EE/CE 468/468: Mobile Robotics

Fall 2023

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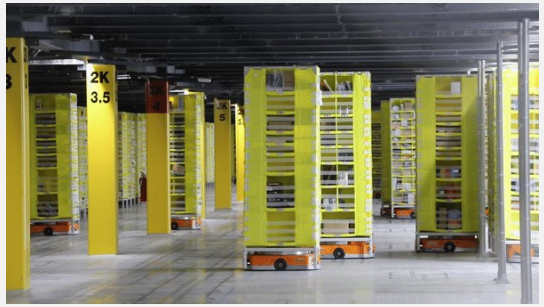
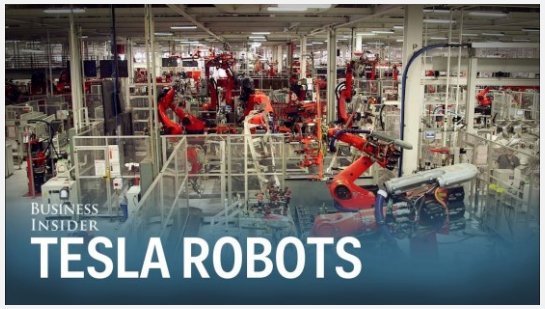


Logistics robots

Delivery Robots



Autonomous manufacturing

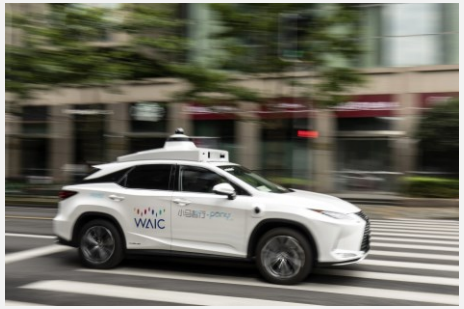
Space Robots

Disaster Robots

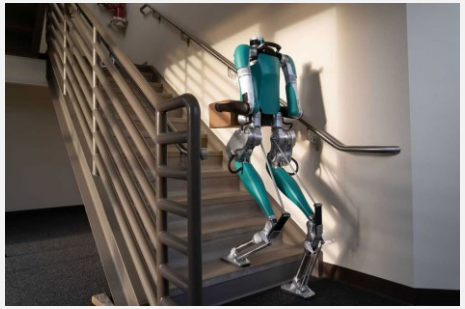
Robot-assisted surgery

Underwater Mining

Agricultural Robots

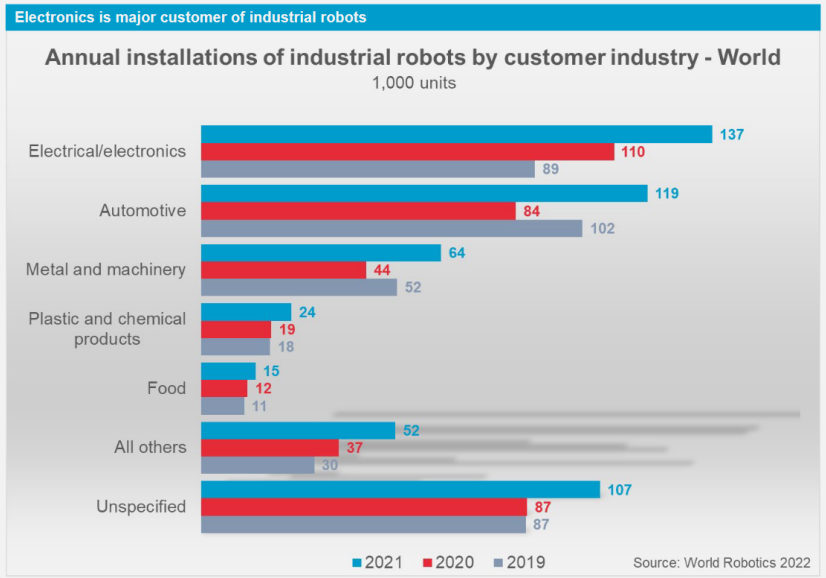


