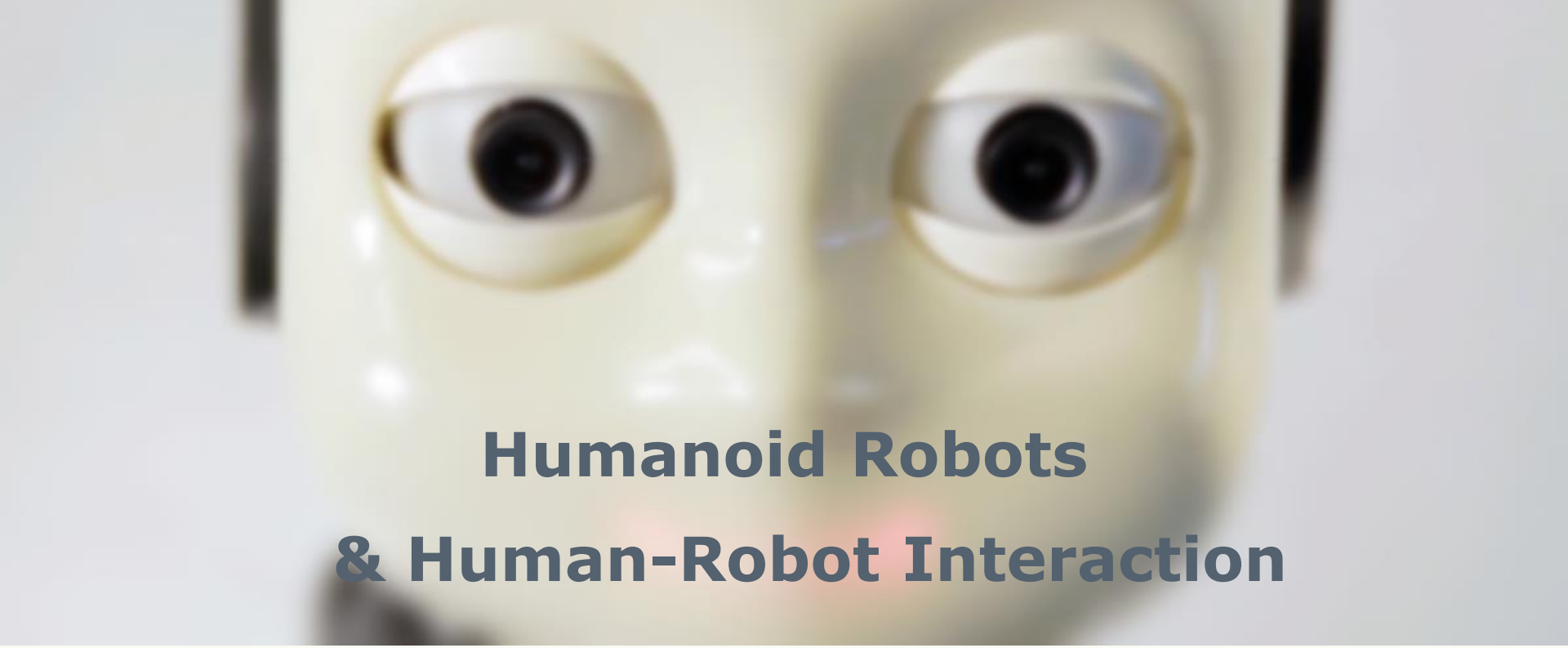


Humanoid Robots
& Human-Robot Interaction

Doc. Mgr. Matěj Hoffmann, Ph.D.
Department of Cybernetics, Faculty of Electrical Engineering
Czech Technical University in Prague
matej.hoffmann@fel.cvut.cz
https://sites.google.com/site/matejhof
https://cyber.felk.cvut.cz/research/groups-teams/humanoids/

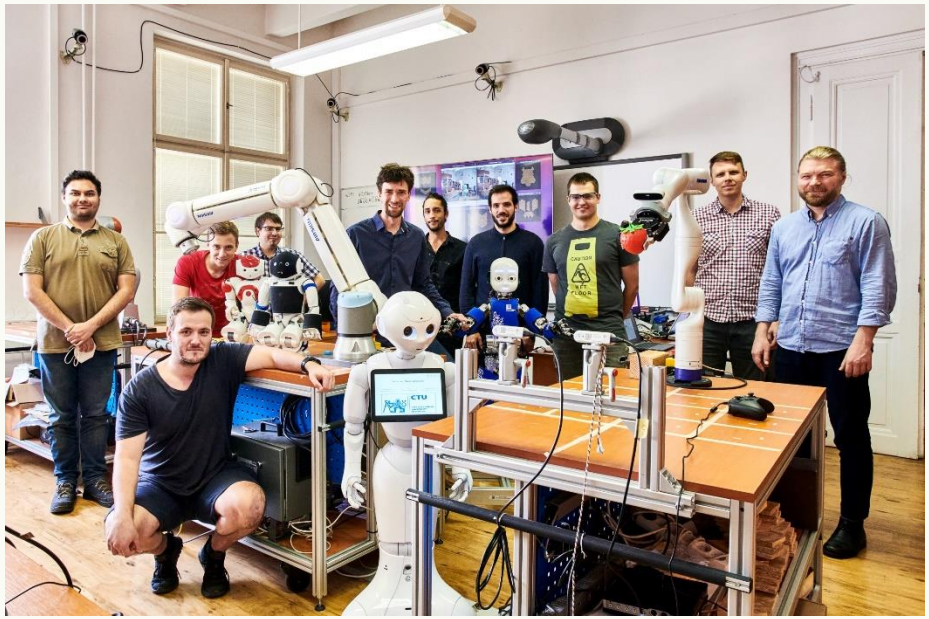
Overview

- Subject description:
  - B3M33HRO Humanoidní roboti / BE3M33HRO Humanoid robots
- Course website and rules of the game:
  - https://cw.fel.cvut.cz/wiki/courses/hro/start
- Literature and resources:
  - lectures and lecture slides
  - https://cw.fel.cvut.cz/wiki/courses/hro/literature

Team

Lectures

Matěj Hoffmann



https://cyber.felk.cvut.cz/research/groups-teams/humanoids/

Labs

Lukáš Rustler

Shubhan Patni

Tomáš Chaloupecký

Jason Khoury

What is a robot?

any **automatically** operated machine that **replaces human effort**, though it **may not resemble human beings** in appearance or perform functions in a humanlike manner.
https://www.britannica.com/technology/robot-technology

a machine that **resembles a living creature** in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)
often: such a machine built to **resemble a human being or animal in appearance and behavior**
https://www.merriam-webster.com/dictionary/robot

[M.H. added emphasis]

What Is a Robot?*
By Rodney Brooks

Shall I compare thee to creatures of God?
Thou art more simple and yet more remote.
You move about, but still today, a clod,
You sense and act but don't see or emote.

You make fast maps with laser light all spread,
Then compare shapes to object libraries,
And quickly plan a path, to move ahead,
Then roll and touch and grasp so clumsily.

You learn just the tiniest little bit,
And start to show some low intelligence,
But we, your makers, Gods not, we admit,
All pledge to quest for genuine sentience.

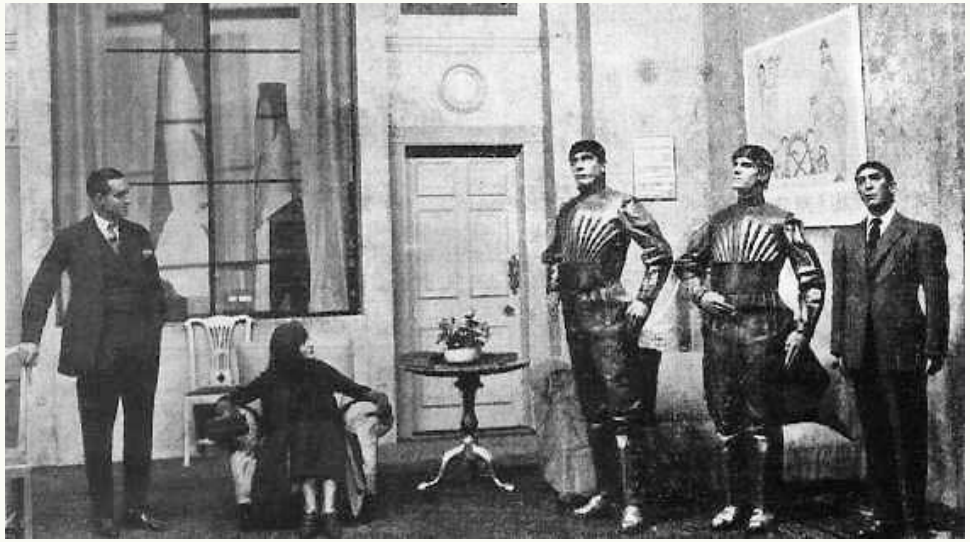
So long as mortals breathe, or eyes can see,
We shall endeavor to give life to thee.

