CMPE 185: Autonomous Mobile Robots

Week 01: Syllabus and Introduction to Mobile Robots

Dr. Wencen Wu

Computer Engineering Department

Course Information

- **Instructor:** Wencen Wu
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  - Office hours: http://cmpe.sjsu.edu/content/office-hours

- **Teaching assistant:**
  - Gazal Shivhare (gazal.shivhare.sjsu.edu)

- **Class days / time:**
  - Monday & Wednesday 1:30pm – 2:45pm

Course Information

- **Textbook**

  Lecture notes developed by instructors.

- **Other readings**
  1. "*Introduction to Autonomous Mobile Robots*", second edition, Roland Siegwart. Illah Reza Nourbakhsh, and Davide Scaramuzza, MIT Press, 2011
  2. "*ROS Robot Programming*", Yoonseok Pyo, Hancheol Cho, Leon Jung, Darby Lim, ROBOTIS, 2017
  3. Turtlebot3 e-manual

Course Information

- **Prerequisite:**
  - ISE 130 or Math 161A, Math 123, CMPE 126 or CS 146
  - Basic understanding of Linear Algebra, Calculus, Statistics, and Physics.
  - Familiarity with Linux and a programming language (C, C++, or Java).

- Students should have computing resources available to prepare coding assignments. Laptops or personal computers should be enough.

Course Information

- ***Homework Assignments***:
  - concepts understanding verifications
  - coding implementations
  - Late submission: deduct 1 point for every minute the assignment is late

- ***Term project***
  - Groups of 3-4 students will be formed to work on a term-long group project related to autonomous mobile robots.
  - Each group member is expected to participate in every phase of the project. The final grade of each member will be proportional to his/her participation in the group, as assessed by the instructor and the student's peers
  - There is a final project presentation. No makeup presentation will be given, unless the case is critical. For the exceptional cases, documented reasons (e.g. physician's statement) are required.

Course Information

- **Midterm exam**
  - October 12, 2022 1:30pm – 2:45pm
- **Final exam**
  - December 13, 2022, 12:15pm – 2:30pm
  - The final exam is comprehensive and the date is determined by the University's Final Examination Schedule. Please plan ahead
- Exams will be conducted using **Canvas Lockdown Browser and Respondus Monitor**. Please make sure you have necessary equipment, i.e., laptop and camera, ready before the exams
- Exams will be a combination of multiple choice and short answer questions and will be based on the individual assignments and course material covered in class.
- No make-up exams

Grading Information

- Homework 20%
- Midterm 25%
- Final Exam 35%
- Group Project 20%

The final grade will be calculated based on the following and possibly be adjusted by the ranking of the students:

- A plus 98 to 100
- A 95 to 98
- A minus 90 to 95
- B plus 85 to 90
- B 80 to 85
- B minus 75 to 80
- C plus 70 to 75
- C 65 to 70
- C minus 60 to 65
- D 50 to 60
- F less than 50

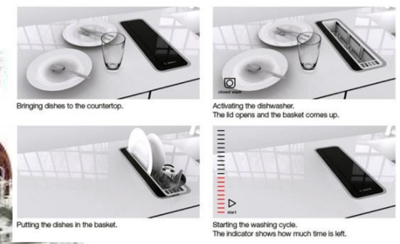
Course Information

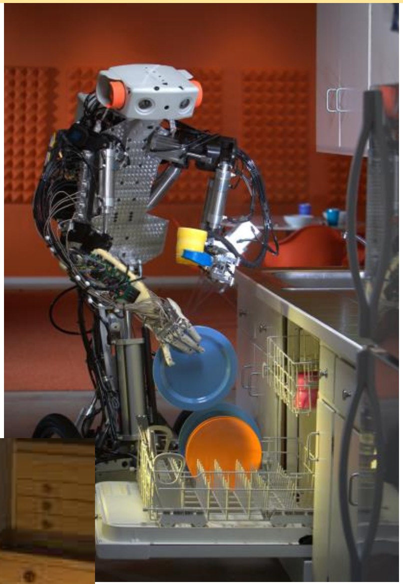
- Course materials such as syllabus, handouts, notes, assignment instructions, etc. can be found on *Canvas Learning Management System course login website* at http://sjsu.instructure.com. You are responsible for regularly checking with the messaging system through one. sjsu at http://one.sjsu.edu and Canvas to learn of any updates.

Introduction to Autonomous Mobile Robots

What is a Robot

- A dishwasher?
- A CNC machine tool?
- A vacuum cleaner?
- A mechanical toy?
- A Disney display?
- An on-line shopping assistant?





What is a Robot?

A physical or virtual **object** that may be commanded to perform **specified tasks** in a **specific environment**.