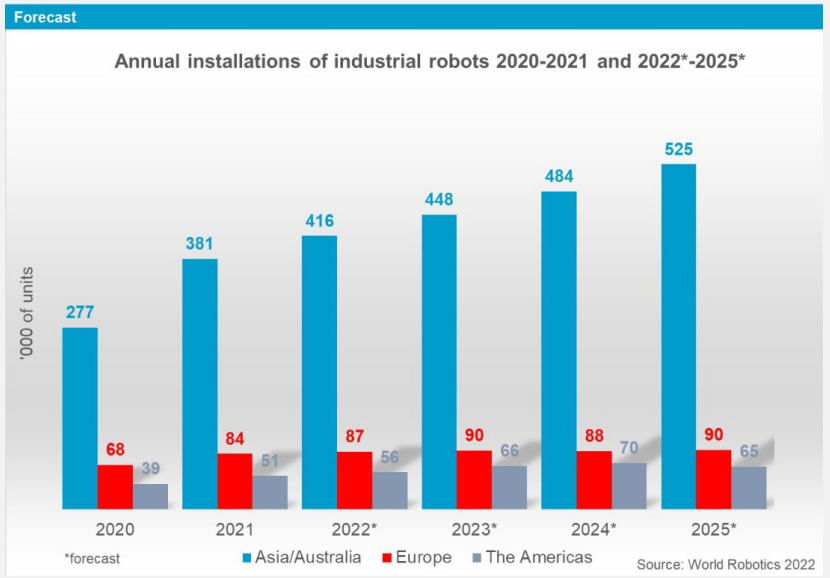
Self-driving cars



Bipedal robots

Snake Robots



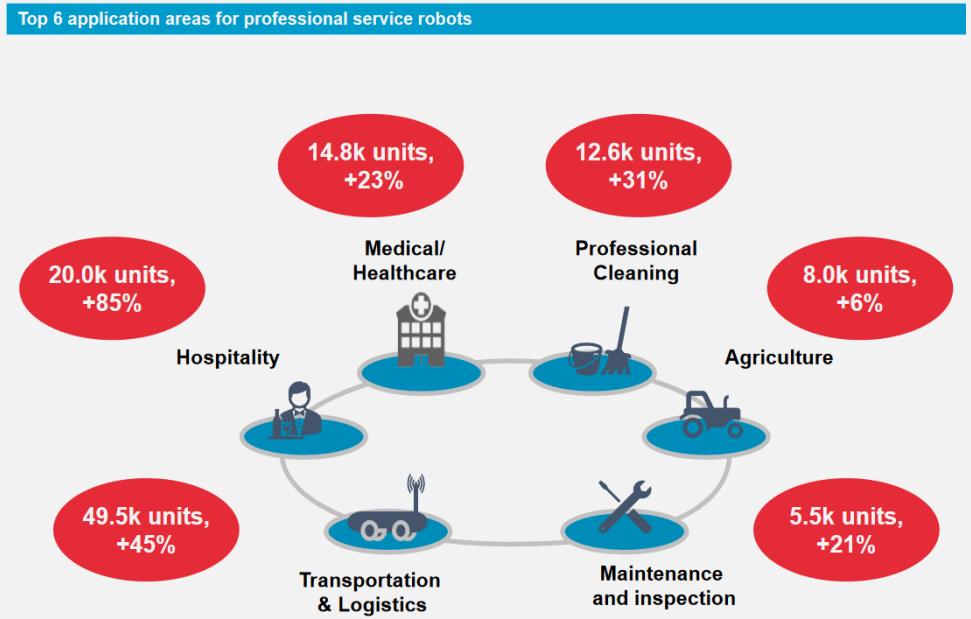


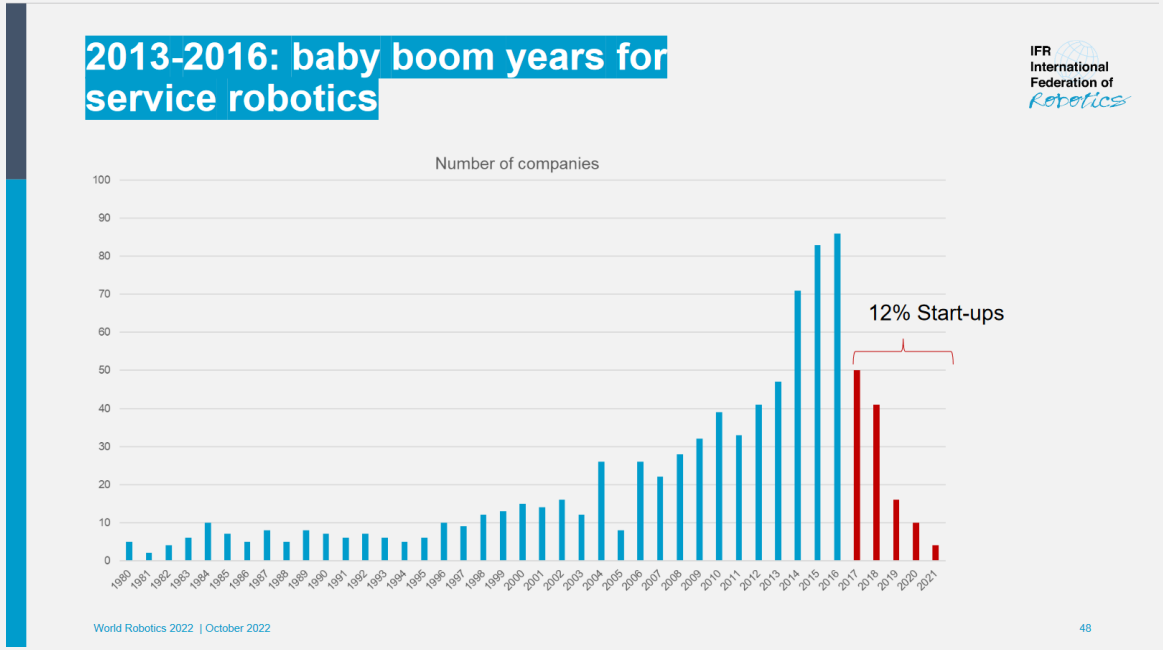
3 D's

Dirty

Dull

Dangerous





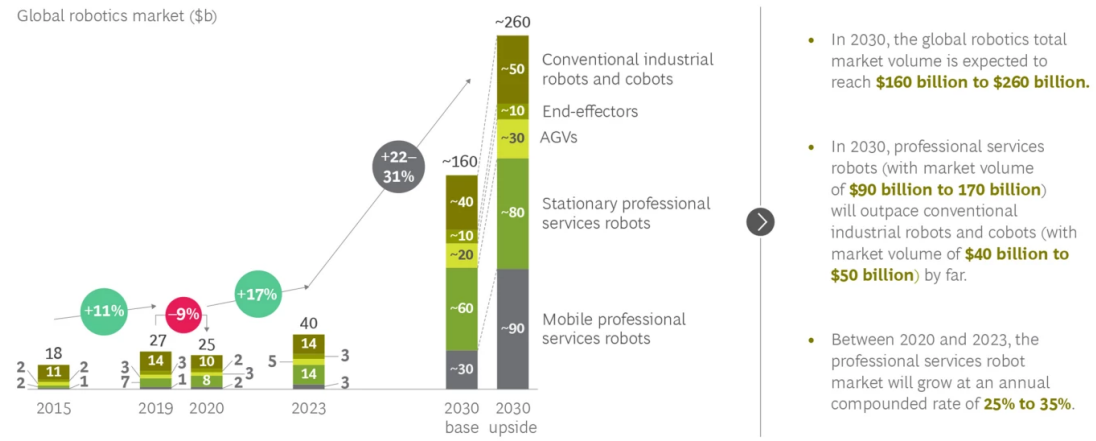
RELATED EXPERTISE: INDUSTRIAL GOODS, DIGITAL, TECHNOLOGY, AND DATA

Robotics Outlook 2030: How Intelligence and Mobility Will Shape the Future

JUNE 28, 2021

By Ralph Lässig, Markus Lorenz, Emmanuel Sissimatos, Ina Wicker, and Tilman Buchner

