



# Humanoid Robots & Human-Robot Interaction

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<https://sites.google.com/site/matejhof>

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



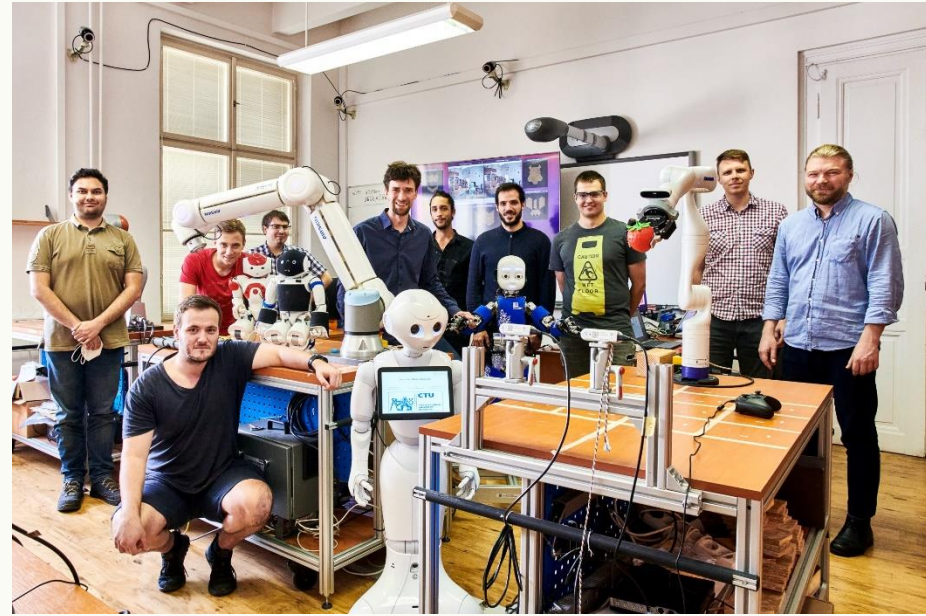
# Overview

- 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/humannoids/>

## 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.

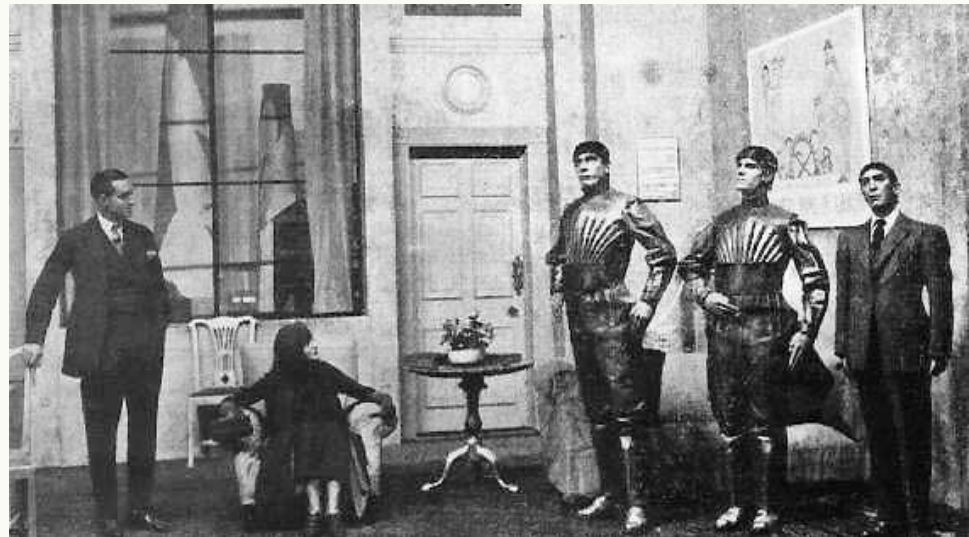
So long as mortals breathe, or eyes can see,  
We shall endeavor to give life to thee.

\* 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



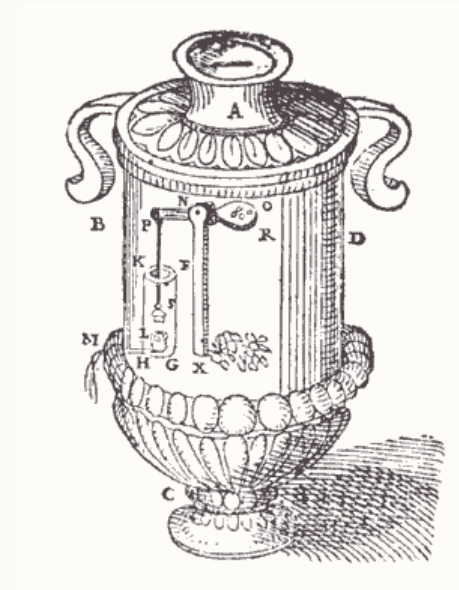
Talos (Τάλως)

Year	Invention
1000BC	<b>Talos</b>
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

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.

