Advanced Robotics

ENGG5402 Spring 2023

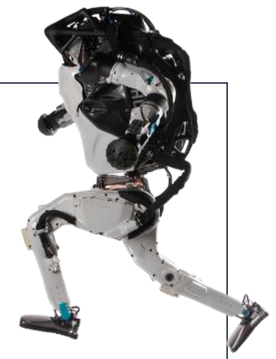
Fei Chen

Topics:

- Introduction to robotics

Readings:

- Siciliano: Chpt. 1

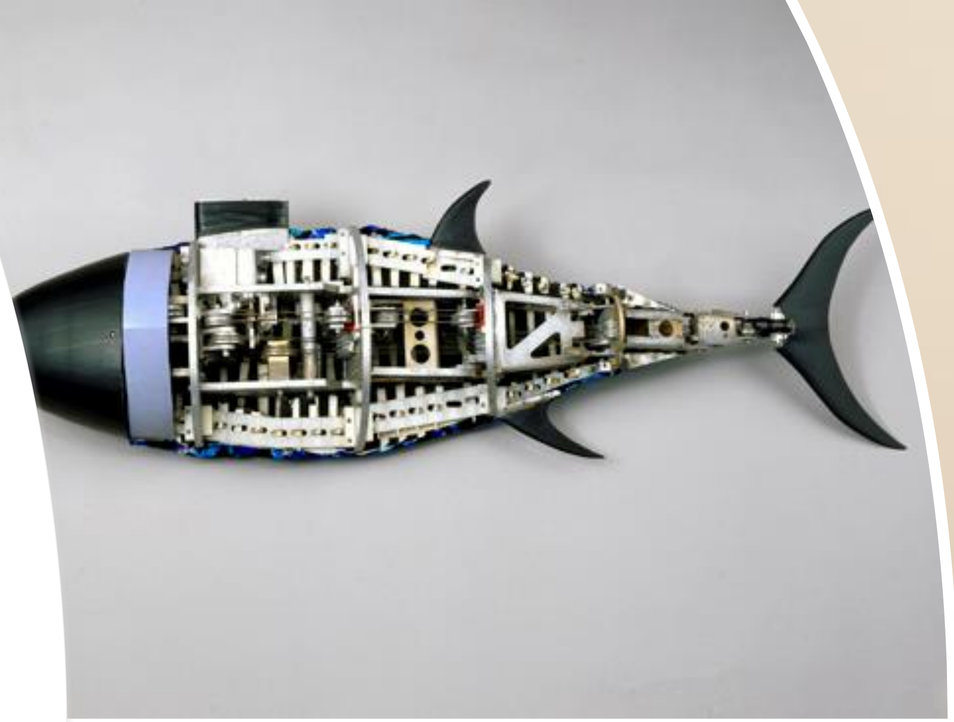


Definition of Robots

- A machine that resembles a human and does mechanical, routine tasks on command (www.dictionary.com)

- Mechanical or virtual artificial agent (Simulation), usually an electromechanical machine that is guided by a computer program (from Wikipedia)

- Machine capable of carrying out a desired task semi- or fully- automatically



Basic Components of a Robot

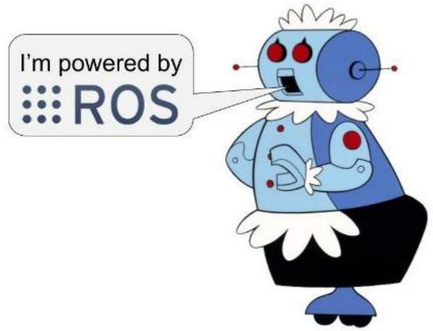
- **Mechanical elements** to interact with the environment
- **Electronics** (include sensors, actuator, computing hardware) to sense, actuate and process information
- **Software** to enable the system to be autonomous

IIT Centauro Robot

Six-Axis Force / Torque Transducers

Integrated Actuation Units

Powerful Customizable Endeffectors



Beginning of Modern Robotics

Master-Slave Tele-Manipulator

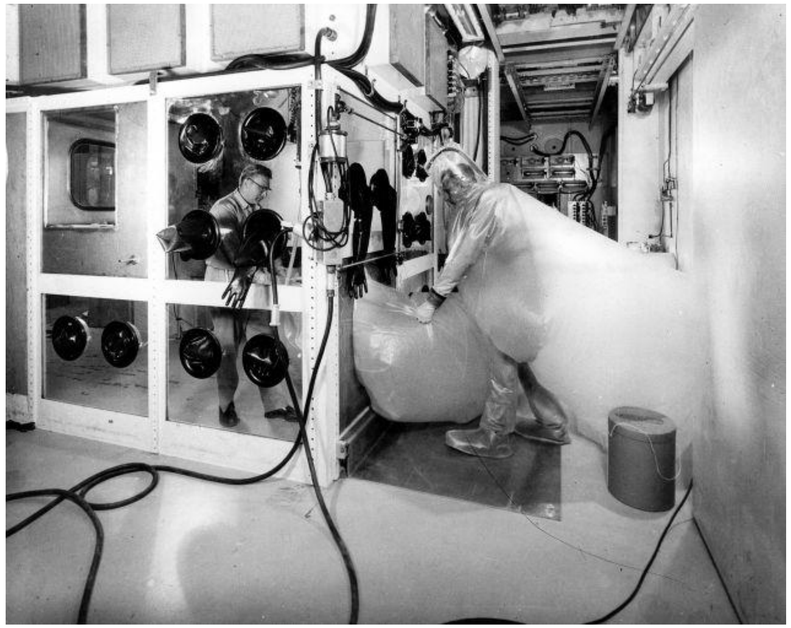
After World War II (1945),

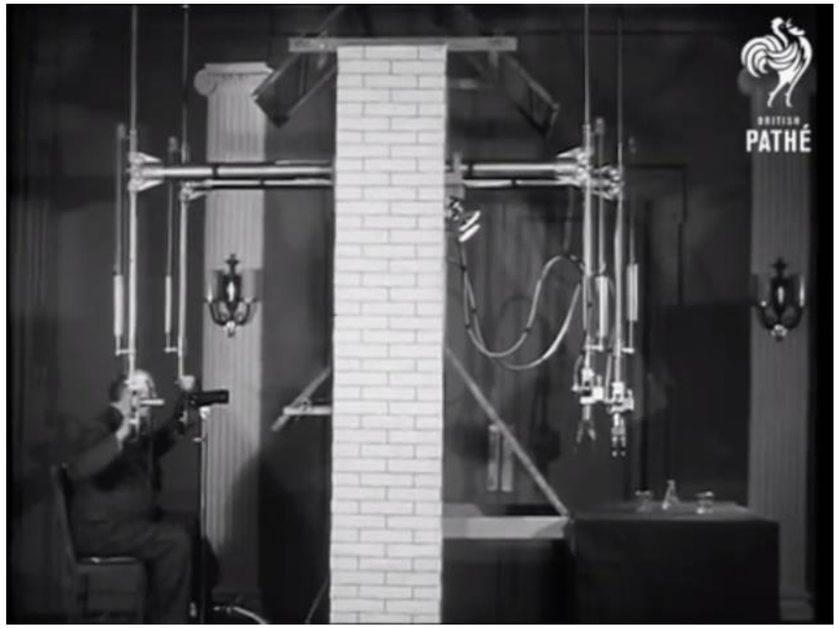
- The early work leading up to Today's robots began in the development of remotely controlled mechanical manipulators to handle radioactive materials at Argonne Oak Ridge National Laboratories, USA
- They defined the concept of Master-Slave teleoperation system, later on force feedback was also added in 1949
- General Electric and General Mills were also involved in this project
- A complex mechanical mechanism without any programmability
- The technology later on become the foundation of tele-robotic surgery