* With thanks to William Shakespeare

History and etymology

The concept of artificial humans predates recorded history (*see* automaton), but the modern term *robot* derives from the Czech word *robota* ("forced labour" or "serf"), used in Karel Čapek's play *R.U.R.* (1920). The play's robots were manufactured humans, heartlessly exploited by factory owners until they revolted and ultimately destroyed humanity.

https://www.britannica.com/technology/robot-technology



Automata in history

Year	Invention
1000BC	**Talos**
100AD	Early automata
1500s	Leonardo da Vinci's Mechanical Lion
1580s	Rabbi Loew's Golem
1700s	Pierre Jaquet-Droz' Writing automaton
1738	Jacques de Vaucanson Mechanical Duck
1816	Mary Shelley
1833	Babbage's difference engines
1926	Metropolis: Maria
1961	George Devol's Unimate

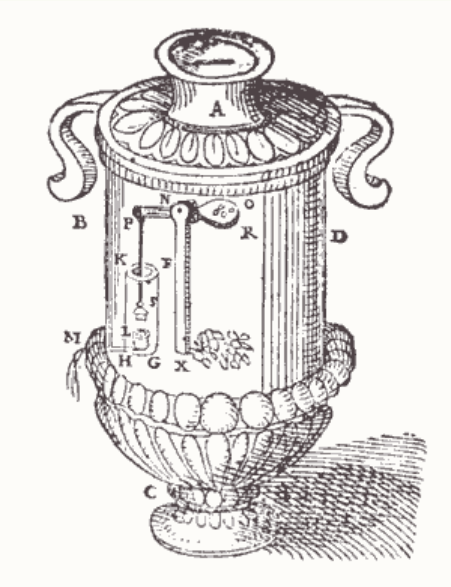
Talos (Τάλως)

From Greek mythology - a giant automaton made of bronze to protect Europa in Crete from pirates and invaders. He circled the island's shores three times daily.

[Slide source – courtesy Alessandro Roncone]

Automata in history

Year	Invention
1000BC	Talos
100AD	**Early automata**
1500s	Leonardo da Vinci's Mechanical Lion
1580s	Rabbi Loew's Golem
1700s	Pierre Jaquet-Droz' Writing automaton
1738	Jacques de Vaucanson Mechanical Duck
1816	Mary Shelley
1833	Babbage's difference engines
1926	Metropolis: Maria
1961	George Devol's Unimate



Heron of Alexandria: the world's first vending machine dispensed holy water. Temple visitors would insert a coin into Heron's machine that would fall onto a lever which would open a valve and let water flow out.

[Slide source – courtesy Alessandro Roncone]

Automata in history

Year	Invention
1000BC	Talos
100AD	Early automata
1500s	**Leonardo da Vinci's Mechanical Lion**
1580s	Rabbi Loew's Golem
1700s	Pierre Jaquet-Droz' Writing automaton
1738	Jacques de Vaucanson Mechanical Duck
1816	Mary Shelley
1833	Babbage's difference engines
1926	Metropolis: Maria
1961	George Devol's Unimate

[Slide source – courtesy Alessandro Roncone]

"Robots" in History

Year	Invention
1000BC	Talos
100AD	Early automata
1500s	Leonardo da Vinci's Mechanical Lion
1580s	Rabbi Loew's Golem
1700s	Pierre Jaquet-Droz' Writing automaton
1738	Jacques de Vaucanson Mechanical Duck
1816	Mary Shelley
1833	Babbage's difference engines
1926	Metropolis: Maria
1961	**George Devol's Unimate**

[Slide source – courtesy Alessandro Roncone]

The First Commercial Robot (Unimate, 1961)

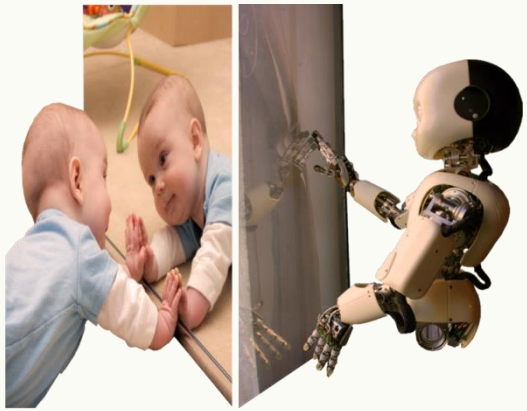
Why humanoid robots?

Humans are so good…
"Moreover, humans are generalists with the ability to perform
a wide variety of distinct tasks. Roboticists would like to create robots with comparable versatility and skill…. Exactly what to borrow from the human example is controversial."

Fig. 56.1 The humanoid robot HRP-1S driving a backhoe (Courtesy of Kawasaki Heavy Industries, Tokyu Construction and AIST). The robot can be teleoperated by a human operator to control the backhoe remotely. The same robot could potentially interface with many different unmodified machines

Human environments.
Stairs, doors, tables, human tools…
Humanoids vs. specialized machines and drive-by-wire….

"The pleasing mirror. Humans are humanity's favorite subject." "People are highly attuned to human characteristics."



Human-like interaction.
Communication…

Test-bed for theories from psychology and neuroscience.
Understanding (human) intelligence by building.

Based on Fitzpatrick, P., Harada, K., Kemp, C. C., Matsumoto, Y., Yokoi, K., & Yoshida, E. (2016). Humanoids. In *Springer handbook of robotics* (pp. 1789-1818). Springer, Cham.

Why humanoid robots (cont.)?

Teleoperation

- Bimanual manipulation needed for dexterity.
- Two cameras needed for depth.
- Head and two arms, set up such that you can see your arms.
- Force feedback through haptic interface.

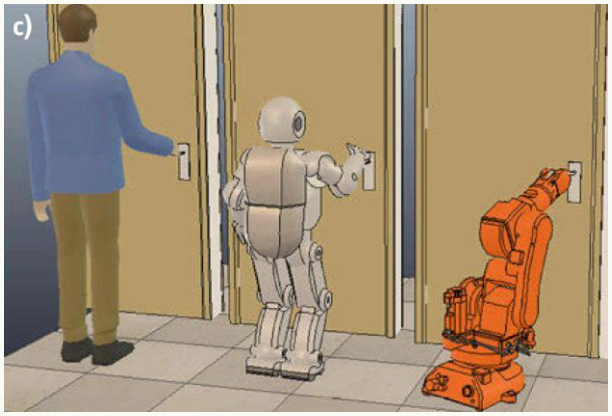
OceanOne – Oussama Khatib & Co., Stanford

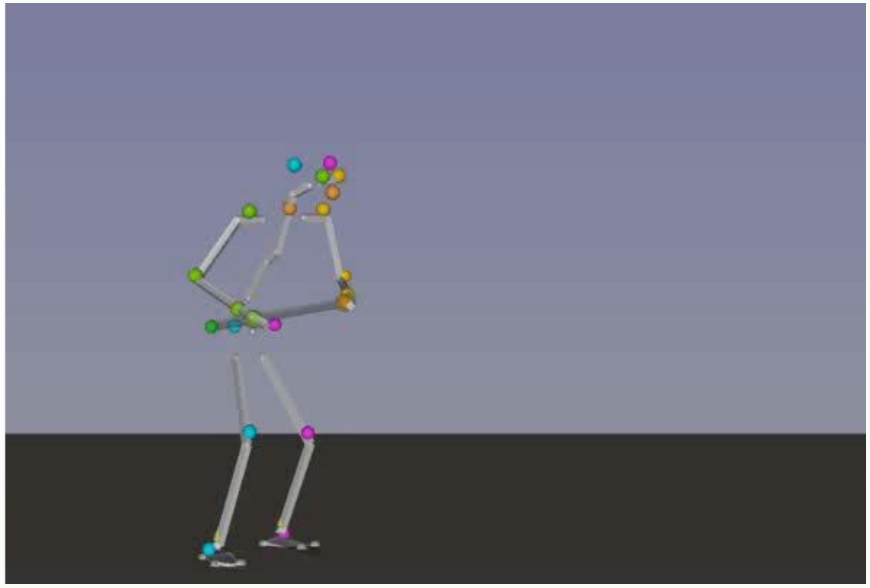
https://youtu.be/plHmgP9I4VY?si=eMkAu0zXD4q3Q275

Why humanoid robots (cont.)?

Learning from humans

Billard, A. G., Calinon, S., & Dillmann, R. (2016). Learning from humans. Springer handbook of robotics, 1995-2014.

