Robotics Introduction

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Outline

1. What is a Robot?
2. Why use Robots?
3. Robot History
4. Robot Applications
5. Fundamental Problems in Robotics

1

What is a Robot?

What is a robot?

- Hollywood's imagination

3PO

Star Wars

R2-D2

What is a robot?

By National Science Foundation (NSF), a "robot" is defined as:

- "Intelligence embodied in an engineered construct, with the ability to process information, sense, plan, and move within or substantially alter its working environment."

Summary of the NSF definition:

1. **Intelligent** – Must have computational methods underpinning decision-making.
2. **Embodied** – Exists in a physical, engineered form.
3. **Percepts & Action** – Should be capable of sensing, planning, and acting—especially in ways that can alter its environment.

2

Why Use Robots?

Why Use Robots?

Increase product quality

- Superior Accuracies (thousands of an inch, wafer-handling: microinch)
- Repeatable precision
- Consistency of products

Increase efficiency

- Work continuously without fatigue
- Need no vacation

Increase safety

- Operate in dangerous environment
- Need no environmental comfort – air conditioning, noise protection, etc

Why Use Robots?

Reduce Cost

- Reduce scrap rate
- Lower in-process inventory
- Lower labor cost

Reduce manufacturing lead time

- Rapid response to changes in design

Increase productivity

- Value of output per person per hour increases

Why Use Robots?

Perform 4A Tasks in 4D environments

4A tasks

- Automation
- Augmentation
- Assistance
- Autonomous

4D environments

- Dangerous
- Dirty
- Dull
- Difficult

3

Robot History

The History of Robotics

1

Ancient Origins

Automata: early mechanical devices mimicked human and animal movements.

2

Industrial Revolution

Unimation Inc. was formed in 1962 and took its first multi-robot order from General Motors on an assembly line in 1968, transformed manufacturing forever.

3

Autonomous Era

The 2004 DARPA Grand Challenge sparked development of self-driving vehicles. It marked a turning point for autonomous systems.

Automata

PUMA manipulator

Pioneering milestones

⚙️ Early Industrial Robotics

1961 - George Devol obtained first patent of industrial robot

1962 - Joe Engelberger formed Unimation Inc. to commercialize robotic arms

1968 - Unimation takes its first multi-robot order from General Motors

🤖 Modern Robotics Evolution

1986 - Honda begins development of **humanoid robots** ASIMO

2000 – Sony releases **AIBO**, a robotic dog with learning capabilities

2002 – iRobot releases the **Roomba**, cleaning robot

🛸 Space and Autonomous Robotics

2004 – NASA's **Spirit and Opportunity** Mars rovers, twin robot geologists

2011 – **Curiosity** rover lands on Mars with autonomous decision-making features

2020 – NASA's **Perseverance** rover + **Ingenuity** drone bring to Mars

🤖🧠 Recent Advances (AI + Robotics)