Exhibit 1 - Professional Services Robots Will Significantly Outpace Industrial Robots and Cobots in 2030

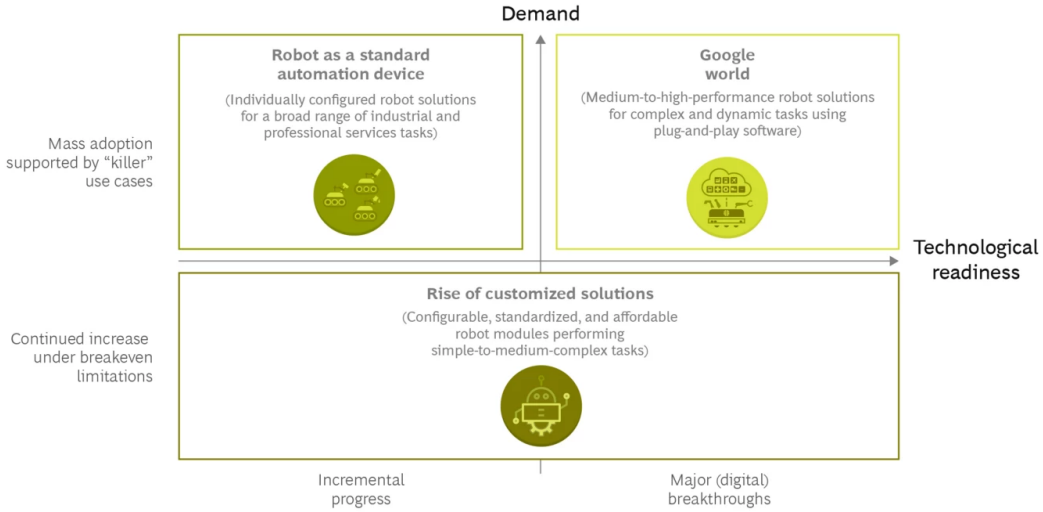


- In 2030, the global robotics total market volume is expected to reach **$160 billion to $260 billion.**
- In 2030, professional services robots (with market volume of **$90 billion to 170 billion**) will outpace conventional industrial robots and cobots (with market volume of **$40 billion to $50 billion**) by far.
- Between 2020 and 2023, the professional services robot market will grow at an annual compounded rate of **25% to 35%**.

Sources: IFR; MarketsandMarkets; BCG market model.

Note: AGVs = automated guided vehicles.

Exhibit 2 - Three Ways the Robotics Industry May Evolve by 2030



Source: BCG analysis.

https://www.bcg.com/publications/2021/how-intelligence-and-mobility-will-shape-the-future-of-the-robotics-industry

What is a robot?

Is thermostat a robot? Is Alexa a robot? Does machine have to look like us to be called a robot?

Some history …

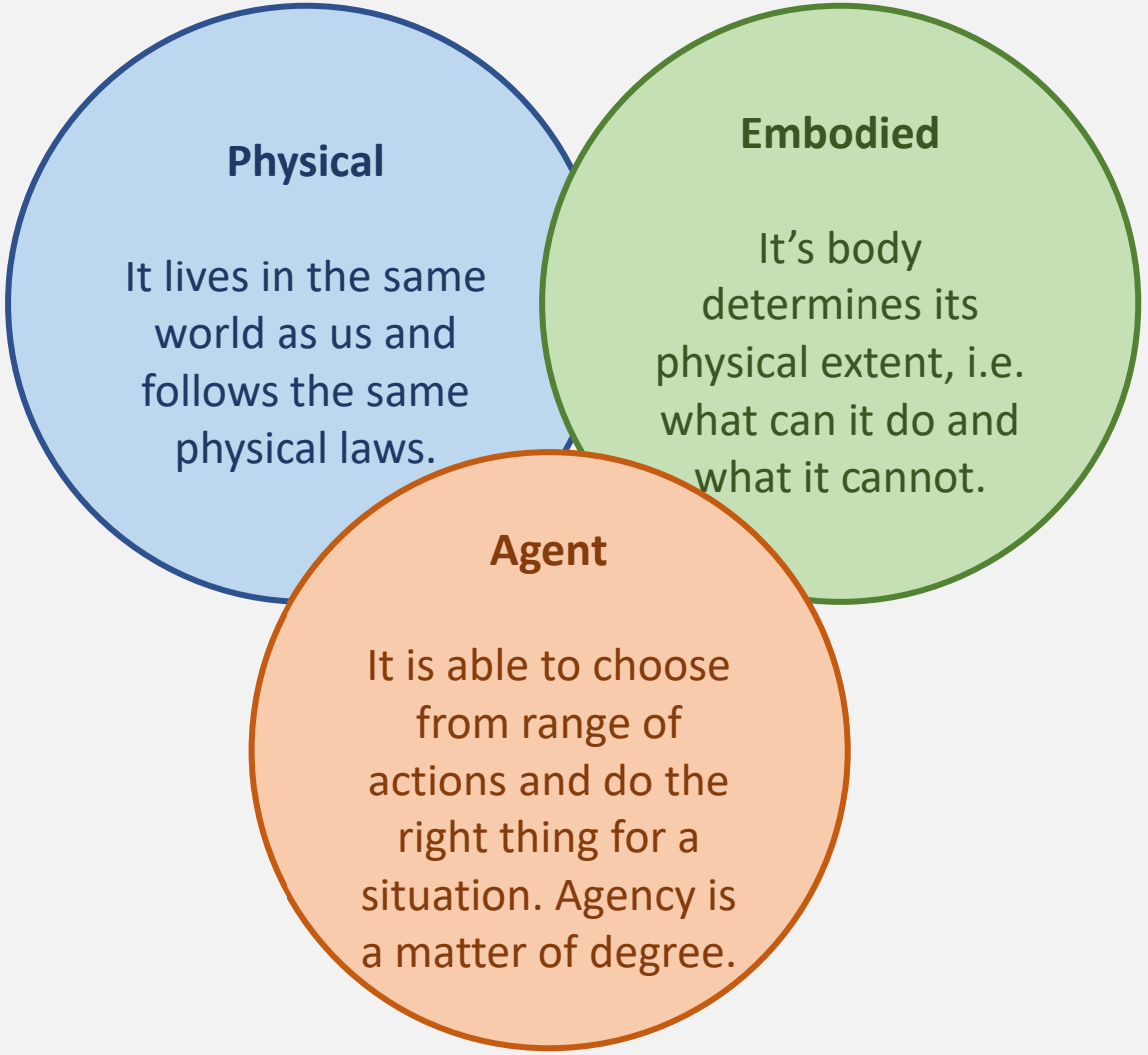
- First use of term “Robot” can be traced to Czech playwright Karel Capek (pronounced Kha-rel Cha-pek) in his 1921 play Rossum’s Universal Robots (R.U.R.), meaning forced labor.
- The word “Robotics” was coined by Asimov based on Capek.

