ELEC 3210
Introduction to Mobile Robotics
Lecture 1

(Machine Learning and Infomation Processing for Robotics)

Huan YIN

Research Assistant Professor, Dept. of ECE

eehyin@ust.hk




Logistics

ELEC 3210

HKUST

Machine Learning and Image Processing for Robotics

- 2020 Fall
  - Prof Ming Liu
- 2021, 2022 Fall
  - Prof Lujia Wang

Introduction to Mobile Robotics

- 2023 Fall
- 50% Changed, 50% Reserved

Inspired by

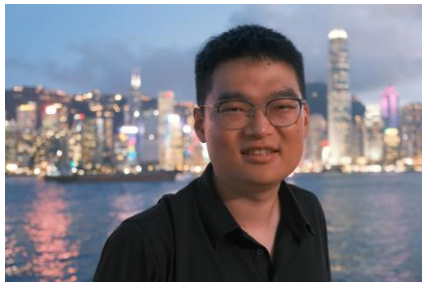
- **自主移动机器人 Autonomous Mobile Robot**
  - Zhejiang University
  - Led by Prof. Rong Xiong (my PhD advisor)
  - work as TA from 2018 to 2020

- **Introduction to Mobile Robots**
  - University of Freiburg
  - Led by Prof. Wolfram Burgard

- **ELEC 5660 Introduction-to-Aerial-Robotics**
  - Hong Kong University of Science and Technology
  - Led by Prof. Shaojie Shen

Teaching Team

- Instructor
  - Huan Yin
    - eehyin@ust.hk
    - Office Hour: by appointment

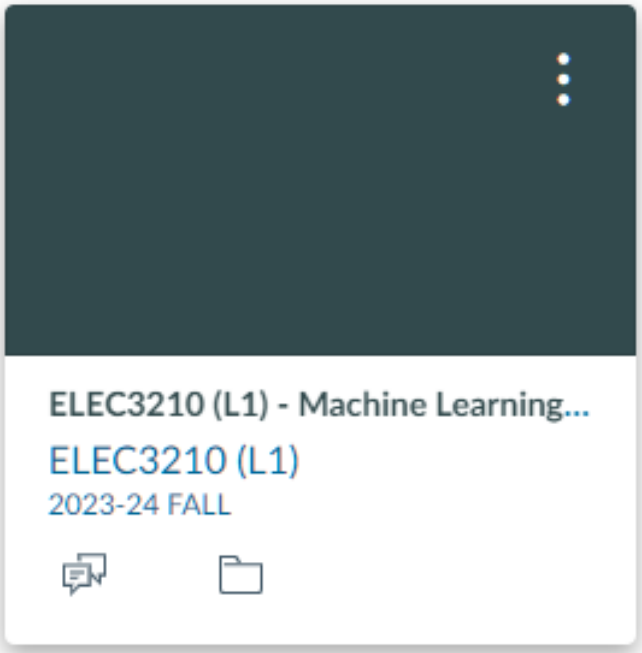


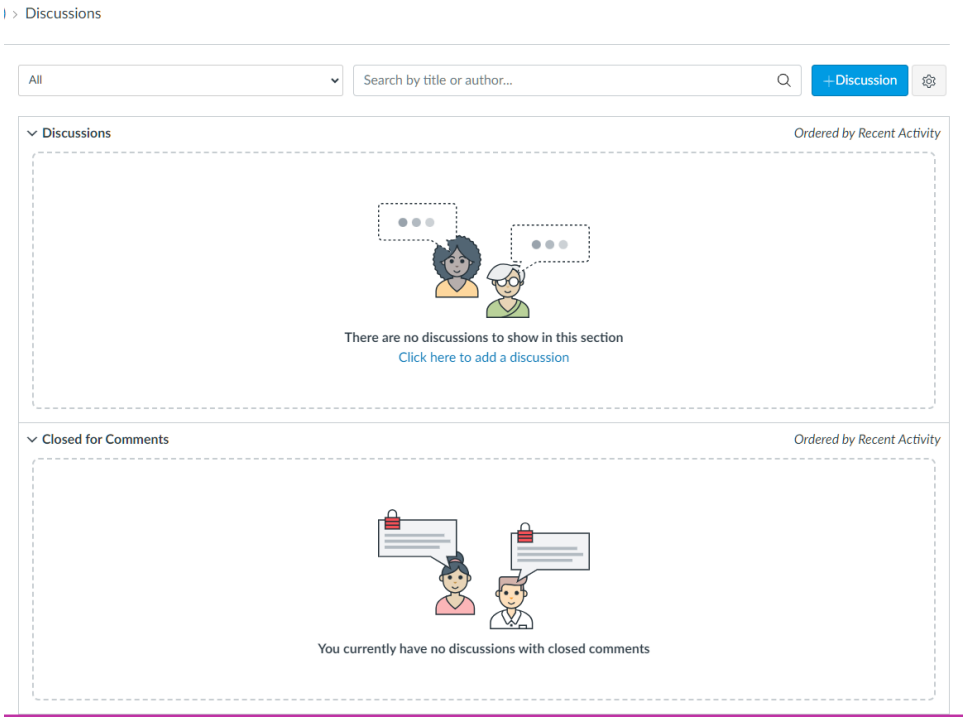
- Teaching Assistants
  - Zhijian Qiao
    - zqiaoac@connect.ust.hk
  - Qiucan Huang
    - qhuangag@connect.ust.hk

- TAs Q&A
  - Meeting Room, Floor G, CKSRI (University Center)
  - Every Thursday 19:00-20:00

Canvas - Discussion

- Open for questions and answers





Administrative Stuff

HKUST

- Lecture
  - Monday 9:00 - 10:20 am
  - Wednesday 9:00 - 10:20 am
  - CYTG003 Room

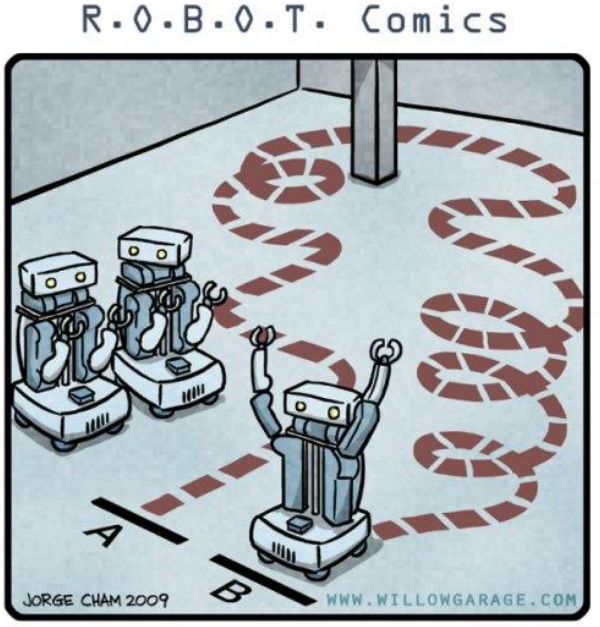
- Students who are not registered are welcome to sit in the lectures, but their assignments will not be graded

- Course Website - Canvas

- I will upload slides (pdf) to Canvas after each lecture

About

- Autonomous Navigation
- Wheeled Mobile Robot
- Sening and Estimation
  - Kalman Filter
  - Particle Filter
  - Graph Optimization
- Motion Planning
  - Path Planning
  - Trajectory Planning
- Frontiers of Mobile Robotics
- 2D Laser-based ROS Projects



Syllabus (Tentative)

- On Canvas

■ Timetable (Tentative)

Lecture	Date	Contents	Projects
L1	04/09	Robotics, Autonomous Mobile Robot	(Install Ubuntu & ROS)
L2	06/09	Pose, ROS	
L3	11/09	Localization, Wheeled Locomotion	
L4	13/09	Sensors	
L5	18/09	Iterative Closeset Point	P1 - ICP odometry
L6	20/09	Map Representations	
L7	25/09	Bayes Theorem, Gaussian Distribution	
L8	27/09	Particle Filter and MCL	
	2/10, 4/10	National Day / IROS 2023 Conference	
L9	09/10	Kalman Filter, EKF	P1 Out
L10	11/10	SLAM and EKF SLAM	P2 - EKF SLAM
L11	16/10	Fast SLAM with Particle Filter	
L12	18/10	Graph SLAM	
L13	25/10	Place Recognition	
L14	30/10	Advanced Topic – Visual SLAM 1 (TBD)	

