Introduction to Mobile Robotics

Lecture 1: Introduction

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Syllabus

Goal of this course:

- Provide an overview of problems and approaches in mobile robotics.
- Hands-on experience (with ROS 2).

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Syllabus

Course schedule:

- **Weeks 1-3: Foundations.** ROS 2 setup, software architecture, and system integration.
- **Weeks 4-6: Robot Motion & Perception.** Locomotion, kinematics (URDF, tf2), and sensors.
- **Weeks 7-8: Core Autonomy.** Simultaneous Localization and Mapping (SLAM) and exploration strategies.
- **Weeks 9-11: Navigation & Advanced Topics.** Path planning, navigation stack (Nav2), and multi-robot systems.
- **Weeks 12-18: Exam & Final Project.**

Full schedule:

`https://yzrobot.github.io/introduction_to_mobile_robotics/`

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References

Textbooks:

- David FILLIAT. **Robotique Mobile**. ENSTA.
- Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza. **Introduction to Autonomous Mobile Robots**. MIT Press.

Extended reading:

- Sebastian Thrun, Wolfram Burgard, and Dieter Fox. **Probabilistic Robotics**. MIT Press.
- Howie Choset, Kevin M. Lynch, Seth Hutchinson, George A. Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun. **Principles of Robot Motion: Theory, Algorithms, and Implementations**. MIT Press.

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Grading

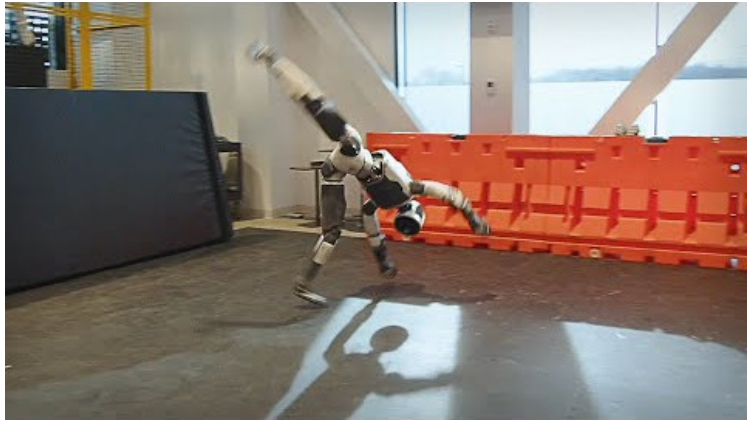
- Project: 40%
- Exam (written and programming): 30%
- Practical work: 30%[1]

[1] Within two weeks of each TP being completed, email me a PDF containing any information you feel demonstrates that you completed that TP (a few words, screenshots, output, code, etc.).

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Mobile Robotics Today

Represented by YouTube celebrity Boston Dynamics:



What Is a Robot?

Origin of Words

- The word **robot** was first used in 1921 by Czech author Karel Capek in his science fiction play R.U.R. (Rossum's Universal Robots).
- It comes from the Czech word "robota", which means "forced labor".

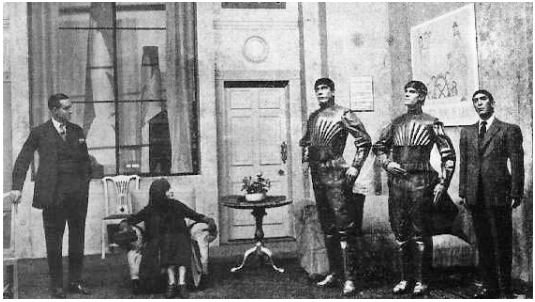


Figure: A scene from the play, showing three robots.

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What Is a Robot?

According to the Oxford Dictionary: A robot is a machine that can perform a complicated series of tasks by itself.

- Definition reflecting to people's expectations for robot **autonomy**.
- Existing robots have a wider range of manifestations: fully autonomous, semi-autonomous, remote controlled, etc.
- The impact on the labor market: a supplement while at the same time generating competition.
- The ethical issues: compliant human ethics, military use, etc.