- **Object**: electromechanical
- **Programmable**: Teleoperated (surgical robots) vs. Pre-taught (auto assembly) vs. sensor feedback (vision: self-driving vehicle)
- **Specified tasks**: pick-and-place (spot welding), trajectory following (arc welding), target following (surveillance), insertion (assembly), load handling (transport, bulky parts)
- **Specific environment**: Factory, home, battlefield, Mars

Robots in Manufacturing: Automotive

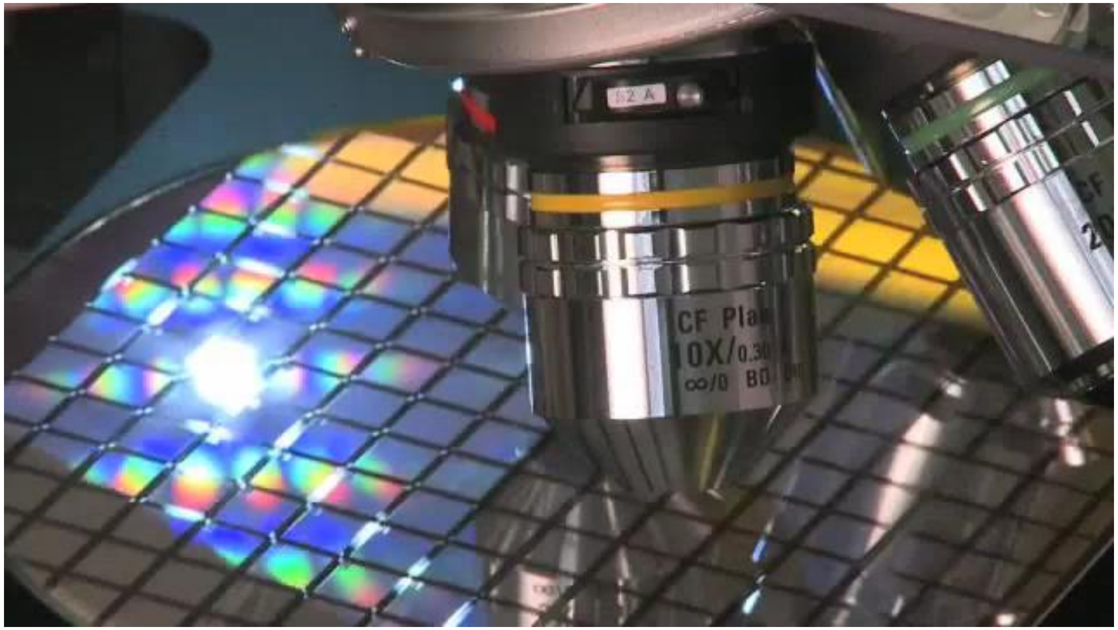
Typical vehicle assembly plant:

- 400-600 robots
- 800-1200 vehicles in system
- 60 vehicles/hr output
- Body shop and paint shop: near fully autonomous
- Heavy/large payload

General assembly: nearly all manual!

Robots in Manufacturing: Cleanroom

- Widely used in wafer processing, inspection, and handling
- Mostly planar operation, SCARA robot
- High speed and precision requirement
- Small workspace
- Light payload, must be vibration-free



Robots in Manufacturing: Food Processing

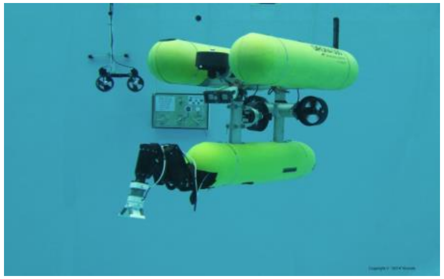
- Emphasis on high speed
- Vision guided
- Soft, flexible material handling
- Low payload weight
- Parallel robot architecture

From Fixed Robots to Mobile Robots

- Fixed robots
  - Robots that mimic the human arms to perform advanced manipulation operations
  - On site tasks
  - Articulated robots

PUMA 500: typical light assembly robot

- Mobile robots
  - Robots with locomotion abilities that are able to move in the surrounding environment, either autonomously or teleoperated by humans



