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

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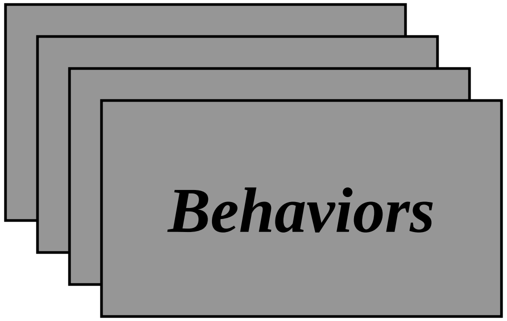
Mobility

- 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

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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

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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?*

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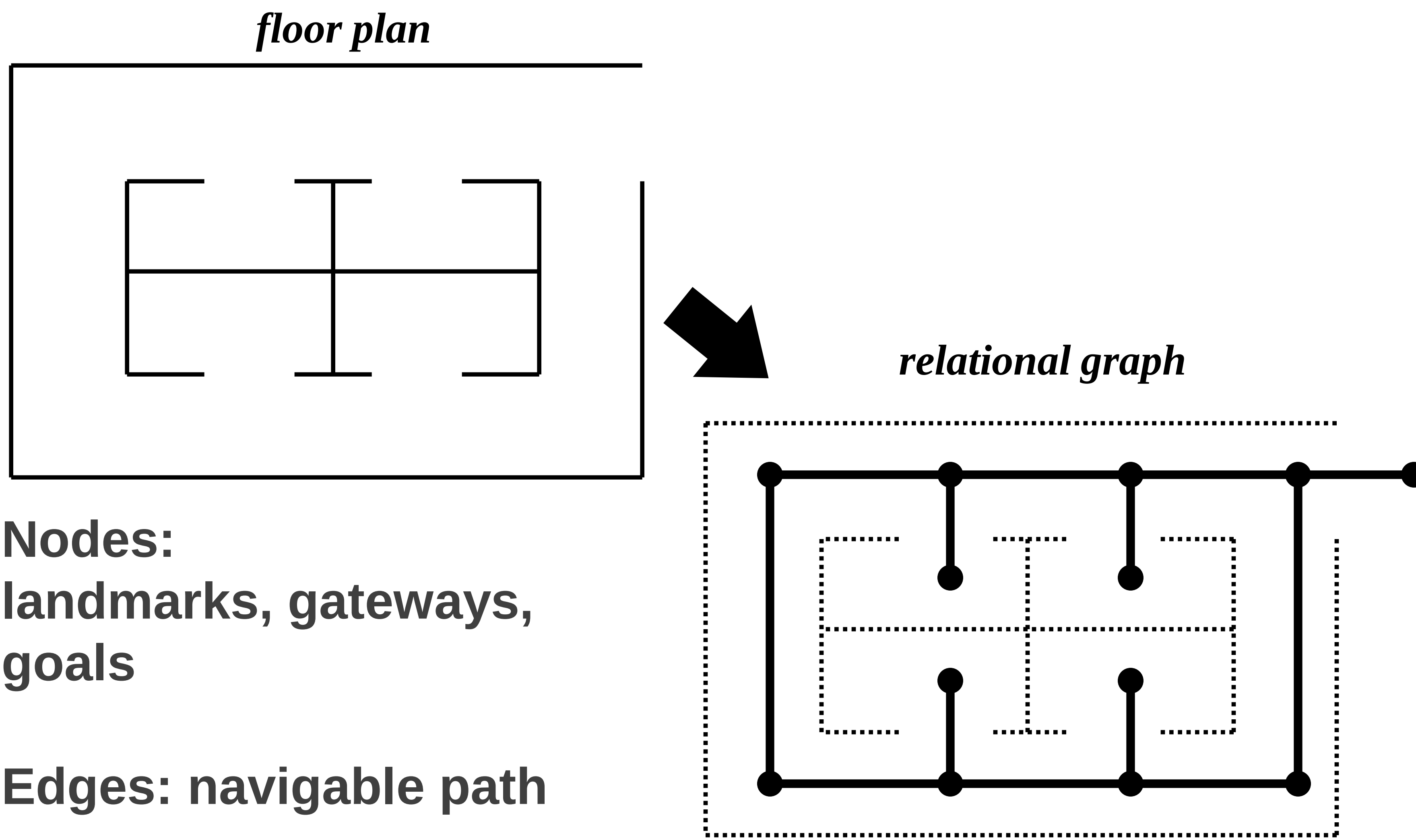
Landmarks