Not About

- Soft Robotics
- Mechanics
- Machine Learning
- Swarm
- Vehicular Communication
- Robot Motion and Control (ELEC 4220 Prof Fumin Zhang)
- Robotic Manipulation (ELEC 4220 Prof Fumin Zhang)
- Drones (ELEC 5660 Prof Shaojie Shen)
- Visual-Inertial SLAM (ELEC 5660 Prof Shaojie Shen)
- etc

Projects Requirements

HKUST

- Form a team with 1 / 2 / 3 people

- For each project, submit report, code and video
  - report 2 page, claim the contribution
  - code in C++
  - video in 1 min

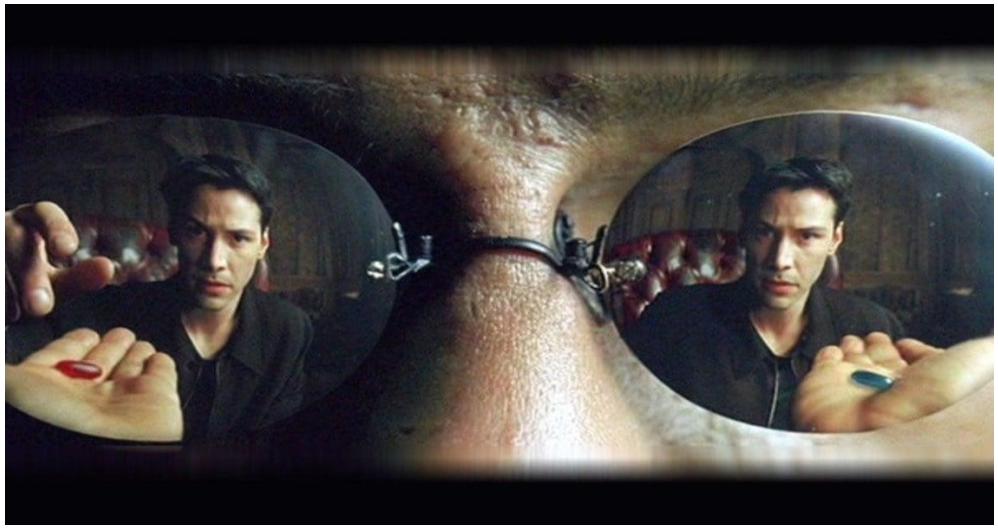
- Install the **Ubuntu and ROS** following the EnvSetup.pdf
  - This is the foundation

Projects Requirements

- 100% Programming for projects
- Virtual labs on ROS (**R**obot **O**perating **S**ystem)
- Will introduce the projects at the end of L1

Requirements

- Love Robots ☺
- Basic Math
  - Linear Algebra
  - Probability
- Programming (Important!)
  - C++
  - Linux + ROS (**R**obot **O**perating **S**ystem)



Grade (Tentative)

HKUST

- Quiz 20%
  - Randomly in lectures
  - 1 page A4 paper
  - Maybe 4~6 times
- Homework 30%
  - Submit after letures in due time
  - Maybe 3 times
- Group Projects
  - Proj 1 10%
  - Proj 2 20%
  - Proj 3 20%

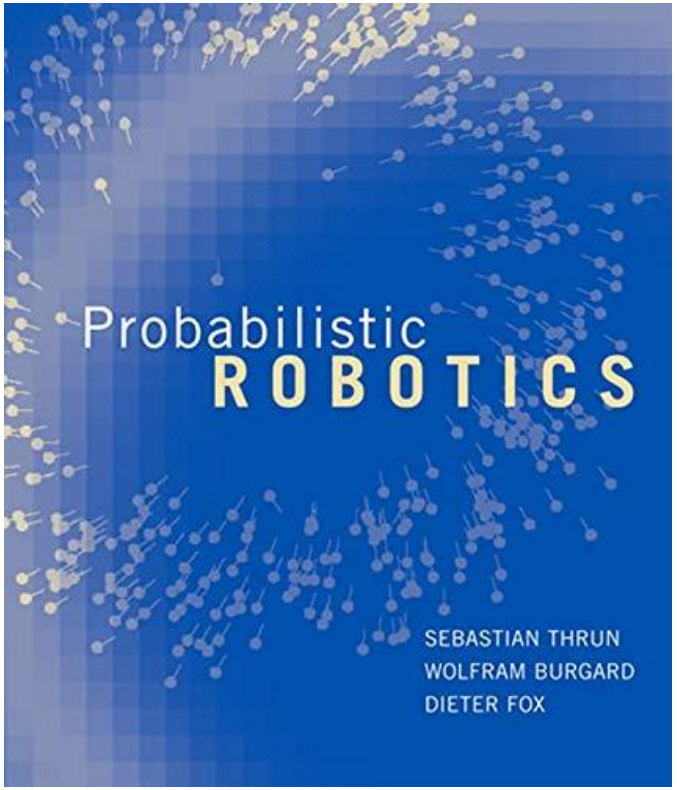
How to fail ELEC 3210?

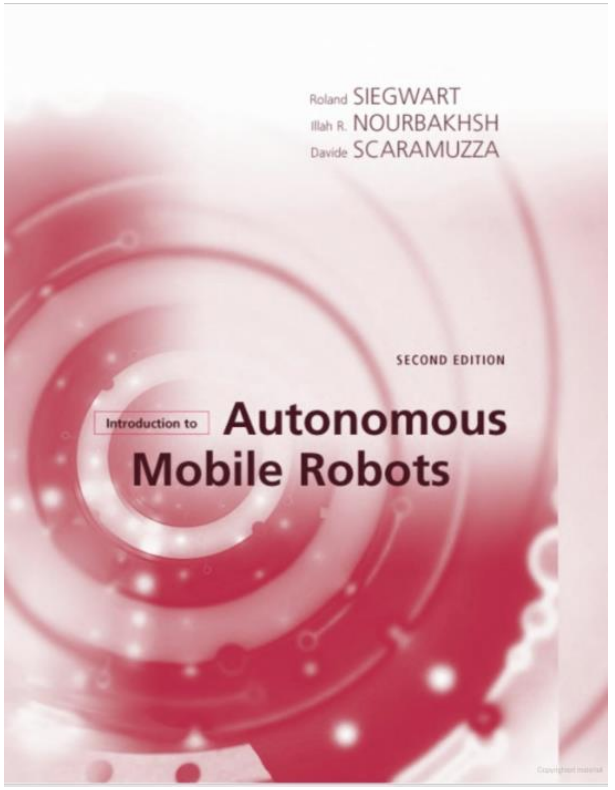
- Missed quizzes multiple times

- Late submissions of assignments
  - Homework
  - Project

Books (Non-Compulsory)

- Probabilistic Robotics
- Introduction to Autonomous Mobile Robots





More Resources

- Books & Online Videos
  - Mastering ROS for Robotics Programming (Help Programming)
  - Handbook of Robotics (a dictionary)
  - State Estimation for Robotics (Lots of Math)
  - 5 Minutes with Cyrill (Prof. Cyrill Stachniss)
  - …

Today's Outline

- Robotics: History and Taxonomy
- Mobile Robots
- Autonomous Navigation System

Robotics: History and Taxonomy

Robot

HKUST

- Definition
  - A robot is a machine—especially one programmable by a computer—capable of carrying out a complex series of actions automatically.
  - Definition of 'robot'. Oxford English Dictionary. Retrieved 27 November 2016.

