Multi-Robot Systems

Lecture 1: Introduction to Multi-Robot Systems I

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In this Lecture

- Why study this area?
- What this course is about
- Course administration
- Basic definitions
- Basic autonomy

Industry Applications

[Amazon]

[Pony.ai]

Why Study Multi-Robot Systems?

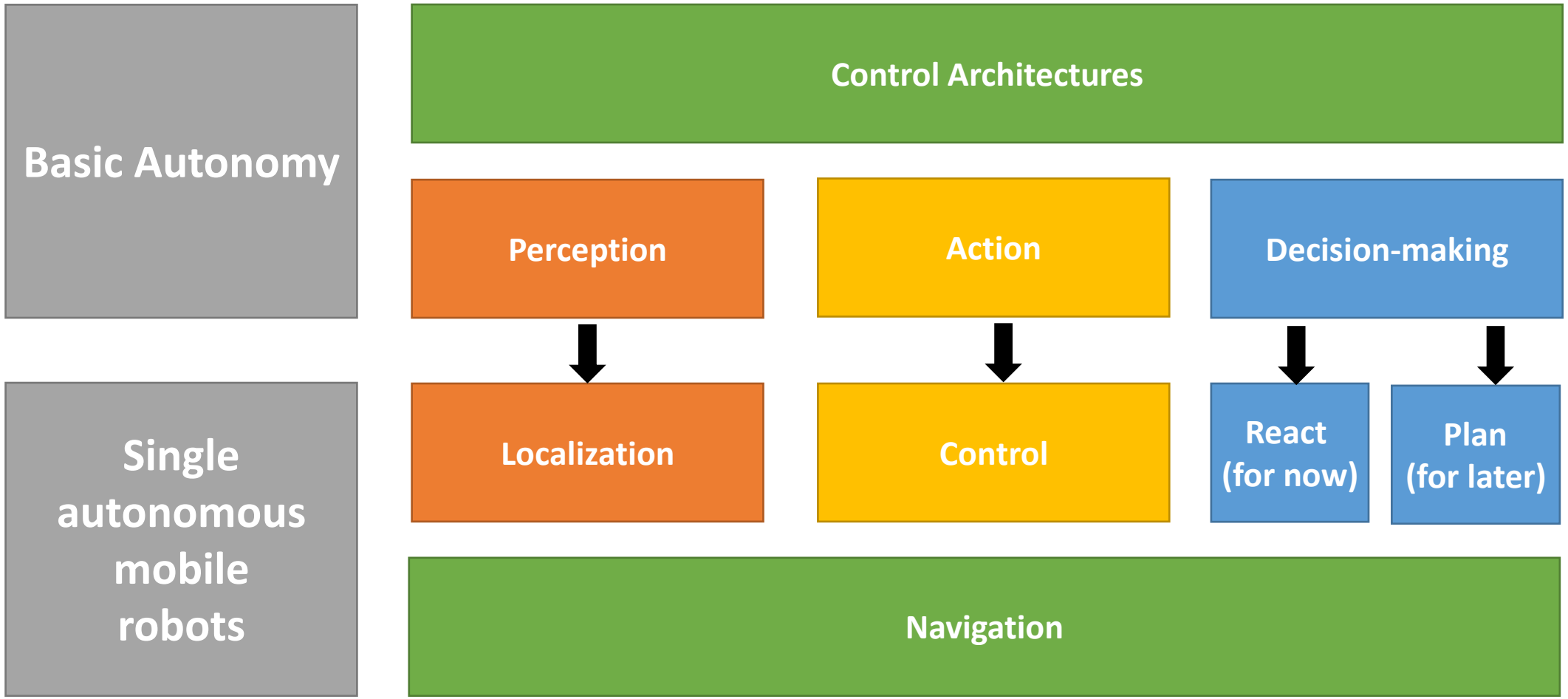
- Maybe you are interested about **Jobs** or **Research** in…
  - Transportation Industry
    - autonomous driving (Waymo, Tesla, Pony.ai)
    - The autonomous (driverless) car market was valued at USD 20.97 billion in 2020
  - Warehouses Industry
    - Amazon had 45,000 robots in its warehouses in 2016…
    - Amazon had more than 100,000 robots in its warehouses in 2018…
  - Social goods
    - search and rescue
    - drones for disaster response and environmental monitoring
    - robots for demining

Why Study Multi-Robot Systems?