Potential Applications of Mobile Robots

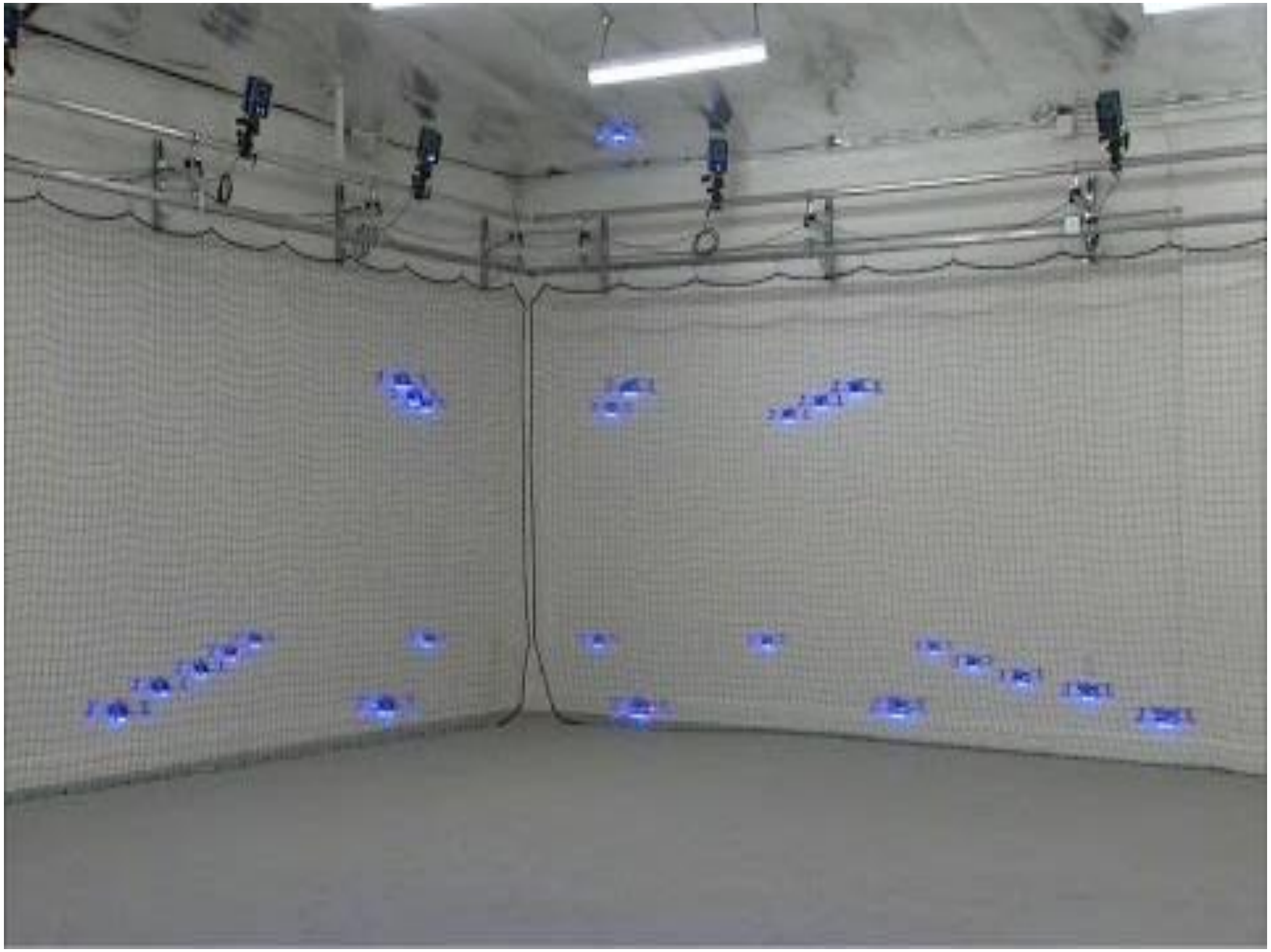
- Indoor applications
  - Cleaning of large environments
  - Service robots (museums, shops, etc.)
  - Domestic surveillance of buildings
  - Merchandise storage in automated warehouses

- Outdoor applications
  - Military applications
  - Mine clearance
  - Space and underwater exploration
  - Civil protection and forests monitoring
  - Automated agriculture