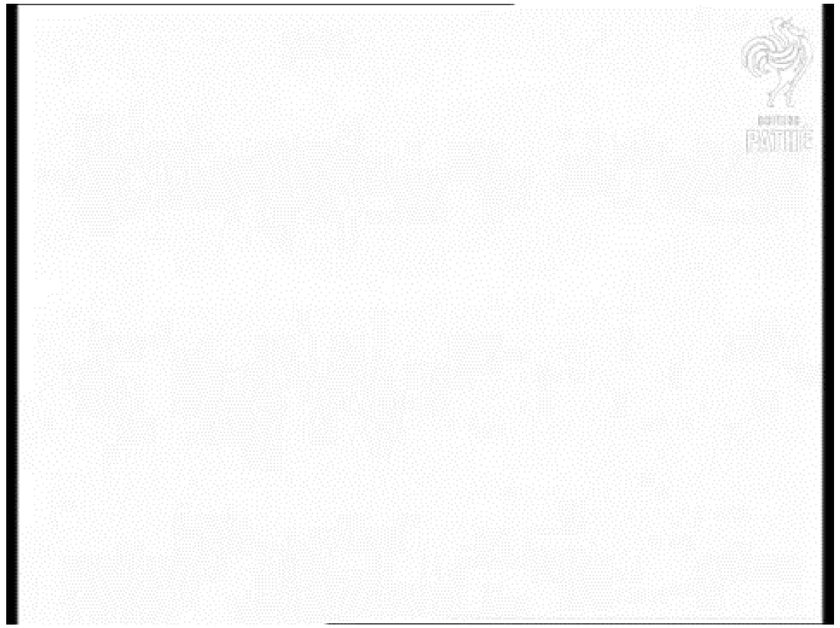
Question: What was the need or reason that drove this robot development ?

Beginning of Modern Robotics

Master-Slave Tele-Manipulator







https://www.youtube.com/watch?v=7YEMMpngZTE

Question: What was the need or reason that drove this robot development ?

Beginning of Modern Robotics

Computer Numerically Controlled (CNC) machine

A bit later, around early 1950s,

- Started to develop the Computer Numerically Controlled (CNC) machine tools for accurate milling of low volume, high performance aircraft parts
- The first robots, developed by George Devol in 1954, has the programmability of CNC machine tool controller. It was called “programmed articulated transfer device”
- The programmability was the key for the next wave of robotic development...
- The patent rights were bought by Joseph Engelberger, who formed the first robotic company called Unimation in Connecticut, 1956
- Japanese company, Kawasaki started their robot development via an acquisition of a patent from Unimation
- Later on, in 1978, Unimation introduced a robot named the Programmable Universal Machine for Assembly (PUMA)

Video source: https://vimeo.com/23372660

Question: What was the need or reason that drove this robot development ?

Robotics Timeline

Academia started to involve actively

The beginning of Modern Robotics started around late 50s and 60s:

- 1959: Artificial Intelligence Laboratory formed at MIT (Founder: Marvin Miskey)
- 1961: Heinrich Ernst develops the MH-1 computer operated hand

Video source: https://www.csail.mit.edu/videoarchive/history/aifilms/robot-15

Robotics Timeline

Academia started to involve actively

The beginning of Modern Robotics started around late 50s and 60s:

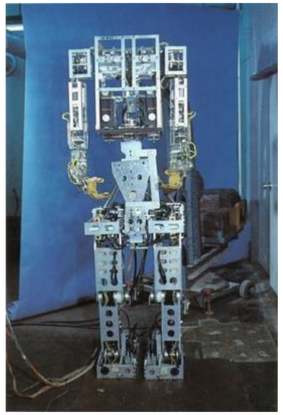
- 1963: Artificial Intelligence Laboratory (SAIL) formed at Stanford (Founder: John McCarthy)
- 1966: Stanford Research Institute creates Shakey, the first mobile robot to reason about its actions
- 1969: Stanford AI Laboratory (SAIL) creates the Stanford Arm, the first computer-controlled arm

Robotics Timeline

In 1970s, people started to use robots in manufacturing extensively…

- 1971: Invention of the microprocessor
- 1973: Kuka built the first six electric motor FAMULUS
- 1973: Wabot-1 first anthropomorphic humanoid robot
- 1974: ABB created the first microcontroller controlled electric industrial robot IRB 6 from
- 1978: Unimation introduced a robot named the PUMA robot
- 1979: Prof. Hiroshi Makino created SCARA robot
- 1979: Robotics Institute at CMU established

The first Kuka robot: Famulus



WABOT-1: First fun-scale anthropomorphic robot

Programmable Universal Machine for Assembly (PUMA)

Robotics Timeline

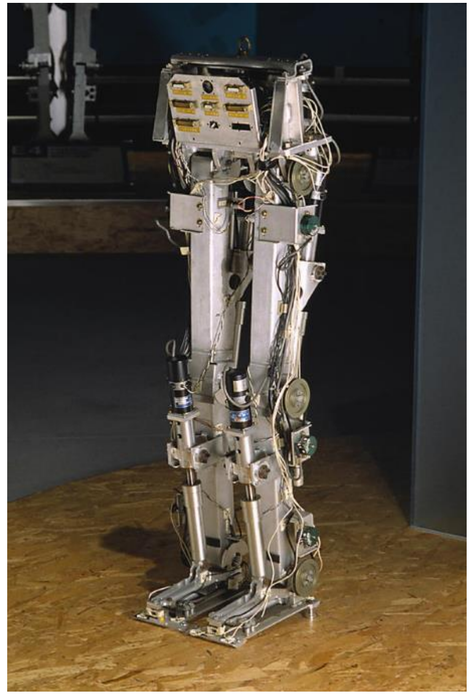
In 1980s, researchers started to focus more on robot intelligenc.

- 1981: Prof. Asada from MIT created the first direct drive arm
- 1984: Douglas Leant started Cyc, common sense database for AI
- 1984: Wabot-2 is capable of playing the organ
- 1985: LEGO began sponsoring the MIT Media Lab
- 1986: Honda begins its humanoid R&D program (Honda E0)
- 1988: LEGO tc Logo released
- 1989: Chess playing programs defeated chess-masters
- 1989: Hexapod robot Genghis (4 microprocessors, 22 sensors and 12 servo motors)

Wabot-2 playing the keyboard


Genghis robot: a six legged hexapod robot

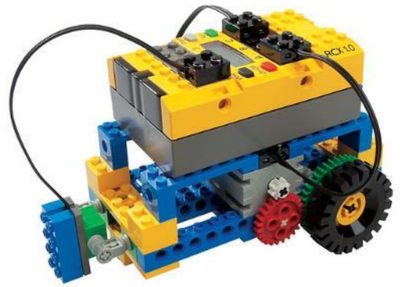
LEGO tc Logo kit


Honda E0 robot

Robotics Timeline

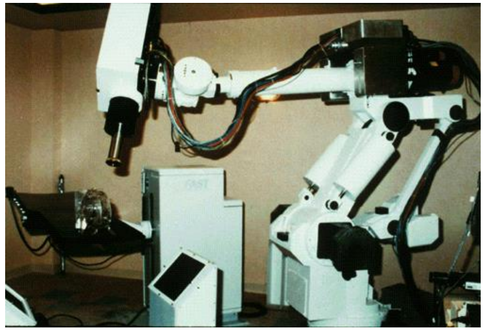
In 1990s, researchers started to apply robotics beyond manufacturing.