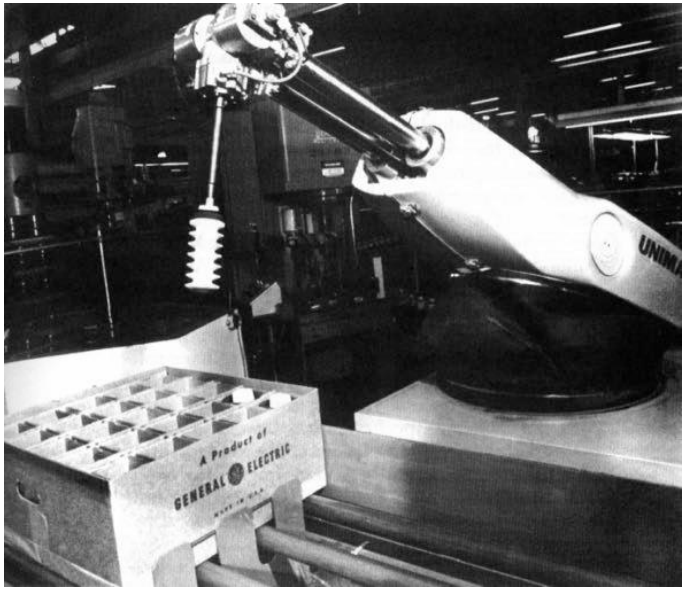
Robot

- Definition
  - A robot is a machine—especially one programmable by a computer—capable of carrying out a complex series of actions automatically.
  - Definition of 'robot'. Oxford English Dictionary. Retrieved 27 November 2016.

- Question
  - Is ChatGPT a robot?

First Robot

- The first digitally operated and programmable robot was invented by George Devol in 1954 and was ultimately called the Unimate



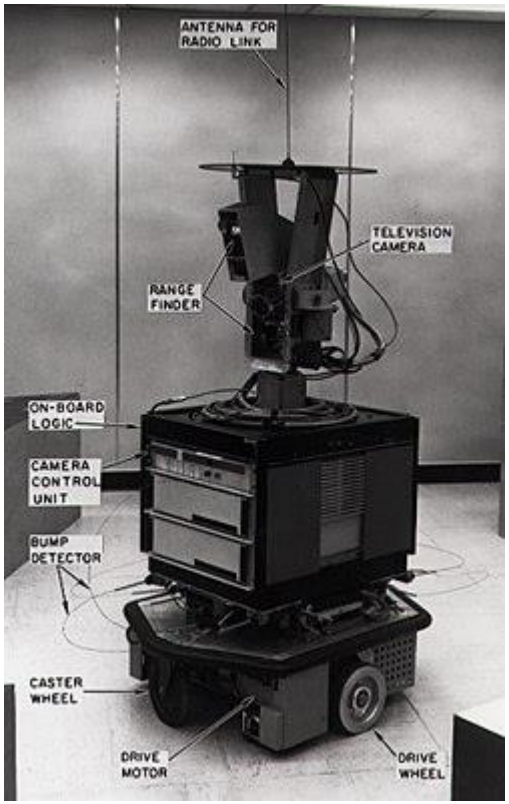
Industrial Robot, 1960s

Pouring Coffee, 1960s

Courtesy: Wikipedia and Rong Xiong

First Mobile Robot

- Shakey the robot
- The first general-purpose mobile robot able to reason about its own actions
- Developed from 1966 to 1972, at the Artificial Intelligence Center of Stanford Research Institute (SRI)
- Still in Computer History Museum



Shakey, 1972

Courtesy: Wikipedia

Experiments using Shakey

Courtesy: YouTube

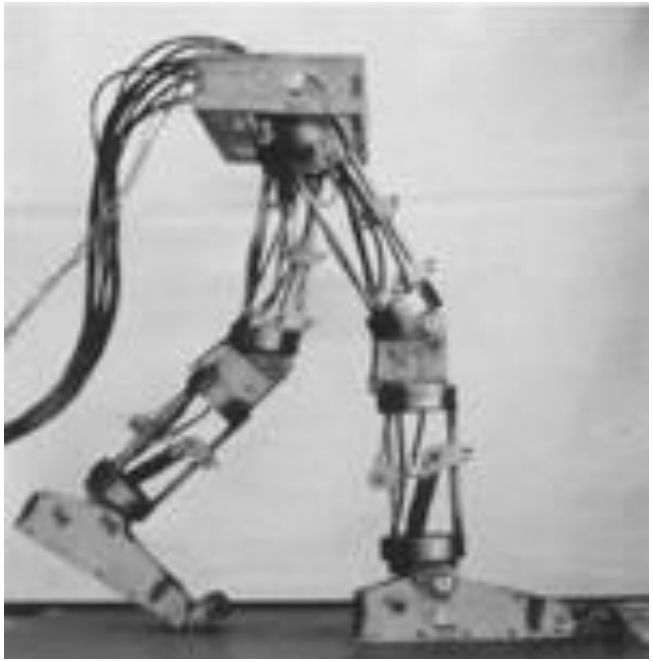
IEEE Milestone Award

Shakey's creators at the 2017 IEEE Milestone award event

Courtesy: Wikipedia

First Biped Walking Robot

- Waseda University, Japan (1968-1969)
- was able to stand up and sit down



WL-3 (1969)

Courtesy: Rong Xiong

First Mars Robot (Rover)

- 1997, named Sojourner
- Equipped with front and rear cameras
- Traveled over 100 meters then lost signal

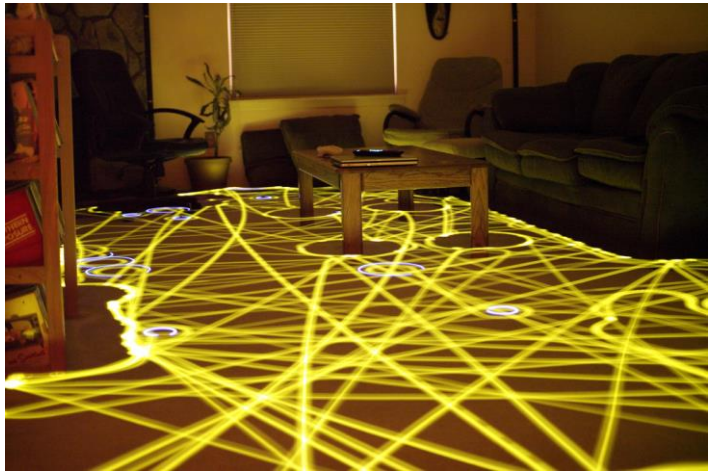
***Sojourner* rover pictured by *Pathfinder* lander**

Controlled by "Rover Control Software" (RCS)

Courtesy: NASA, Wikipedia

First Robot Cleaner

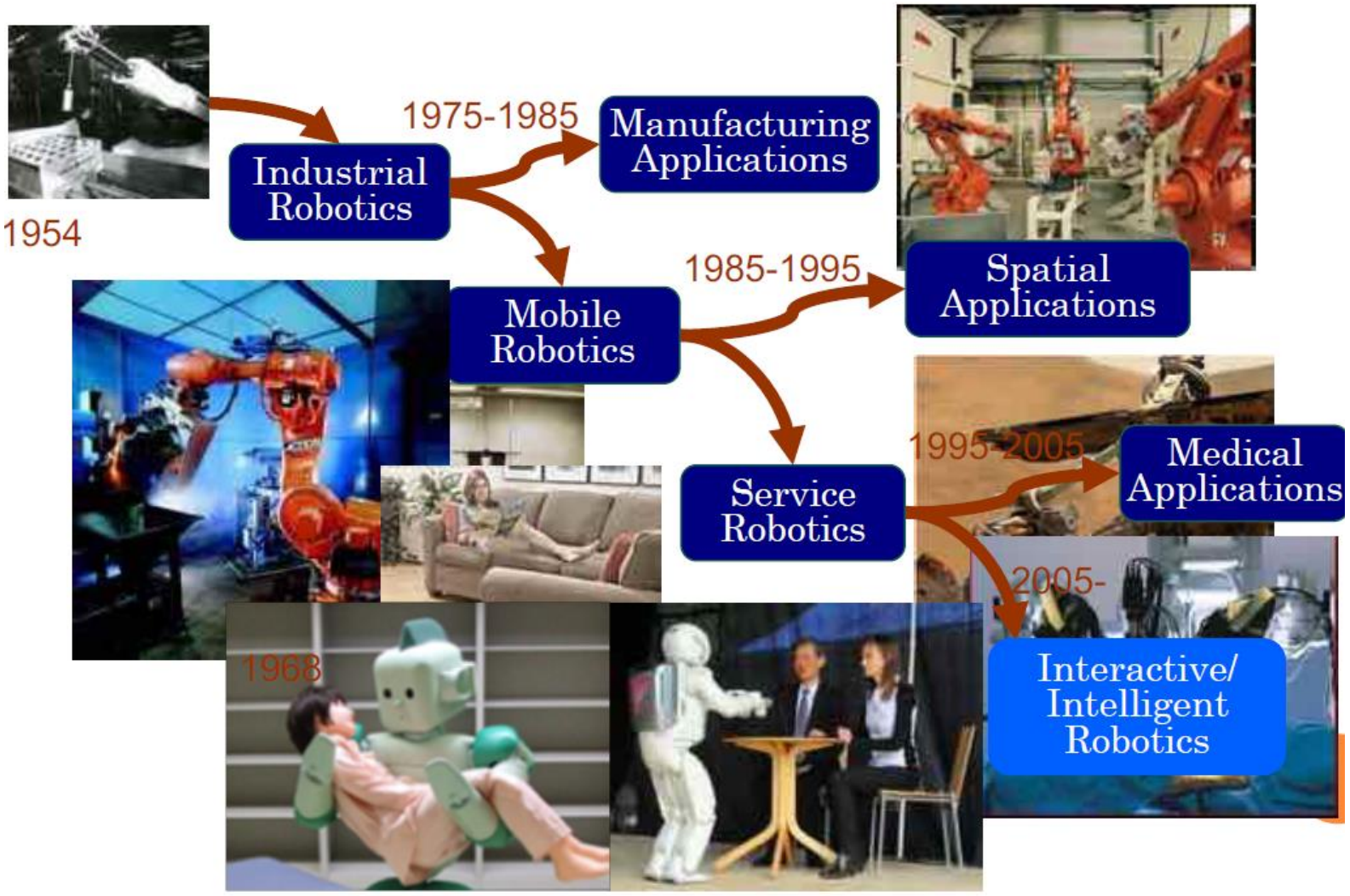
- Roomba, the autonomous robotic vacuum cleaners
- Made by the company iRobot, 2002
- Why so late for commercial-used mobile robot?