Example: Service Robots

https://www.youtube.com/watch?time_continue=1&v=P_zRwq9c8LY&feature=emb_title

Example: Autonomous Drone Swarms



https://www.youtube.com/watch?v=MlFtHuXPbv4&feature=emb_title

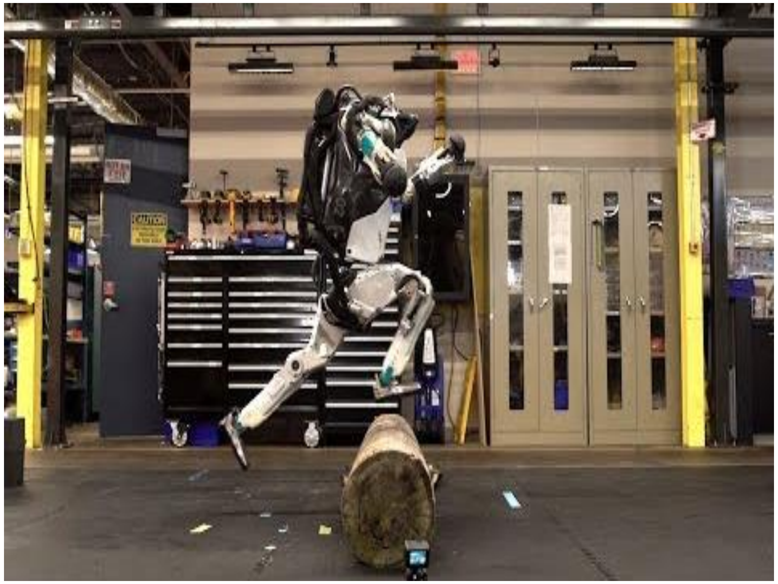
Example: Autonomous Underwater Vehicles

https://www.youtube.com/watch?v=doUzOtGKr1o&feature=emb_title

Example: Boston Dynamics

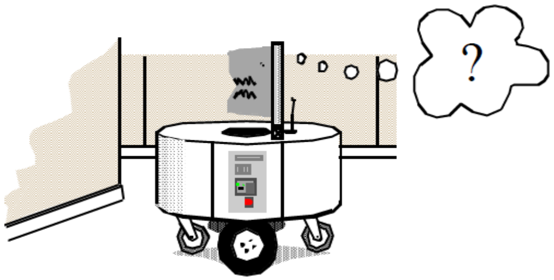
- Boston Dynamics YouTube Channel

  https://www.youtube.com/channel/UC7vVhkEfw4nOGp8TyDk7RcQ

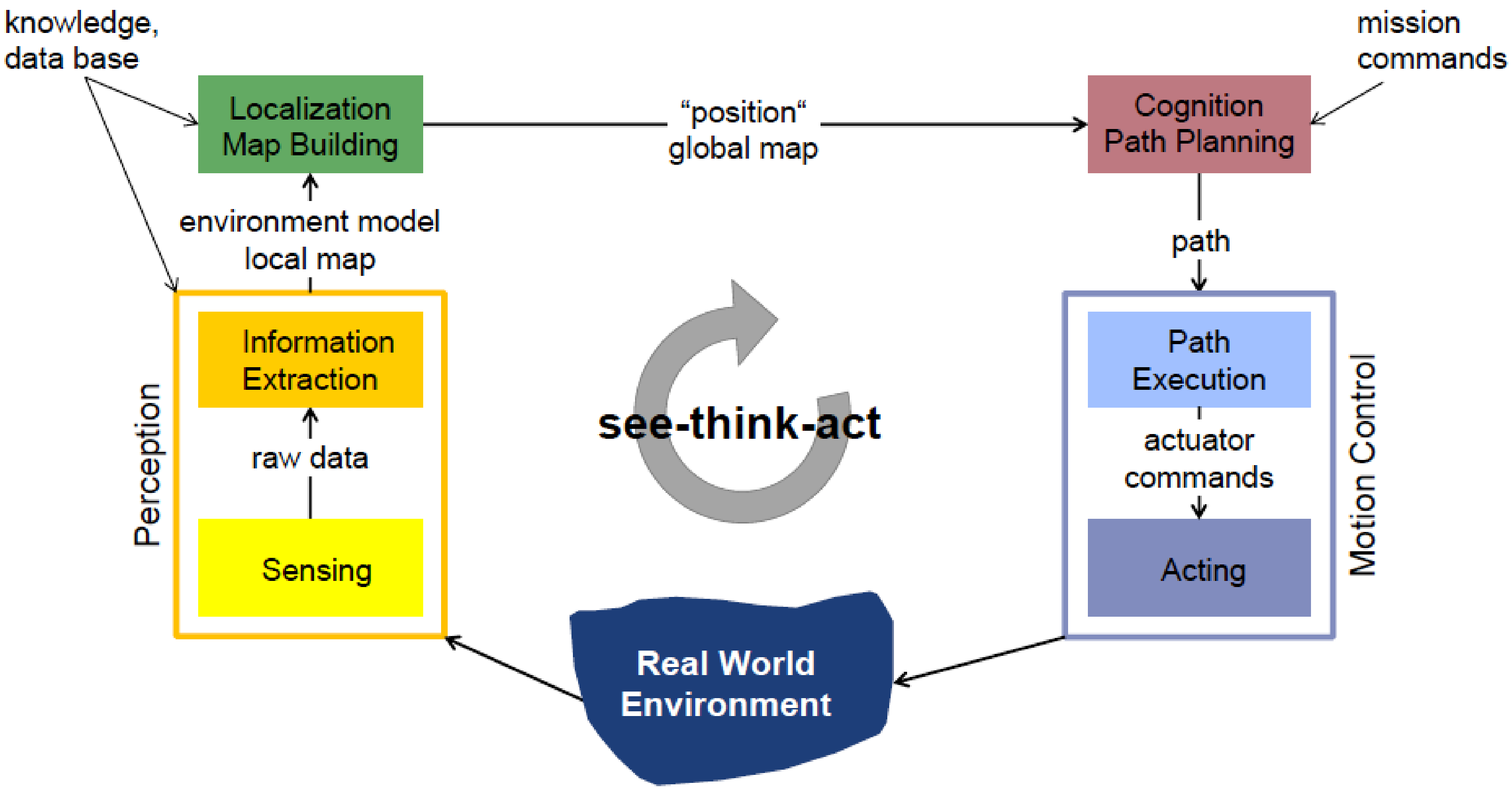


Autonomous Mobile Robot – the Key Questions

- The three key questions in mobile robotics
  - Where am I?
  - Where am I going?
  - How do I get there?
- To answer these questions, the robot has to