# Automata in history

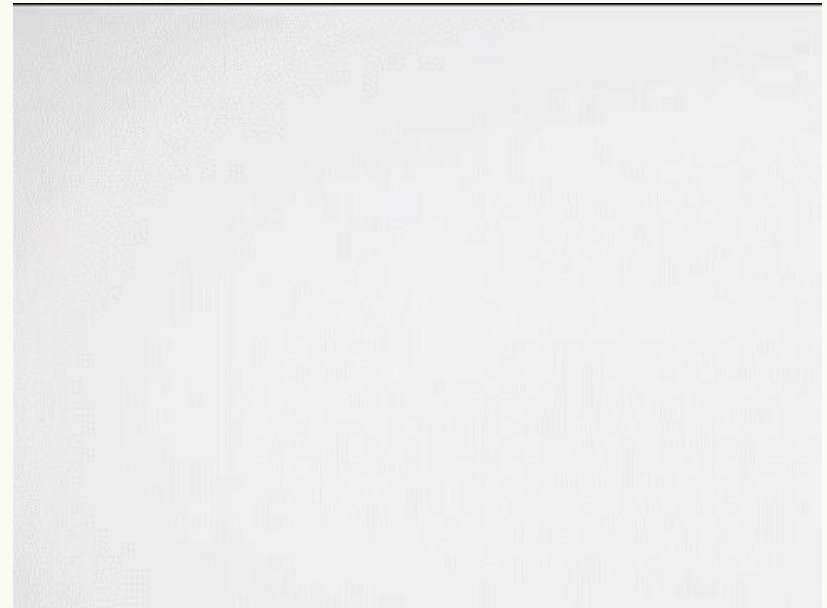
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1961	George Devol's Unimate



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.

# Automata in history

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# “Robots” in History

Year	Invention
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100AD	Early automata
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1700s	Pierre Jaquet-Droz' Writing automaton
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1926	Metropolis: Maria
1961	<b>George Devol's Unimate</b>



[Slide source – courtesy Alessandro Roncone]

# The First Commercial Robot (Unimate, 1961)



# Why humanoid robots?

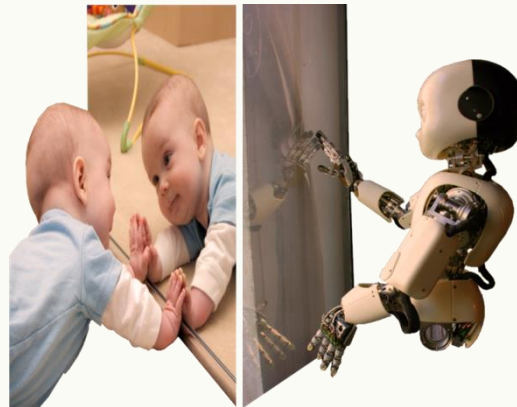
Humans are so good...  
“Moreover, humans are generalists with the ability to perform a wide variety of distinct tasks. Roboticists would like to create robots with comparable versatility and skill.... Exactly what to borrow from the human example is controversial.”

“The pleasing mirror. Humans are humanity’s favorite subject.” “People are highly attuned to human characteristics.”

Human-like interaction.  
Communication...



**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



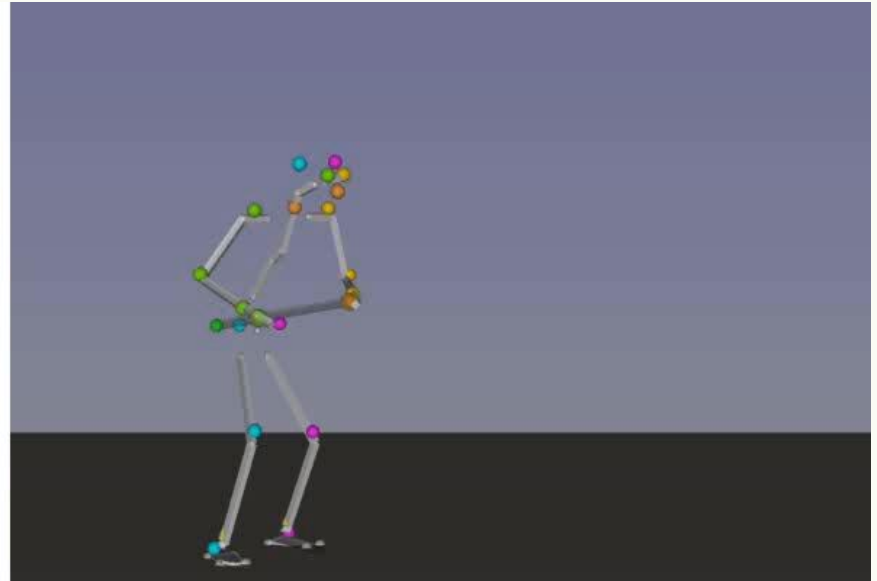
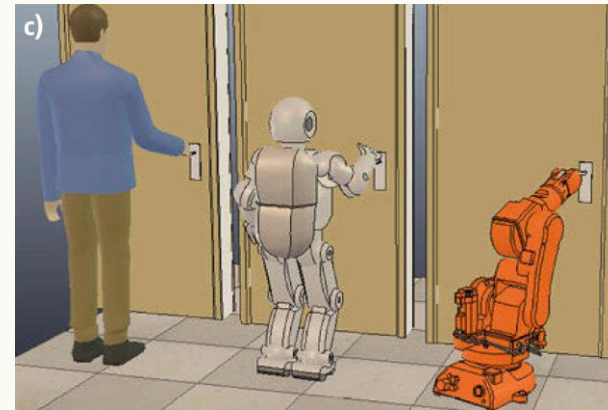
Human environments.  
Stairs, doors, tables, human tools...  
Humanoids vs. specialized machines and drive-by-wire....