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A Brief History of Robotics

- **Ancient Times:** Concepts of automatons and mechanical servants appear in myths and early engineering.
- **1954:** George Devol patents the "Unimate," the first industrial robot arm.
- **1966:** "Shakey" the robot is developed at Stanford Research Institute (first mobile robot to reason about its own actions).
- **1990s:** Rise of behavior-based robotics (Genghis from MIT).
- **1997:** Sojourner rover successfully explores Mars.
- **2000s:** DARPA Grand Challenge accelerates autonomous vehicle research. Roomba popularizes domestic robots.
- **2010s-Present:** Deep learning revolutionizes perception. Advanced humanoids (Atlas) and widespread use of drones and warehouse robots (Amazon Kiva).

From fixed industrial arms to intelligent, mobile machines.

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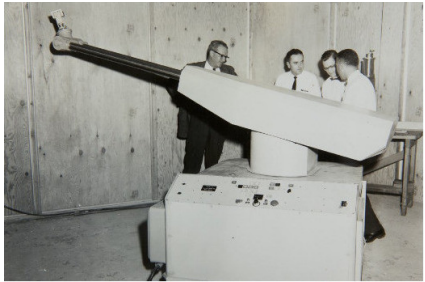
Robot Taxonomy

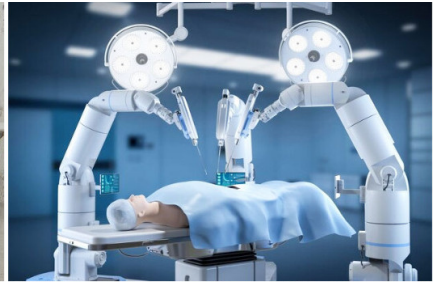
According to the International Federation of Robotics (IFR), existing robots can be divided into two categories:

- **Industrial robot**: An automatically controlled reprogrammable multipurpose manipulator, programmable in three or more axes.
- **Service robot**: A robot that performs useful tasks for humans or equipment excluding industrial automation applications.

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Robot Taxonomy









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Industrial vs. Service Robots

Industrial robots

- **Purpose:** Precision tasks in structured, controlled environments like factories.
- **Key feature:** Work in constrained workspaces (rely on absolute position measurements and don't need complex perception of the surroundings).
- **Example:** A robotic arm on an assembly line.

Service robots

- **Purpose:** Assistance in unstructured, dynamic environments.
- **Key feature:** Operate in unconstrained environments (require advanced perception to determine the position and avoid obstacles).
- **Example:** A robotic vacuum cleaner or a surgical robot.

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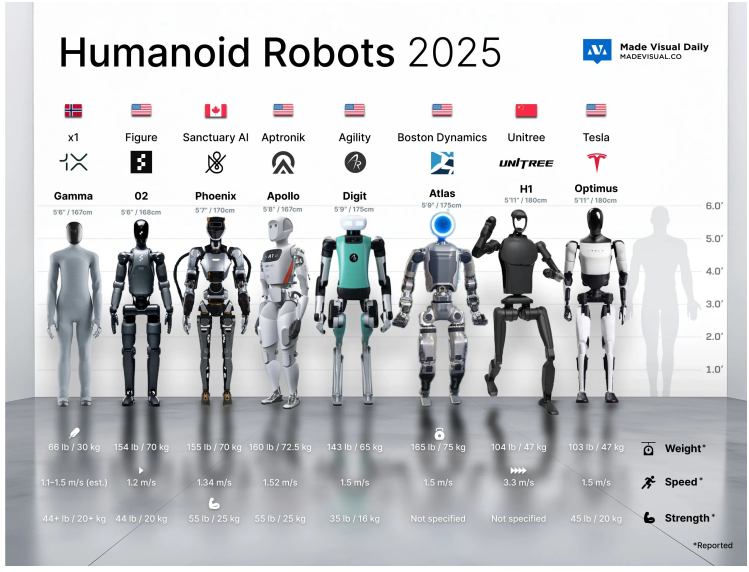
Industrial vs. Service Robots

Current Status:

- Industrial robots: Large-scale deployment.
  $\Longrightarrow$ Simpler, more controllable setups make them easier and more reliable to implement.
- Service robots: Steadily increasing deployment.
  $\Longrightarrow$ Huge market and promising prospects, accompanied by numerous technical challenges.

