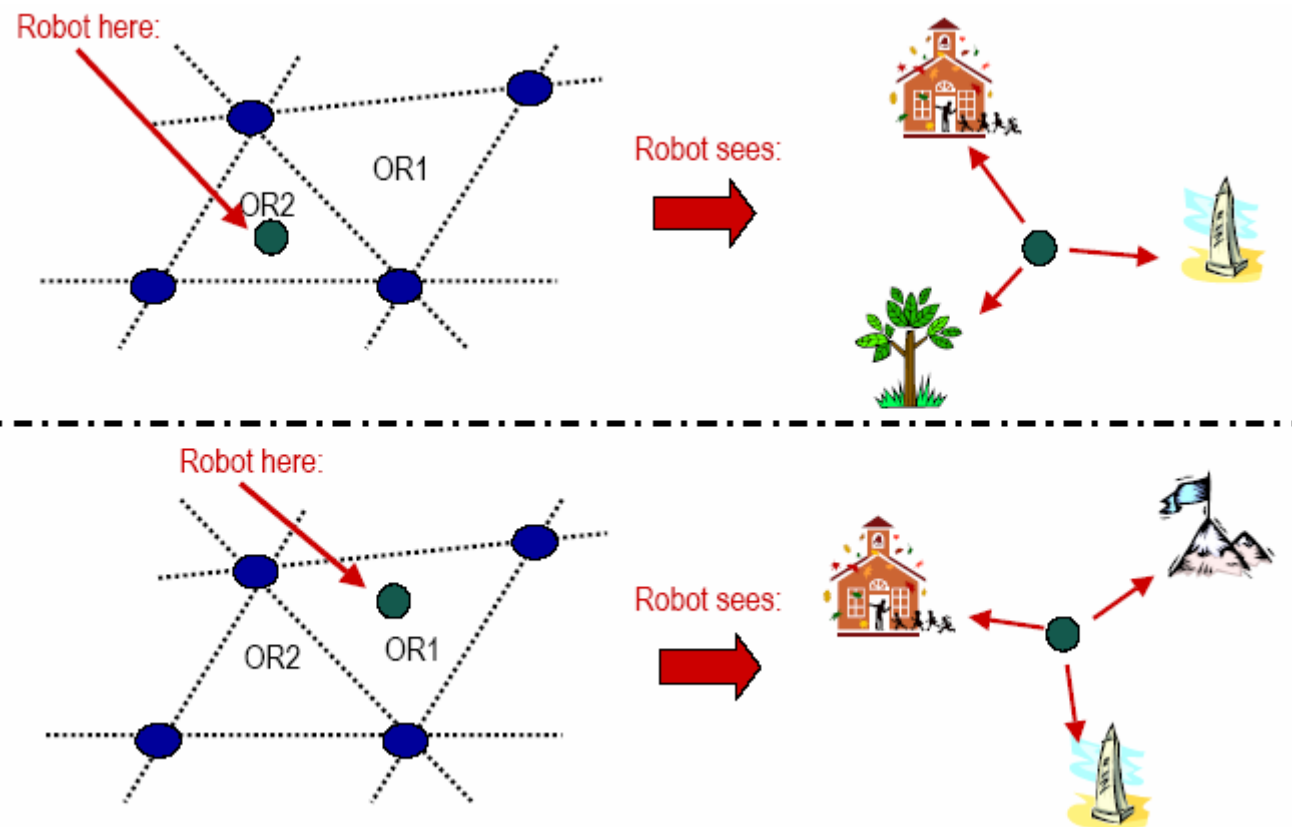


Metric Map:



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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

Route versus Map

How do humans find their ways?

→ Psychological data and theories

- Human Landmarks != robotic distinctive places
- Siegel & White's hypothesis:
landmarks → routes → map
- Recently:
landmarks & implicit map → routes



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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