Ask ISO

- **Industrial robot:** an "**automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes**", which can be either fixed in place or mobile for use in industrial automation applications. (ISO 8373)

- **Service robot:** a robot "**that performs useful tasks for humans or equipment excluding industrial automation applications**". (ISO 8373).
  - According to ISO 8373 robots require "a degree of autonomy", which is the "ability to perform intended tasks based on current state and sensing, without human intervention".

Roboticist: A robot is a physically embodied agent



Is there difference between Automated and Autonomous?

Automated

automatic (adj.)

"self-acting, moving or acting on its own," 1812 (*automatical* is from 1580s; *automatous* from 1640s), from Greek *automatos* of persons "acting of one's own will;" of things "self-moving, self-acting," used of the gates of Olympus and the tripods of Hephaestus (also "without apparent cause, by accident"), from *autos* "self" (see **auto-**) + *matos* "thinking, animated," ***men-*** (1) "to think."

- Repeats the same motions

Autonomous

autonomous (adj.)

1777, "subject to its own laws" (in translations of Montesquieu); 1780, "pertaining to autonomy;" from Greek *autonomos* "having one's own laws," of animals, "feeding or ranging at will," from *autos* "self" (see **auto-**) + *nomos* "law" (from PIE root ***nem-*** "assign, allot; take"). Compare **privilege**. Used mostly in metaphysics and politics; see **autonomic**. Related: *Autonomously*.

- Choose actions to maximize its chances of success

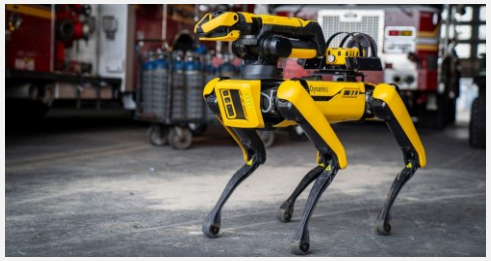
Taxonomy

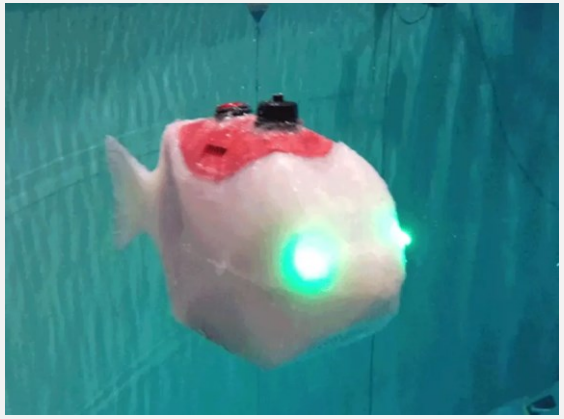
Stationary vs Mobile Robots

Mobile robots have to perform in a large space.

Based on Operational Environment

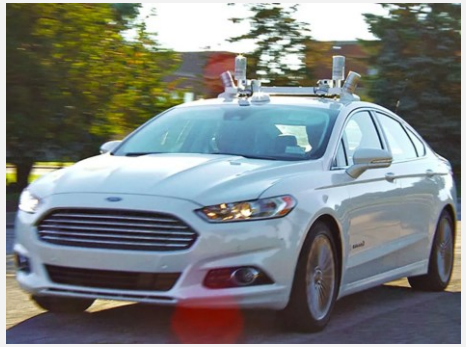
- Ground
- Underground
- Underwater
- Surface
- Aerial