  - Have a model of the environment (given or autonomously built)
  - Perceive and analyze the environment
  - Find its position/situation within the environment
  - Plan and execute the movement



Introduction to Mobile Robots

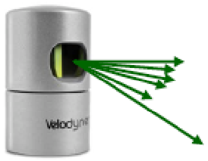


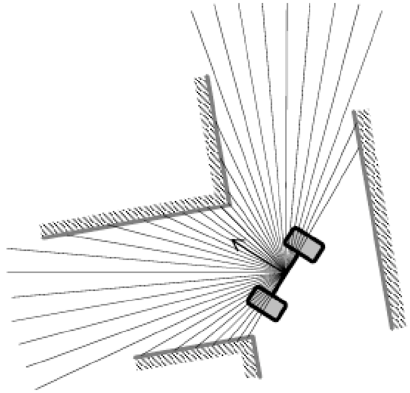
How can mobile robots achieve these?

ETH Zurich Autonomous Systems Lab

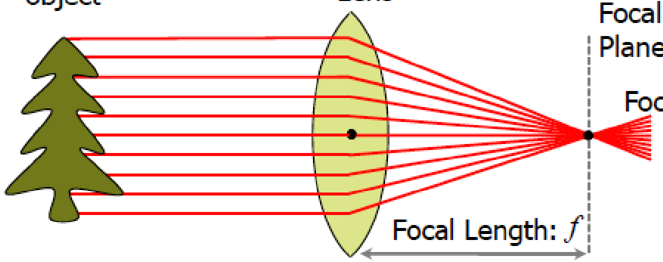
Key Tech: Perception | Sensing

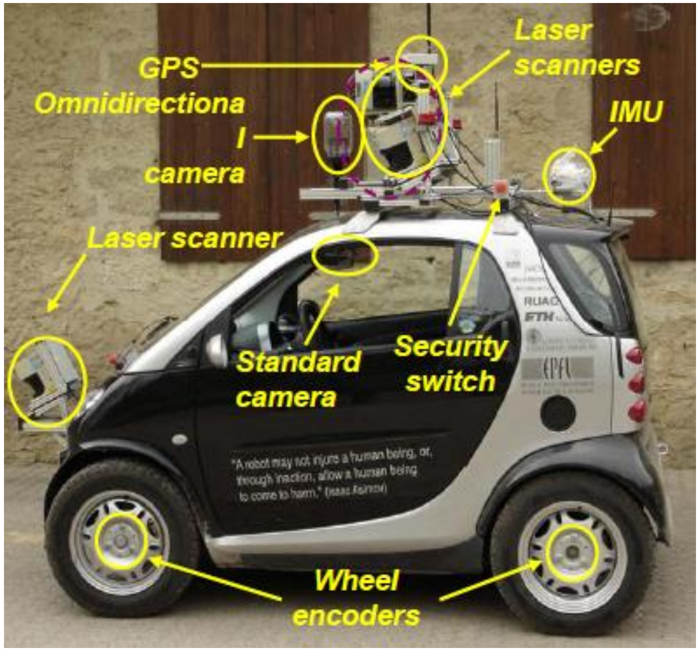
- Laser scanner
  - time of flight





- Camera

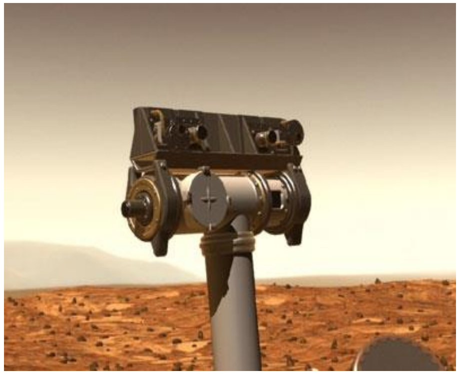




- Other types of sensors:
  - Lidar, Infrared sensors
  - Inertia measurement units (IMU)
  - Force/torque sensors, tactile sensors, pressure sensors