Long exposure photo showing path taken by a Roomba as it cleans

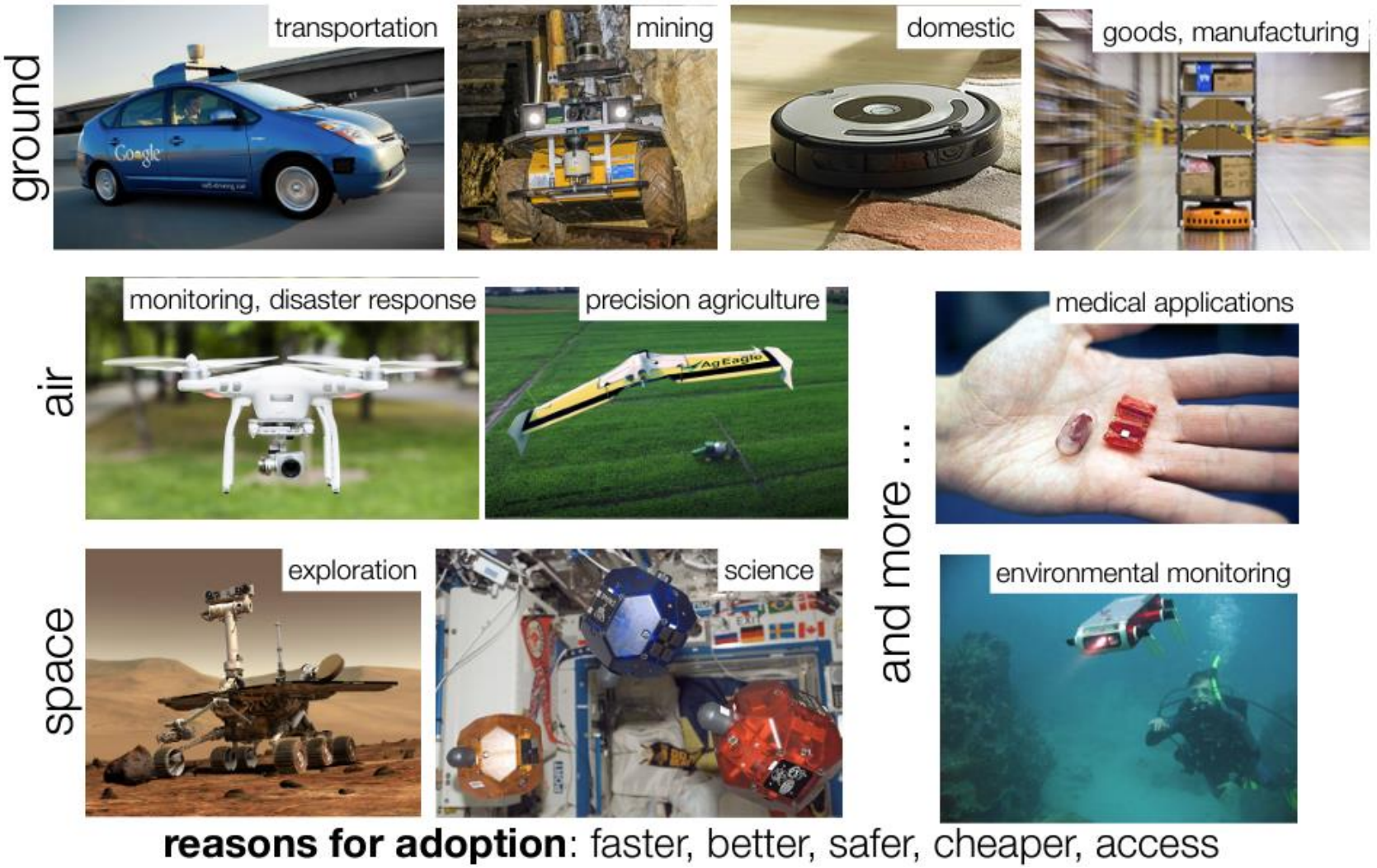
Courtesy: Wikipedia

History



Courtesy: Rong Xiong

These are all mobile robots



Courtesy: Luca Carlone

Taxonomy of Mobile Robot

HKUST

- In terms of
  - woking environments
    - indoor, outdoor, underwater, space etc
  - mobility
    - drones, legged, trunk, track, wheeled etc
  - applications
    - medical, transportation, algriculture, construction etc
  - etc