- 1994: Dr. John Adler invented the Cyberknife
- 1993: Honda P1 humanoid robot
- 1996: Prof. Stuart Wilkinson invented Gastrobot
- 1996: Dr. David Barrett built the RoboTuna (fish)
- 1996: Honda P2 humanoid robot
- 1997: Honda P3 humanoid robot
- 1998: LEGO Mindstorms first introduced
- 1999: Sony AIBO dog released

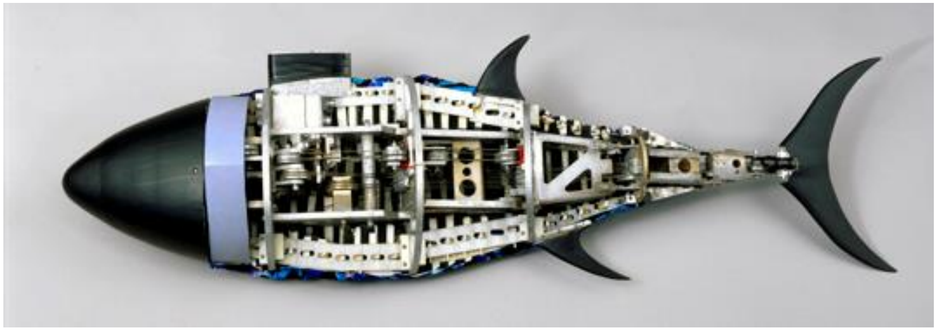


Lego Mindstorm

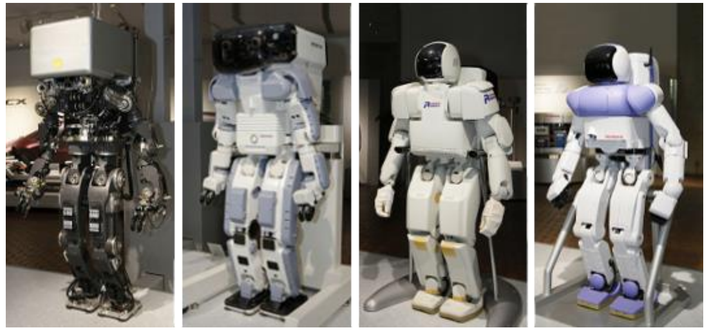
Sony AIBO



Cyberknife



RoboTuna



Honda P-series, from P1 (most left), P2, P3 and P4 (most right)

Robotics Timeline

The 2000s saw robotics found other applications…

- 2000: Honda ASIMO humanoid robot
- 2000: FDA approved the Da Vinci Surgical System
- 2001: FDA clears the CyberKnife for tumour removal anywhere in the body
- 2001: iRobot PackBot searches at the US WTC
- 2002: iRobot released the Roomba vacuum cleaner
- 2003: NASA launches the MER-A “Spirit” for Mars, the 1st rover to Mars

…

iRobot Roomba

iRobot PackBot

Honda ASIMO

Spirit

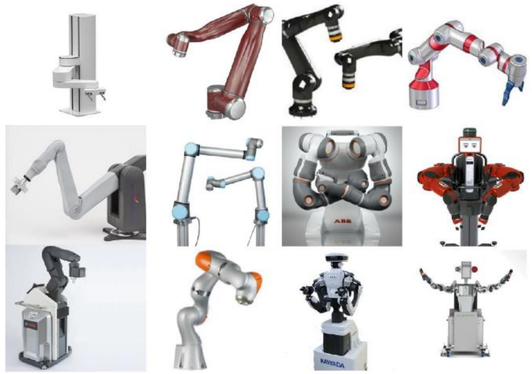
Da Vinci Surgery Robot

Locomat – Robotic Treadmill

Robotics Timeline

The 2010s/2020s robotics technologies are moving forward rapidly, meeting AI.

- More areas reached: Medical, Service, Manufacturing, Military, Agriculture, Entertainment
- Medical: surgery, rehabilitation, prosthetic hand, etc
- Service: humanoid, mobile robots
- Manufacturing: robot arms, KUKA, UR, Franka Emika
- Military: wearable robotics
- Agriculture: harvesting, weeding, etc
- Entertainment and education: little humanoids, droves, legged robots
- Research: highly dynamic robots, legged robots



Collaborative robot arms

Agility Robotics: Digit

Boston Dynamics:
Atlas & Spot

UBTECH: Walker

IIT: Prosthetic hand

Agriculture robots

Classification of Robots

There are many ways to classify robots, such as:

- By *form*
- By *function*

Form refers to the way it looks

- Robot arm vs humanoid vs bird vs mobile robot

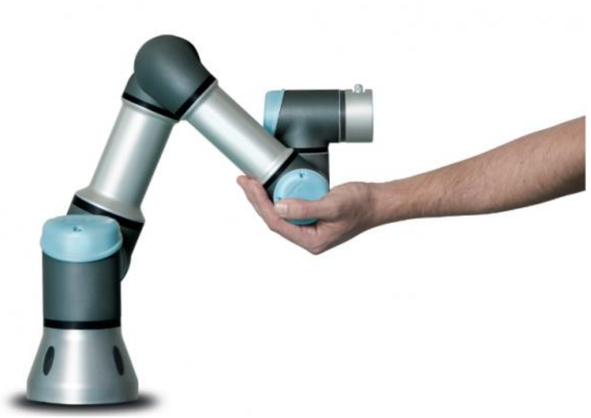
Function refers to its use/application

- Industry vs medical vs agriculture

Classification of Robots

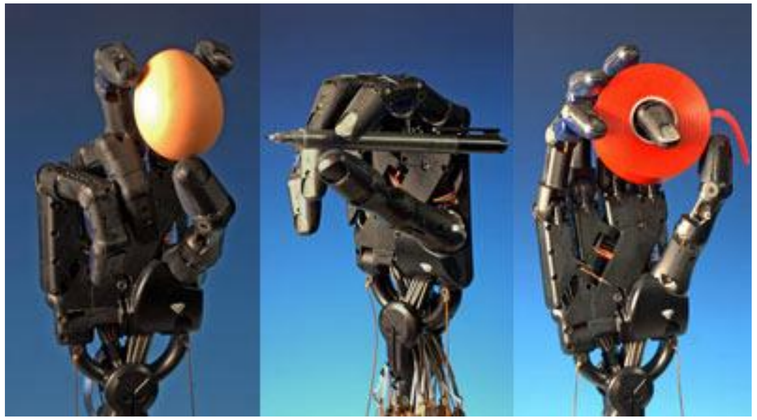
By Form – Arm and Hands

Kuka LWR (KUKA Lightweight robot)



Universal Robotics UR3

Barrett Hand



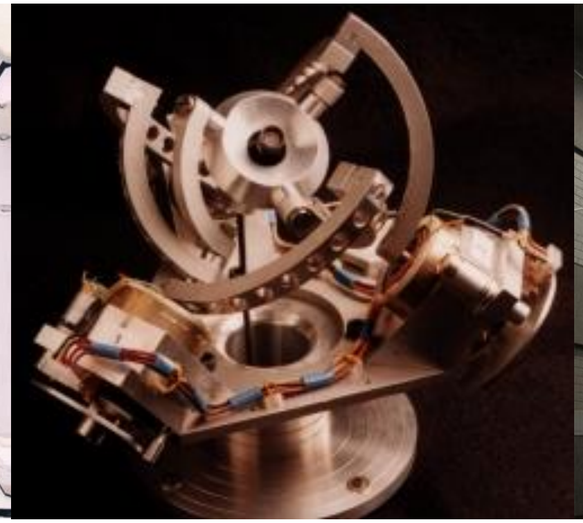
Shadow Robotics hand

Classification of Robots

By Form – Parallel Manipulators

Lufthansa using Stewart platform

ABB FlexPicker delta robot



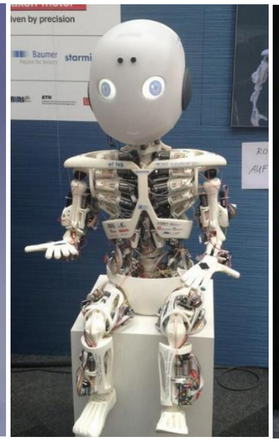
Laval University Agile Eye

Fraunhofer IPA cable simulator

Classification of Robots

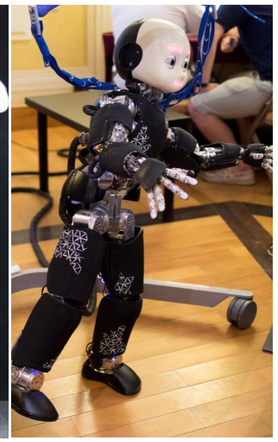
By Form – Humanoid Robots

Honda ASIMO
(Japan)