- 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

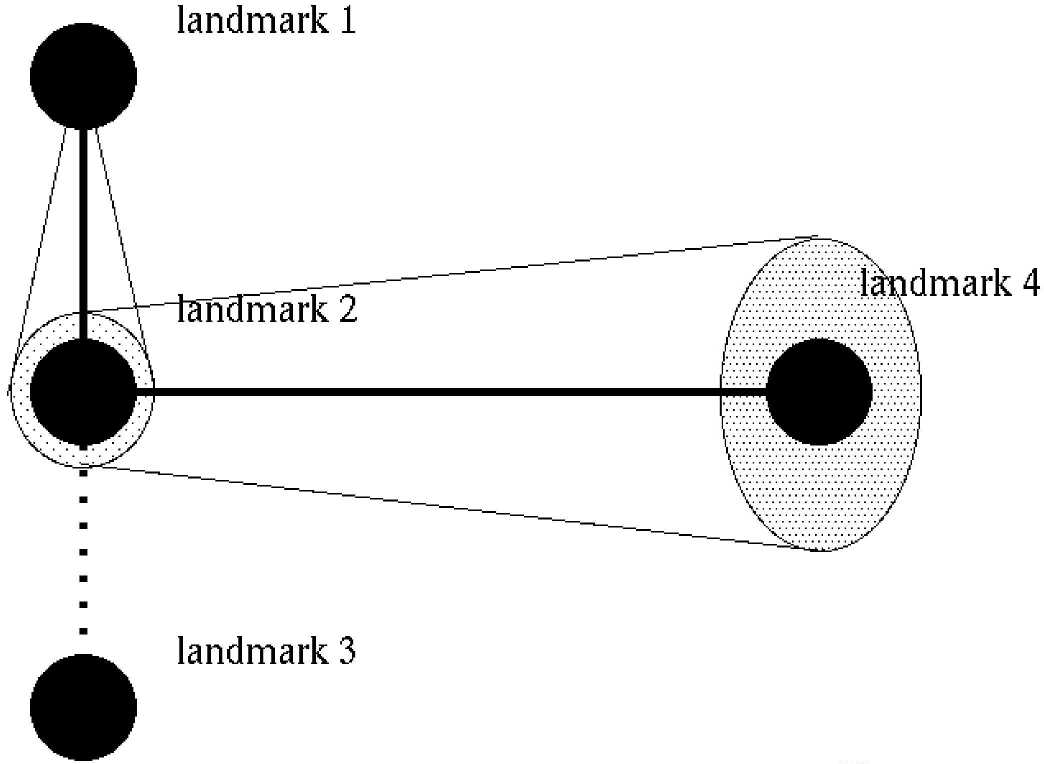


Nodes:
landmarks, gateways, goals

Edges: navigable path