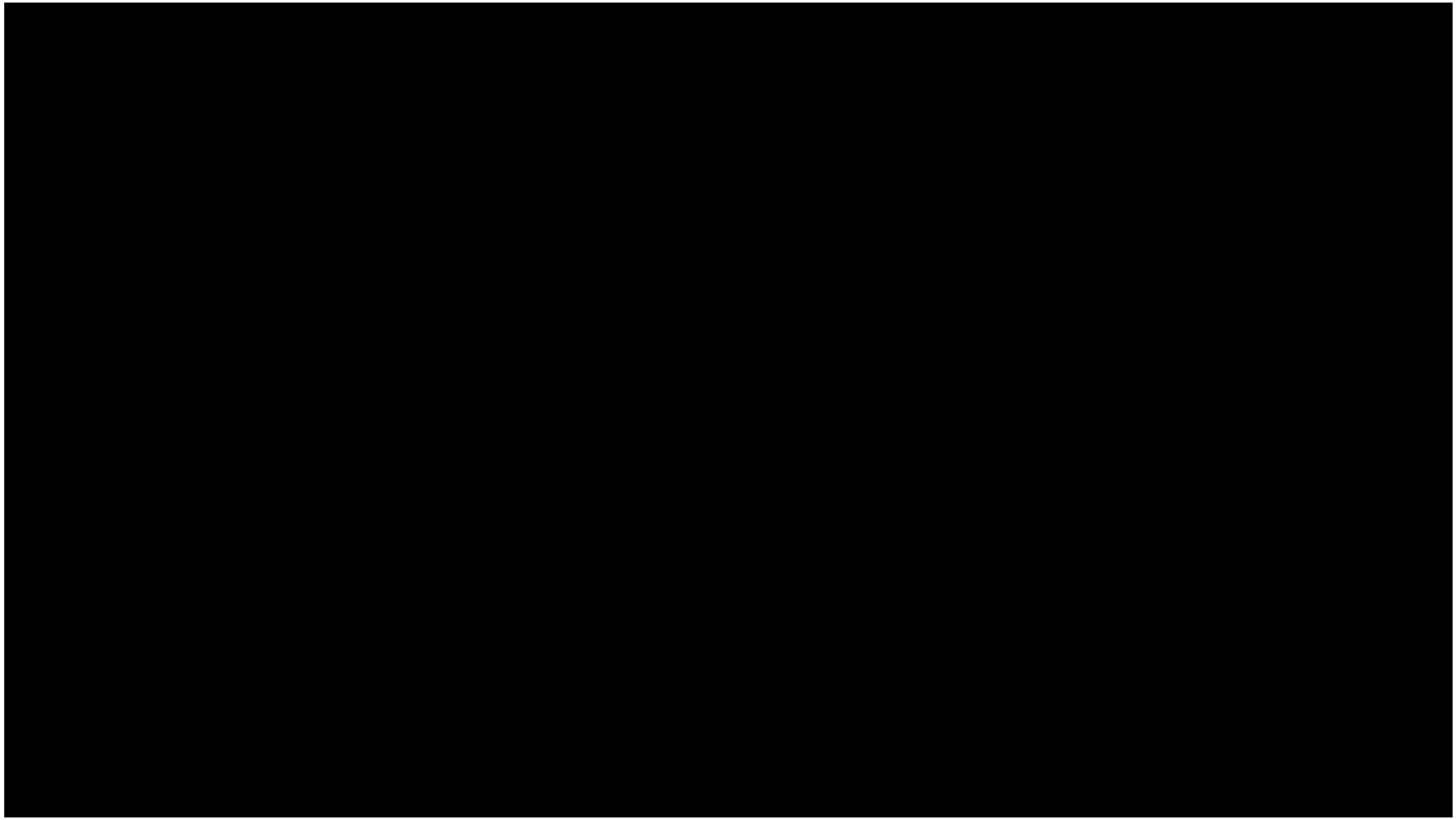
Mobility - Flying

- Video 2016 from HKUST UAV Group

Courtesy: Shaojie Shen

Mobility - Trunk

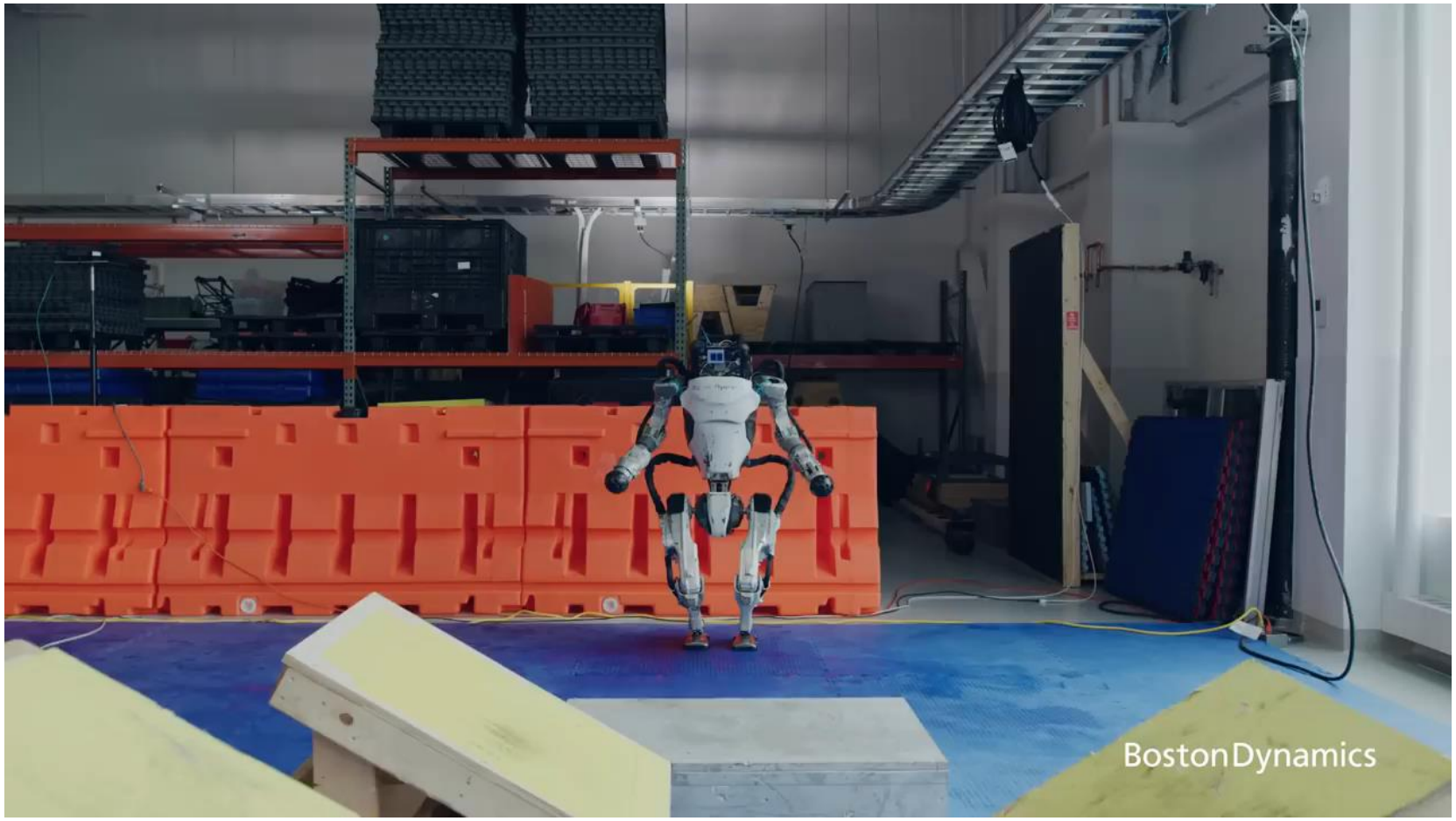
- CMU Snake Robot



Courtesy: CMU RI

Mobility - Legged

- Atlas, best robot in the world (my opinion)



Courtesy: Boston Dynamics

Taxonomy of Mobile Robot

HKUST

- In terms of
  - woking environments
    - indoor, outdoor, underwater, space etc
  - applications
    - medical, transportation, algriculture, construction etc
  - mobility
    - wheeled, flying, legged, trunk, track, etc

Application - Transportation

- Self-Driving at Shanghai SeaPort

Courtesy: Huan Yin

Application - Transportation

- Autonomous vehicle at HKUST Campus

Courtesy: HKUST SENG

Application – Manufactoring

- Autonomous mobile robot at Amazon Warehouse

Courtesy: Amazon

Application - Soccer Game

- RoboCup Kid-Size Humanoid League in 2016

Courtesy: Huan Yin

Autonomous Mobile Robots (AMR)

Two basic branches

Robot Manipulator

Mobile Platform

Courtesy: Rong Xiong

Mobile manipulator

- A robot system built from a robotic manipulator arm mounted on a mobile platform, still challenging nowadays
- For Algricultural Applications

Courtesy: YouTube

Why intelligent or autonomous?

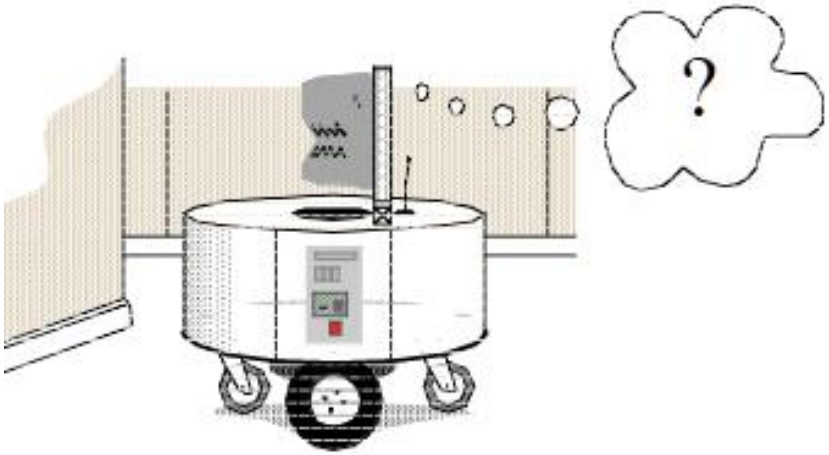
- Get rid of Human Control
- Save Time, Save Money, More Safety
  - Semi-Autonomy with Human-Robot Collaboration
  - Fully autonomous without human