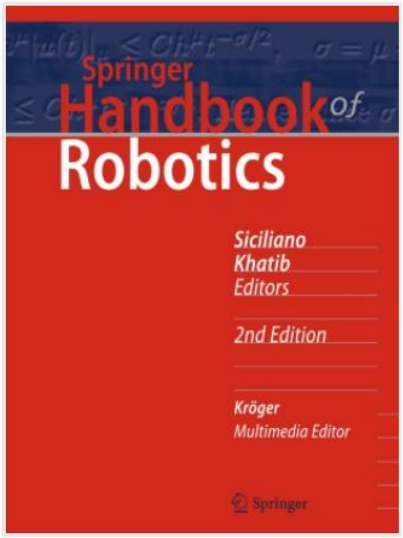




[Li, Sedlar, Carpentier, Mansard, Laptev, Sivic, Best paper finalist CVPR 2019; Extended version, IJCV 2022]

Robots and humans

Robots and Humans



Humanoid robots - history

Humanoid robots – history – WABOT

- 1973 – WABOT-1 - Ichiro Kato et al. @ Waseda University

"The WABOT robots integrated functions that have been under constant elaboration since: visual object recognition, speech generation, speech recognition, bimanual object manipulation, and bipedal walking."

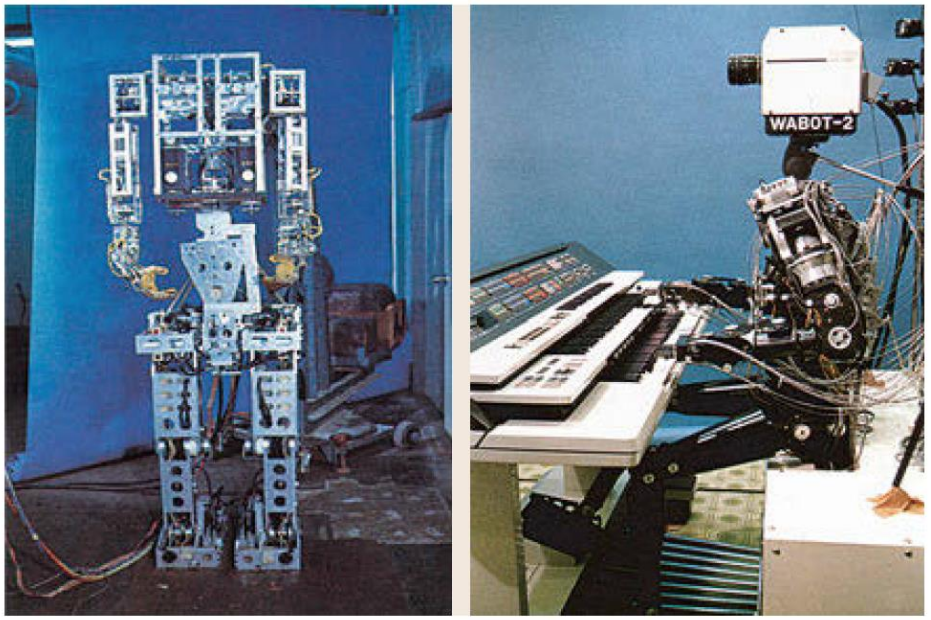
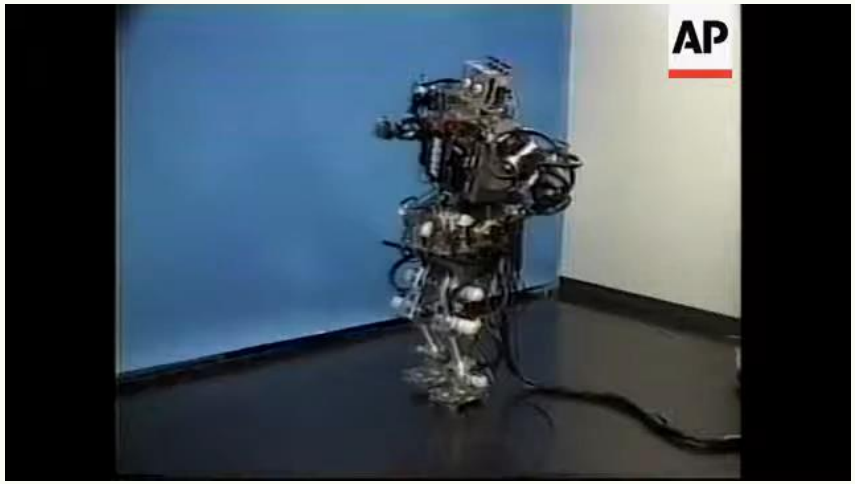


Fig. 67.8 (a) WABOT-1 (1973) and (b) WABOT-2 (1984; courtesy Humanoid Robotics Institute, Waseda University)



check also
https://robots.ieee.org/robots/

https://youtu.be/E9PyANzjeoY

Based on Fitzpatrick, P., Harada, K., Kemp, C. C., Matsumoto, Y., Yokoi, K., & Yoshida, E. (2016). Humanoids. In *Springer handbook of robotics* (pp. 1789-1818). Springer, Cham.

Humanoid robots – history – Honda ASIMO

- Honda project, i.e. not a university project
- Started in 1986 as a confidential project to create a humanoid biped.
- In 1996, Honda unveiled the Honda Humanoid P2
  - first full-scale humanoid capable of stable bipedal walking with onboard power and processing
- leap forward in sturdiness, using specially cast lightweight high-rigidity mechanical links, and harmonic drives with high torque capacity.

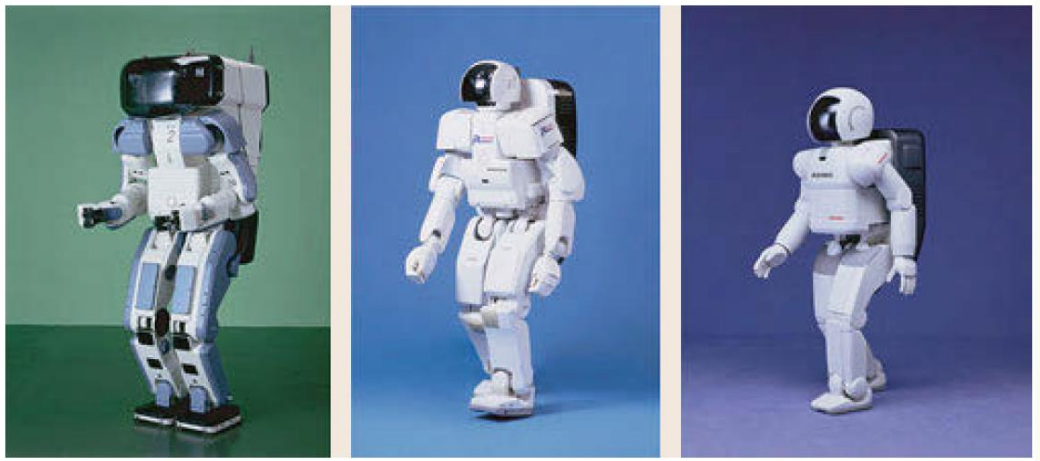


Fig. 67.9 (a) Honda P2 (180 cm tall, 210 kg), (b) P3 (160 cm, 130 kg), and (c) advanced step in innovative mobility (glossnoidx-ASIMOadvanced step in innovative mobility) (120 cm, 43 kg) (after [67.31]; courtesy Honda)