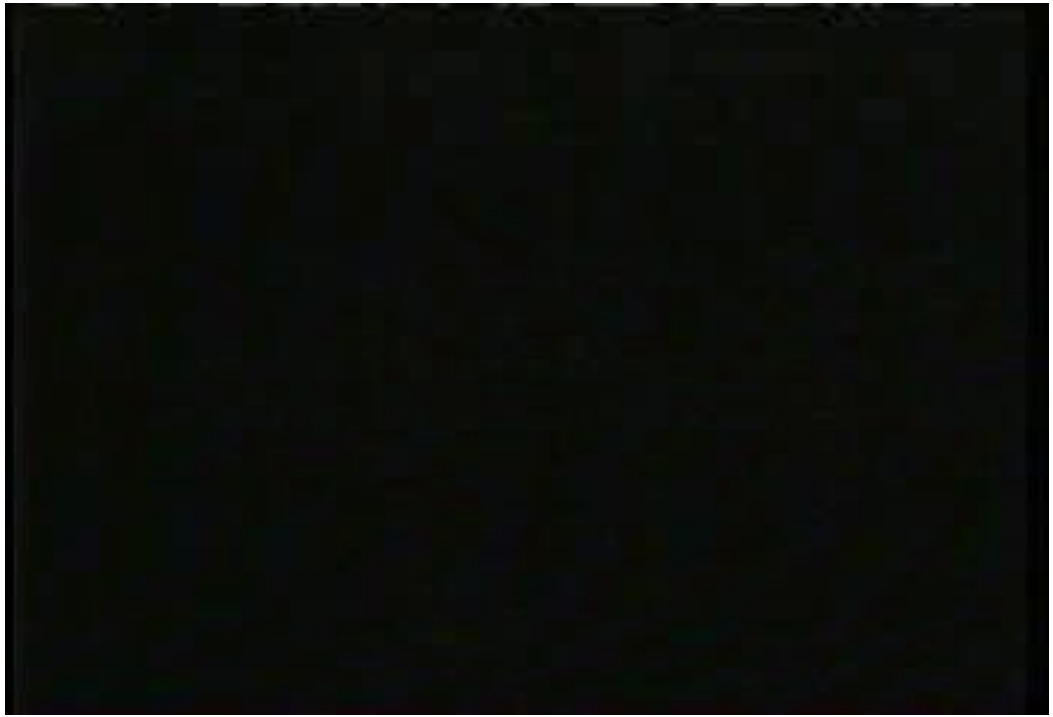
2016 – Boston Dynamics achieves breakthroughs in robot agility

2017 – **Sophia** (Hanson Robotics) becomes the first robot granted "citizenship" (Saudi Arabia)

2023–2025 – Explosion in **AI-powered general-purpose robots** (OpenAI + Figure, 1X, Sanctuary AI, etc.)

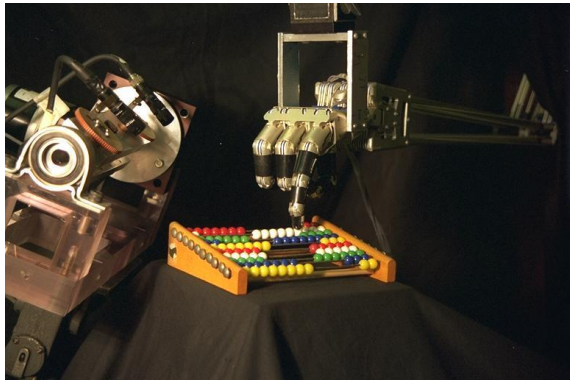
Robot History

- The patent and industrial robot



How are they used?

- Industrial robots
  - 70% welding and painting
  - 20% pick and place
  - 10% others
- Research focus on
  - Manipulator control
  - End-effector design
    - Compliance device
    - Dexterity robot hand
  - Visual and force feedback
  - Flexible automation



Robot Arm Dexterity

The start of AI

Autonomous UGVs

The Honda Humanoid (1997)

4
Robot Applications

Industrial Robots (Manipulators)

- Operate in structured environments, specifically designed to facilitate robotic operations (e.g. production line)
- Programmed to faithfully carry out specific repetitive actions over and over again without variation and with a high degree of accuracy.

- **World Robotics 2024 report** from the International Federation of Robotics (IFR):

There are **4,281,585 industrial robots** actively operating in factories around the world by the end of 2023—a **10% increase** over the previous year

Industrial Robots Installations

🤖 Top 10 Countries by 2023 Installations of Industry Robots

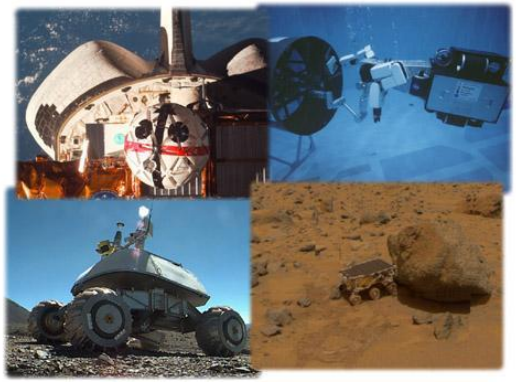
Rank	Country / Region	Units Installed	Global Share
1	**China**	276,288	**51 %**
2	**Japan**	46,106	8.5 %
3	**United States**	37,587	7.0 %
4	**Republic of Korea**	31,444	5.8 %
5	**Germany**	28,355	5.2 %

Industrial Robot Companies

- ABB, Adept, Fanuc Robotics, Kuka, Staubli, etc.