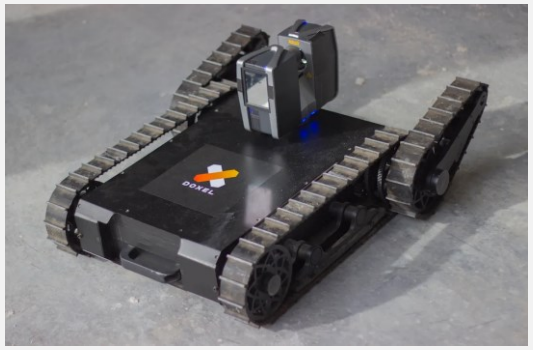




Based on Mode of locomotion

- Wheeled
- Tracked
- Legged
- Modular
- Leggless

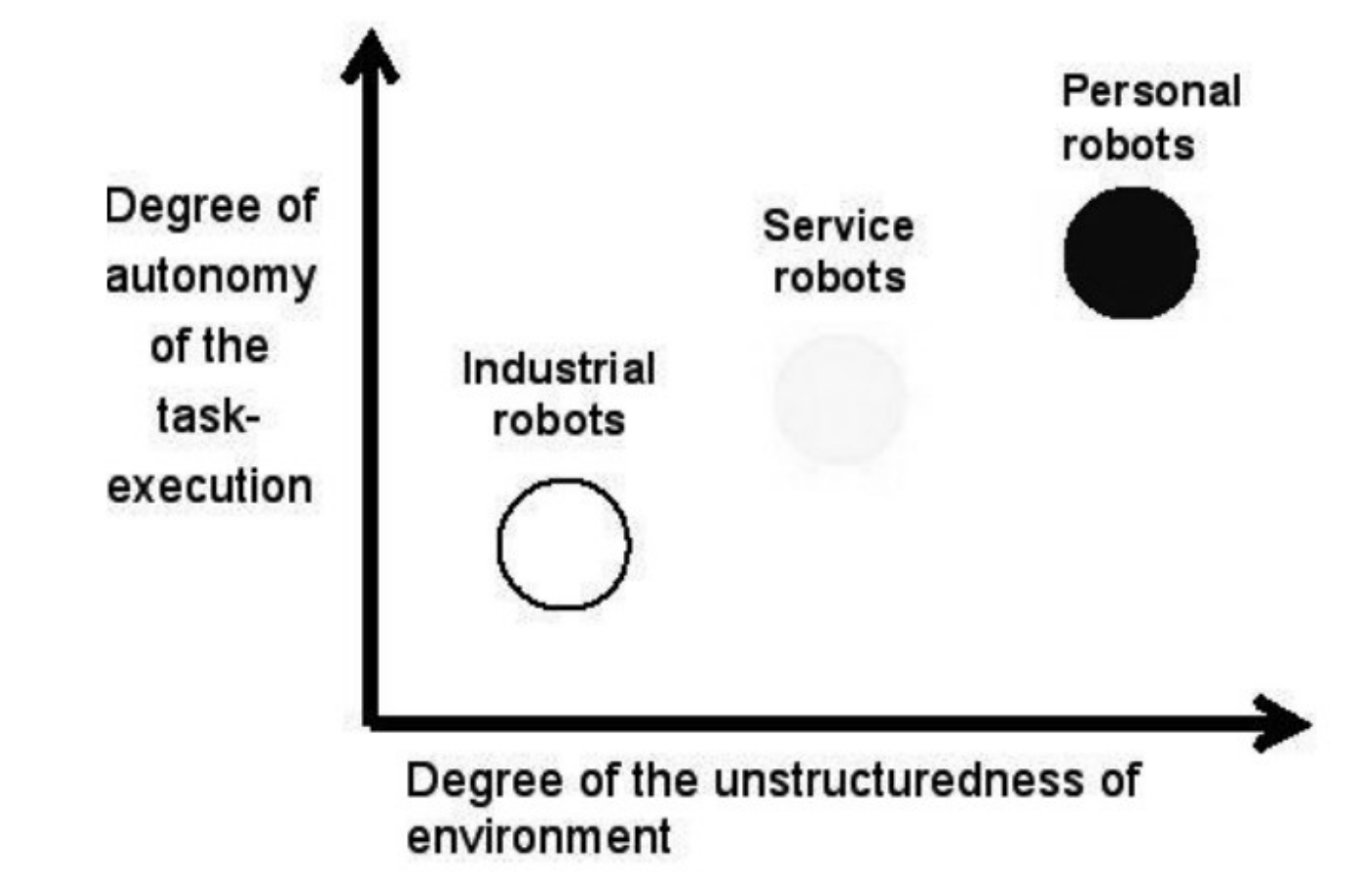




Based on Autonomy

- Fully autonomous
- Semi-autonomous
- Remote-controlled

Based on Field of application



Source: Autonomous Land Vehicles book

What about this course?

It is about Autonomous Wheeled Robots

- Learn a **small** set of fundamental tools that solve a **wide** range of robotic problems for all mobile robots.

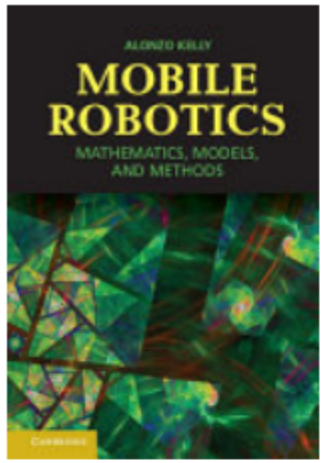
Prerequisites

- Linear Algebra
- Probability
- Geometry
- Physics, sometimes

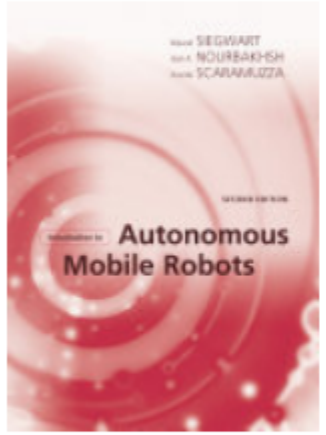
Canvas is go-to location for all information

- Weekly content table on Canvas will provide links to material on Canvas and references to relevant book sections.