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

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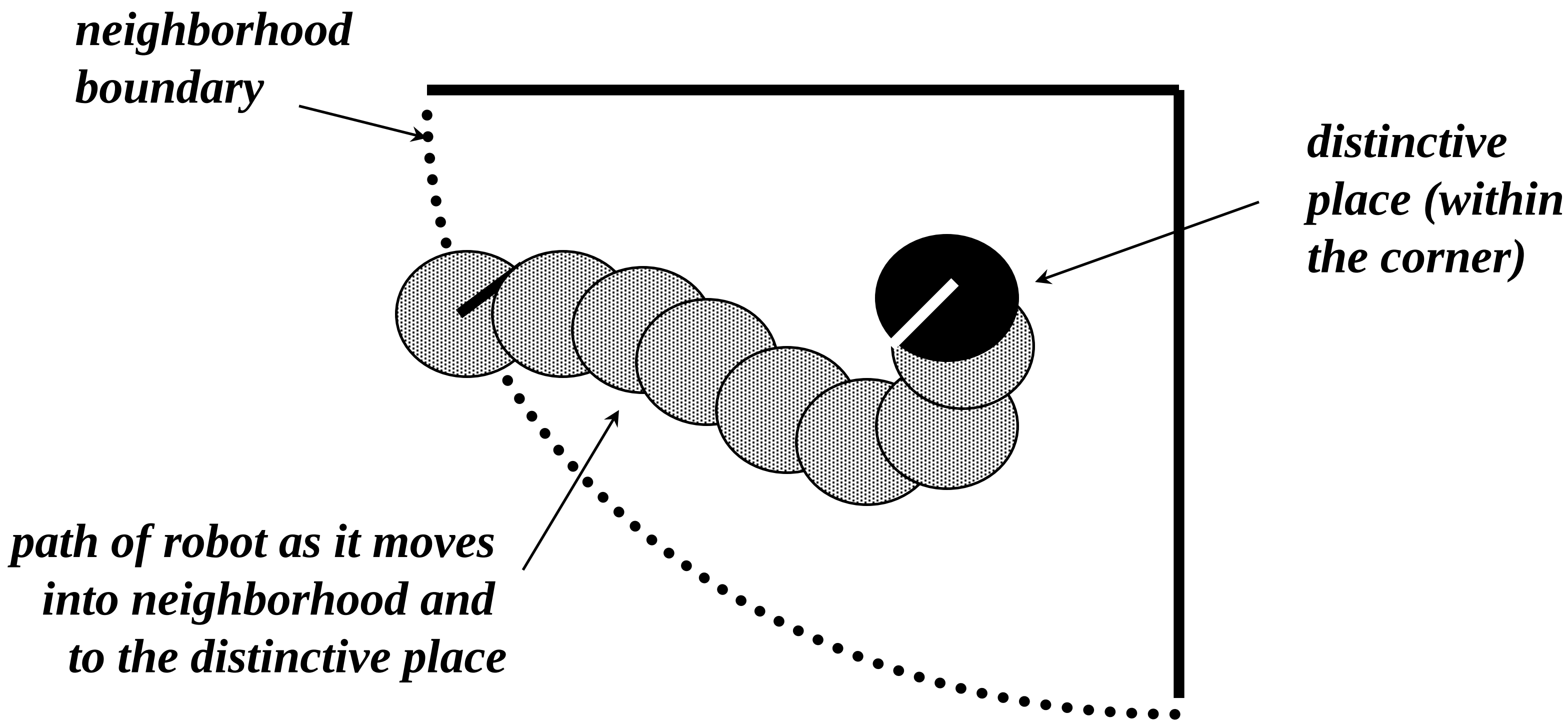
Getting to a Distinctive Place: *Neighborhoods*