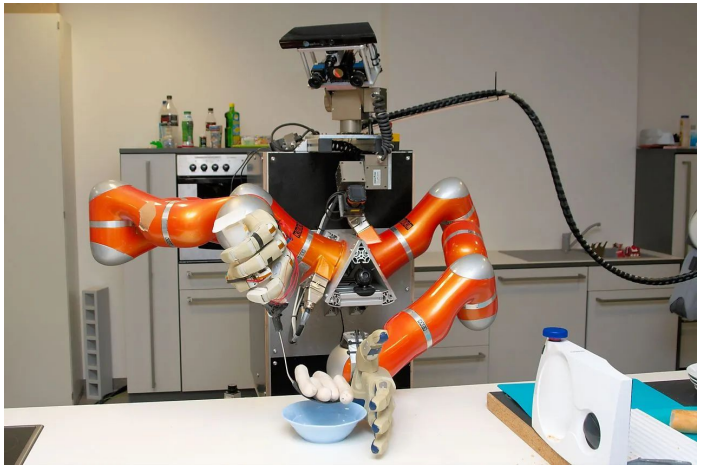
Robotics: a much bigger industry

- Robot Manipulators
  - Assembly, automation
- Field robots
  - Military applications
  - Space exploration
- Service robots
  - Cleaning robots
  - Medical robots
- Entertainment robots



Robot Applications

- Robots for Assistive Technology and Health Care

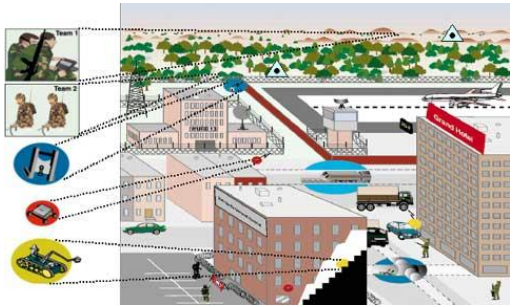


RoboHow Robot Chef

Robotic-Assisted Surgery

Robot Applications

Military Applications

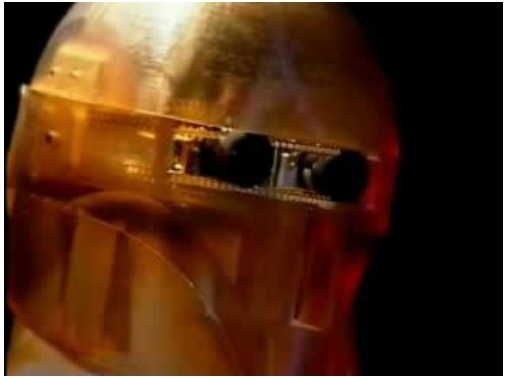


UAV Drones

Boston Dynamic BigDOG

Space Applications

- NASA/DARPA Robonaut:
  - Robonaut: a humanoid robot that can function as an astronaut equivalent for spacewalks.



