E11 - Autonomous Vehicles

Lecture 16 – Robot Navigation

Approaches to Control

- Planning Based Control
  - Traditional methods born out of AI (1960’s +)
- Reactive (i.e. Behavior) Based Control
  - More recent (mid to late 1980’s)
- Mixture of Planning and Reactive
  - Today

Planning Based Control

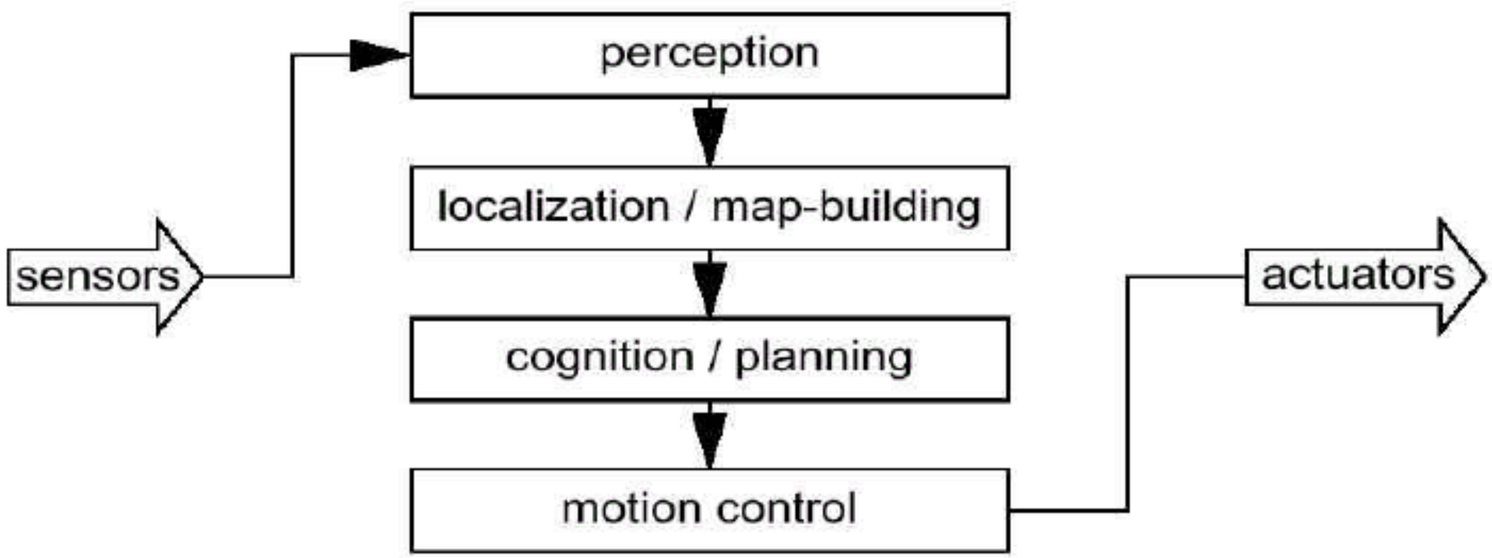
- Through **perception**, a model of the “real” world is captured in memory.
- A goal is given and a **plan** is generated, assuming the “real” world is not changing.
- Then, the plan is **executed**, one (abstract) operation at a time.

Planning Based Control

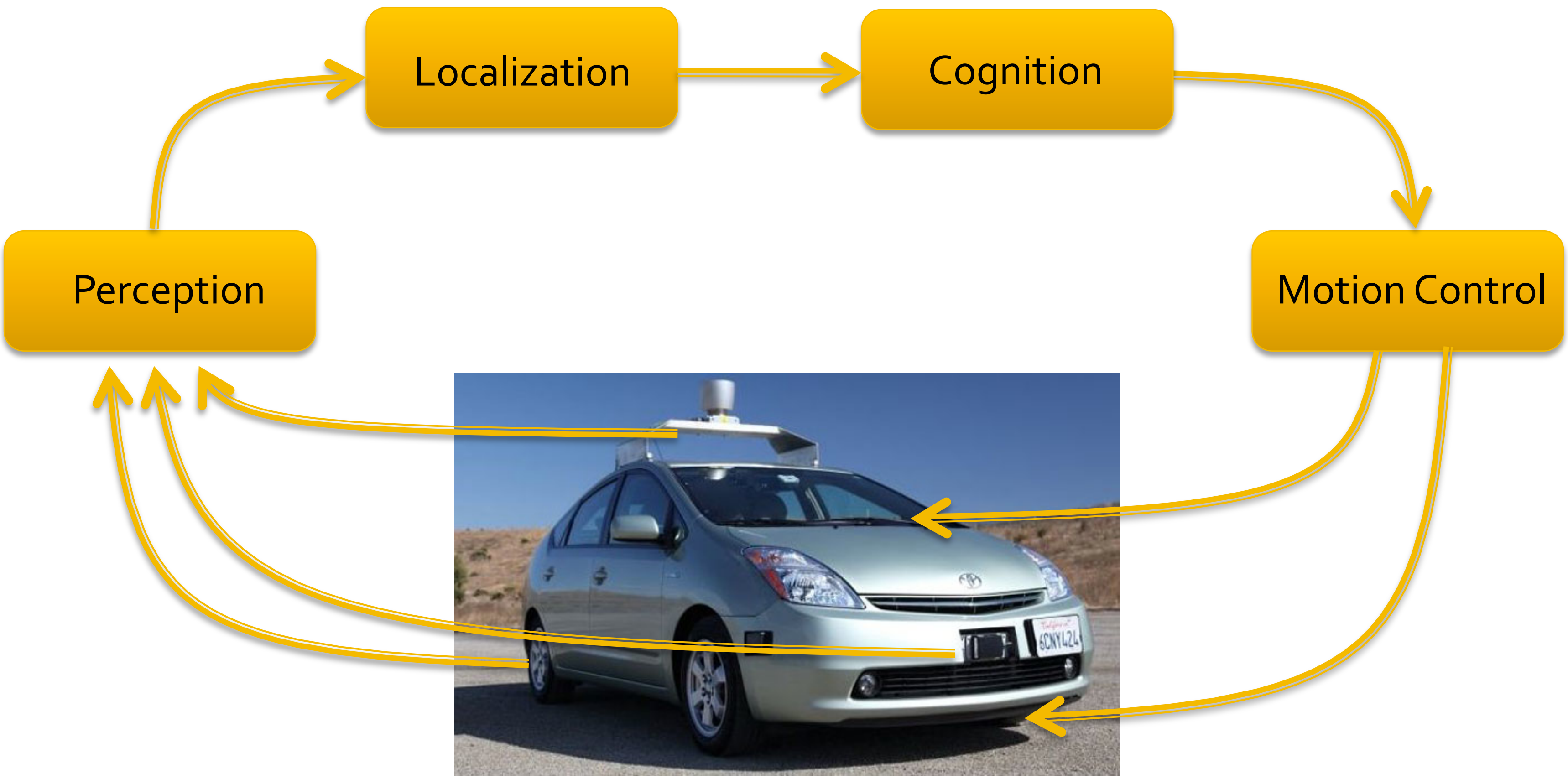
- Questions:
  - What is “interesting” in the “real” world to be captured?
  - At what level of details should we represent the “real” world?
  - What if during plan execution, the “real” world changes? e.g., drop part A.