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

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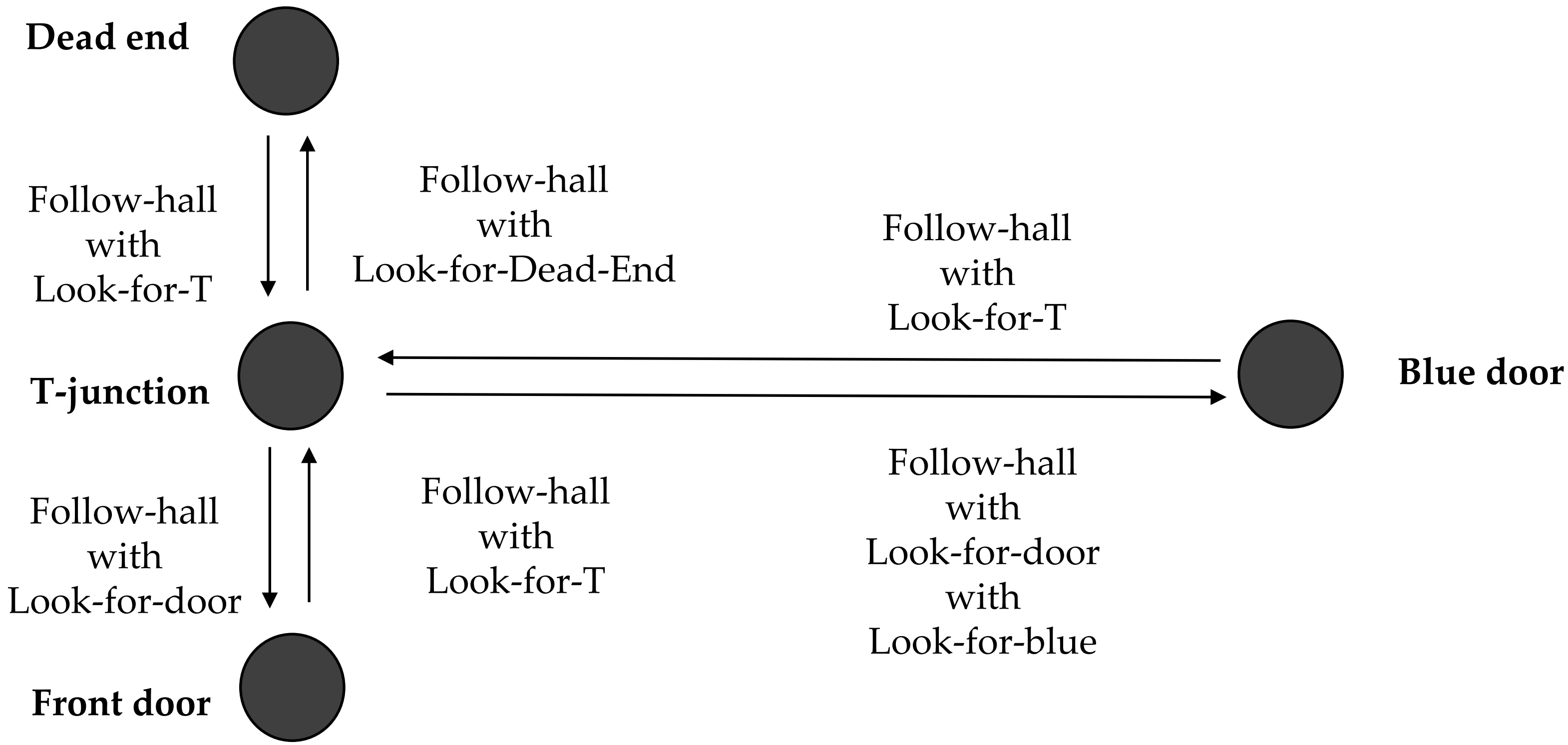
relational graphs with behaviors



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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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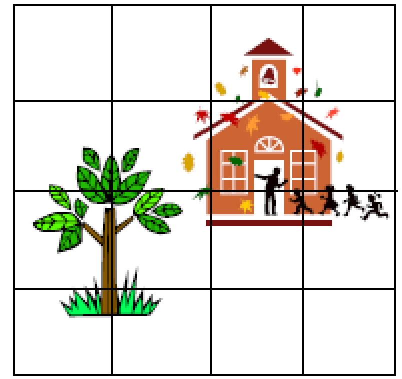
Visual Homing

- 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

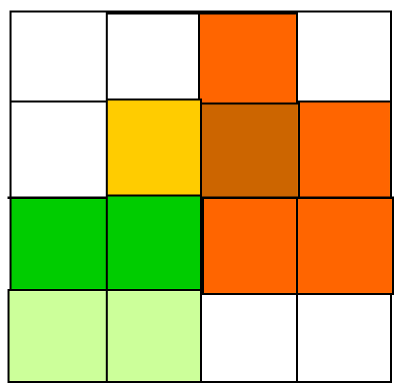
Image Signatures

The world



Tessellated (like faceted-eyes)

Resulting signature



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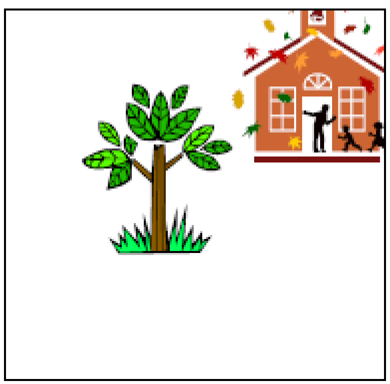
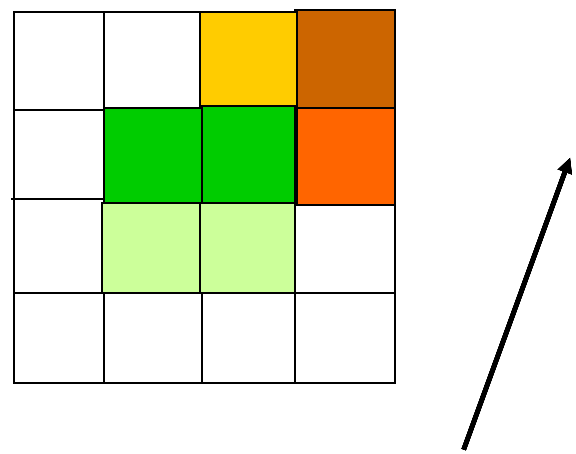
Direction of movement