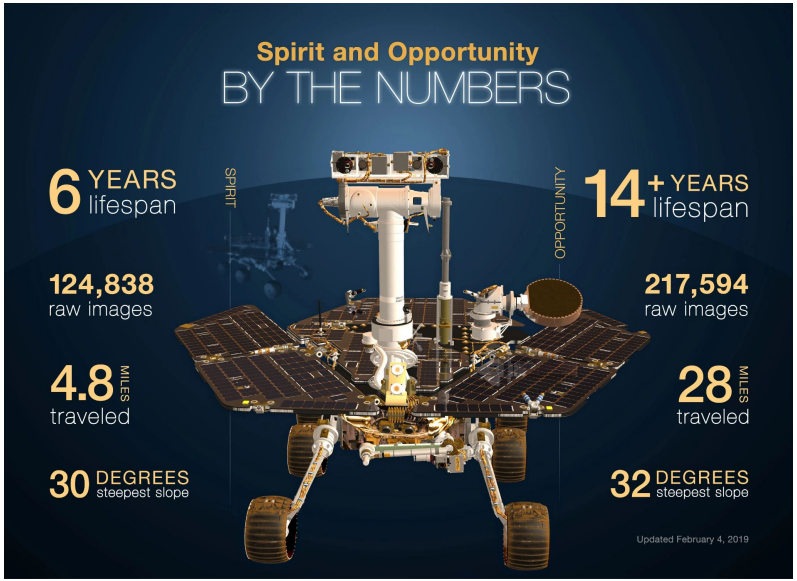
When will the Robonauts take over space travel?

Space Applications

- MARS Exploration:

Mars Rovers: Spirit and Opportunity twin robot geologists landed on Mars: Jan 3, and Jan 24, 2004.