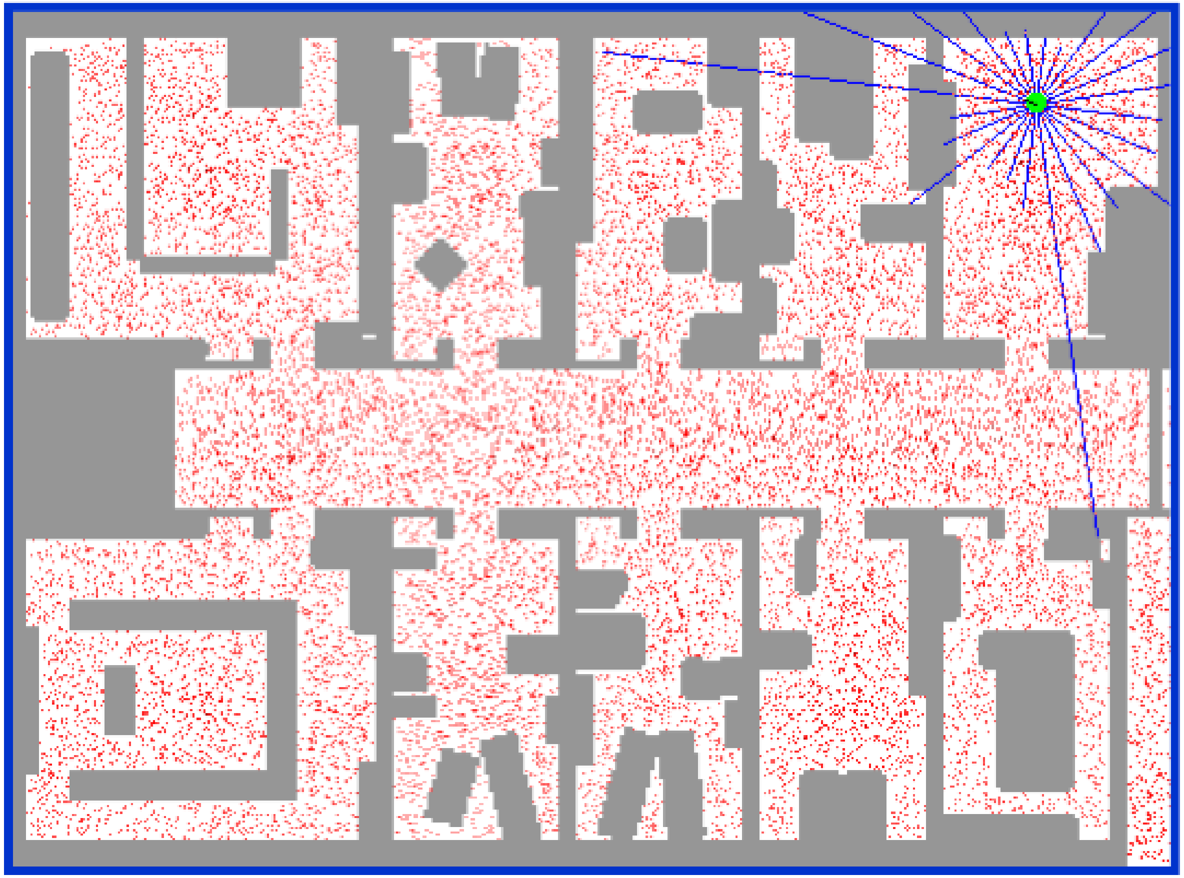
Key Tech: Perception | Sensing

- Any information a robot collects about itself or its environment requires sensing
- Robots that want to learn, map and/or navigate need to collect information about their surroundings
- All sensors have some degree of uncertainty
- Uncertainty can be reduced by multiple measurements.