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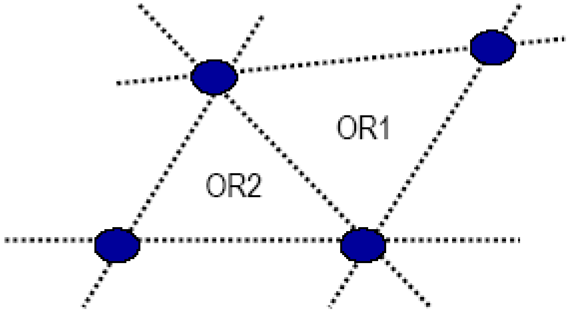
QualNav

- 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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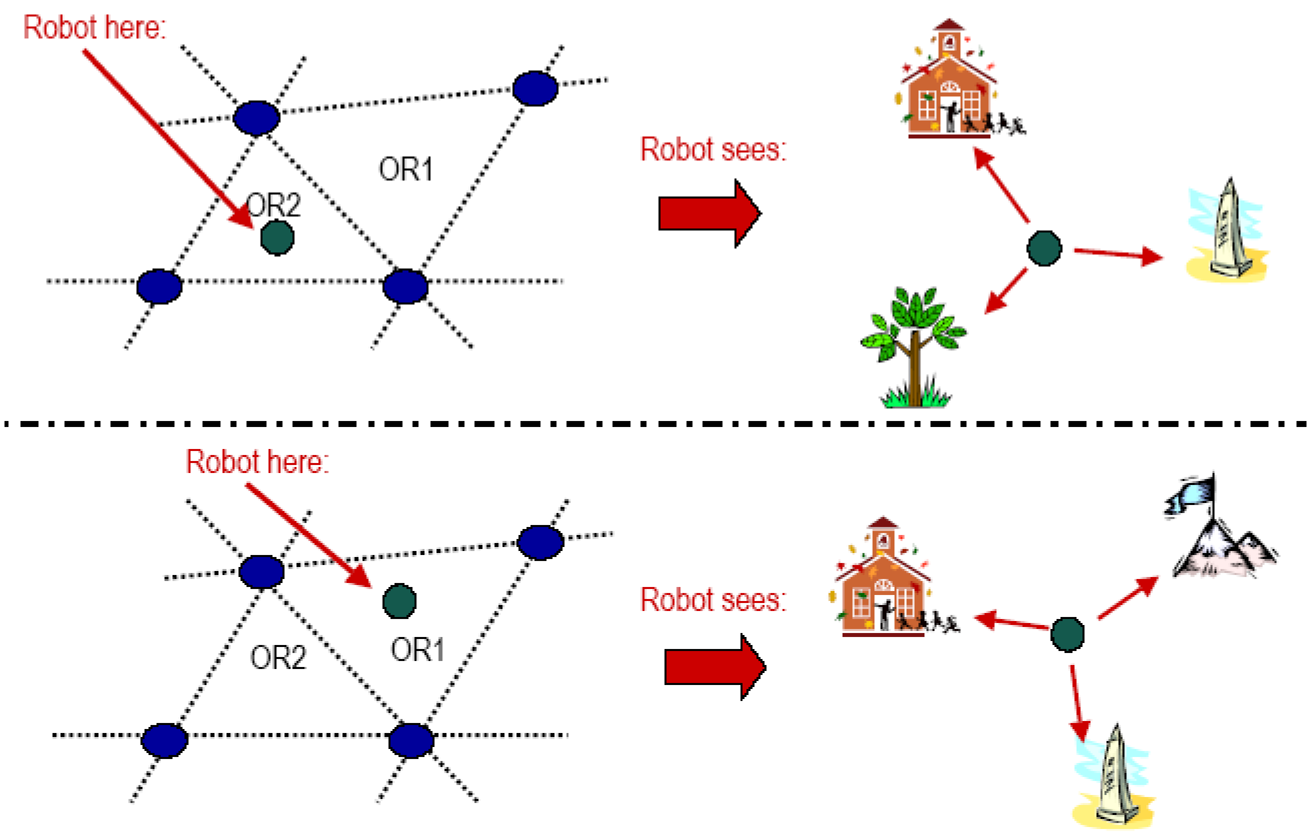
Entering new orientation region