- Some foundational **topics**…
  - Perception
  - Planning
  - Motion control
  - Communication
  - Coordination
  - Optimization
  - Probabilistic reasoning
  - Learning

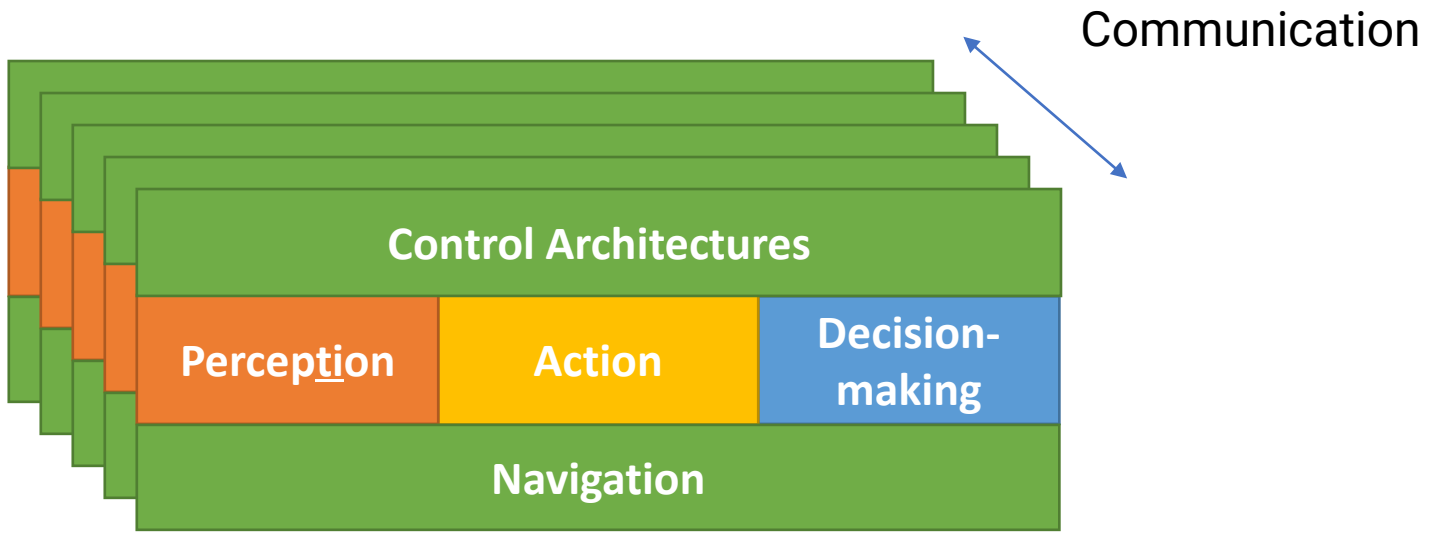
What This Course is About

- Autonomy of **single autonomous mobile robots**



What This Course is About

- Course Schedule
- Main target: **autonomous mobile robots**
- A **group** of single robots→ **multi-robot systems**
- More complex tasks in high-dimension space
- Communication for Coordination



Course Schedule

- About 30 weeks
  - 22 weeks about basic SLAM and learning based control
  - 6 weeks about game theory
  - 2 weeks about mechanism design
- Reference / Extension
  - Famous Papers about related topics
  - Important parts in some books

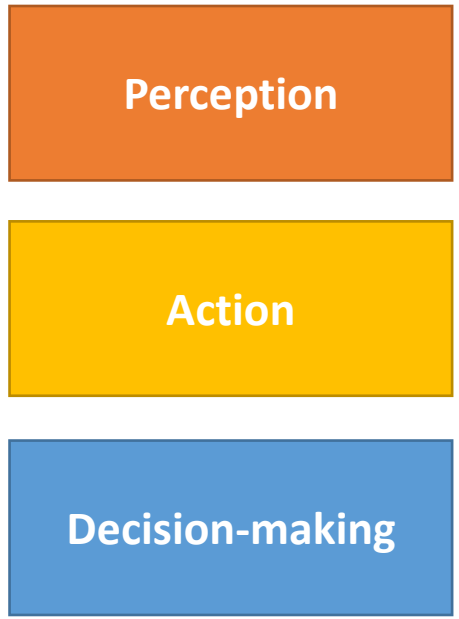
How will most of lectures be structured?