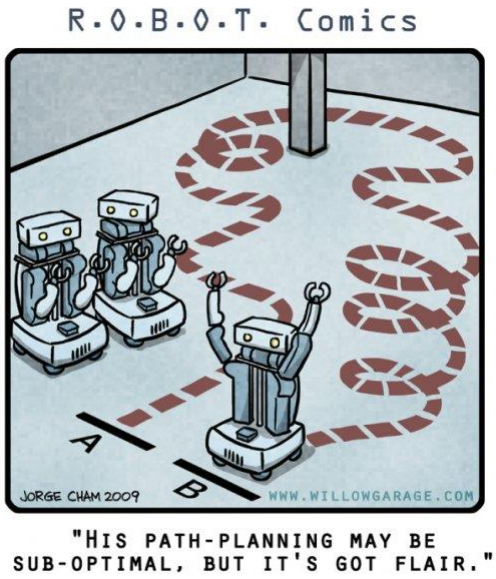
semi-autonomous mobile drilling robot, HILTI Group

fully-autonomous mobile robot, warehouse in Amazon

Three questions for AMR

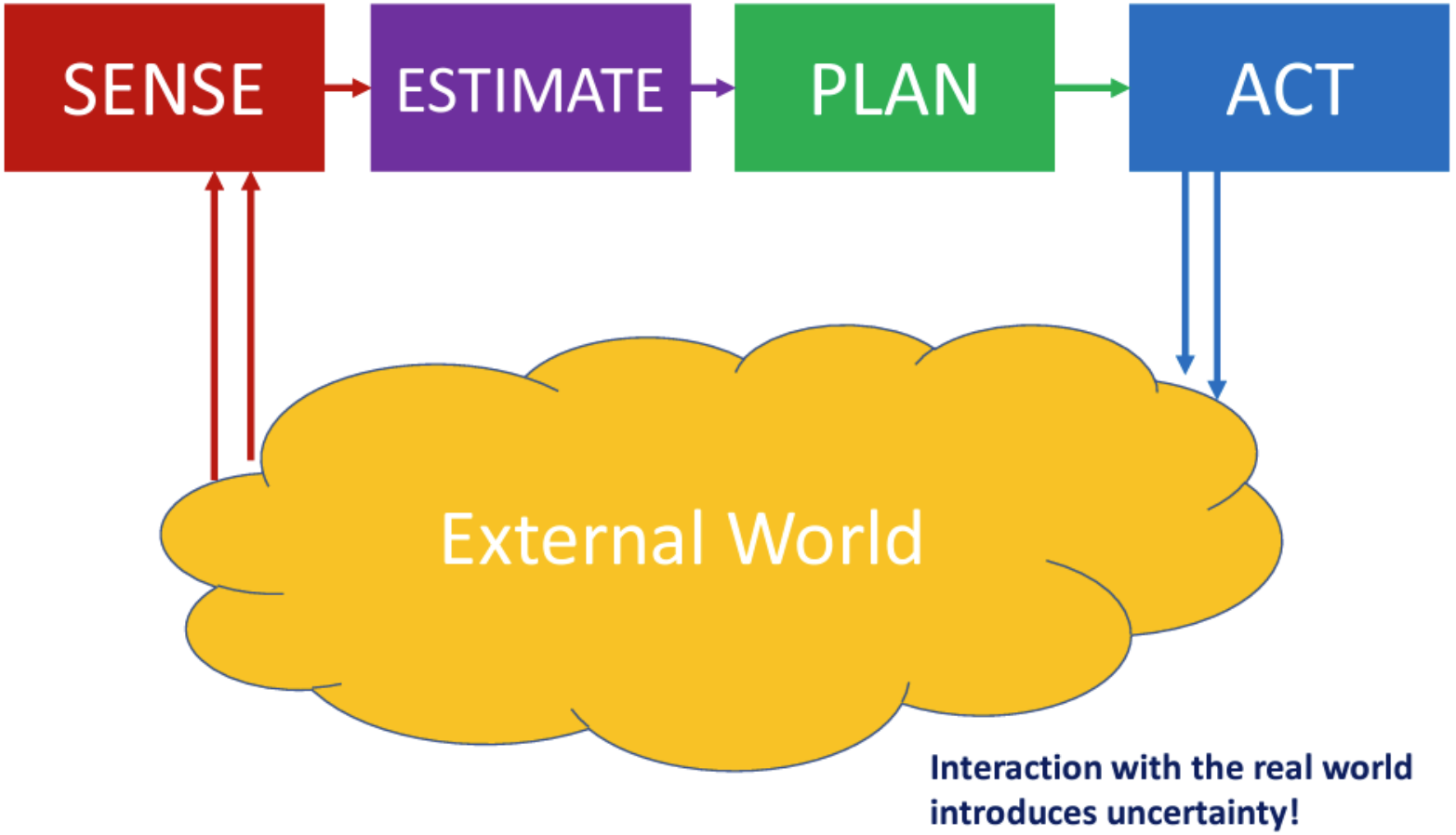
- Where am I ? (Sensing/Estimation)
- Where am I going ? (Planning)
- How do I get there ? (Control)





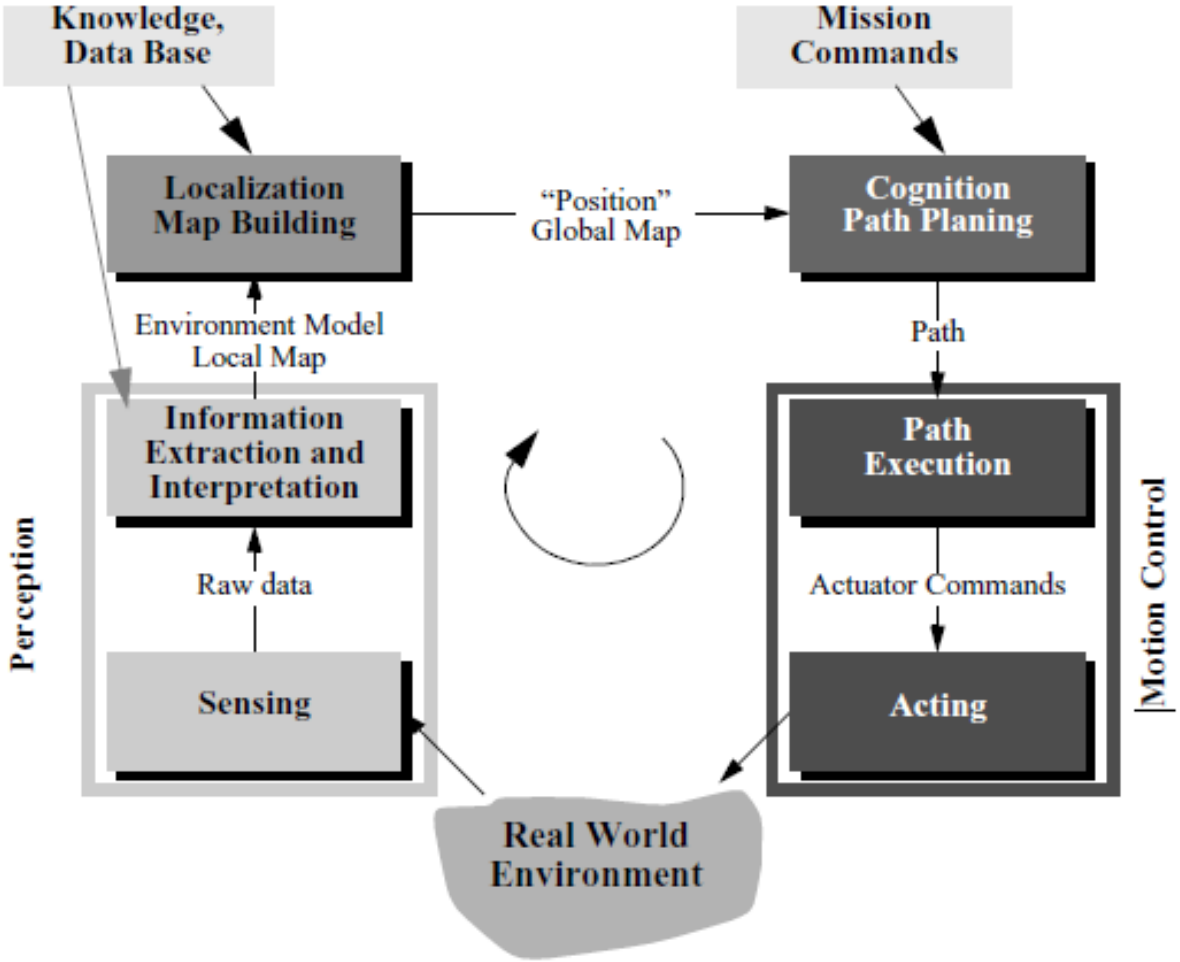
AutoRobot Scheme

- Sensing, Estimation, Planning, Control (Act)