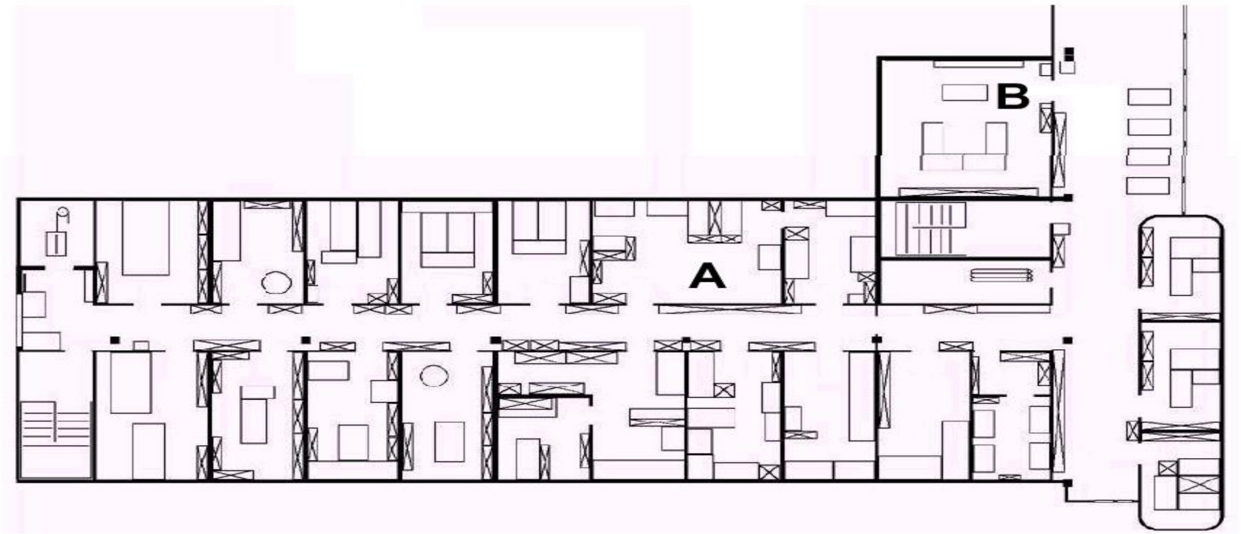
Key Tech: Localization

- How to localize the robot in an unknown environment based on sensor measurements, i.e., camera, Lidar, radar, etc. ?



Key Tech: Mapping

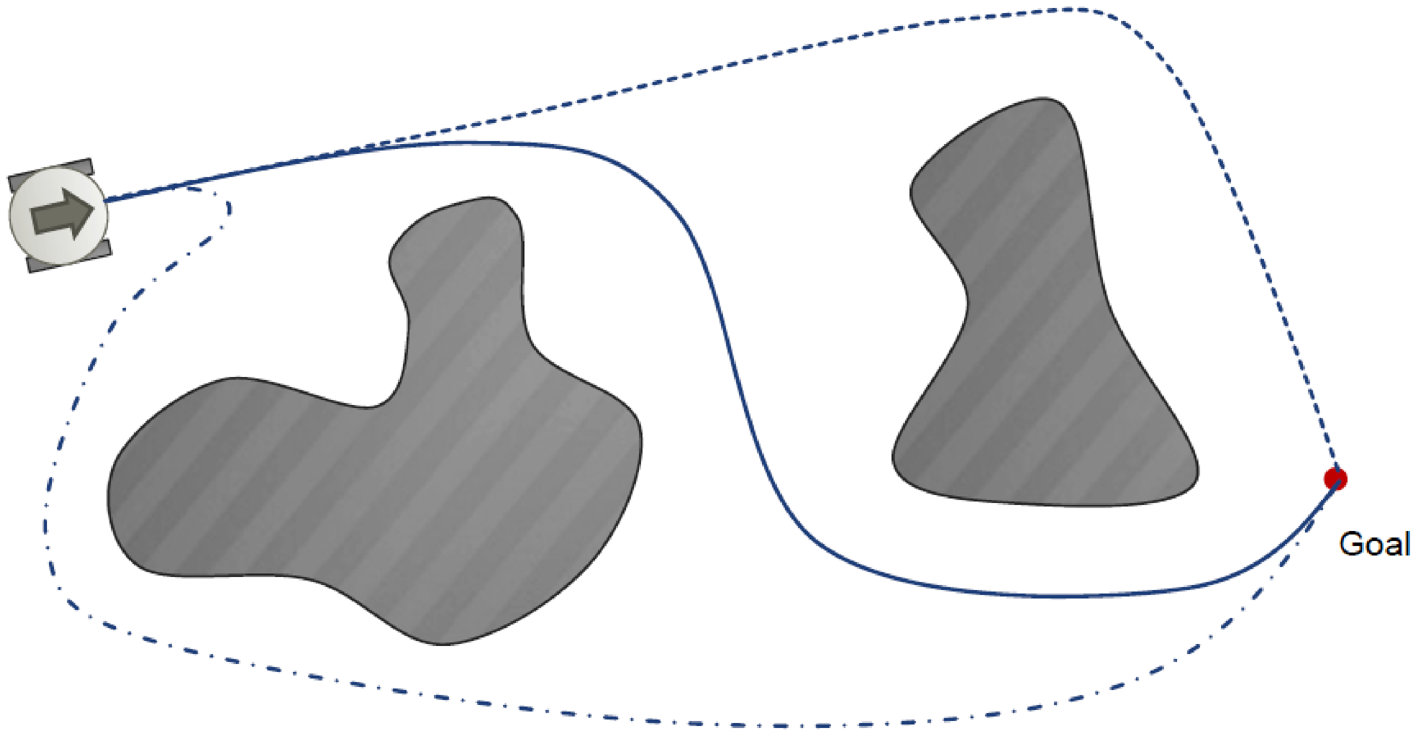
- Maps are required to help a robot get from point A to B
- Map representations can be continuous or discrete
- Maps can be built a priori and/or dynamically