https://youtu.be/NZngYDODfW4

Note: anthropomorphization

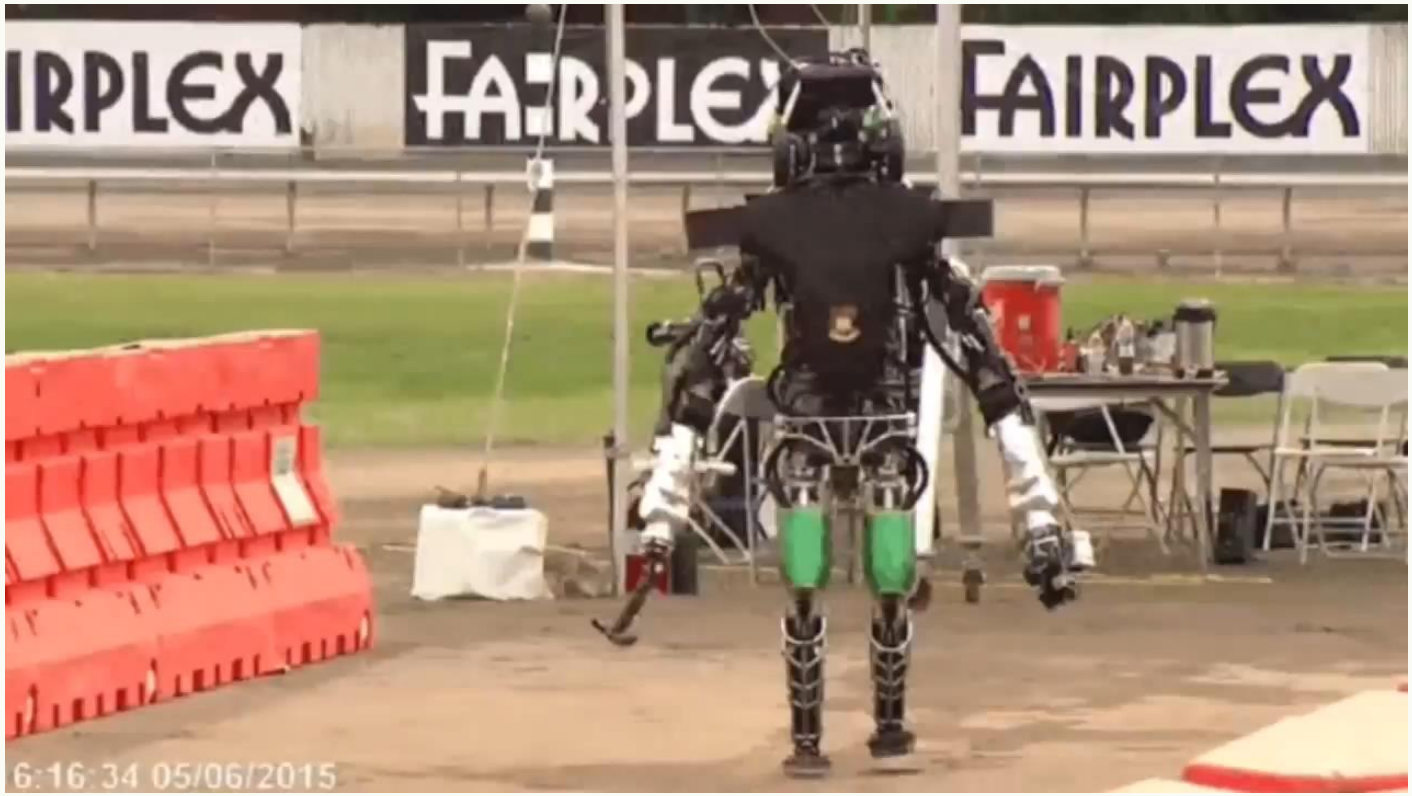
Based on Fitzpatrick, P., Harada, K., Kemp, C. C., Matsumoto, Y., Yokoi, K., & Yoshida, E. (2016). Humanoids. In *Springer handbook of robotics* (pp. 1789-1818). Springer, Cham.

Humanoid robots – present

Humanoid robots – immediate past

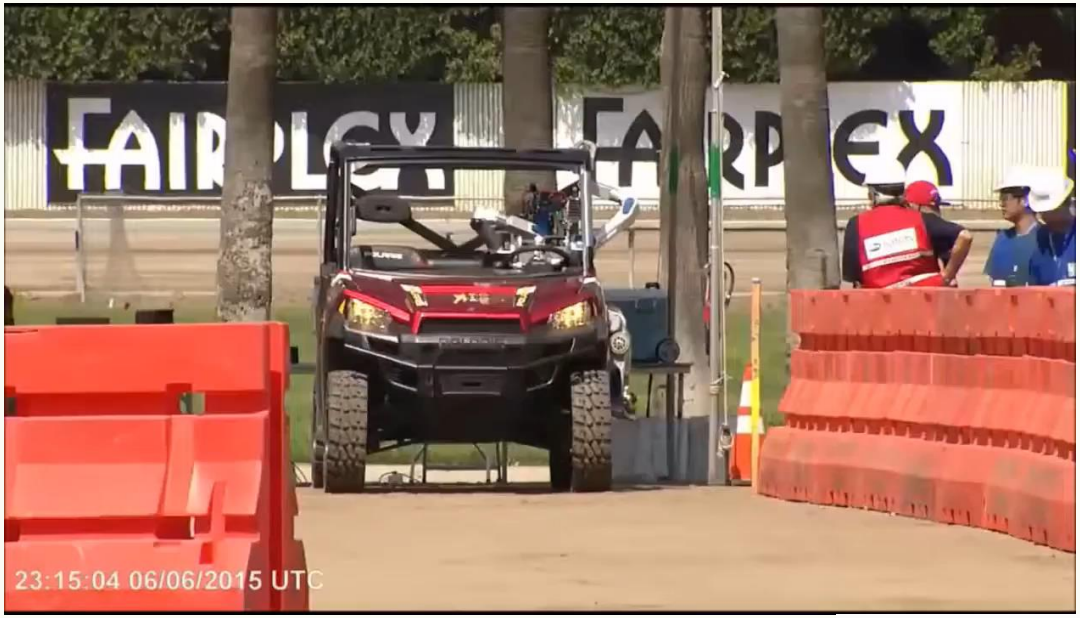
DARPA Robotics Challenge (DRC) (2012-2015)

- aimed to develop semi-autonomous ground robots that could do "complex tasks in dangerous, degraded, human-engineered environments”
- 7/18 teams with Atlas (Boston Dynamics)



https://youtu.be/g0TaYhjpOfo

Alternative designs



Winner: KAIST – DRC Hubo
https://youtu.be/H3PptkxA5CU

3rd – CHIMP CMU Tartan Rescue
https://youtu.be/Wi2WsPUYDoY

DARPA Robotics Challenge

NREC National Robotics Engineering Center

Carnegie Mellon University TARTAN RESCUE

PIs: Tony Stentz, Alonzo Kelly, Herman Herman, Eric Meyhofer
Systems Lead: David Stager

DARPA PM: Dr. Gill Pratt

7/18 teams at DRC with Atlas.

Atlas (Boston dynamics)

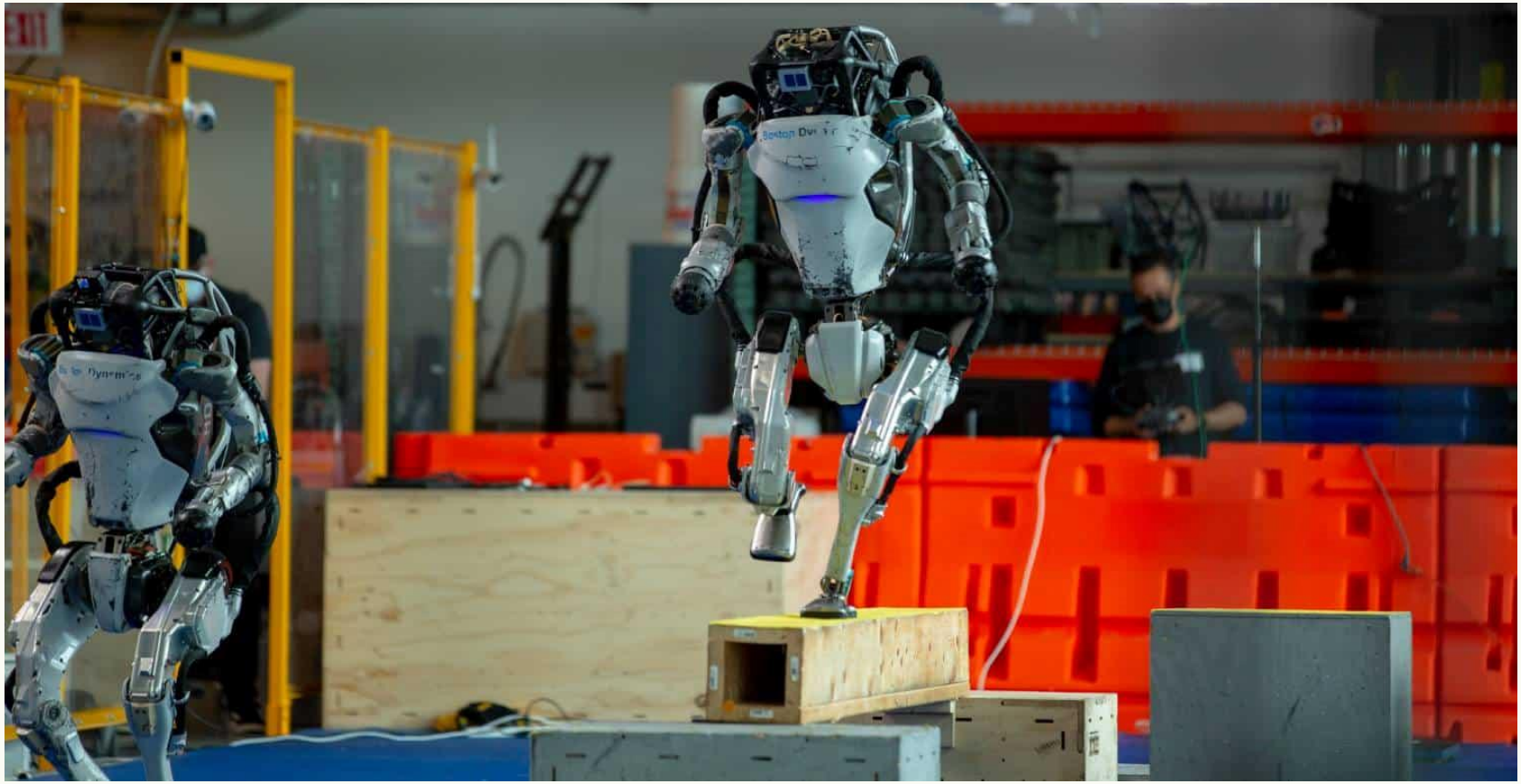
How smart / autonomous do you think the robot actually is?