Devanthro Roboy
(Switzerland)

JSK Kojiro
(Japan)

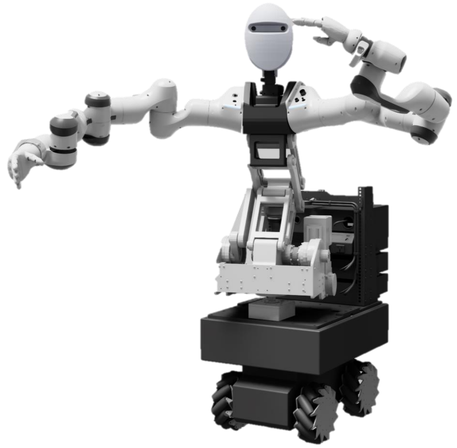


RobotCub iCub
(EU-IIT-Italy)

AIST HRP-4
(Japan)

TORO
(DLR, Germany)

Rollin' Justin
(DLR, Germany)



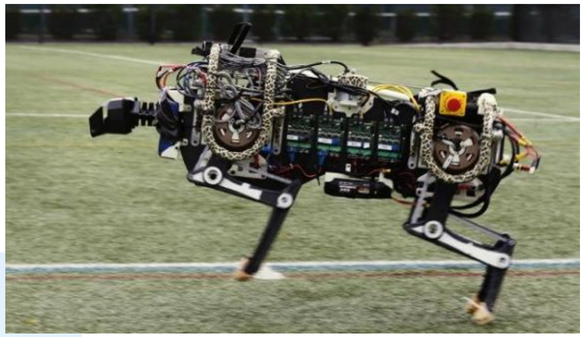
CURI
(CUHK, Hong Kong)