Simultaneously Localization and Mapping (SLAM)

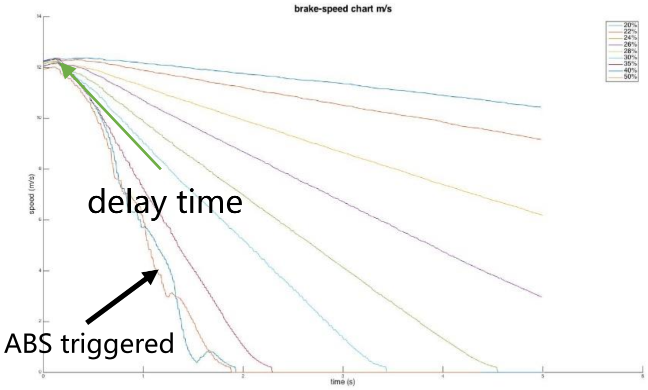
Key Tech: Path Planning

- Where am I going? How do I get there?

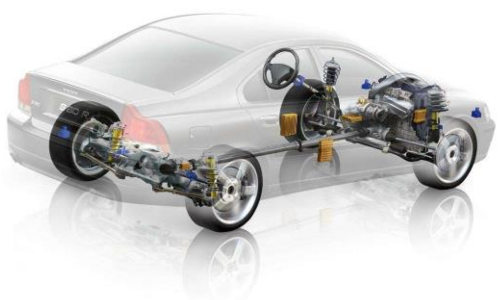


Key Tech: Control

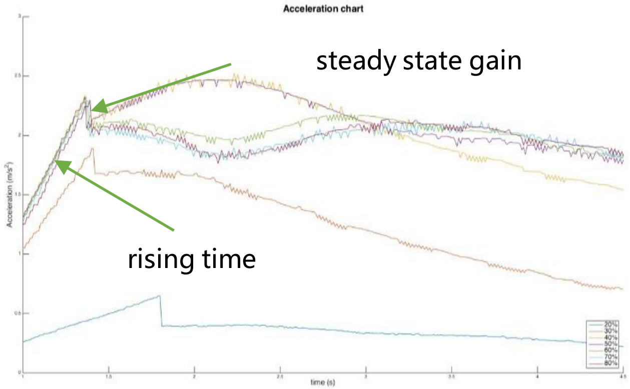
- Giving the map and the planning path, how to contr the mobile robots to move from A to B?
- PID control v.s. more advanced control methods



Break-Deceleration



By-wire systems

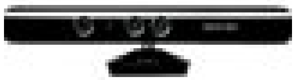


Throttle-Acceleration

Distributed Architecture

Given a collection of sensors, actuators, and processors, how do we get them to talk to each other and program and control them?

- [Robot Operating System (ROS)](https://www.ros.org/)
- https://www.ros.org/





What will one learn in this course?

- How to build a robot?
- How to design a robot?
- How to program a robot?

What will one learn in this course?

- Upon successful completion of the course, students will be able to
  - Describe different types of mobile robots and the applications.
  - Explain the major software and hardware components of a mobile robot.
  - Understand the kinematics of a mobile robot and use it for robot navigation.
  - Understand the state-of-the-art algorithms used in mapping, localization, perception, path planning, and control for mobile robots.
  - Demonstrate effective communication and teamwork skills through technical presentations and reports in course projects.

What is ROS

- The Robot Operating System (ROS) is a flexible framework for writing robot software.
- It is a collection of tools, libraries, and conventions that aim to simplify the task of creating complex and robust robot behavior across a wide variety of robotic platforms.

ROS is an open-source, meta-operating system for your robot. It provides the services you would expect from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers.

http://www.ros.org/

Tentative Schedule

Week	Date	Topics
1	8/22, 8/24	Introduction and locomotion concepts
2	8/29, 8/31	Coordinate transformation and introduction to ROS
3	9/7	Kinematics
4	9/12, 9/14	Odometry and PID control
5	9/19, 9/21	Sensor characteristics and types
6	9/26, 9/28	Line extraction based on range sensor
7	10/3, 10/5	Learning based object detection based on camera
8	10/10, 10/12	Project proposal, midterm review and Midterm
9	10/17, 10/19	Probabilistic mobile robots
10	10/24, 10/26	Markov, Kalman filter, and particle filter localization
11	10/31, 11/2	Simultaneous localization and mapping (SLAM)
12	11/7, 11/9	Configuration space, path planning overview
13	11/14, 11/16	Path planning: BFS, DFS, and A* algorithm
14	11/21	Path planning: sampling-based algorithms
15	11/28, 11/30	Obstacle avoidance: bug algorithms, project presentation
16	12/5	Project presentation and final review
Final Exam	12/13	12:15pm – 2:30pm

- Thank you!