Atrias (Oregon State U., J. Hurst)

Oregon State University team at DRC.

Humanoid robots – present

Atlas (Boston dynamics)

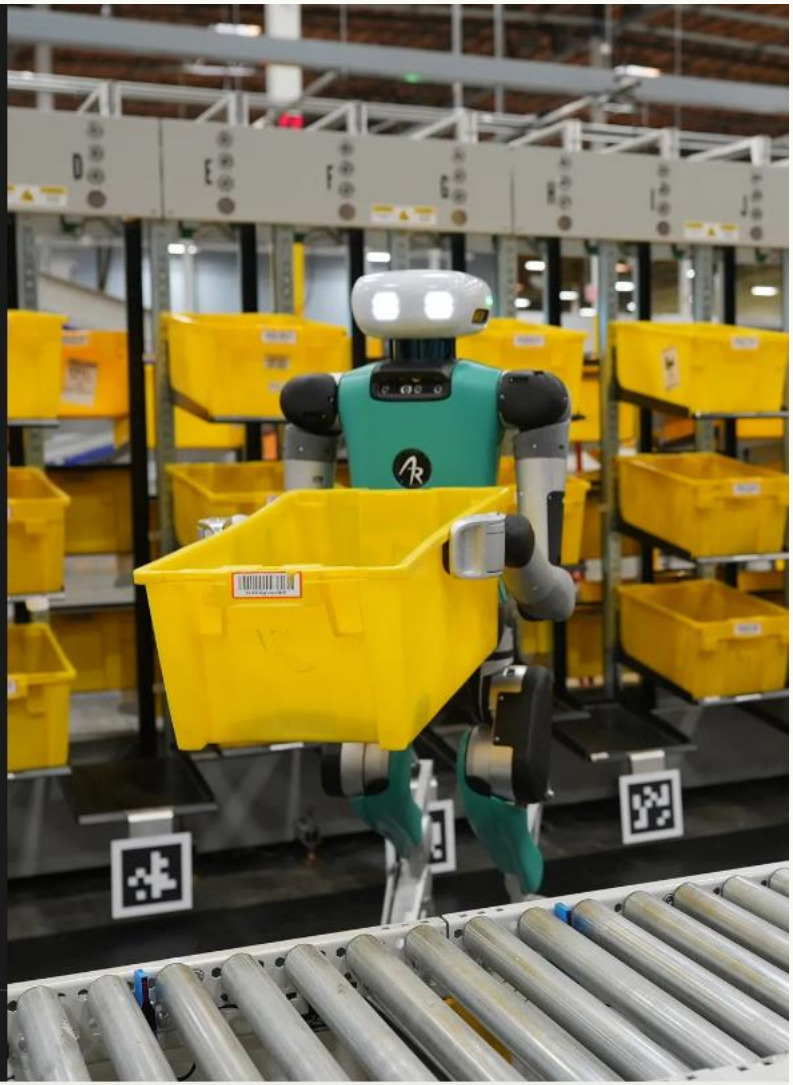


https://bostondynamics.com/atlas/

HUMANOID ROBOTS ARE GETTING TO WORK

Humanoids from Agility Robotics and seven other companies vie for jobs

BY EVAN ACKERMAN
30 DEC 2023 | 7 MIN READ |



Agility Robotics' Digit carries an empty tote to a conveyor in an Amazon research and development warehouse. AGILITY ROBOTICS

https://spectrum.ieee.org/humanoid-robots

Digit – Human-centric vs. humanoid

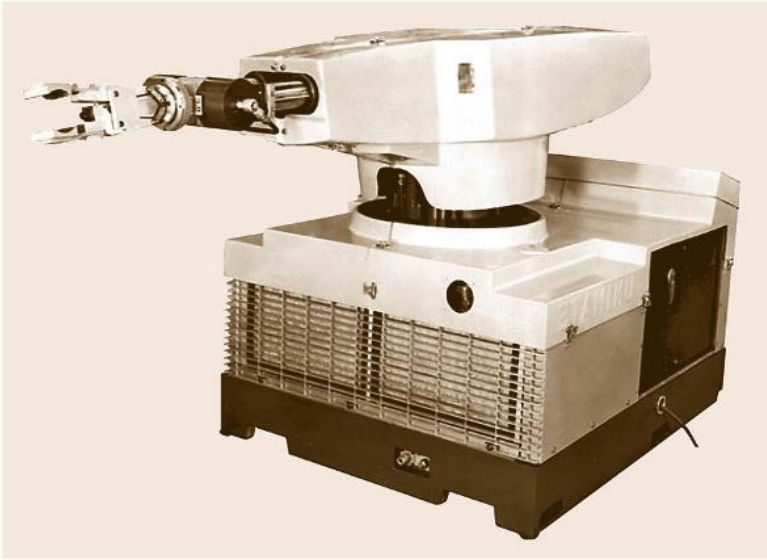
https://youtu.be/RgT3fLz-9tA?si=J8tqe6ormHlqdHwR

From robots replacing people…

D³ = Dull, Dirty, and Dangerous tasks

[Gill Pratt]

Increase of automation leads to increase of productivity



[Slide source – courtesy Alessandro Roncone]

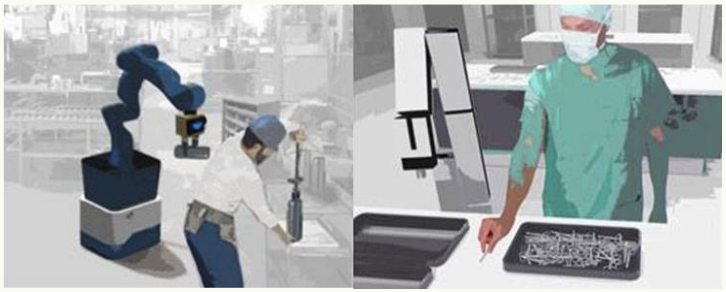
…to people helping robots…

D^3 = Dull, Dirty, and Dangerous tasks [Gill Pratt]

Increase of **collaboration** leads to increase of productivity

[Slide source – courtesy Alessandro Roncone]

…or robots helping people



[Slide source – courtesy Alessandro Roncone]

Stretch

- Boston Dynamics product (unlike Atlas)
- less human-centric & humanoid…

https://youtu.be/8WZoVJIV9V0?si=5JkuO6AqTUCAL7qU

Mass production of humanoids

TECH

Agility Robotics is opening a humanoid robot factory, beating Tesla to the punch

PUBLISHED MON, SEP 18 2023•11:27 AM EDT | UPDATED MON, SEP 18 2023•1:34 PM EDT

Lora Kolodny
@IN/LORAKOLODNY/

SHARE

KEY POINTS

- Agility Robotics is opening a first-of-its-kind factory in Salem, Oregon where it will mass produce a line of humanoid robots called Digit.
- The new factory, which Agility has dubbed the RoboFab, will produce up to 10,000 units a year and employ 500 people, according to COO Aindrea Campbell, formerly Apple's senior director of iPad operations.
- Digit was designed to function as a "robotic co-worker" that can maneuver around warehouses and factories, traversing steps or crouching into small spaces.

TRENDING NOW

Barclays announc strategic

Russia d Russian treason; North Ko luxury ca

Capital C Discover Services all-stock

Disney st CEO: Bri launches startup b VCs

Magnific exceed a country i Should w

Tech / Tech Trends

World's first mass-produced humanoid robot? China start-up Fourier Intelligence eyes two-legged robots with AI brains

- The Shanghai-based company plans to begin mass production of its GR-1 robot by end of 2023 and deliver thousands of units next year
- Fourier hopes to collaborate with major AI companies to work on the 'brain' of its bipedal robot