Biped

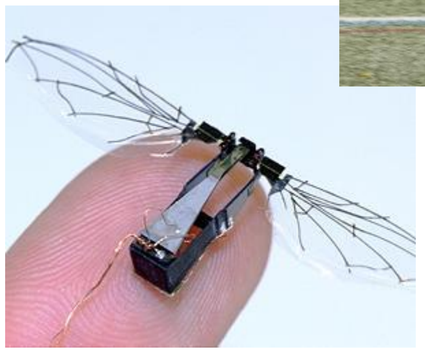
Mobile

Classification of Robots

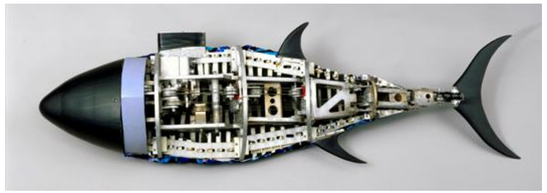
By Form – Bio-Inspired Robots



MIT Cheetah robot

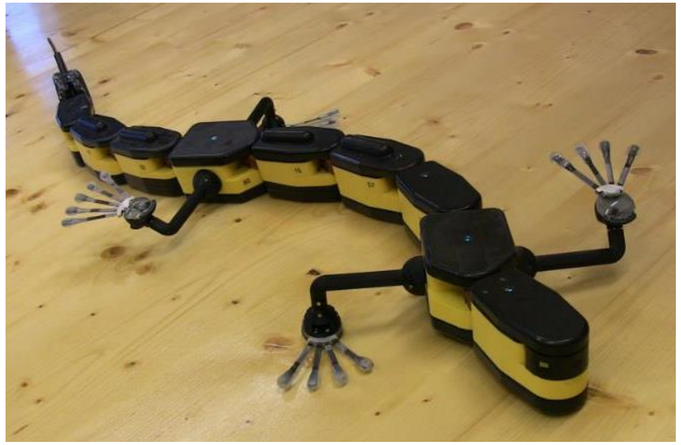


Harvard
Microfly



RoboTuna

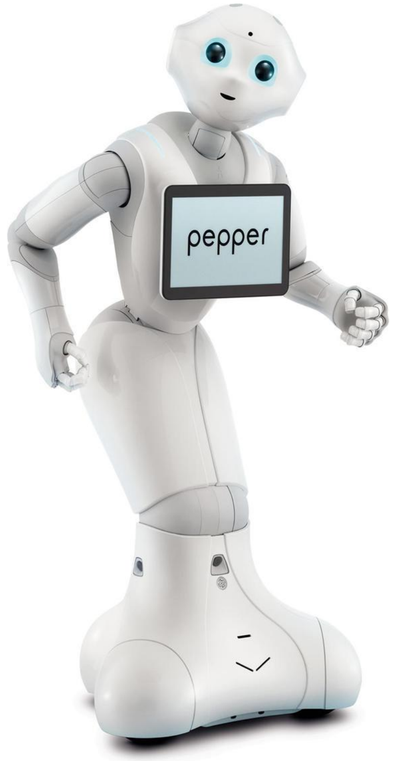
CMU snake robot



EPFL salamander robot

Classification of Robots

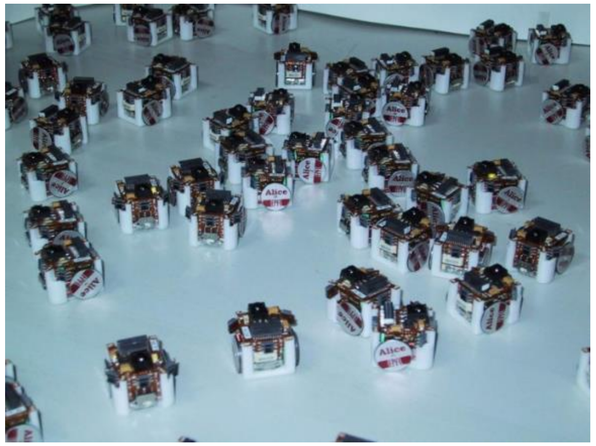
By Form – Mobile Robots



Softbank
Pepper

iRobot PackBot

Cambridge Unmanned Aerial Vehicle



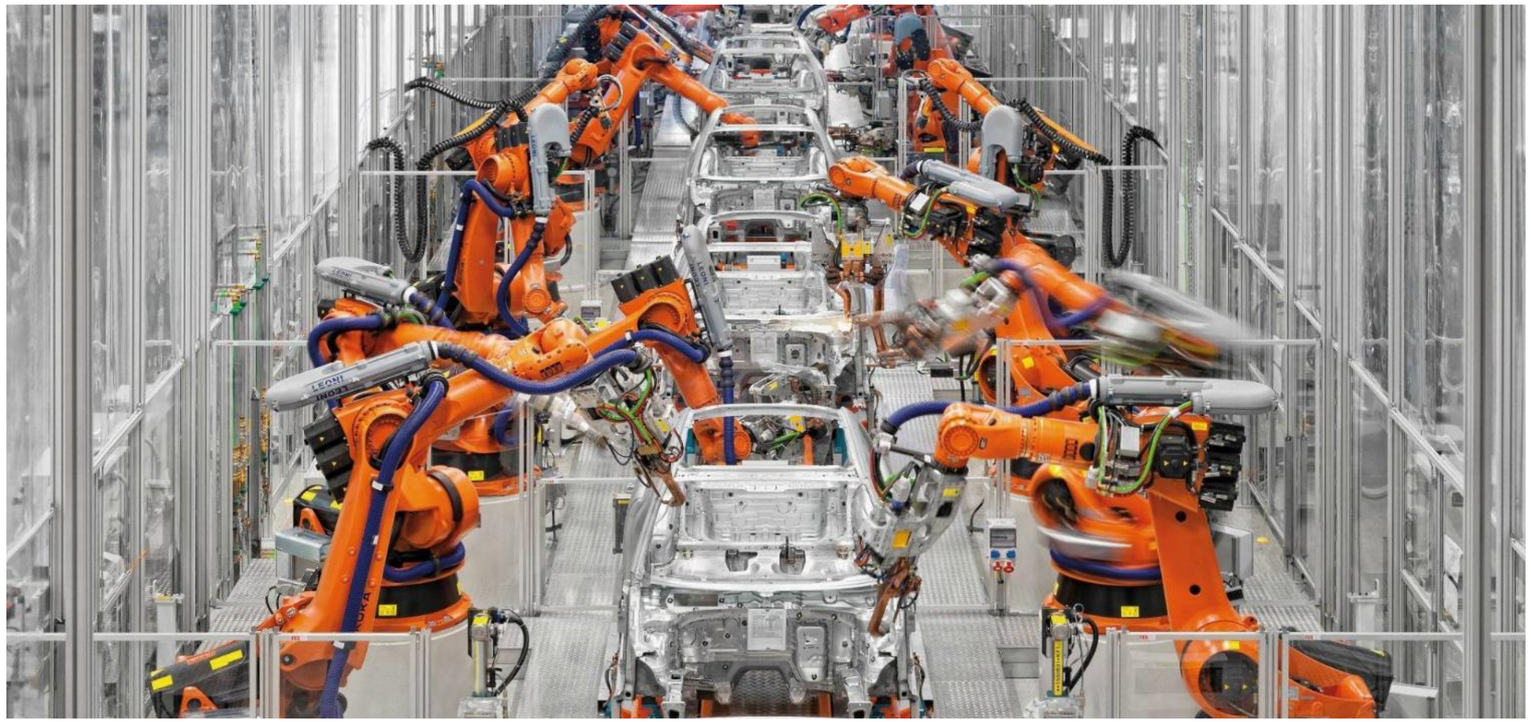
EPFL Alice swarm robot

TU Eindhoven soccer robots

Classification of Robots

By Function – Industrial Robots

- Good at addressing the routine (or dangerous) tasks that require precision: painting, assembly, welding, cutting, vision inspection, monitoring
- Are we saturated in this field?
- What are the remaining challenges in this field?



Industrial robots working in car factory

Classification of Robots

By Function – Agriculture Robots

- Agri-Robots help automate tasks at farms
  - Shoot weeds, monitor and tend crops
- Challenges in environment sensing
  - How to localise and manoeuvre within such a large space
  - How to sense at the farms and react, vision, soil sensors etc.
- Just observed some commercialization activities recently, still have some time to prove their usability…

Australian Centre of Field Robotics: RIPPA

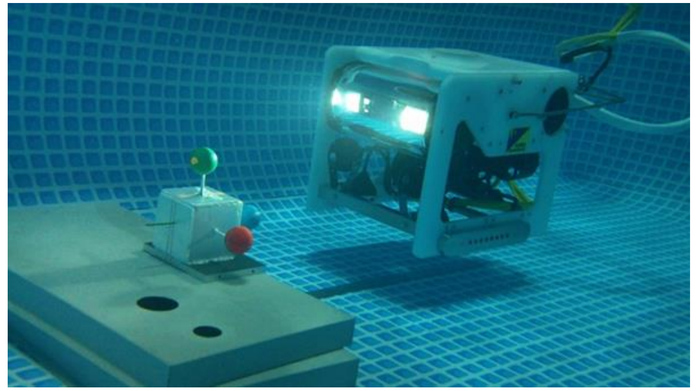
Universidad Politécnica de Madrid (UPM): Rosphere

UAV at vineyards

Classification of Robots

By Function – Hazardous and Rescue

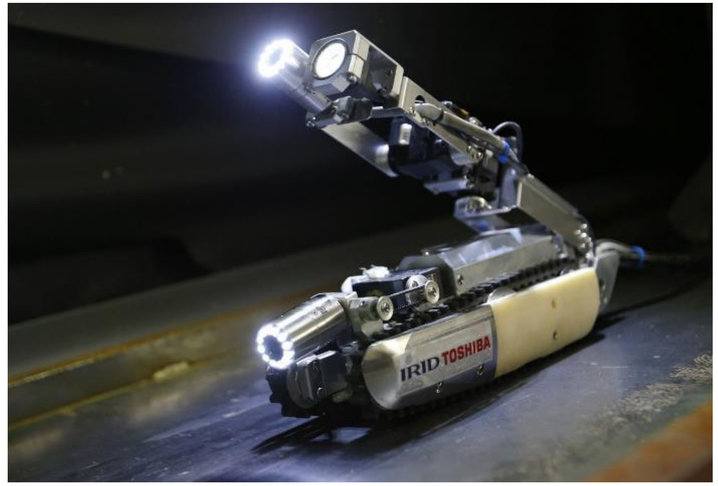
- Take advantage of robots to operate in environments that humans cannot operate in or are dangerous to
  - Small environments
  - Large spaces
  - Extreme hazardous environments
- Some challenges include:
  - How to design robots to operate in such unstructured environments
  - How to localise effectively in the environment
  - How to operate as a team to improve search efficiency
  - How to manipulate and interact with the environment



Okayama University Autonomous Underwater Vehicle

RoboCue (Japan)

Battlefield Extraction-Assist Robot (US)

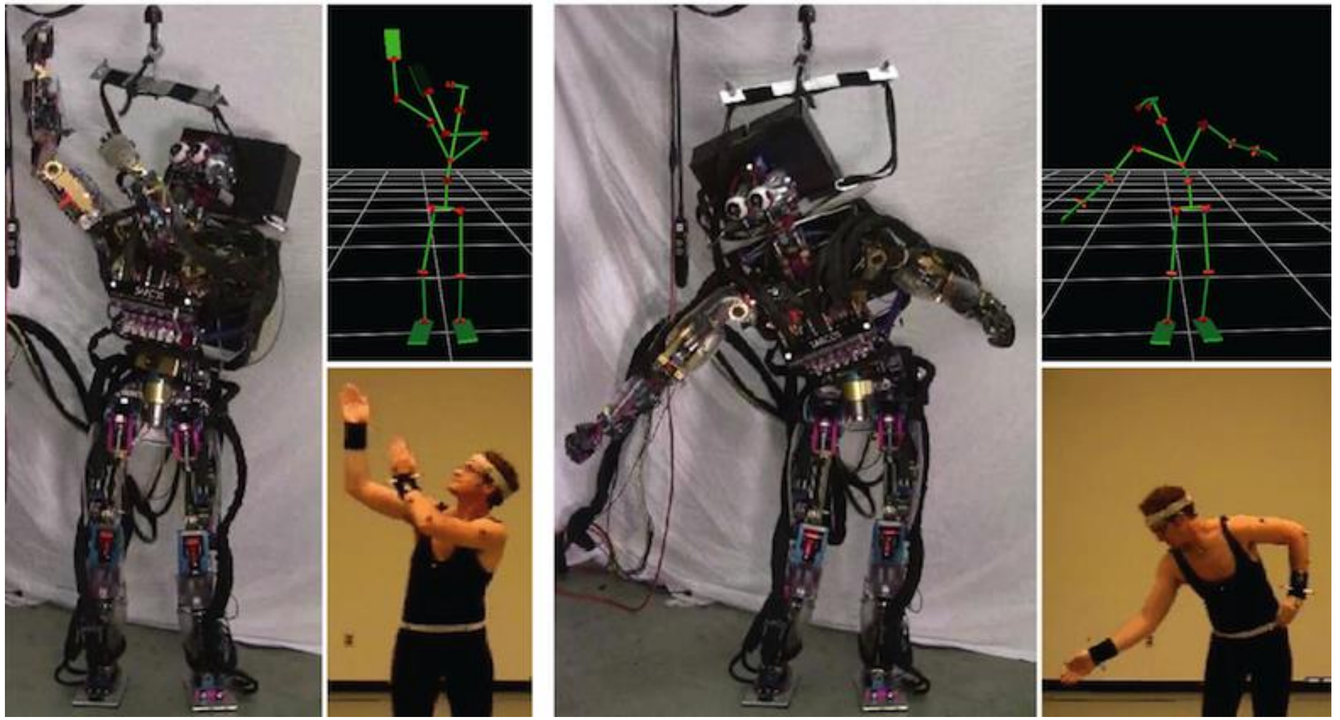


Nuclear Plant Inspection Robots (Toshiba, Japan)