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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

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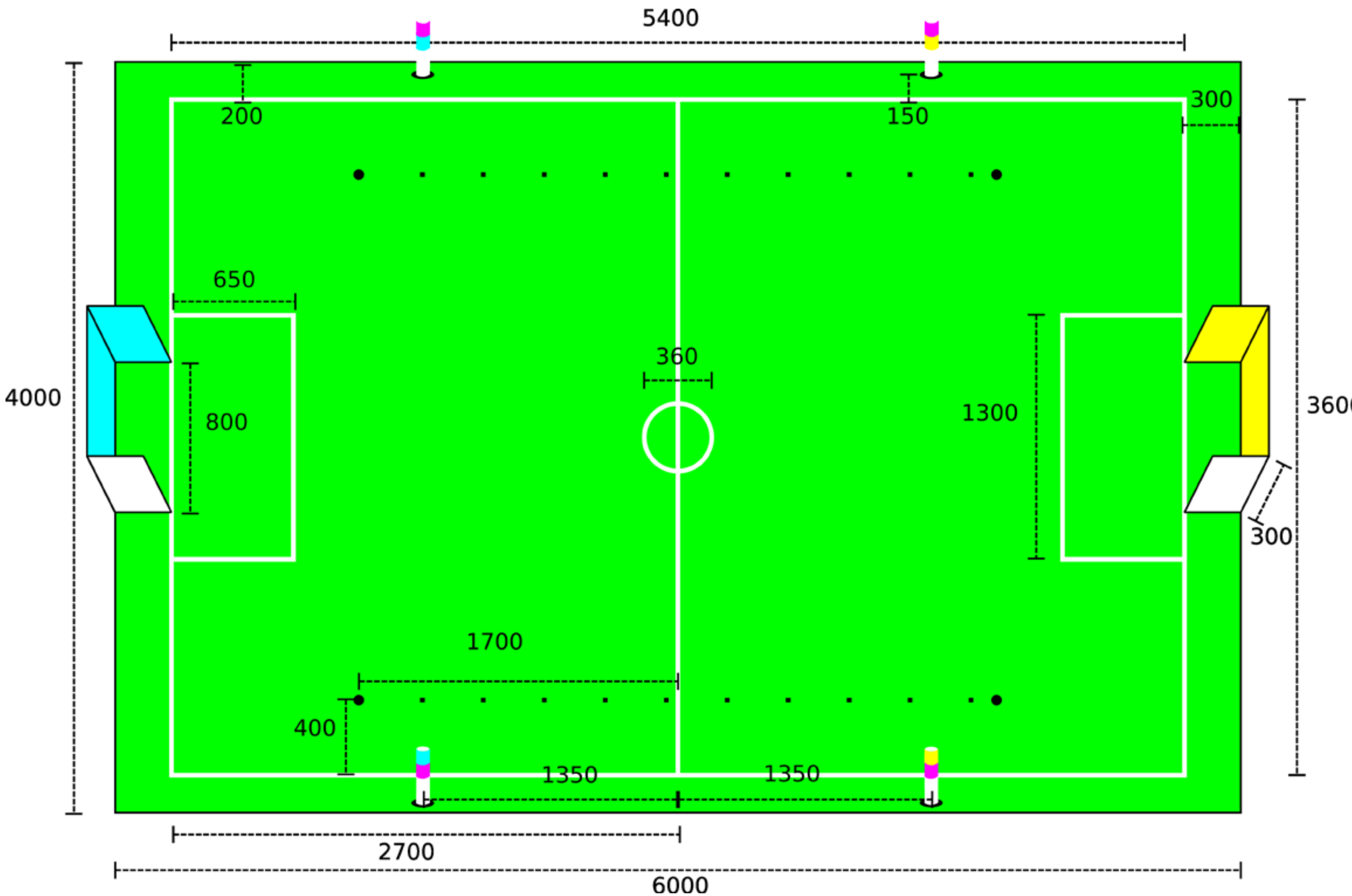
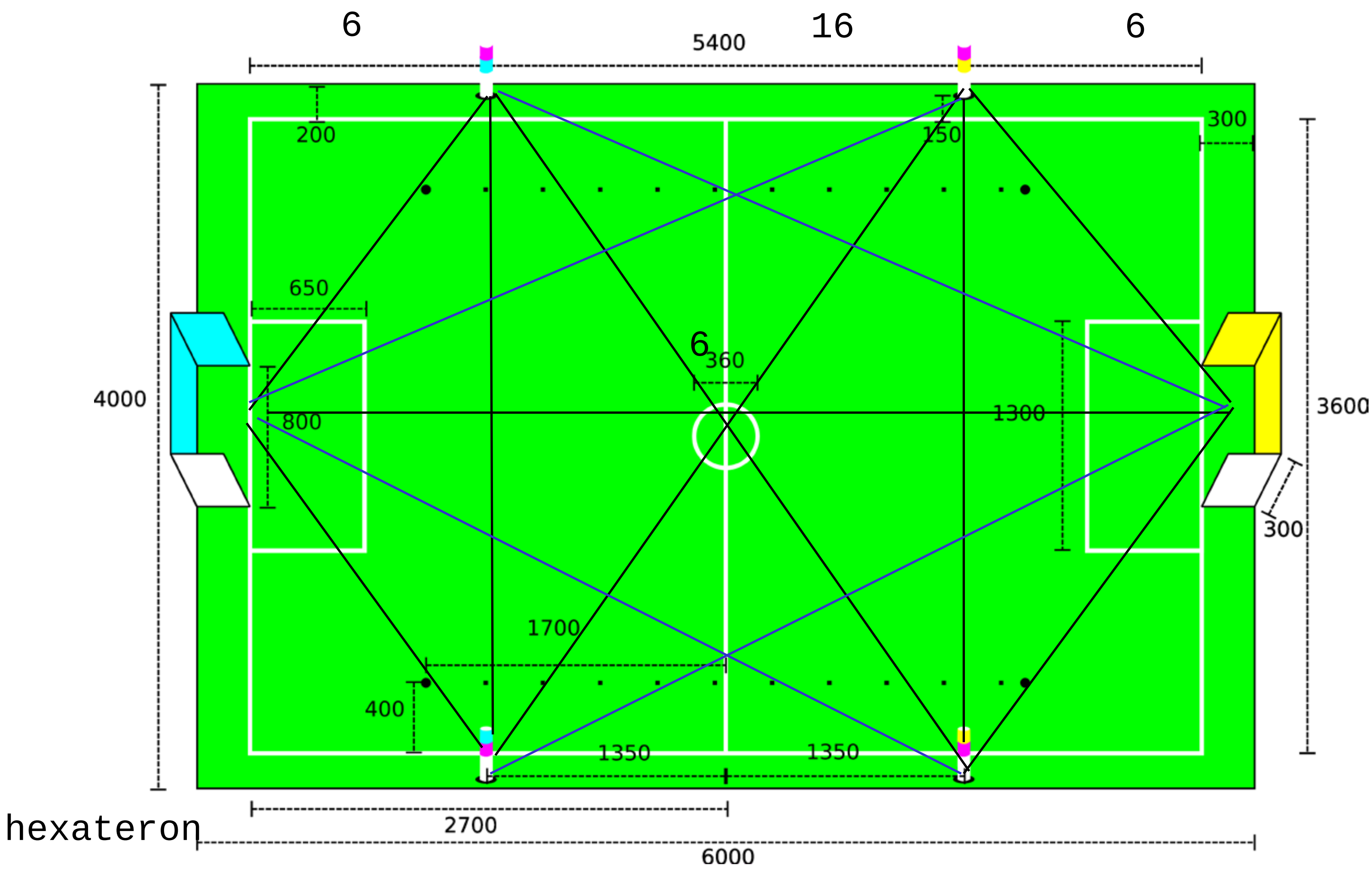
Conclusions

- 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

Orientation Regions



Orientation Regions



Homework

- Read the following paper:
  Mandyam V Srinivasan, Visual control of navigation in insects and its relevance for robotics, Current Opinion in Neurobiology, Volume 21, Issue 4, August 2011, Pages 535-543.
  http://www.sciencedirect.com/science/article/pii/S0959438811000882
- 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

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