Courtesy: Nikolay Atanasov

AMR Scheme

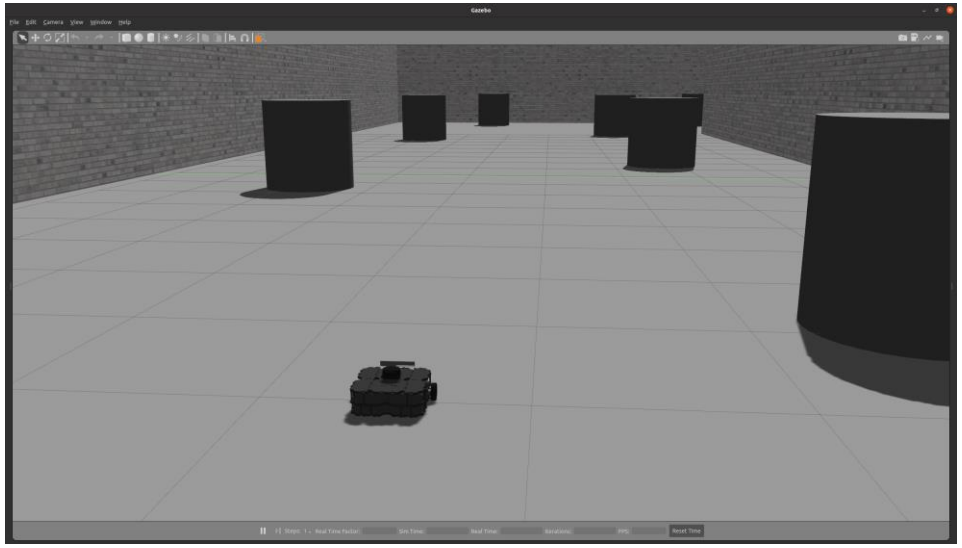


Courtesy: Introduction to Autonomous Mobile Robots

Projects

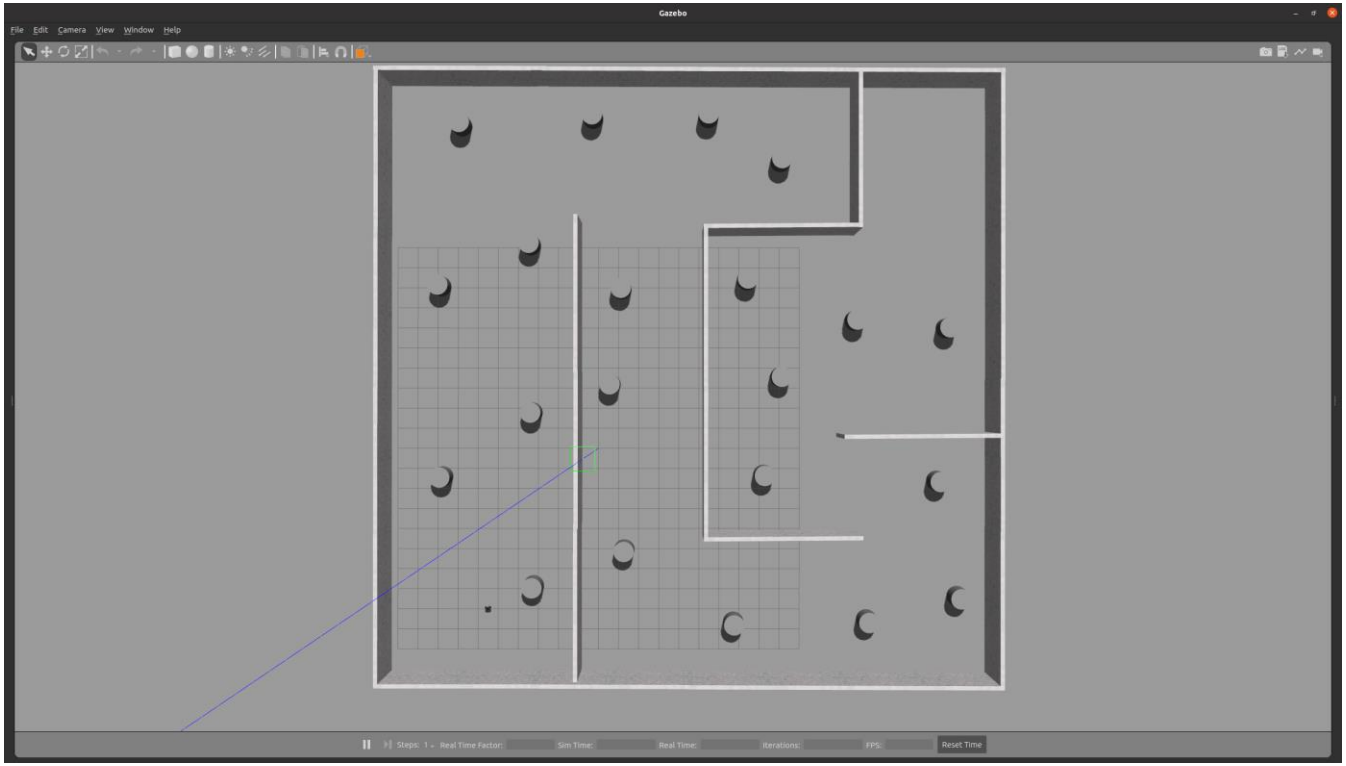
Virtual Lab

- No lab time, On your PC
- A mobile robot with a LiDAR Scanner



Virtual Lab

- on Gazebo, ROS
- Provide Rosbag for projects



P1 -ICP Mapping

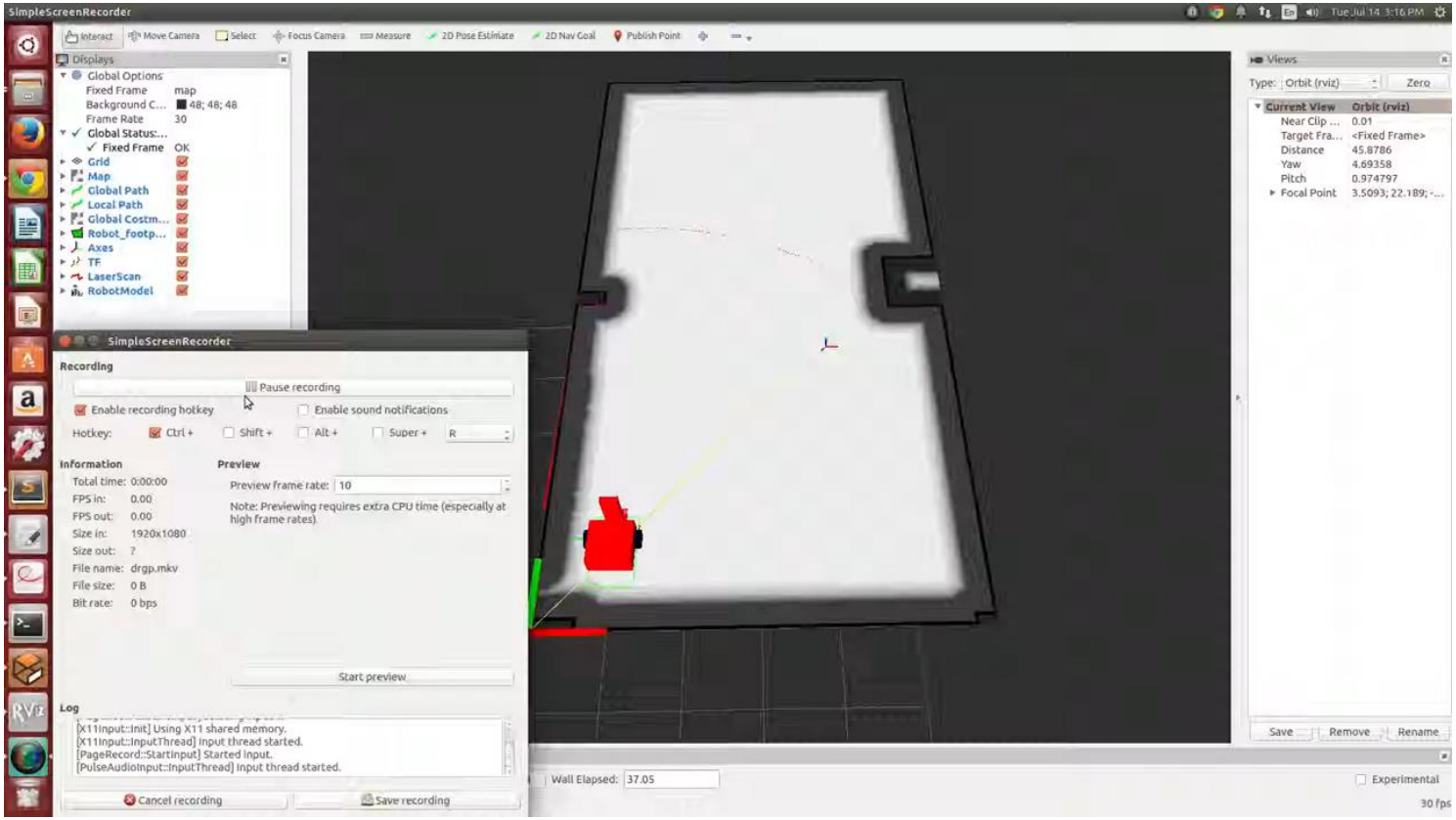
- LiDAR Odometry and Mapping by Iterative Closest Point (ICP)