Classification of Robots

By Function – Entertainment Robots

Music playing robots by Toyota

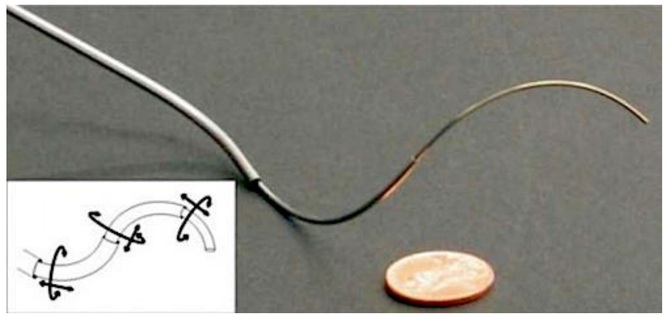


Disney Research: human motion replication using motion capture

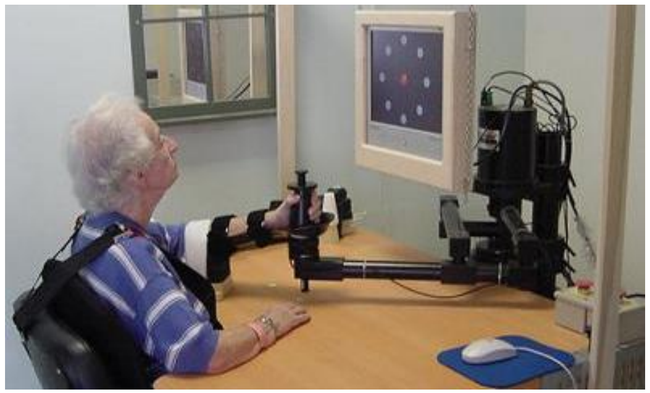
Classification of Robots

By Function – Medical Robots

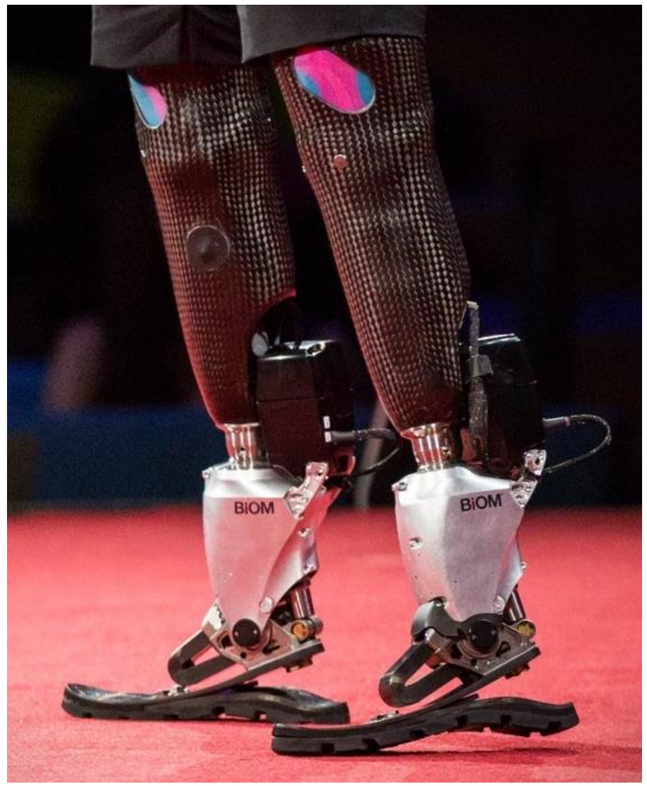
- An area that has great impact to the society
  - Rehabilitation robotics and prosthetics
  - Surgical robotics
  - Micro/nano manipulation for cell-manipulation



Vanderbilt University: steerable needle



MIT Newman Laboratory for Biomechanics and Human Rehabilitation



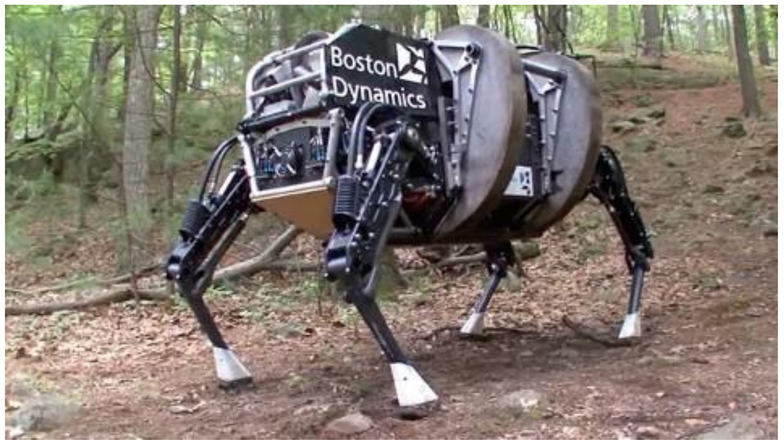
MIT Media Lab: bionic ankle-foot

IIT – Rehab Robots

ETHZ: Nanomag on an inverted microscope for cell manipulation

Classification of Robots

By Function – Military Robots



DARPA Big Dog

Foster-Miller TALON

Raytheon’s Sacros XOS 2 military exoskeleton

Classification of Robots

By Function – Service Robots

- Another very promising field that fits the society's needs
  - Aging population increasing
  - Robots will become more common in the society

Softbank Pepper

UVD-Robots fight covid-19

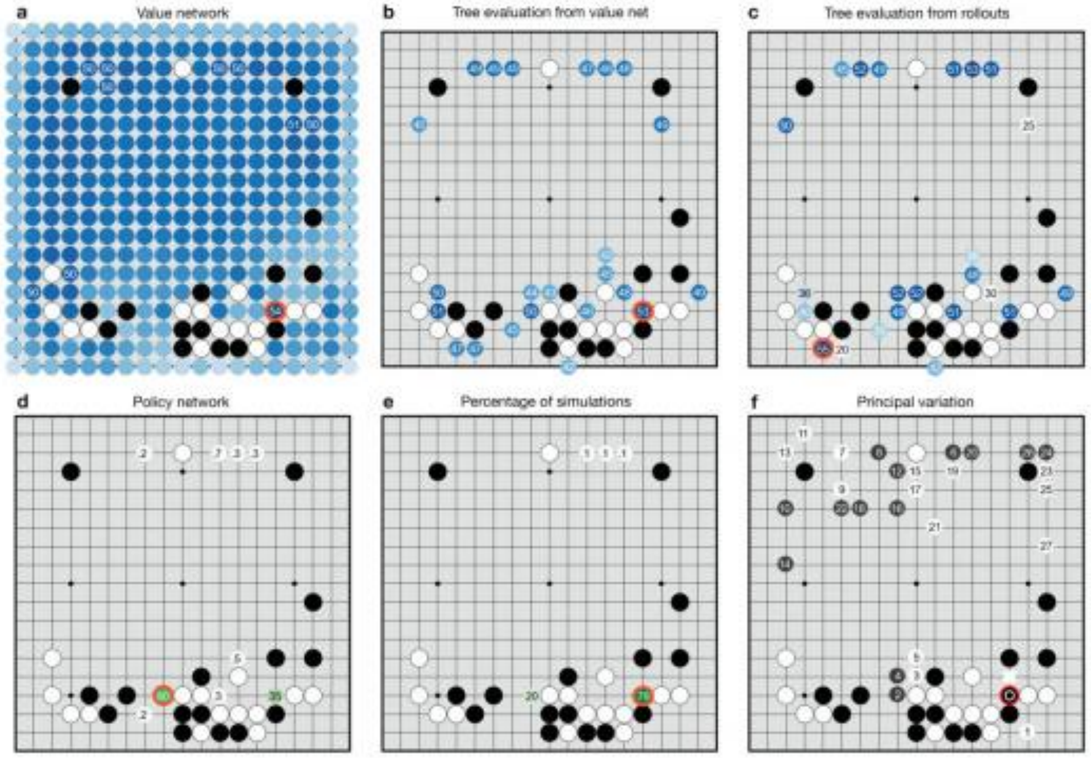
Fraunhofer IPA: Care-O-bot 4

Are We There Yet?