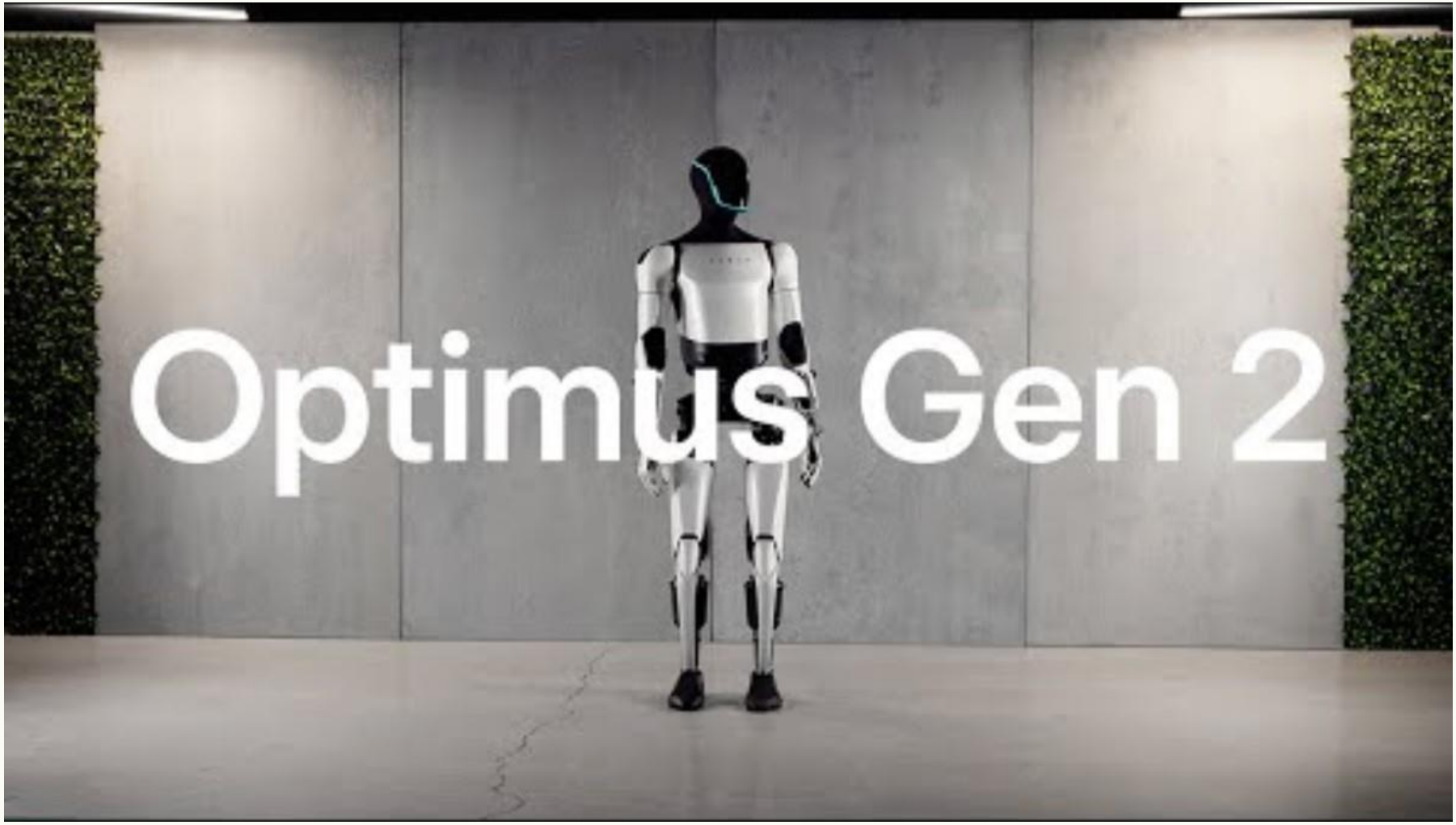
Listen to this article

Ann Cao in Shanghai + FOLLOW
Published: 8:00am, 13 Aug, 2023

Why you can trust SCMP

Fourier Intelligence's GR-1 robot walks past the company logo at its headquarters in Shanghai. Photo: Handout

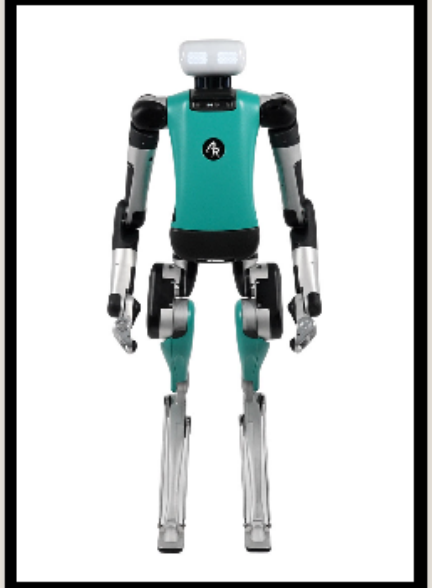
Tesla bot / Optimus



https://youtu.be/cpraXaw7dyc?si=yNrfcVEh7xjLzFli

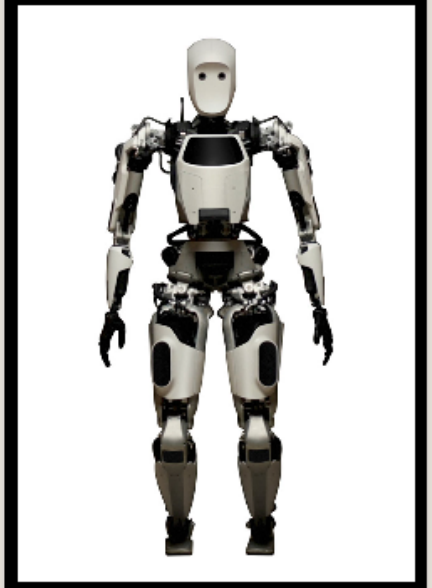
Robots to Look for in 2024

Digit
Agility Robotics



Digit is most accurately described as "bipedal" rather than "humanoid." It has two legs, but its legs look more like those of an ostrich rather than a human's. This is a side effect of Agility's design process, the goal of which was to maximize the efficiency and robustness of legged locomotion.

Apollo
Apptronik



Apptronik has worked on more than half a dozen humanoid robots over the past eight years, including NASA's Valkyrie. Apollo is the culmination of all this experience and is designed for manufacturability. Apptronik plans to field its robots in 10 pilot projects in 2024, with a full commercial release of Apollo in 2025.

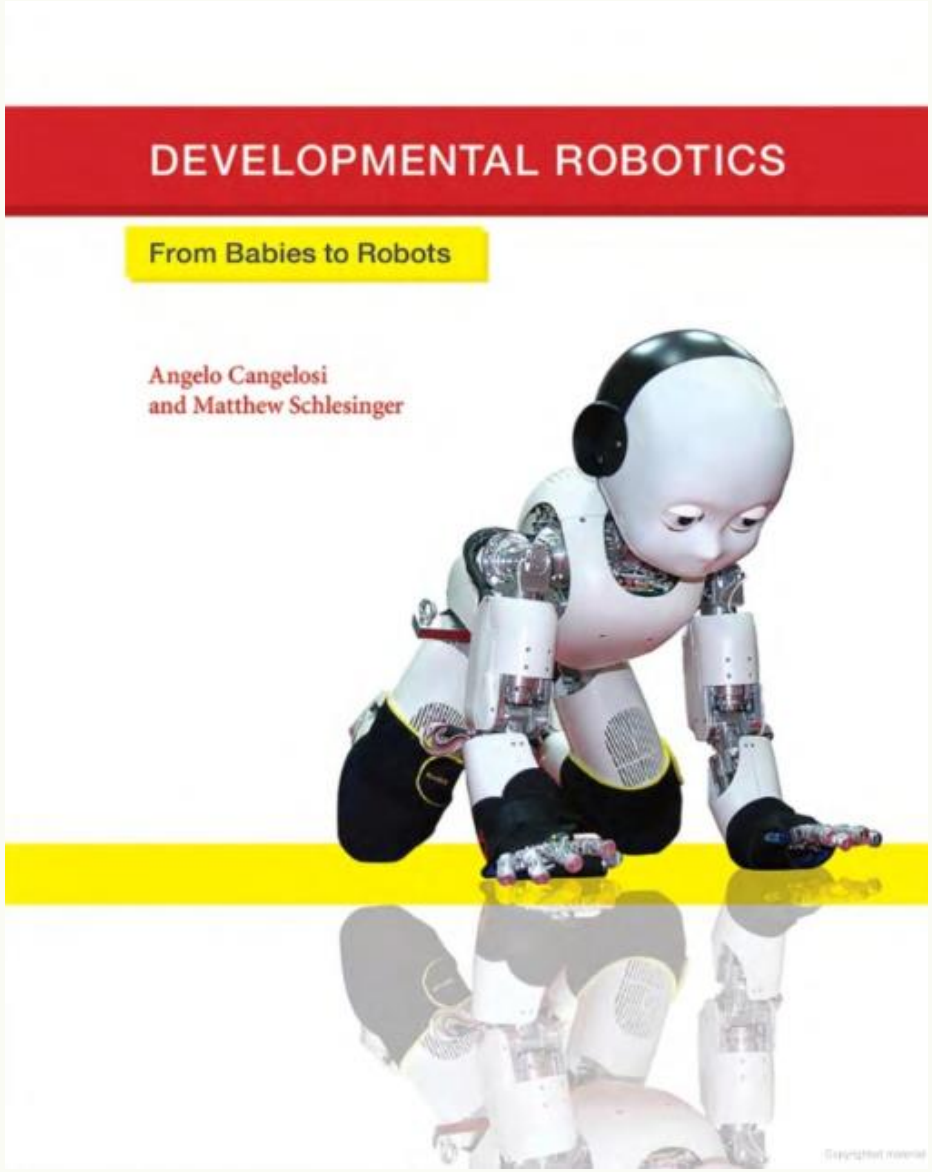
Neo
1X Technologies

1X's soft, tendon-based robot is designed to have very low inertia with the goal of building a robot that's safe for humans to be around. The robot will weigh just 30 kilograms, with a carrying capacity of up to 20 kg. 1X, backed by OpenAI, hopes that Neo will become "an all-purpose android assistant to your daily life."