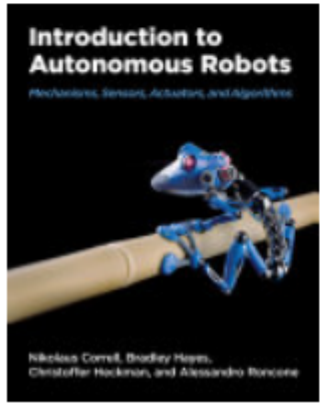
Books



Mobile Robotics
ISBN: 9781107031159
Authors: Alonzo Kelly
Publisher: Cambridge University Press
Publication Date: 2013-11-11



Introduction to Autonomous Mobile Robots, second edition
ISBN: 9780262015356
Authors: Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza
Publisher: MIT Press
Publication Date: 2011-02-18



Introduction to Autonomous Robots
ISBN: 9780262047555
Authors: Nikolaus Correll, Bradley Hayes, Christoffer Heckman, Alessandro Roncone
Publisher: MIT Press
Publication Date: 2022-12-20
Open access link:

Course Evaluation

Assessment	Weight in course grade
Homework Assignments (4-5, every 2-3 weeks)	40%
Quizzes (3-4)	30%
Project	25%
Discussions	5%

Late Submission Policy: Late submissions will be accepted up to only a week after the due date. Every hour, 0.12% of the maximum assessment score will be deducted.

Homework Assignments

- You'll work in pairs and make a single submission.
- Coding assignments in MATLAB.
- Last question is individual. Each student shares their understanding of the included content.
- OK to look at online resources (cite when you do!), but don't use code.
- Policy about generative AI will be shared with each homework.
- **Academic Integrity:** Zero tolerance for collusion, plagiarism, cheating

Quizzes

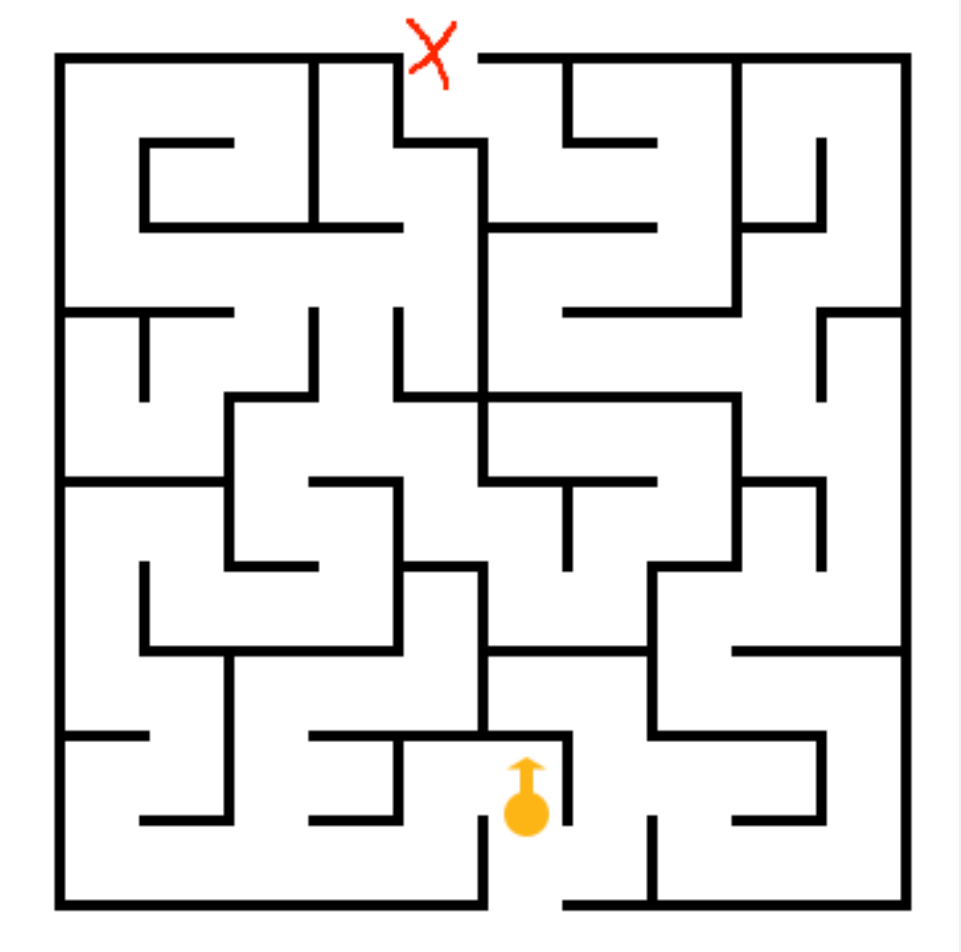
- Fundamental ideas.
- In-class.
- May have to be scheduled on a working Saturday.

Project

- Group
- Timeline to be shared.
  - Idea paper
  - Literature Review
  - Testing plan
  - Final conference-style paper
- Build a mobile robot in simulation

Time to be a roboticist

- You know there is a chest of gold hidden somewhere in this maze.
- You cannot go in search of it yourself and so you decide to send a robot.
- Unfortunately, you don’t have a map of the maze.
- If you find the chest, you can only take couple of coins at a time and bring them to your car parked at the exit.



Pair up and think about these questions:

- Think about a strategy that will let you harvest maximal coins in minimal time.
- What kind of robot will you use?
- What will be its sensing and action abilities?
- What thinking abilities will your robot need?

If you could not use these abilities, what will you do?

- What if your robot was blind?
- What if it had no memory of the past?