Advanced Robots
The Era of AI!

Are We There Yet?

AlphaGo is a computer program that plays the board game G



AlphaGo

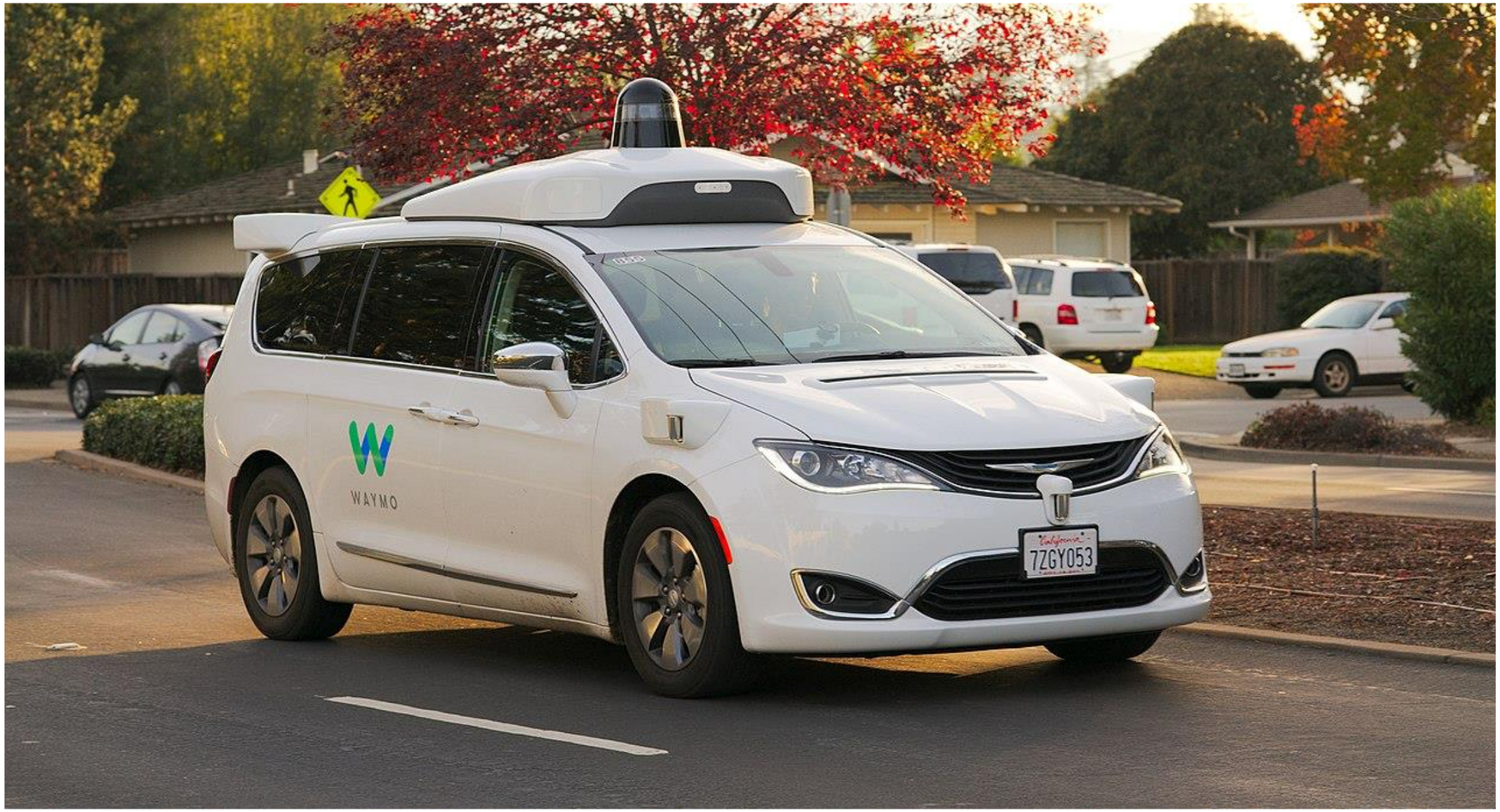
Are We There Yet?

Nvidia Isaac Gym Enables Robot to Learn Dexterous Manipulation

https://youtu.be/ReM3lVkcS2w

Are We There Yet?

Autonomous Driving



Are We There Yet?

The most agile running ever ?

https://youtu.be/5hwkbdmUijg

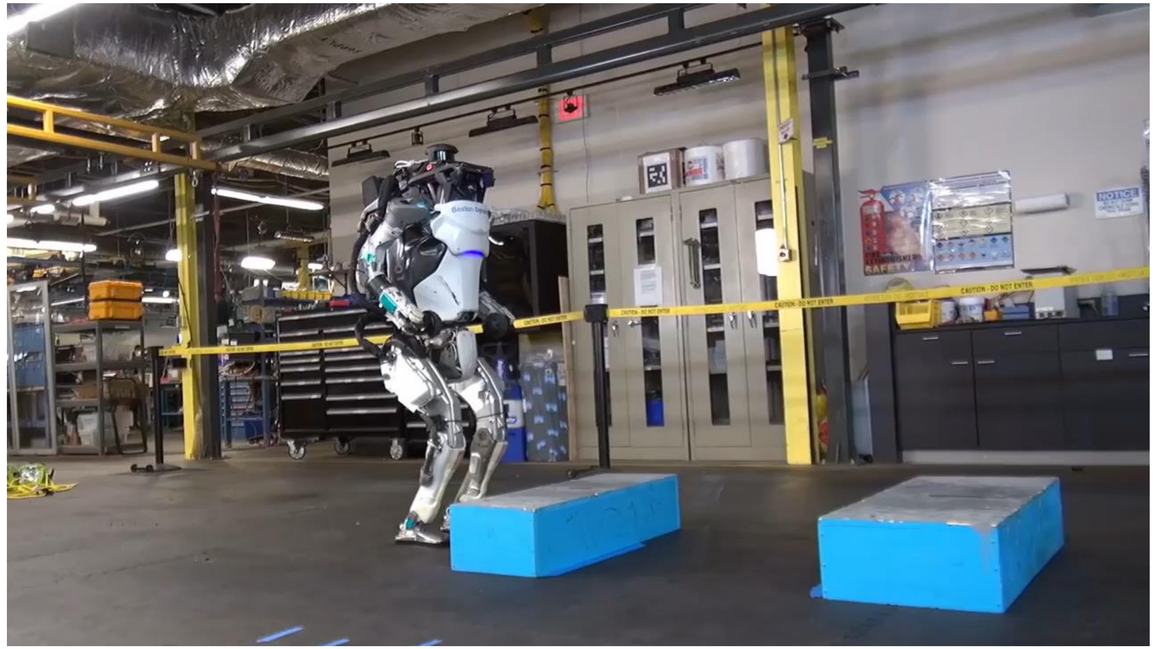
https://youtu.be/wE3fmFTtP9g

Animal v.s. Robot

Are We There Yet?