Planning Based Control

- Planning-based navigation architecture



Planning Based Control



Planning Based Control

- Perception, modeling and planning are *computationally intensive*.
- Our model of the “real” world must be at all times *accurate* (consistent and reliable).
- Sudden changes in the world may not be reflected *instantly* in our model.
- This approach works well in a *predictable* world.

Robot Navigation

Behavior-Based Control

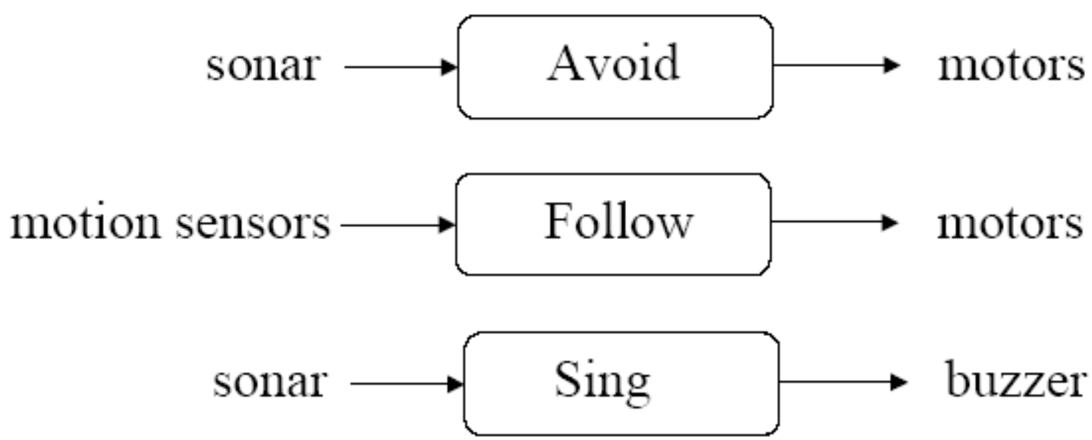
- Actions are connected to precepts via **behaviors**.
- **No internal model**: The real world is our model.
- A robot **reacts** to changes and exhibits complex behaviors due to both internal and external interactions.

Behavior-Based Control

- A robot is equipped with many **simple** behaviors.
- Each behavior defines its **own** sensor data and actions.
- Interactions among the behaviors are resolved by **coordination**.
- These behaviors are **concurrent** and **independent**; they **react** to changes instantly.

Behavior-Based Control

- Example: A simple roaming mobile robot is equipped with the following behaviors:

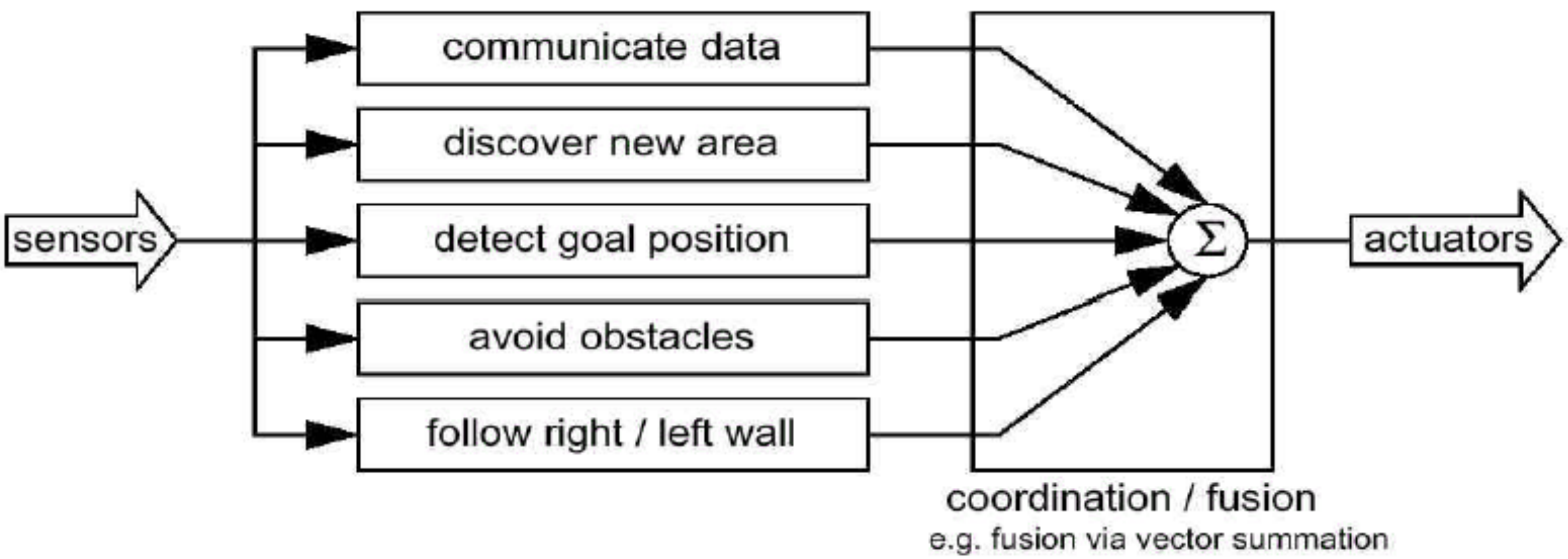


Behavior-Based Control

- Different behaviors may **share** same sensors and/or actuators.
- **Competitive** or **cooperative** actions are handled by careful coordination.
- Behaviors may be added or deleted **incrementally**.

