E160 – Lecture 13
Autonomous Robot Navigation

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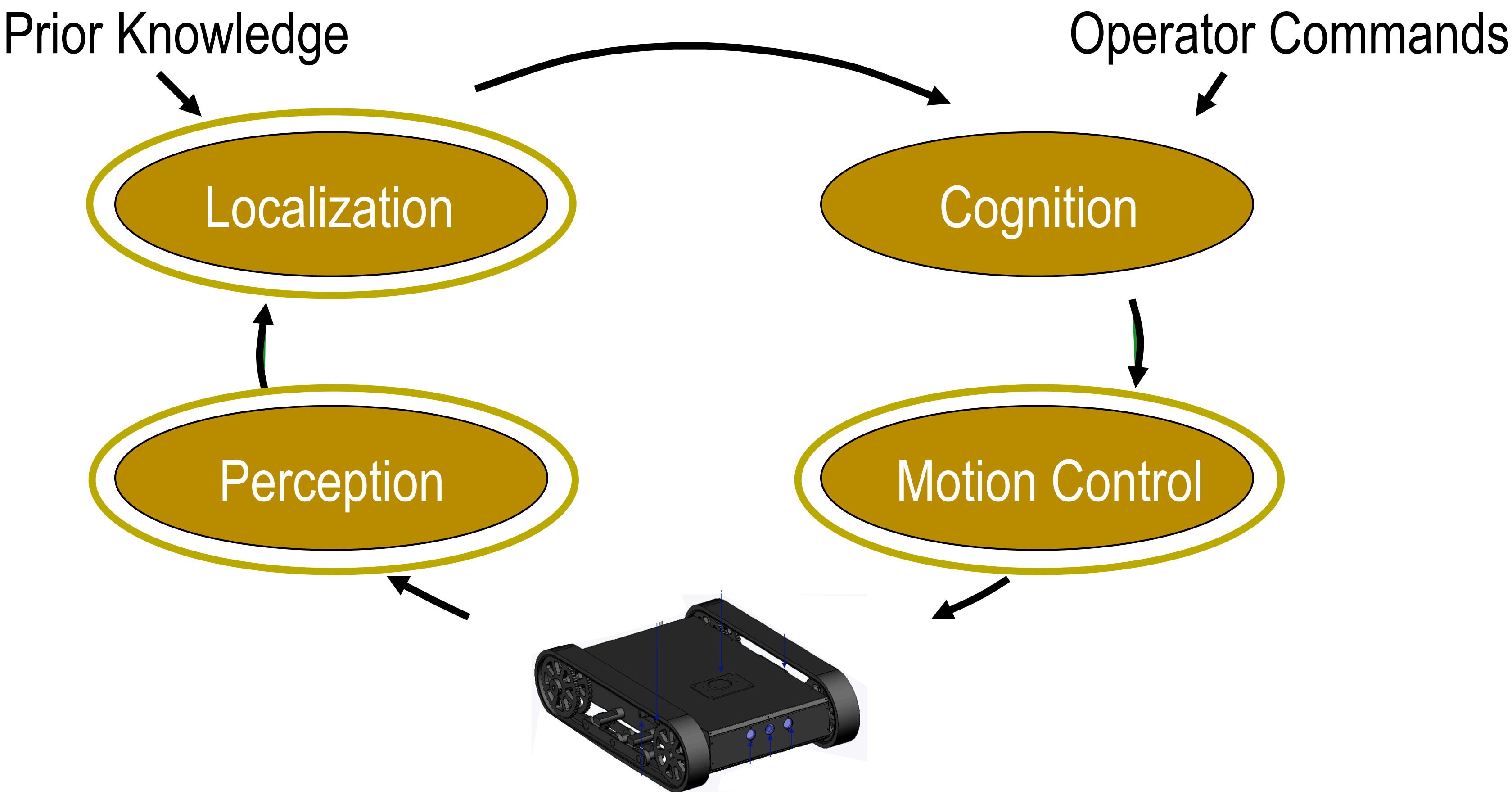
Semester: Spring 2016

Figures courtesy of Probabilistic Robotics (Thrun et. Al.)

Control Structures
Planning Based Control



Format

- Multiple Choice
- Short Answer
- Long Answer

Format

- Know the algorithms
  - How to iterate through examples
  - Trade-offs
- Know the math
  - Kinematics
  - Trigonometry

Multiple Choice

- Particle Filtering should be used instead of Kalman Filtering

    a) When 100000 particles minimum are needed.

    b) When the initial robot position is unknown.

    c) When the robot is operating in an environment without any locations that produce identical sensor measurements.

    d) None of the above

No Cheat Sheet

Some Equations that might be useful:

$$d = c\,t\,/\,2$$

$$\lambda = c/f$$

$$D = f\,l\,/x$$

$$p\,(A \wedge B\,) = p\,(A \mid B\,)\,p\,(B\,)$$

$$E[X_1\,X_2] = E[X_1]\,E[X_2]$$

$$\Delta\theta = (\Delta s_{right} - \Delta s_{left})\,/\,b$$

$$\Delta s = (\Delta s_{right} + \Delta s_{left})\,/2$$

$$p\,(x_t \mid o_t) = \Sigma_{x'}\;p\,(\,x_t \mid x'_{t-1}\,,\,o_t\,)\,p\,(x'_{t-1}\,)$$

$$p\,(x_t \mid z_t) = \frac{p\,(z_t \mid x_t\,)\,p\,(x_t\,)}{p\,(z_t\,)}$$

$$x = \frac{b(x_l + x_r)/2}{(x_l - x_r)} \qquad y = \frac{b(y_l + y_r)/2}{(x_l - x_r)}$$

$$z = bf/(\,x_l - x_r)$$

$$p(x'_{i,t}) = \Sigma\,p\,(\,x_{i,t} \mid x_{j,t-1}\,,\,o_t\,)\,p\,(x_{j,t-1}\,)$$

Q1: Coordinate Frames

- An X80 robot has been equipped with two cameras c_1 and c_2, both placed at the center of the robot. They are facing in the respective direction angles of α, $-\alpha$ relative the X axis of the robot's local coordinate frame.
  - If the robot is located at state (x, y, θ) in the global coordinate frame, and c_2 detects a landmark at range ρ and angle of β with respect to the direction of the camera, what is the position of the landmark with respect to the robot's local coordinate frame?
  - What is the position of the landmark with respect to Global coordinate frame?
  - Use a figure with all variables labeled.

Q2: P-Control

- A robot's error states follow the following equations.

$$de_1/dt = -2e_1 + 6e_2$$

$$de_2/dt = e_1 - e_2$$

  - Show all errors will not be driven to zero if they follow these equations.
  - If the first error equation can be modified by adding a P-Control term (Ke_2), show how the error states can be driven to zero.

Q3: Wall Mapping

- An X80 robot's range sensors are all broken except a left facing IR range sensor. It drives beside a wall and measures the range ρ_i to the wall from 3 position/ orientations (hence $i=1..3$). Each measurement has it's own associated error variance σ_i^2.
  - If the robots odometry is perfect, calculate the locations (x_i, y_i) where the range sensor hit the wall.
  - Use these locations to describe the wall as a line of the form $y = mx + b$.