The best flip ever ?

https://youtu.be/zM5tjn8T9mg



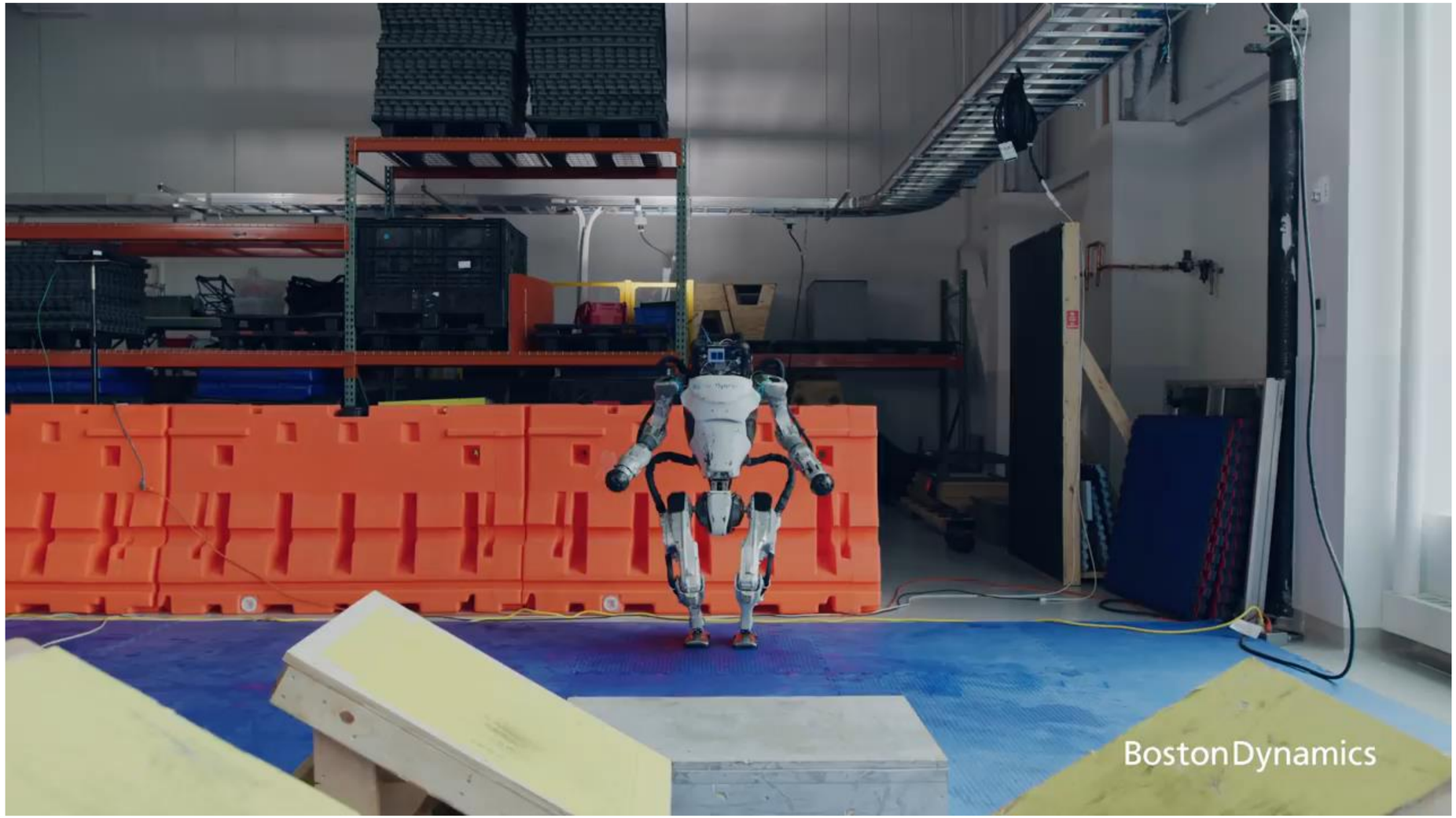
https://youtu.be/fRj34o4hN4I

Human v.s. Robot

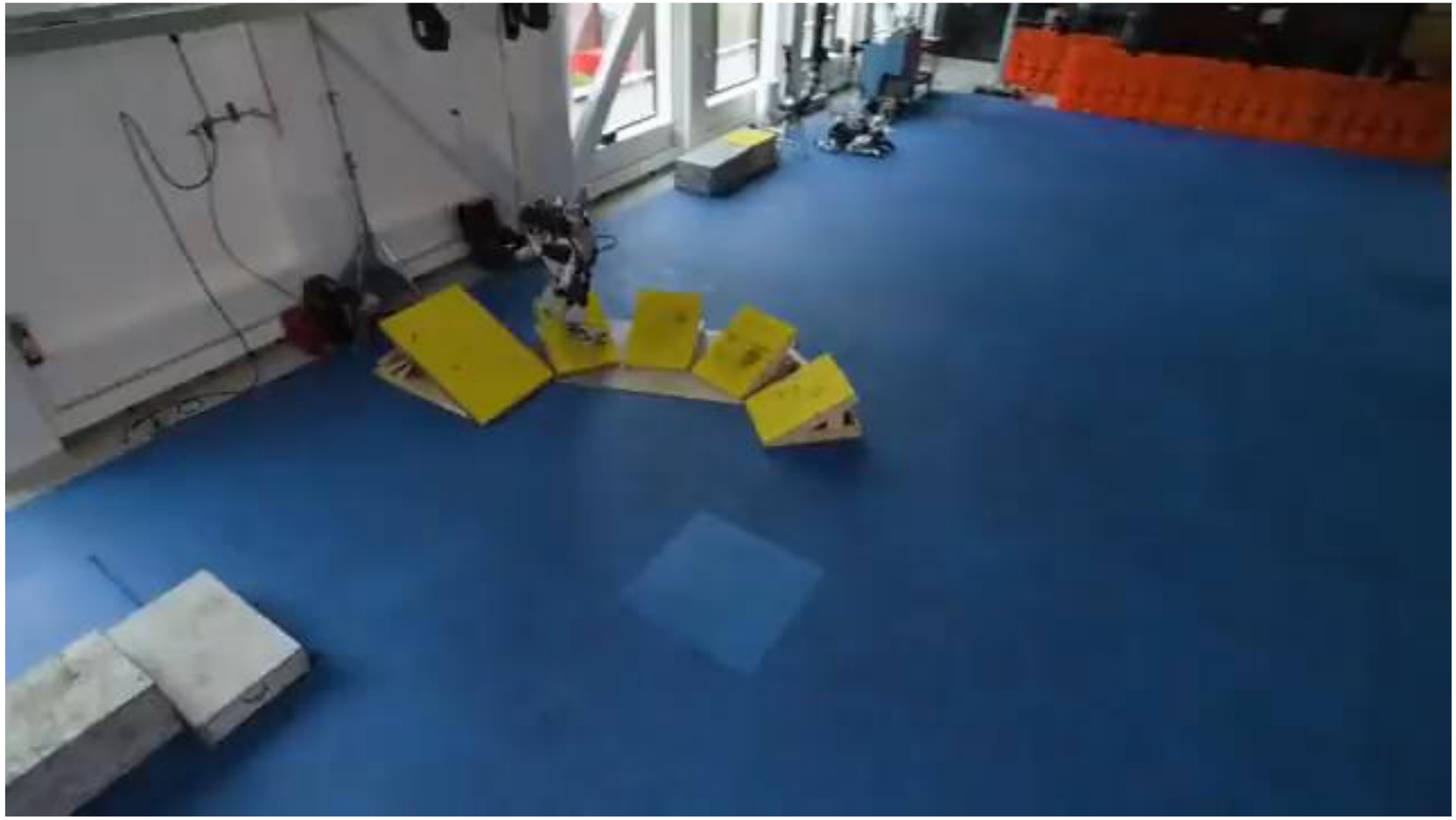
Are We There Yet?

ATLAS – Boston Dynamics

28 hydraulic joints
1.5 meters per second
1.5 meters height
89 KG weight



Robotics is Advanced Technology Yet Still Hard!



It’s Your MISSION!

To Advance the Robotic Technologies

ENGG5402

Tend to Offer Necessary Knowledges for Advanced Robotics

Q&A