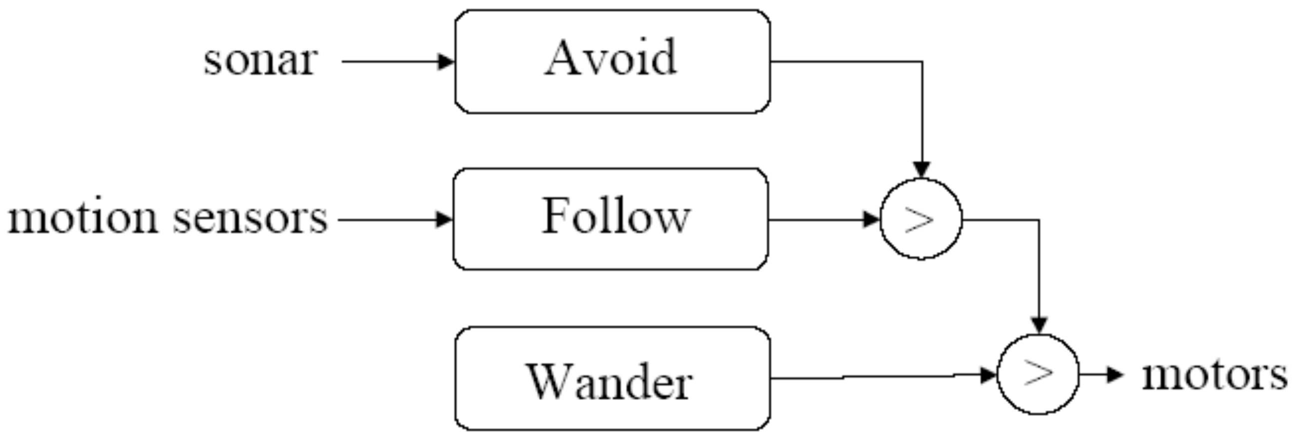
Behavior-Based Control

- Subsumption Architecture

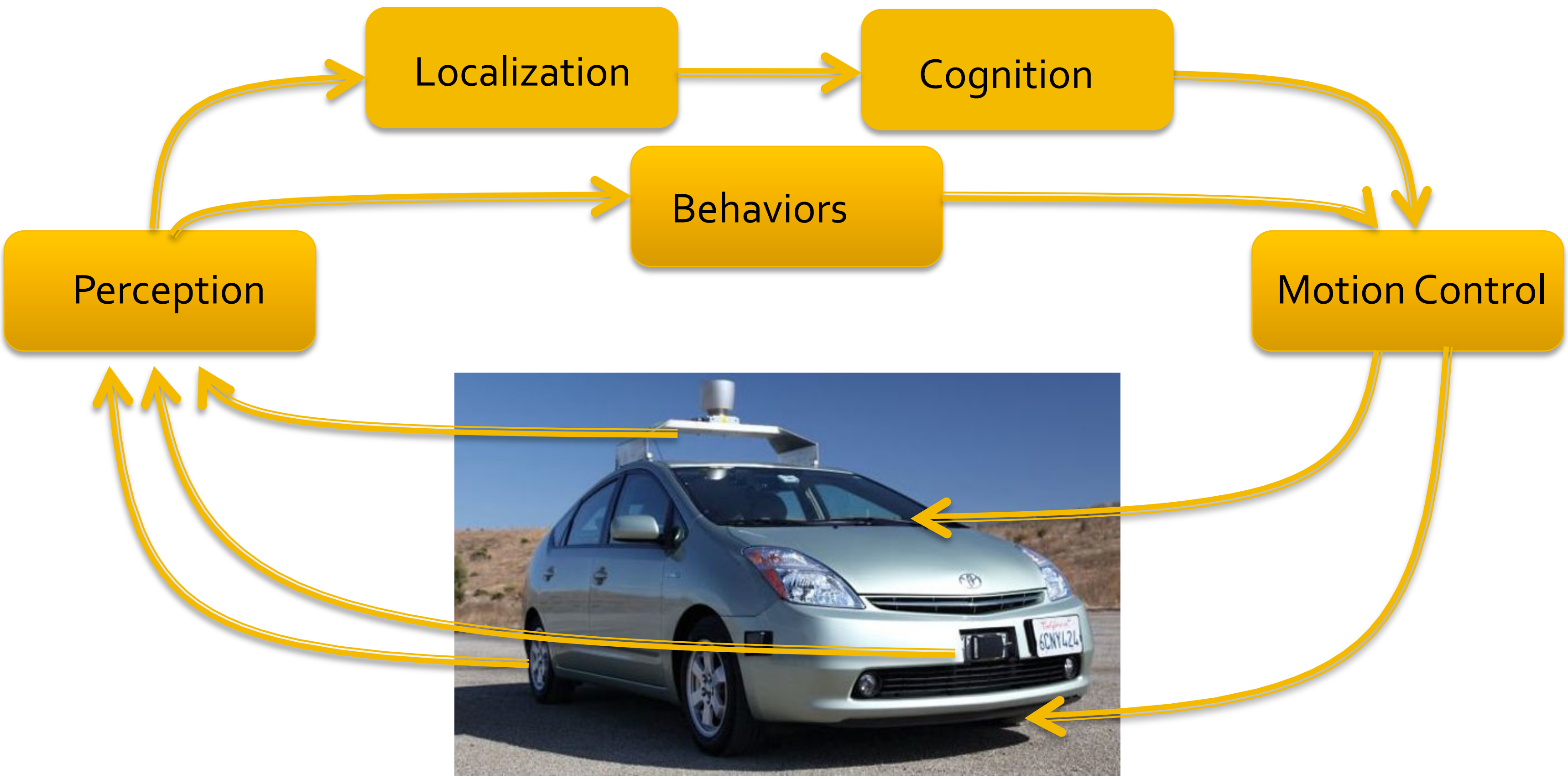


Behavior-Based Control

- Subsumption Architecture
  - Behavioral coordination can be based on a **fixed** priority of suppression.



Robot Navigation

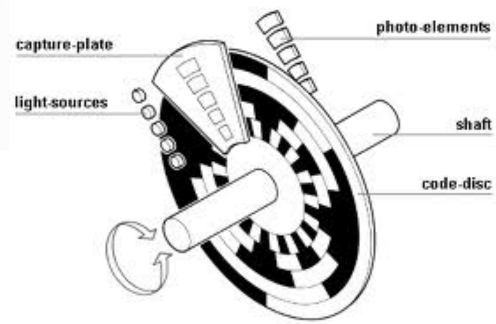


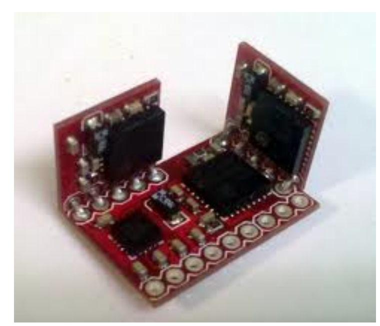
Robot Navigation

- Perception
- Localization
- Cognition
- Motion Control

Perception

- Proprioceptive
  - Compass
  - Encoders
  - Accelerometers
  - IMU – Inertial Measurement Unit





Images from elechouse.com, hightechsa.blogspot.com inmotion.pt, xkyle.com.

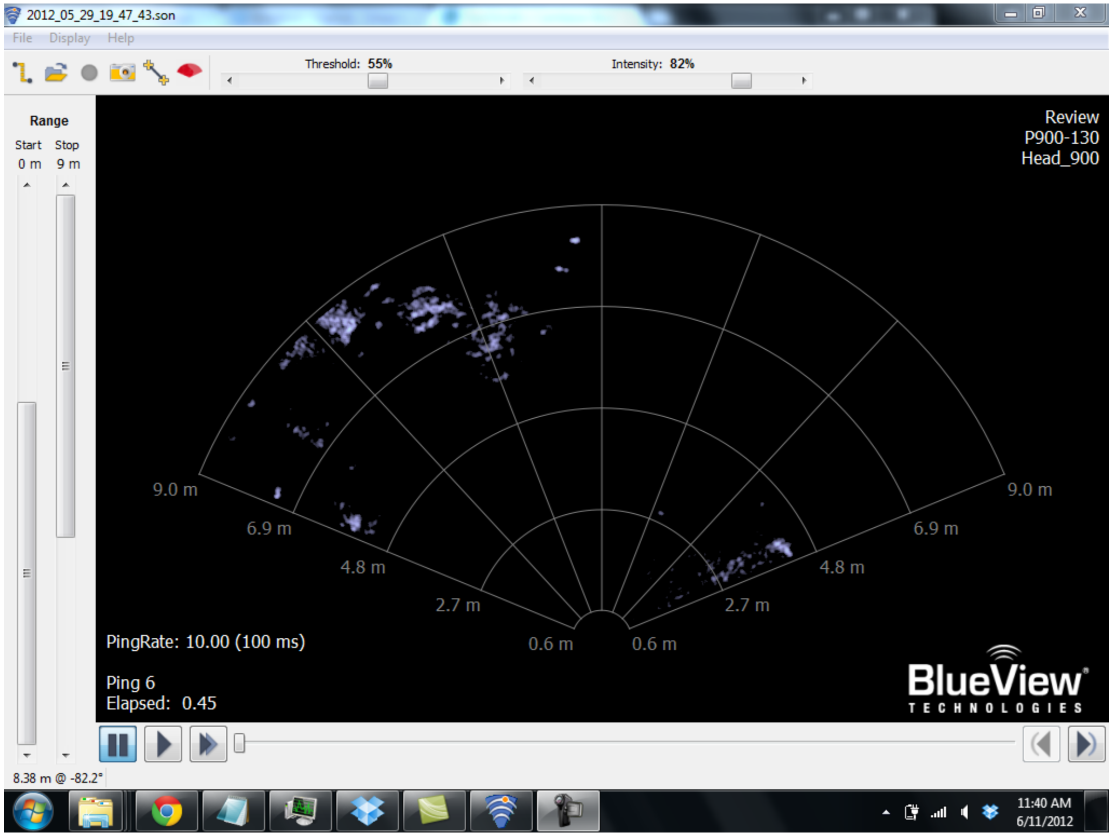
Perception

- Exteroceptive
  - Range Sensors
  - Vision Systems

Images from nauticexpo.com, acroname.com, robots.com, www8.garmin.com, .