Core challenges in mobile robotics

- **Where am I going?**
- **What is the best way there?**
- **Where have I been?**
- **Where am I?**
- **How do I get there?**

Survey

https://hulms.instructure.com/courses/3110/quizzes/8111

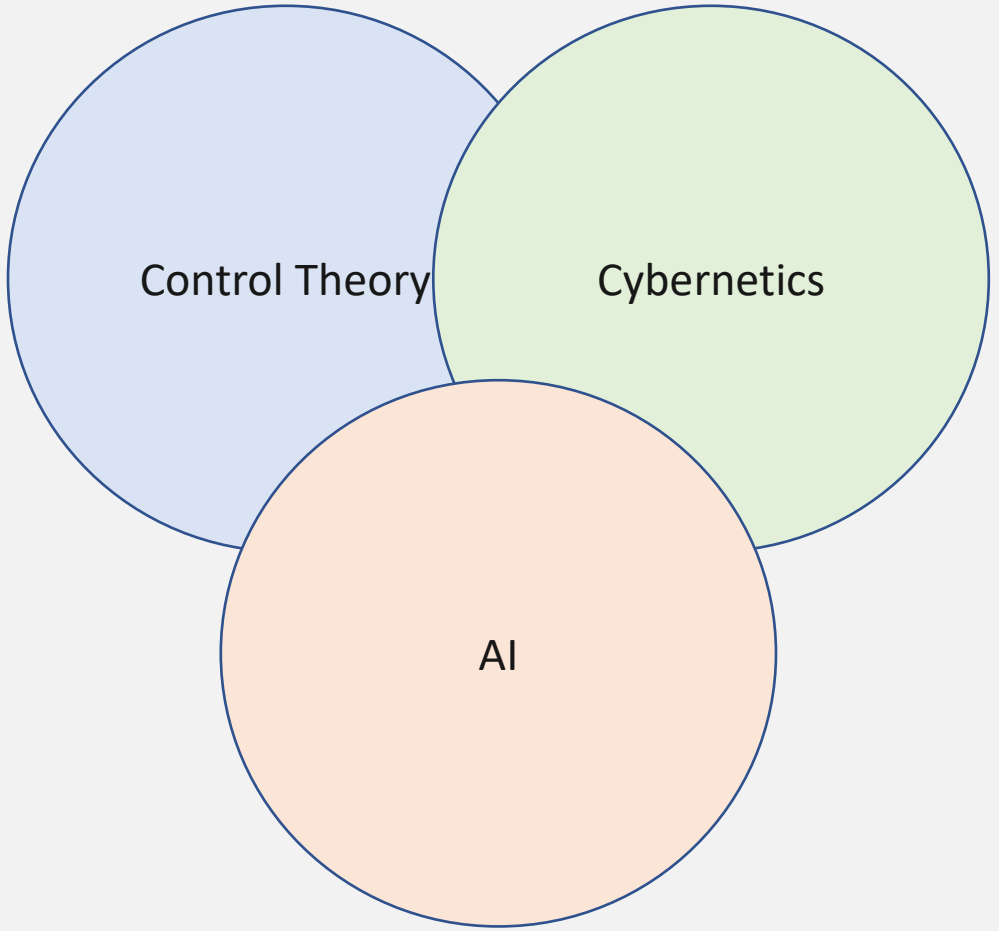
Thank you

History of Robotics

Some history …

- Pygmalion created statue of Galatea and asked Venus to breathe in life into it - ‘android’ today
- Hephaestus had metallic figures to assist him in his workshop
- Ktesibios, 3rd century BC, created pneumatic birds for clock
- Automaton in some form or another since then

Roots of present-day robotics

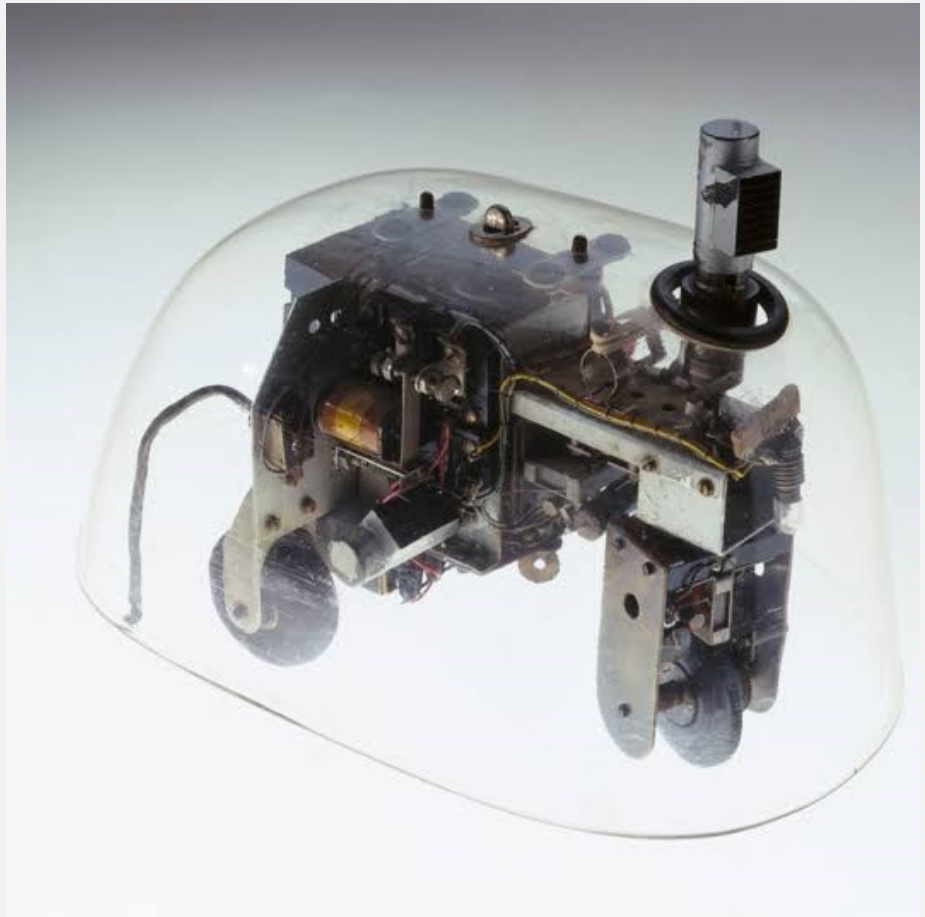


The world around 1940s

- **Control Theory:** Science of building automated systems. It was well-established. Being used for windmills, steam engines, electronic amplifiers.
- **Cybernetics:** Pioneered by Norbert Weiner in 1940s.
  - Using control theory to understand biological systems.
  - Focuses on coupling, combining, and interaction between mechanism or organism and environment.
  - Proponents studied biological systems and tried to implement in simple robots using methods from control

What is the first known robot according to our definition of robot?