IEEE Spectrum

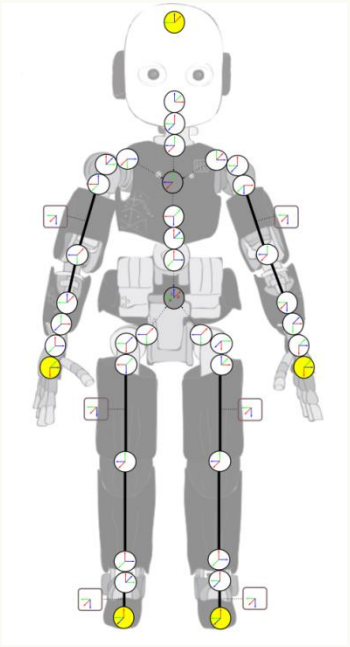
https://spectrum.ieee.org/humanoid-robots

Baby humanoid robots



The iCub humanoid (2004 – now)

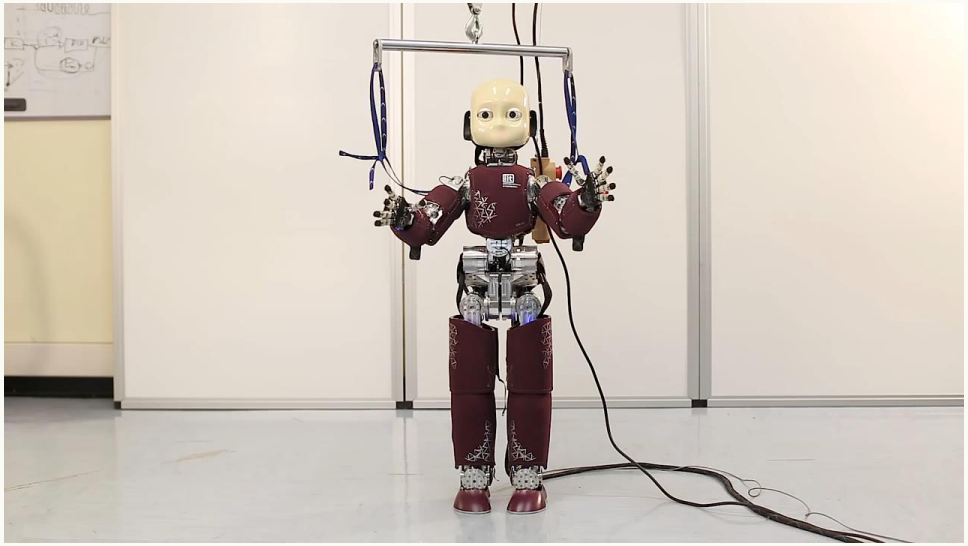
- Size of a 4 year old child
- Motor / proprioception (joint angles)
  - 53 DOF
- **Tactile information**
  - cca 4000 pressure-sensitive tactile elements (taxels) on the whole body
- Vision
  - 2 standard cameras in biomimetic DOF setup (pan, tilt, vergence)
- Force/torque sensors
- Inertial sensors
- Microphones…

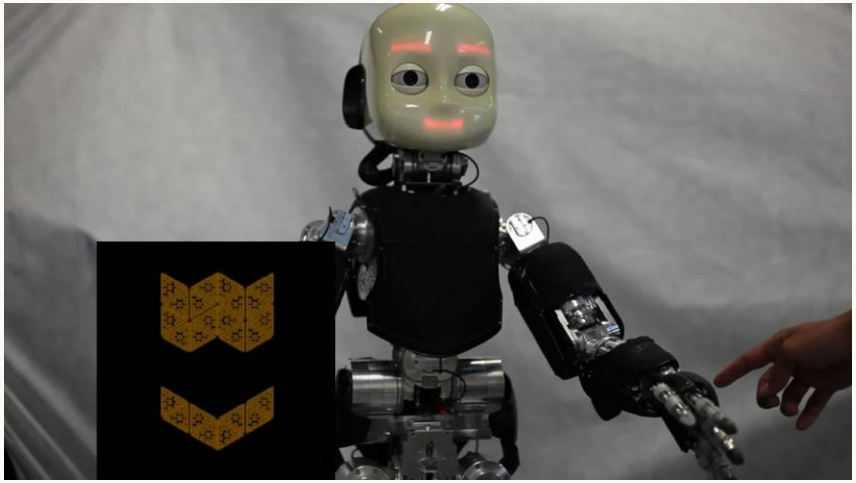


iCub (videos)

iCub youtube channel: https://www.youtube.com/channel/UCXBFWo4IQFkSJBfqdNrE1cA

https://youtu.be/UPOLcEIvwA0





https://youtu.be/pfse424t5mQ

Roncone, A.; Hoffmann, M.; Pattacini, U. & Metta, G. (2014), Automatic kinematic chain calibration using artificial skin: self-touch in the iCub humanoid robot, in 'Robotics and Automation (ICRA), 2014 IEEE International Conference on', pp. 2305-2312.

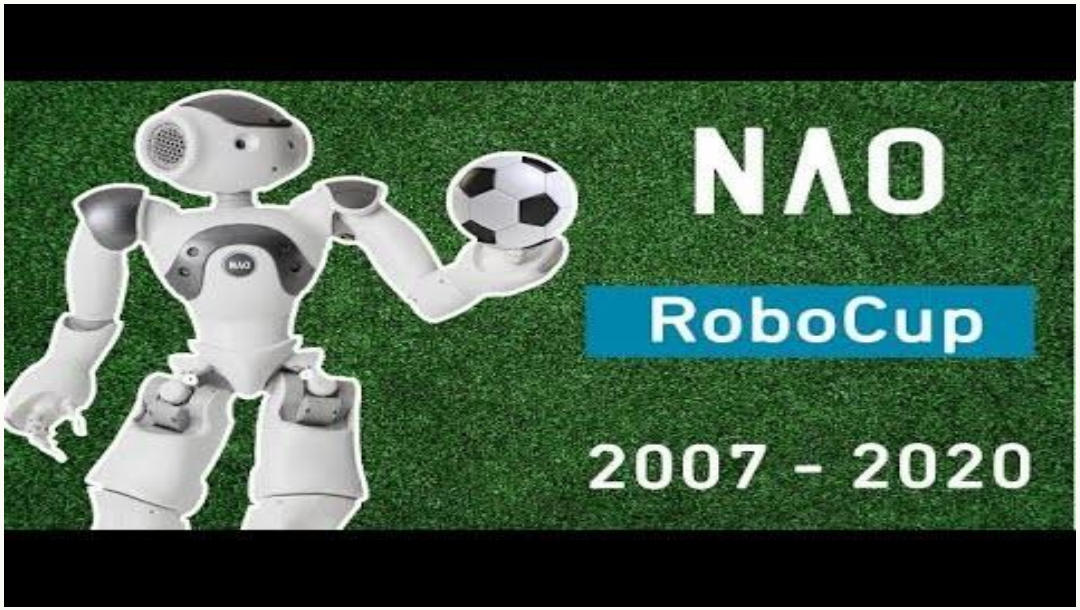
iCub at the center of this course

- Why?
  - it is a universal versatile platform – we can study kinematics, dynamics, reaching, grasping, gaze, walking, balancing, …
  - it is a standard research platform – with 50 exemplars around the world (see https://robot-bazaar.iit.it/robots)
  - it is open source; large collection of modules and training materials available (https://github.com/robotology, https://github.com/vvv-school, https://github.com/icub-training)
  - it is available in our lab!