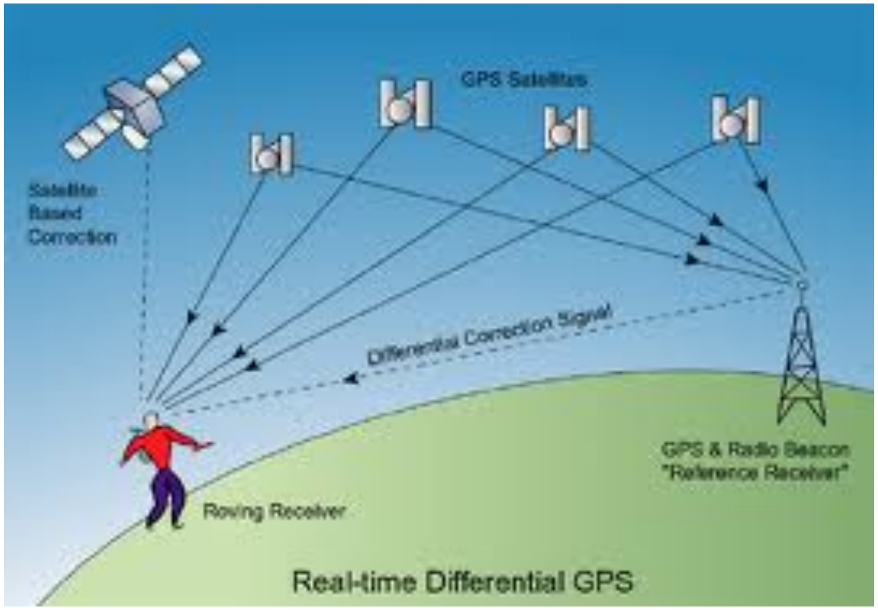
Perception

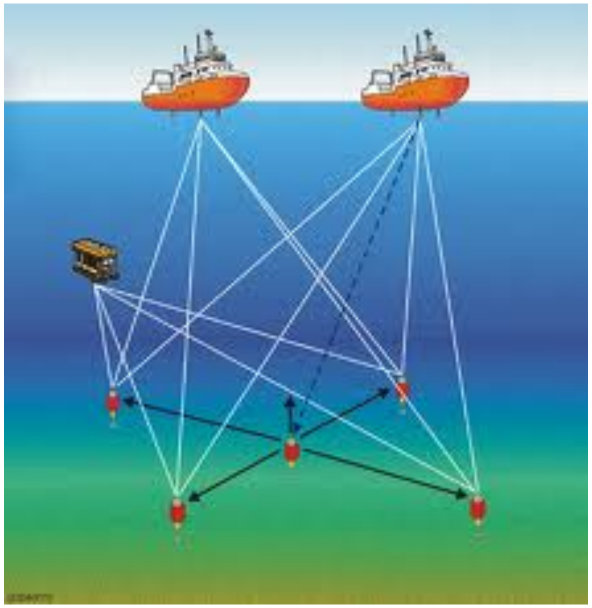
- Exteroceptive
  - Sonar



Perception

- Exteroceptive
  - Positioning Systems (e.g. GPS)





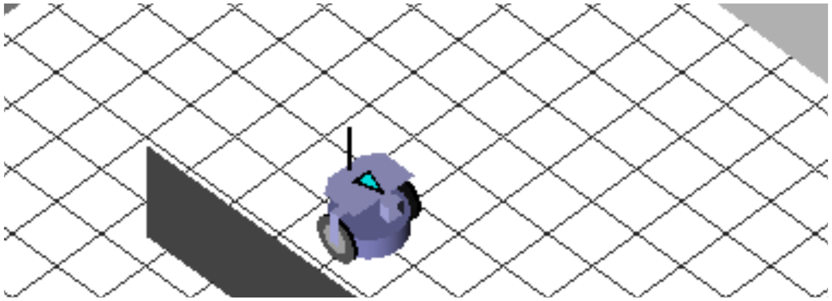
Images from 660audio.com, km.kongsberg.com.

Robot Navigation

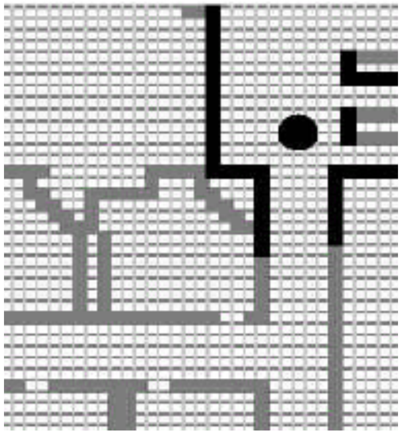
- Perception
- Localization
- Cognition
- Motion Control