- Problem settings
- Key idea/intuition
- Math / algorithm derivation for “clean” setting
- Extensions
- Applications
- Recap some former issues (repeating)

Basic Autonomy

- Missions
  - Modeling and Perception for environment
  - Data processing and Control (Action)
  - Reasoning and Planning under uncertainty

- What are the goals of our multi-robot system?
  - Techniques related to each of these 3 parts
  - Techniques (architectures) related to the combination of these 3 parts



Perception

Where am I (modeling environment)?

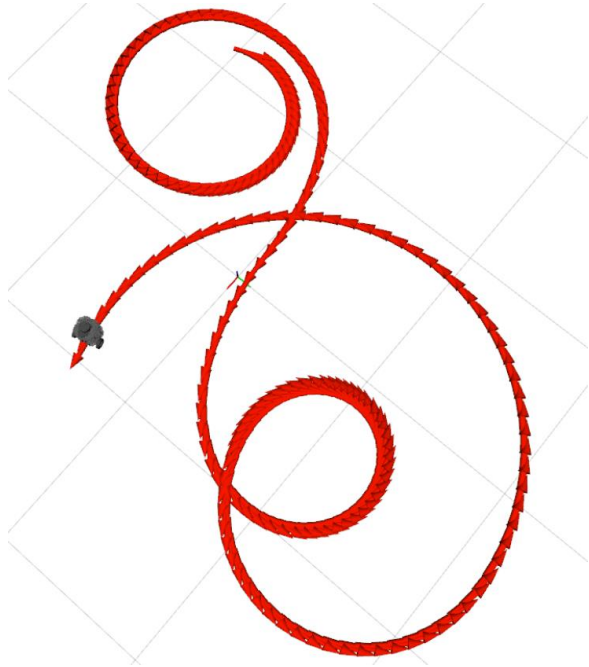
What am I doing (modeling self)?

Any other living creature (modeling other agents)?

Example (Localization):

Turtlebot3 with 360 Laser Distance Sensor

Mapping based



Odometry based

Perception

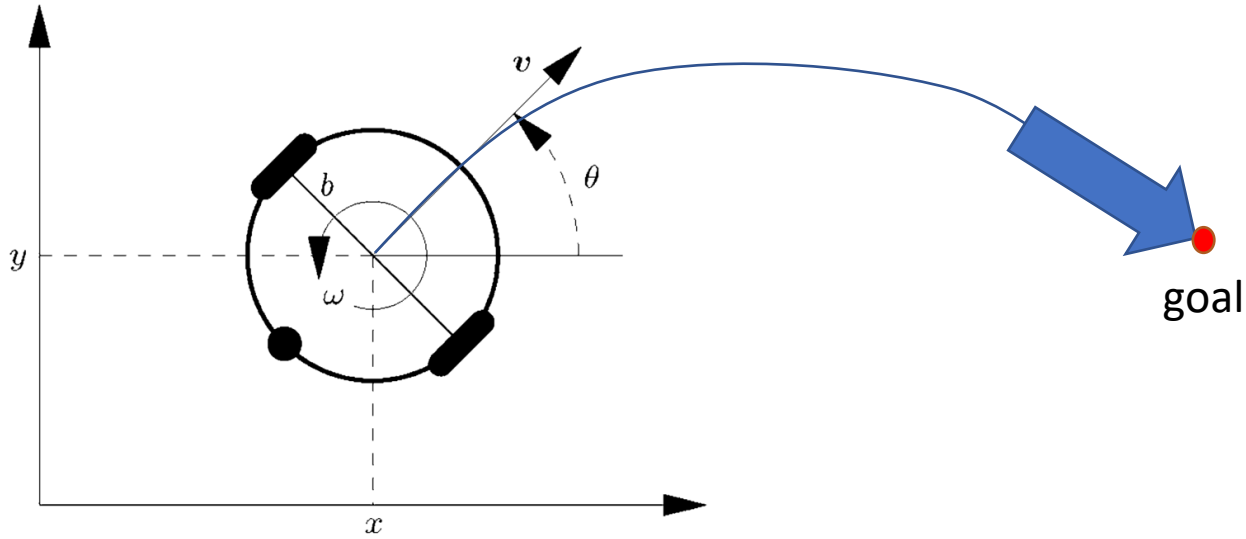
Basic Action

What electrical signal should I give my motors to make my robot moving?