Mars Exploration Rovers: Spirit and Opportunity - NASA Science

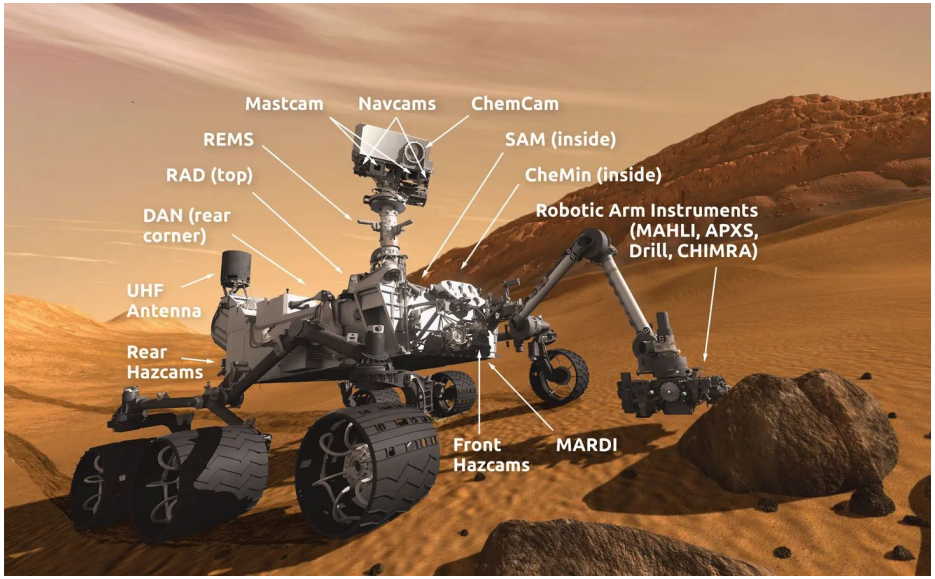


Space Applications

- MARS Exploration:
  - Mission: Search for water and life on Mars

Mars Rover Curiosity launched in Nov. 2011, landed on Mars, Aug. 6, 2012

Mars Science Laboratory: Curiosity Rover



Robot Applications

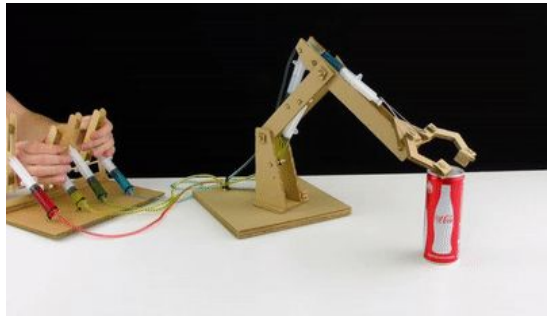
- Entertainment Industry

5 Robotics Fundamentals

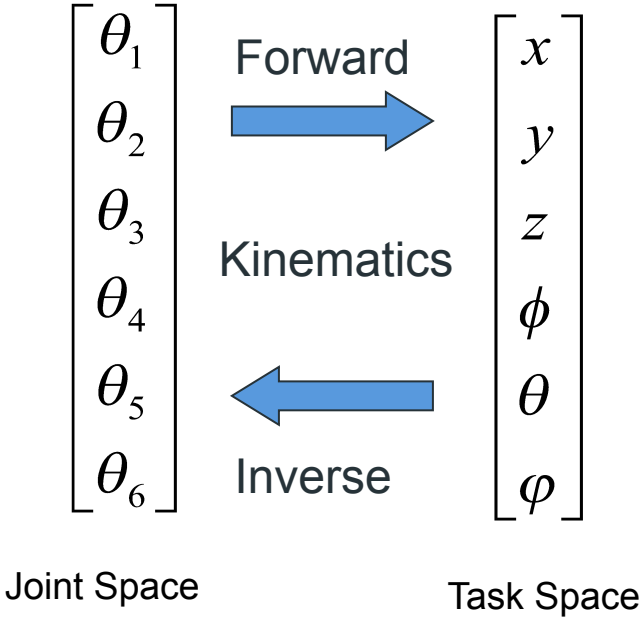
Industrial Robot (Manipulators)

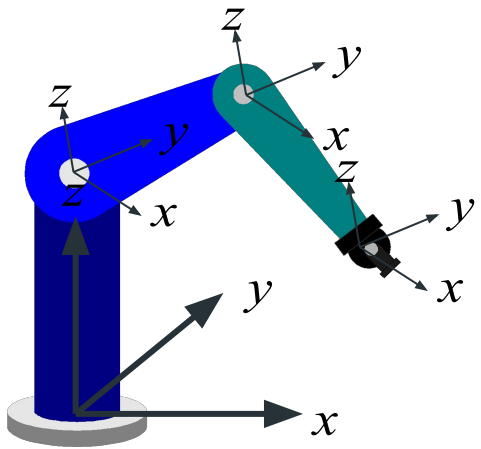
1. Joint Level Control

2. Task Space Control

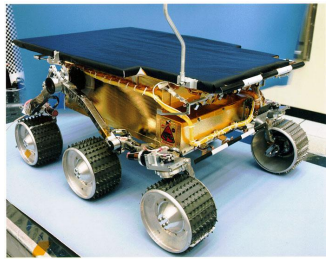


Kinematic Model: Given joint variables, what is the end-effector position and orientation?





Research Problems in Mobile Robot



high-level

Abstraction level

low-level

Autonomous Drive: How to explore unknow world -- SLAM (simultaneous localization and mapping)

Motion Planning: Given a known world, how do I get there from here ?

Localization: Given sensors and a map, where am I ?

Computer vision: If my sensors are eyes, what do I do?

Mapping: Given sensors, how do I create a useful map?

Bug Algorithms: Given an unknowable world but a known goal and local sensing, how can I get there from here?

Kinematics: if I move this motor somehow, what happens in other coordinate systems ?

Control (PID): what voltage should I set over time ?

Motor Modeling: what voltage should I set now ?

Summary

- Robotics--interdisciplinary research
  - Mechanical design
  - Electrical engineering
  - Computer science and engineering
  - Cognitive psychology, perception and neuroscience
- Research open problems
  - Manipulation, Locomotion
  - Control, Navigation
  - Human-Robot Interaction
  - Learning & Adaptation (AI)

Personal Robot?

- Just as the personal computer is used for automated information management even in households, robots can be used to execute domestic tasks.
- Manipulation of bits of information (PC)
- Manipulation of physical objects (PR)

Conclusion: Embracing the Robotic Age

Address Challenges

Develop ethical frameworks, technical solutions, inclusive policies for responsible robotics.

Invest in Development

Support research, education, and cross-sector collaboration to advance robotic capabilities.

Shape the Future

Ensure robotics serves humanity by creating sustainable, accessible, and beneficial technologies.