Localization

- Representations
  - Continuous

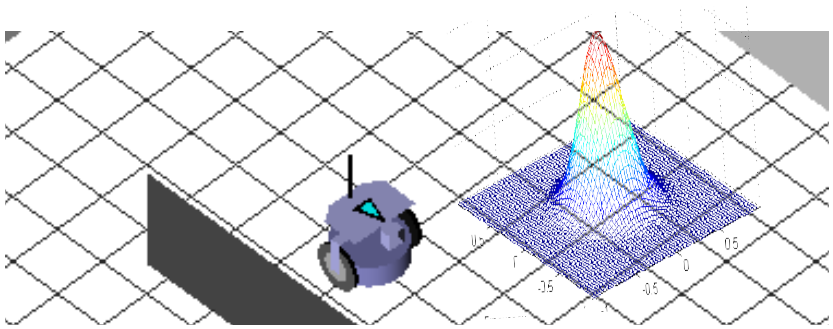


  - Discrete

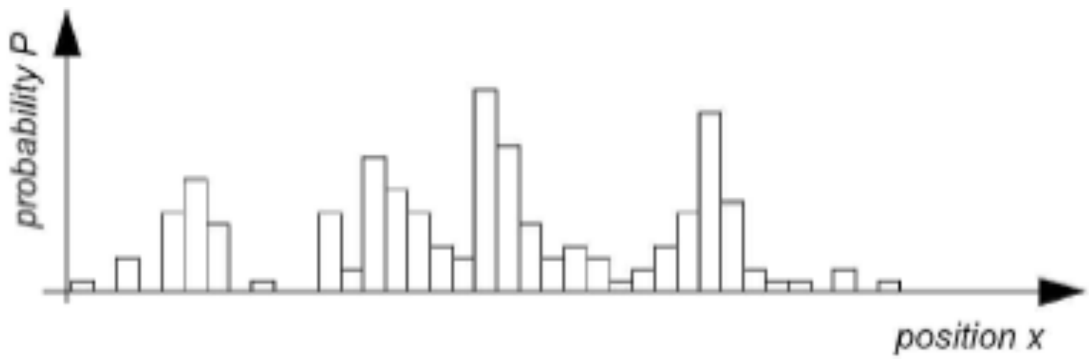


Localization

- Probabilistic Representations
  - Continuous



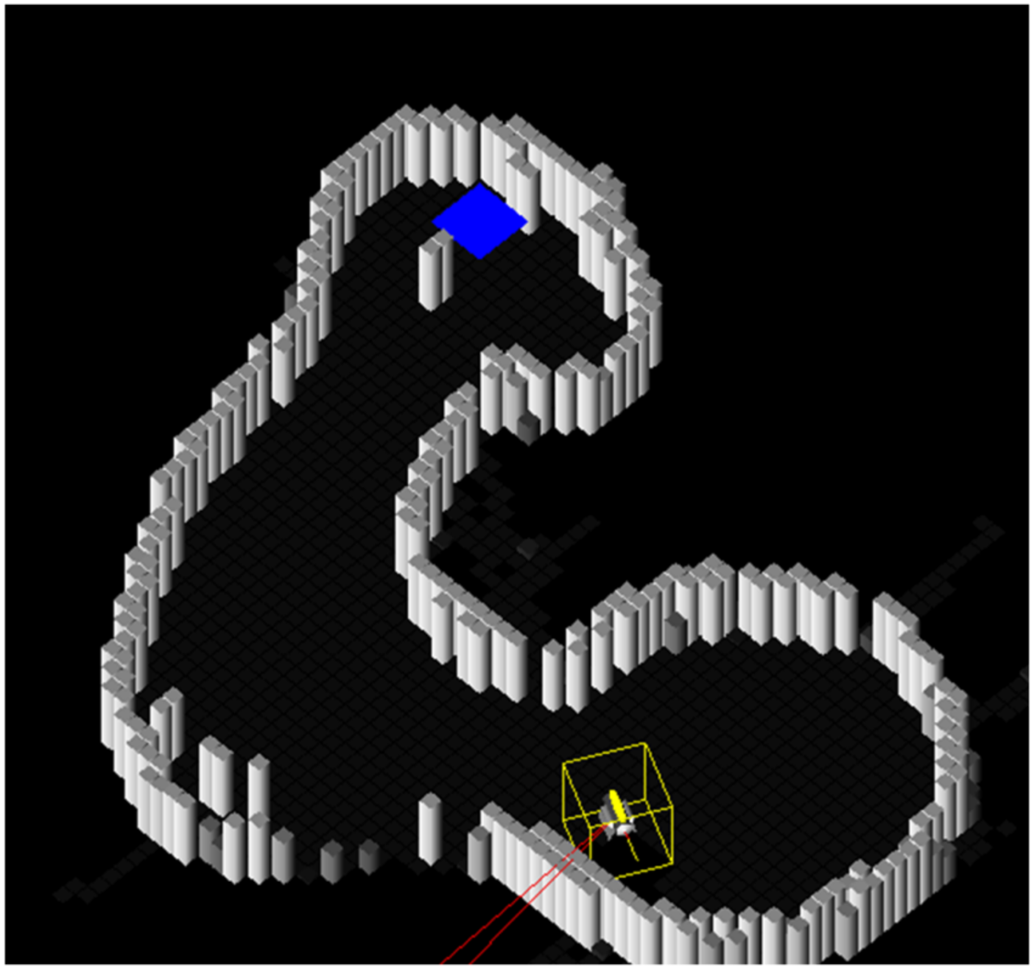
  - Discrete



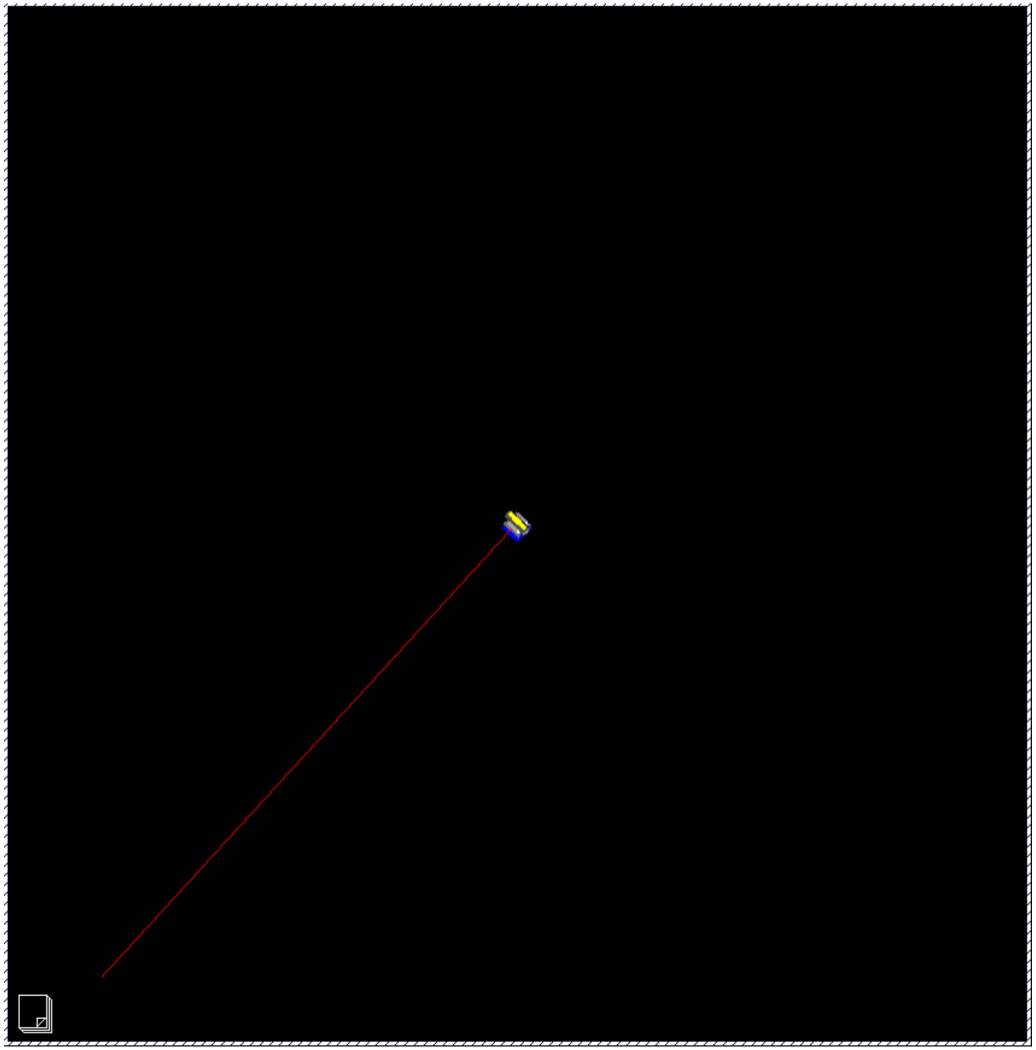
Localization

- Probabilistic Algorithms
  - Kalman Filter Based
    - Assumes Gaussian representation of robot state