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Service Robots



Asimov's Three Laws

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

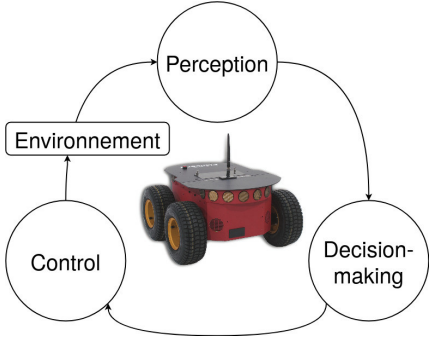
— *short story "Runaround", 1942, by Isaac Asimov*

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Service Robots

Operational definition:

- The "sense-think-act" paradigm: perception, decision-making, and control.
- An abstract imitation of human activities: I feel (see/smell/listen/touch/etc.), I think, and I react.



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Service Robots

Operational definition:

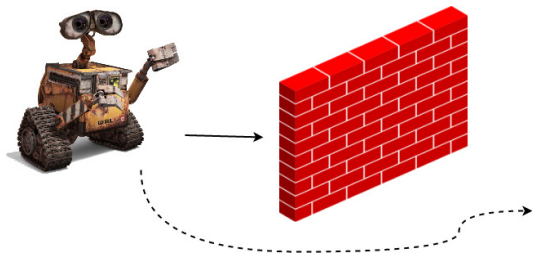
- **Perception**: What looks like around me?
- **Decision-making**: What should I do?
- **Control**: How do I achieve the action?

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An Example

When a robot encounters an obstacle while moving autonomously, it:

- **senses (perception)**: There is an obstacle (i.e. a wall) in front of me.
- **thinks (decision-making)**: Turn slightly to the right to avoid and go around the obstacle.
- **acts (control)**: Adjust the speed of the wheels.



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Service Robots

Current trends:

- Logistics and warehousing (Amazon Kiva)
- Autonomous vehicles (Waymo, Tesla)
- Exploration (Mars rovers, underwater drones)
- Agriculture (automated tractors, harvesting)
- Domestic service (vacuum cleaners, lawnmowers)
- Medical (delivery in hospitals, telepresence)
- Search and rescue
- Security and surveillance
- etc.



Service robots are changing all walks of life!

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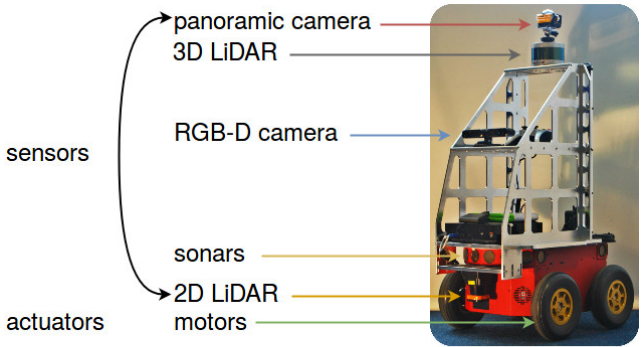
Mobile Robotics

Mobile robotics is concerned with a fundamental question of service robots, namely, how to move in the physical world.

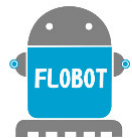
- 3 fundamental questions:
  - Where am I?
  - Where am I going?
  - How to get there?
- To answer these questions the robot must:
  - Take measurements.
  - Model the environment.
  - Locate itself.
  - Plan a path to its goal location.

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An Example







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Questions?

Next: Practical Work 1 - ROS 2 Installation

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