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

# 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

### Front Matter

Pages 1789-1789

### Humanoids

Paul Fitzpatrick, Kensuke Harada, Charles C. Kemp, Yoshio Matsumoto, Kazuhito Yokoi, Eiichi Yoshida  
Pages 1789-1818

### Human Motion Reconstruction

Katsu Yamane, Wataru Takano  
Pages 1819-1834

### Physical Human–Robot Interaction

Sami Haddadin, Elizabeth Croft  
Pages 1835-1874

### Human–Robot Augmentation

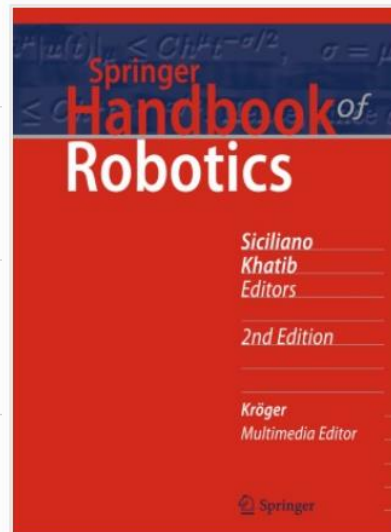
Massimo Bergamasco, Hugh Herr  
Pages 1875-1906

### Cognitive Human–Robot Interaction

Bilge Mutlu, Nicholas Roy, Selma Šabanović  
Pages 1907-1934

### Social Robotics

Cynthia Breazeal, Kerstin Dautenhahn, Takayuki Kanda  
Pages 1935-1972



### Socially Assistive Robotics

Maja J. Matarić, Brian Scassellati  
Pages 1973-1994

### Learning from Humans

Aude G. Billard, Sylvain Calinon, Rüdiger Dillmann  
Pages 1995-2014

### Biologically Inspired Robotics

Fumiya Iida, Auke Jan Ijspeert  
Pages 2015-2034

### Evolutionary Robotics

Stefano Nolfi, Josh Bongard, Phil Husbands, Dario Floreano  
Pages 2035-2068

### Neurorobotics: From Vision to Action

Patrick van der Smagt, Michael A. Arbib, Giorgio Metta  
Pages 2069-2094

### Perceptual Robotics

Heinrich Bülthoff, Christian Wallraven, Martin A. Giese  
Pages 2095-2114

### Robotics for Education

David P. Miller, Illah Nourbakhsh  
Pages 2115-2134

### Roboethics: Social and Ethical Implications

Gianmarco Veruggio, Fiorella Operto, George Bekey  
Pages 2135-2160

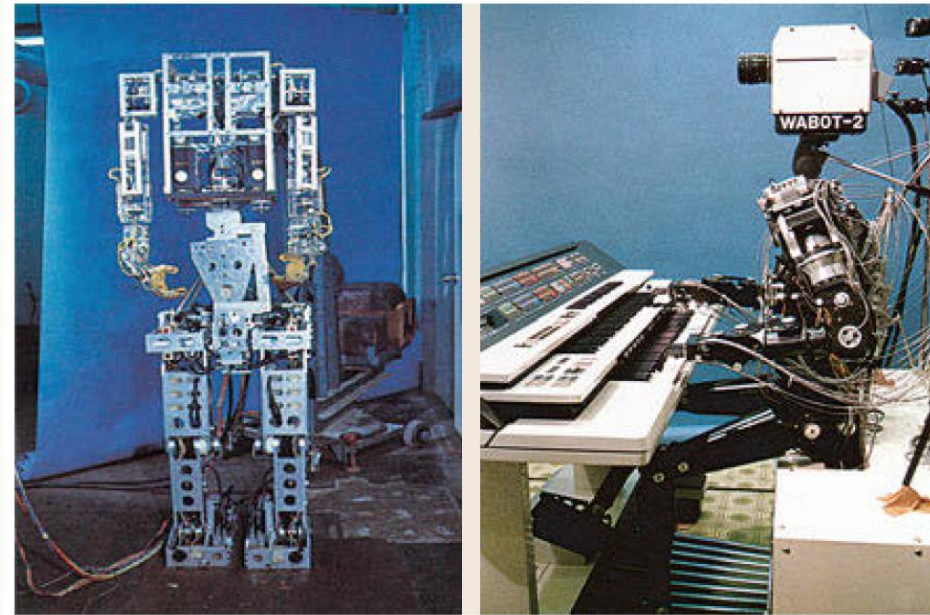


# Humanoid robots - history

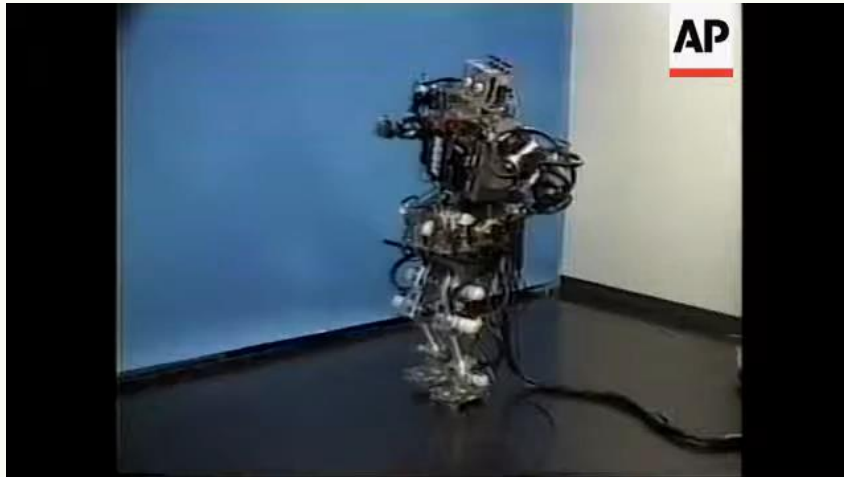
# Humanoid robots – history – WABOT

- 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/E9PyANzjeaY>