    - Compact representation good for real time implementation
  - Particle Filter Based
    - Uses many particles to represent robot state, each particle is an estimate of the robot position with an associated weight.

Localization



Localization

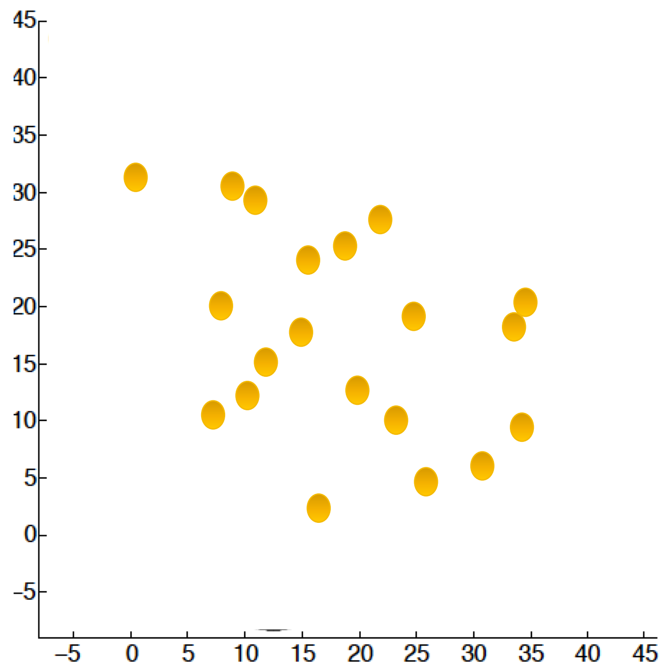


Robot Navigation

- Perception
- Localization
- Cognition
- Motion Control

Cognition

- Task Planning
  - Given a set of tasks (e.g. task locations), identify ordering sequence for the tasks.