P2 - EKF SLAM

- Landmark-based Laser EKF SLAM
  - Extended Kalman filter (EKF)
  - Simultaneous localization and mapping (SLAM)

P3 - Path Planning

- Path Planning for mobile robot
  - A* / RRT

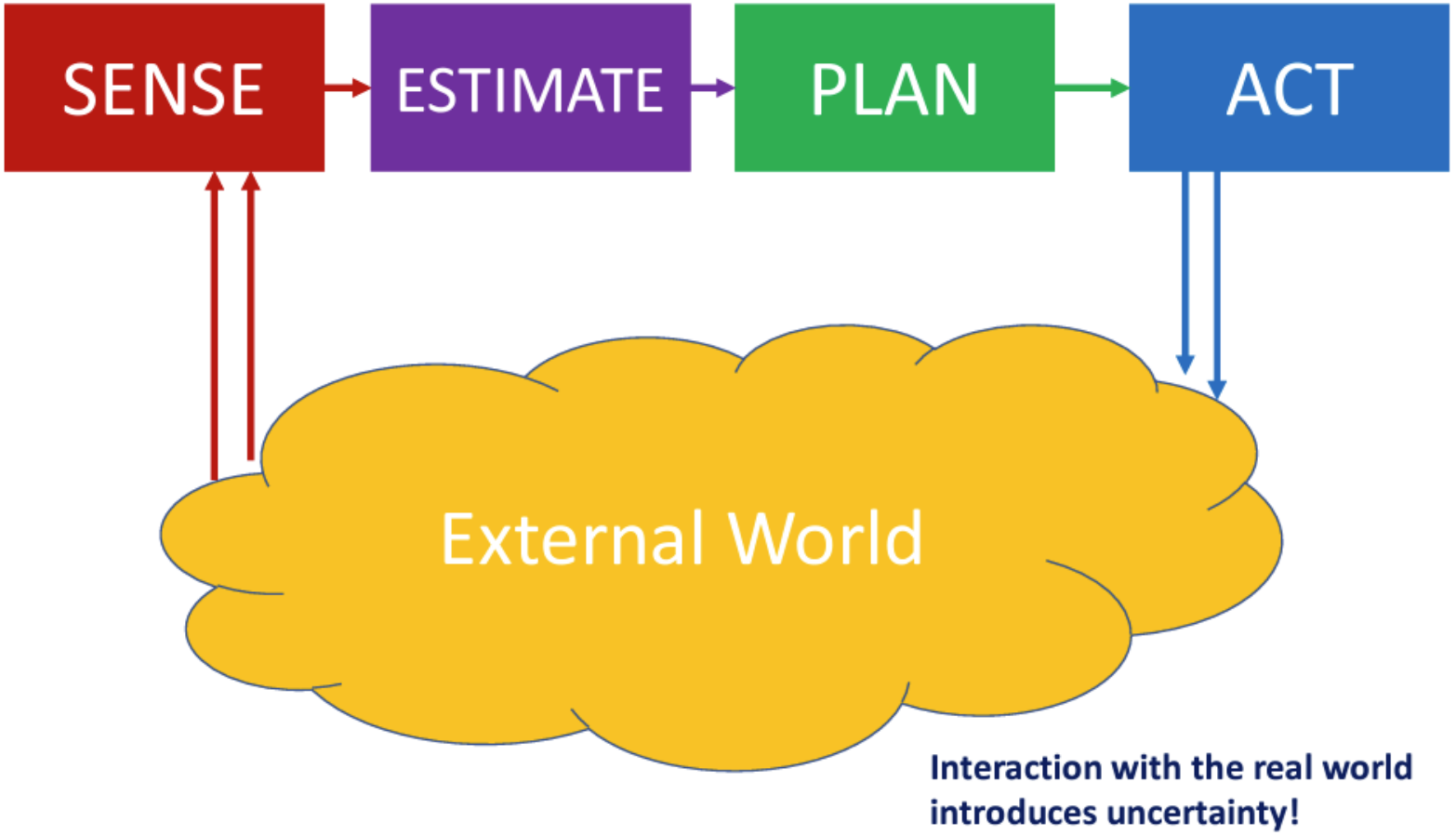


Summary

- Logisitics of ELEC 3210
- Robotics: History and Taxonomy
- Autonomous Mobile Robots (AMR)

Back to Scheme

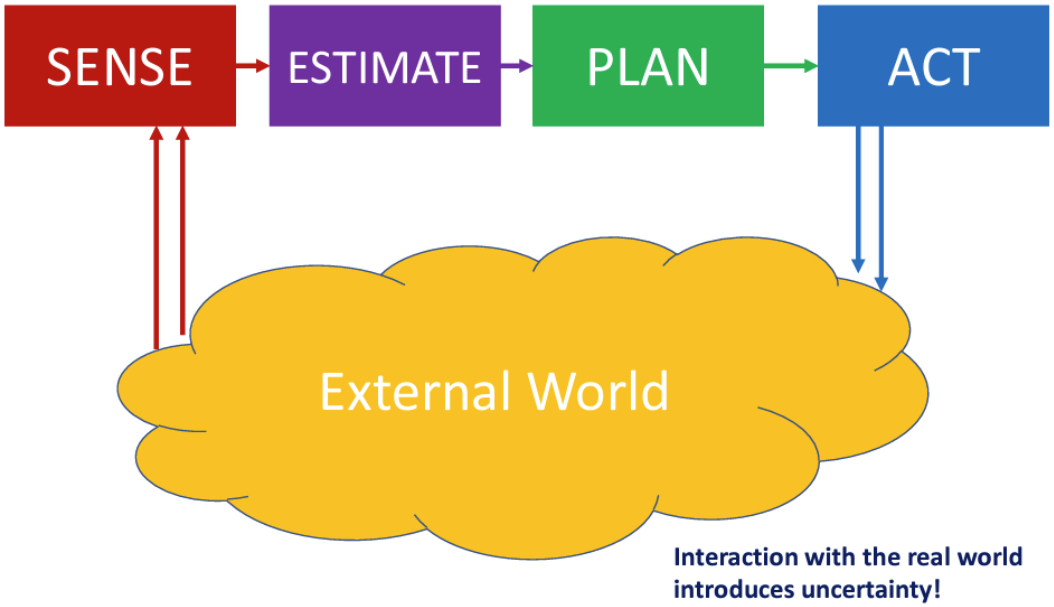
- What is the flow?



Courtesy: Nikolay Atanasov

From a "pose" perspective

- Sensing&Estimation - Estimate current and past robot pose
- Planning - Generate future robot pose
- Control - Stabilize robot pose



Courtesy: Nikolay Atanasov, PyPose Video

Next Lecture

- Pose
- Robot Operating System (ROS)
  - If have time