Action

Example (motion control for Turtlebot3):

Compute rotational velocity (w) and forwards velocity (v) (or acceleration w’ and v’).



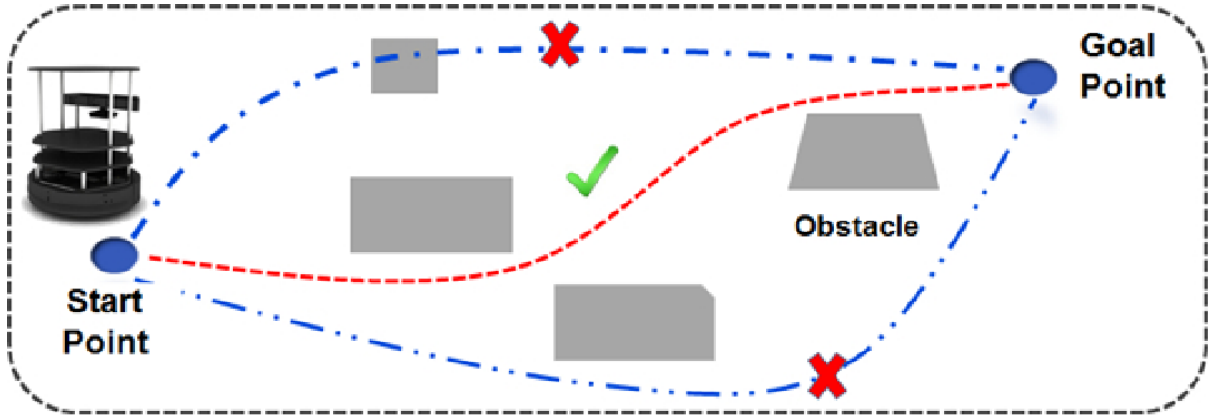
Basic Decision-Making

What is my path-planning to arrive my goal?

Decision-making

Example (deliberative planning with Turtlebot3):

Compute an optimal path considering obstacles avoidance and robot kinetic models.



Compute the optimal path for Turtlebot3

Basic Coordination

What are our best actions / decisions as a group of robots?

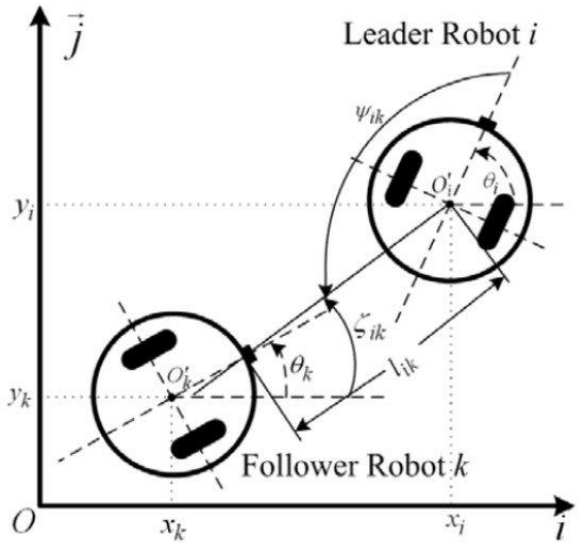
Perception

Action

Decision-making

Example (control a robot team to complete a leader-following job):