Educational and social robots

Nao robot (2008 – now)

- 2008, Aldebaran/Softbank
- Currently in V6
- Used as a unified platform for research, social HRI in particular
- Used also for robot football - Robocup
- Allows easy control via Choregraphe



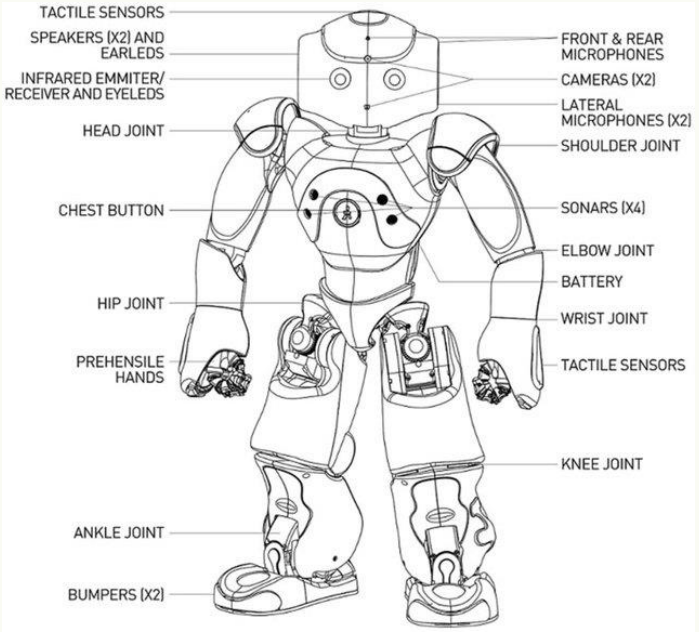
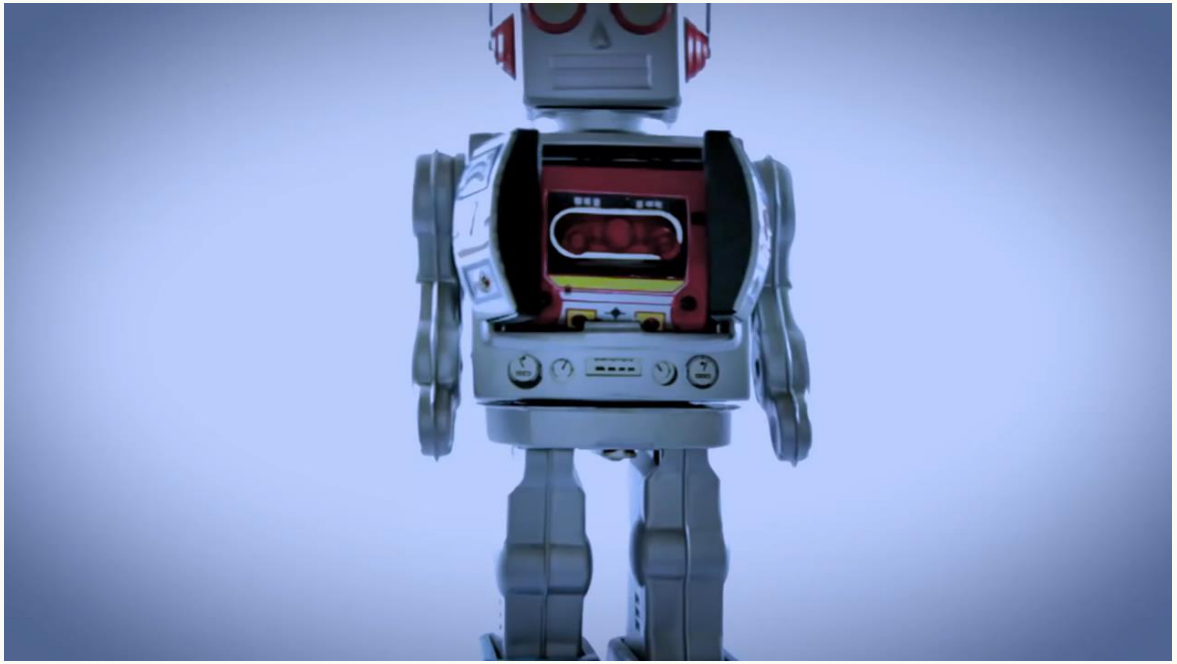


image courtesy of Softbank robotics

https://youtu.be/-WpAbjNR7Y4

Pepper robot (2014 – now)

- Spiritual successor to Nao, 2014
- Humanoid robot aimed at social interaction
- More widely used in practice (e.g., stores)
- Similar basic design, equipment, and software



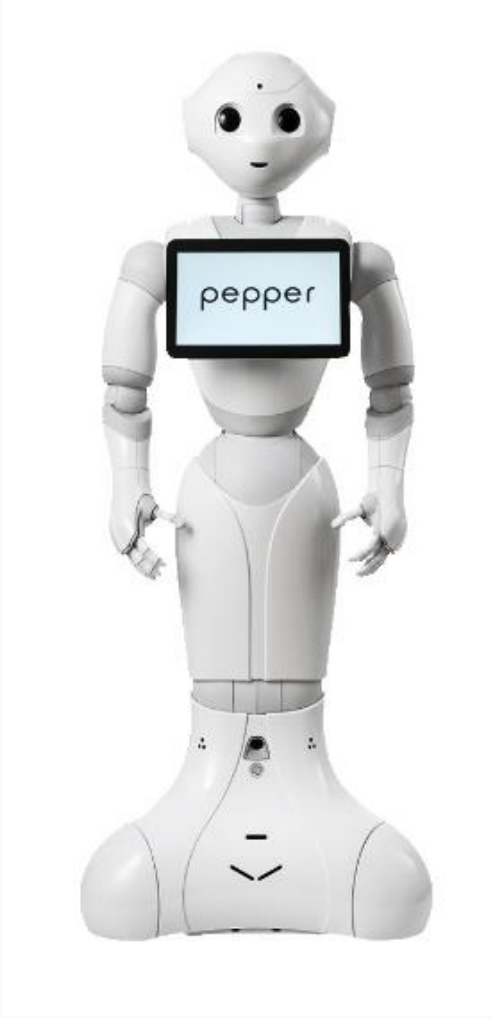
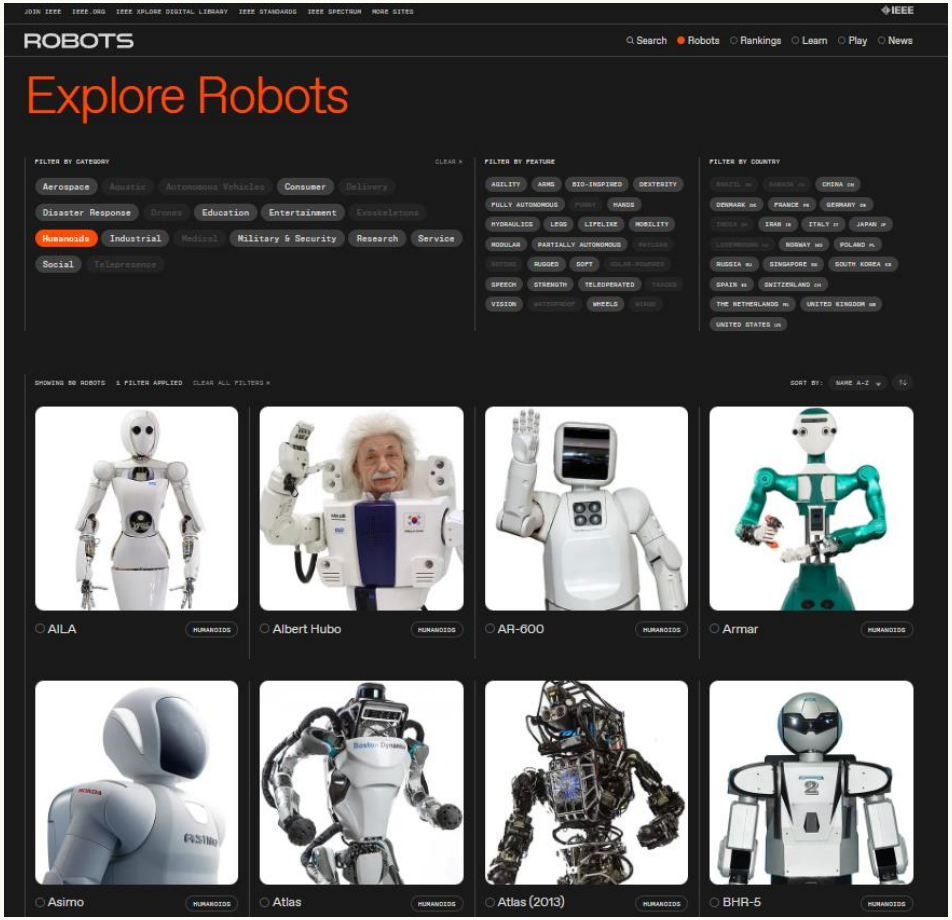


image courtesy of IEEE robots

https://youtu.be/oDeQCIkrLvc

Resources

- Nenchev, D. N., Konno, A., & Tsujita, T. (2018). *Humanoid robots: Modeling and control*. Butterworth-Heinemann. [LINK]
- Fitzpatrick, P., Harada, K., Kemp, C. C., Matsumoto, Y., Yokoi, K., & Yoshida, E. (2016). Humanoids. In *Springer handbook of robotics* (pp. 1789-1818). Springer, Cham.
- Slides from Alessandro Roncone @ University of Colorado Boulder (Introduction to Robotics and Physical Human-Robot Interaction).



https://robotsguide.com/