- Grey Walter's Tortoises (1940s)
- Biomimetic
- Motors; Tricycle model
- Photocell; Bump sensor
- Analog circuit
- Behaviors:
  - Head or back away from light
  - Turn and push to avoid obstacles



What else was happening?

- Manhattan project
- Telemanipulators for handling nuclear material

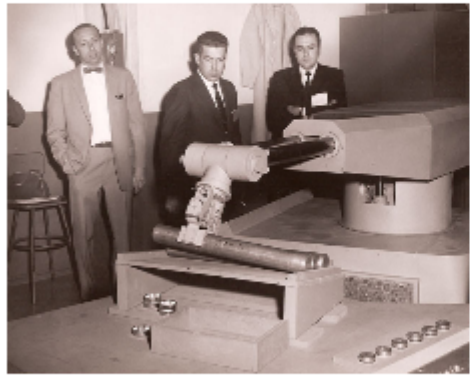
Figure 1.2 A Model 8 Telemanipulator. The upper portion of the device is placed in the ceiling, and the portion on the right extends into the hot cell. (Photograph courtesy Central Research Laboratories.)

Photo source: AI Robotics

A beginning to industrial manipulators

Development of the first industrial robot by George Devol and Joseph Engelberger

1959



It weighed two tons and was controlled by a program on a magnetic drum. They used hydraulic actuators and were programmed in joint coordinates, i.e. the angles of the various joints were stored during a teaching phase and replayed in operation. They were accurate to within 1/10,000 of an inch.

Unimation installed the first industrial robot at GM

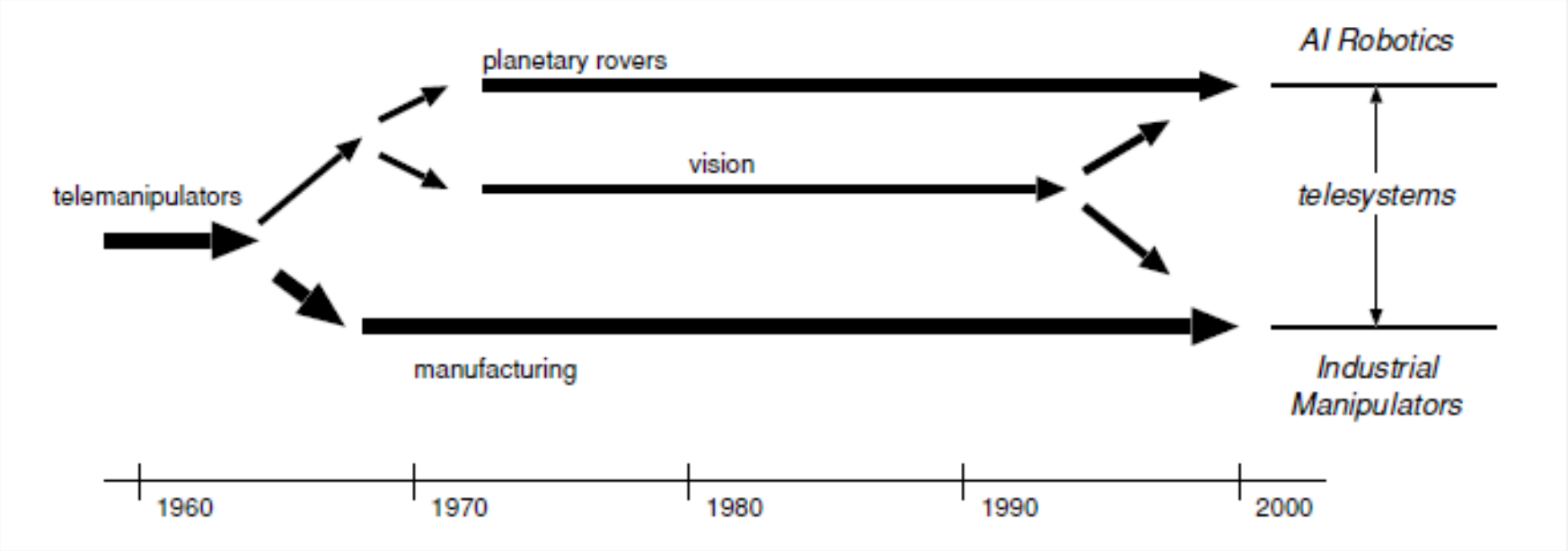
1961

The world's first industrial was robot used on a production line at the GM Ternstedt plant in Trenton, NJ, which made door and window handles, gearshift knobs, light fixtures and other hardware for automotive interiors. Obeying step-by-step commands stored on a magnetic drum, the Unimate robot's 4,000 pound arm sequenced and stacked hot pieces of diecast metal. The robot cost US$ 65,000 to make but Unimation sold it for US $18,000.

Artificial Intelligence

- Dartmouth summer research project, 1956
- Create intelligence in machines

Two paths in robotics development



Next major development?

- Shakey, developed at Stanford (1960s)
- Camera, Contact sensors
- Plans its movement
- Used to shake a bit when it executed its plans.
- Used **AI** algorithms