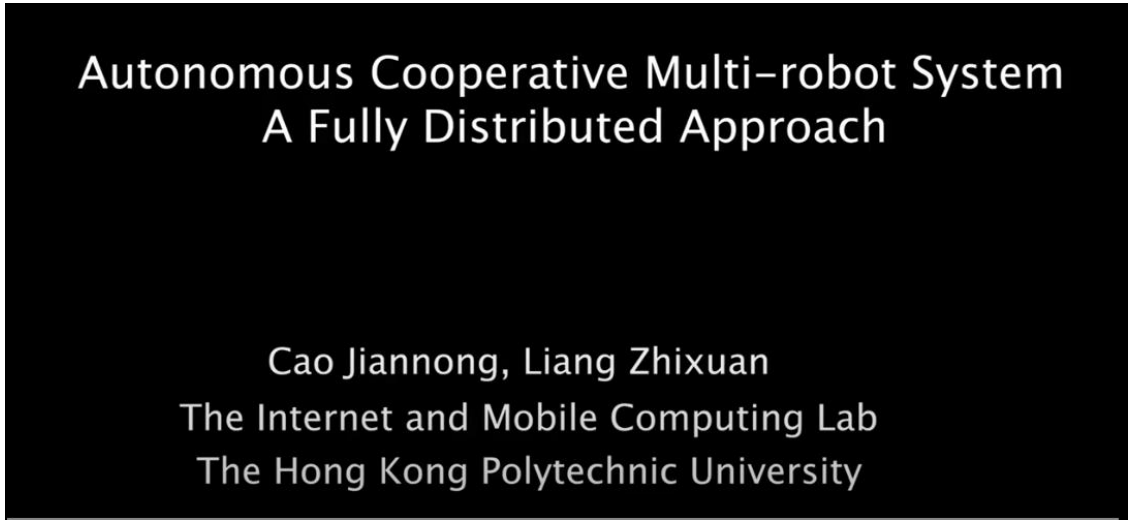
Maintaining formation during group movement.



Leader-follower control

Two Research Cases

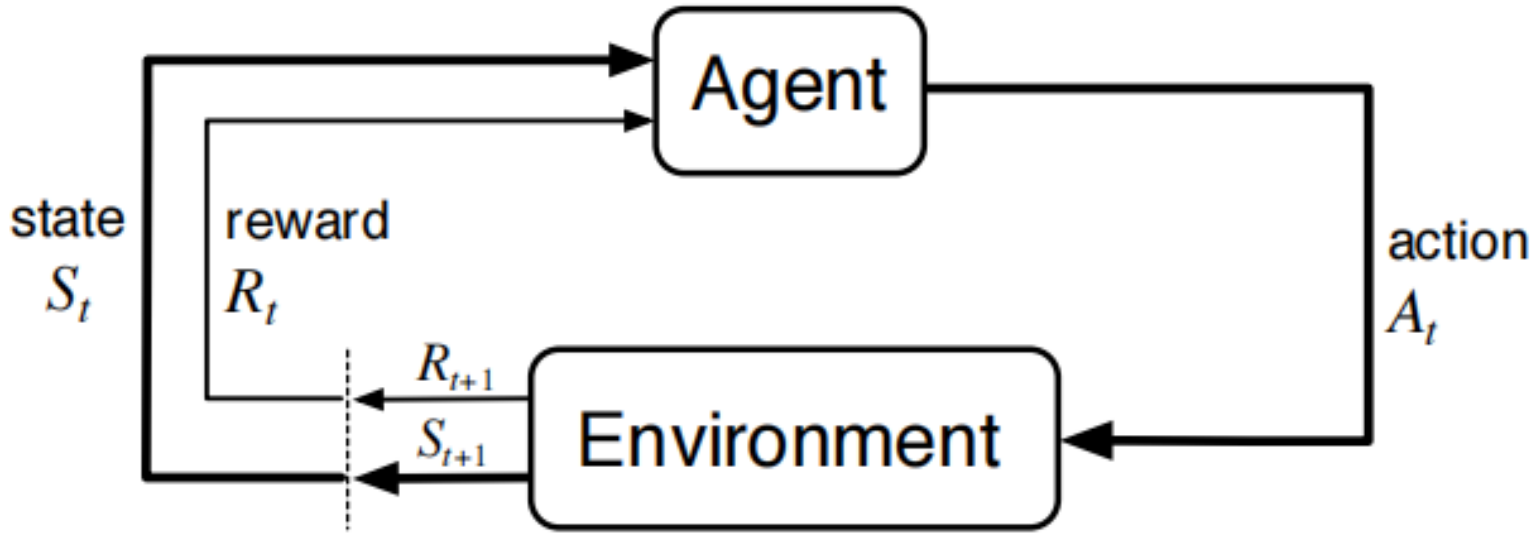
https://youtu.be/MNvh03xYDIs



https://www.youtube.com/watch?v=twXeOgdj6Jw

Reinforcement Learning

After class task: to know basic Markov Decision Process (MDP)



An MDP loop

https://www.deadsecond.com/

Check this website, scroll down, unfold the Reinforcement Learning part for getting some beginner-level resources