Cognition

- Task Planning
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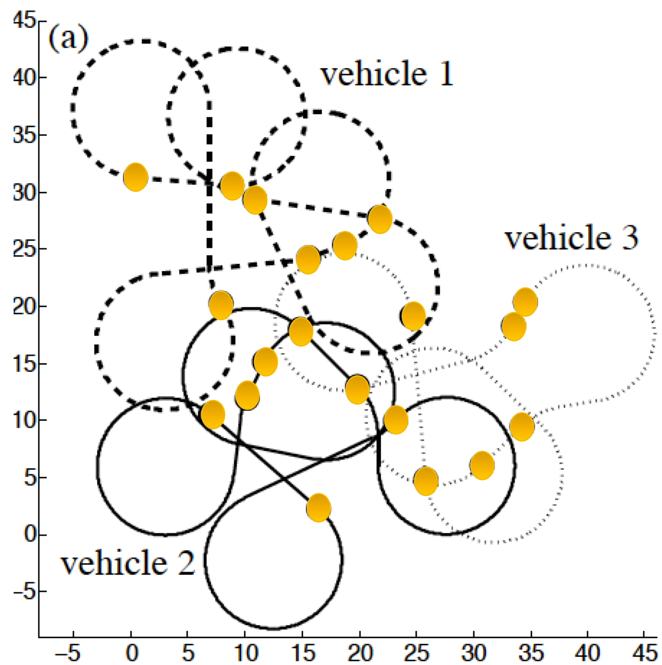
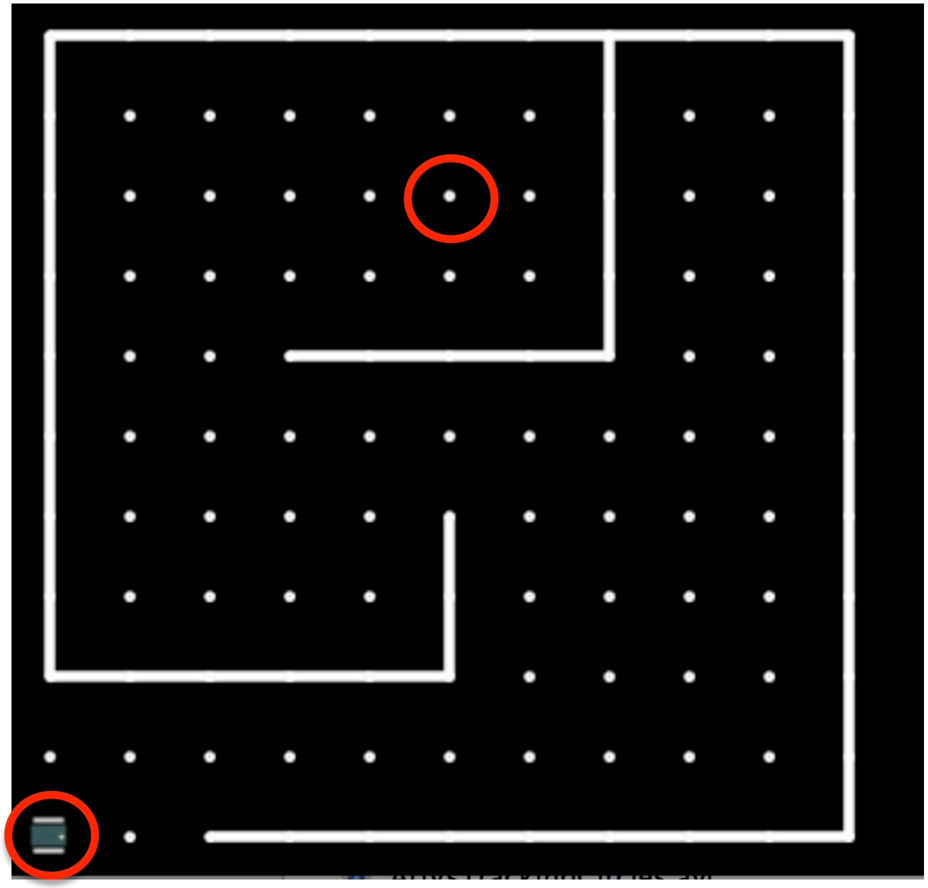
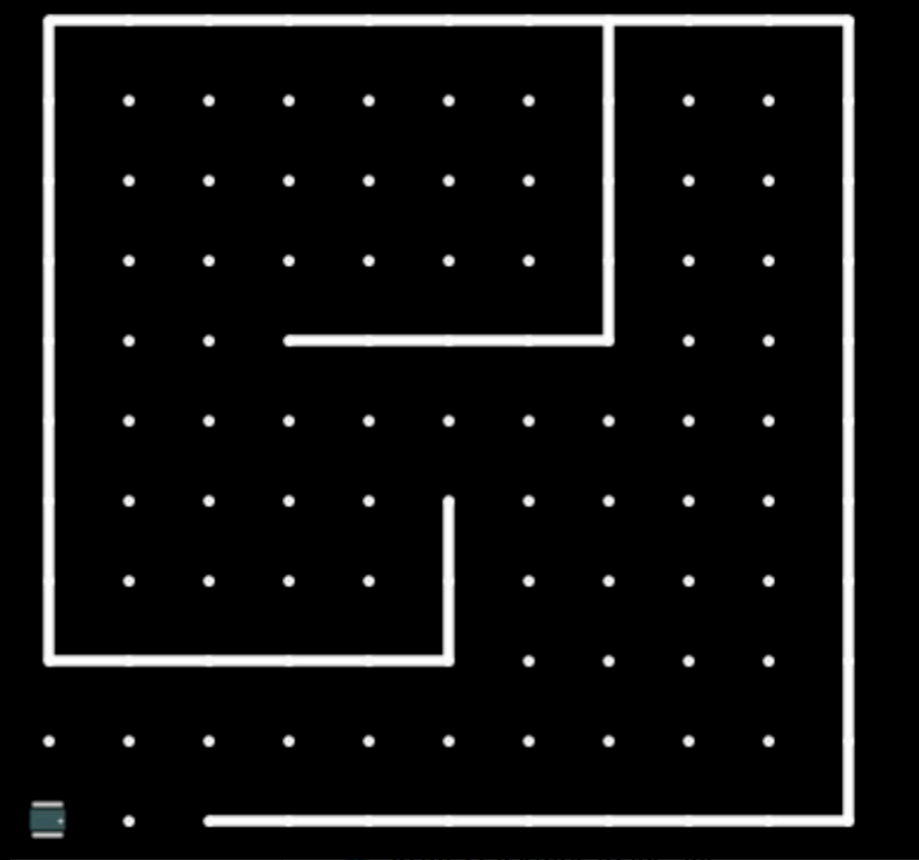


Cognition

- Motion Planning
  - Given a robot's Start Configuration and Goal Configuration, construct a collision free trajectory from Start to Goal





Robot Navigation

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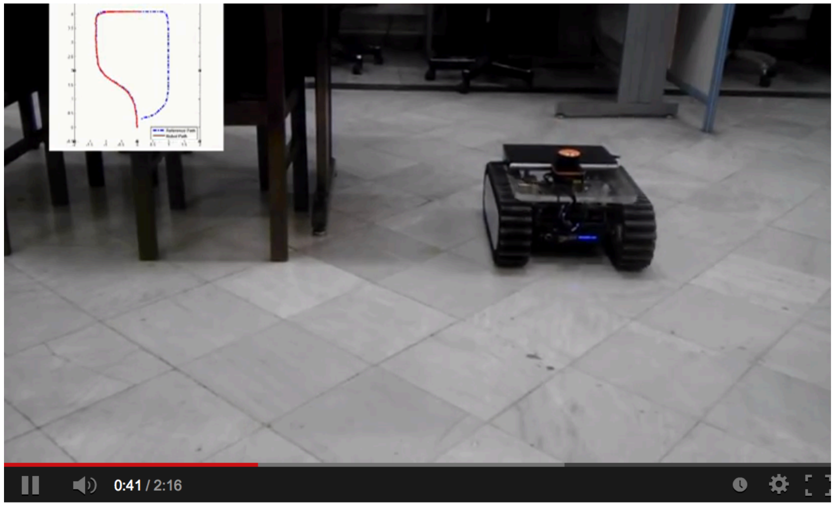
Motion Control

- Trajectory Tracking Control
  - Given a trajectory, determine the control signals sent to actuators that guarantee the robot will follow the trajectory.



  - http://www.youtube.com/watch?v=SWJ-etF4b2g