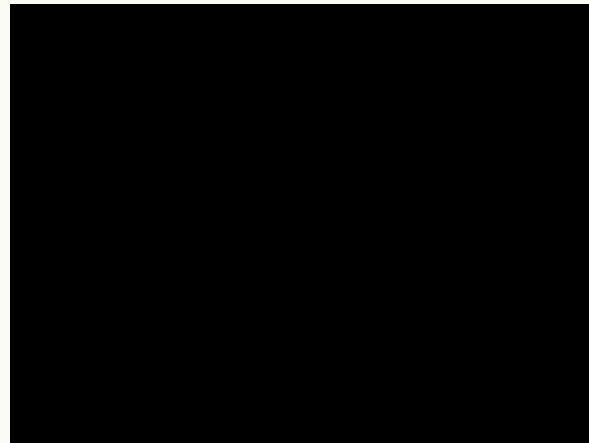
# Humanoid robots – history – Honda ASIMO

- 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-ASIMO advanced step in innovative mobility) (120 cm, 43 kg) (after [67.31]; courtesy Honda)

<https://youtu.be/NZngYDDdfW4>



Note:  
anthropomorphization





**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/g0TaYhjp0fo>

# Alternative designs



Winner: KAIST – DRC Hubo

<https://youtu.be/H3PptkxA5CU>

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

## DARPA Robotics Challenge



Carnegie Mellon University  
**TARTAN RESCUE**

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

DARPA PM: Dr. Gill Pratt

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# Atlas (Boston dynamics)



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

# Atrias (Oregon State U., J. Hurst)





# **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...

D<sup>3</sup> = Dull, Dirty, and  
Dangerous tasks  
[Gill Pratt]

Increase of automation  
leads to increase of  
productivity



...to **people helping** robots...



D<sup>3</sup> = Dull, Dirty, and Dangerous tasks [Gill Pratt]

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



# ...or robots helping people



# Stretch

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



<https://youtu.be/8WZoVJIV9V0?si=5Jku06AqTUCAL7qU>

# Mass production of humanoid robots

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  
@LORAKOLODNY

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### 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  
announces  
strategic



Russia d  
Russian r  
treason;  
North Ko  
luxury ca



Capital O  
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](#)

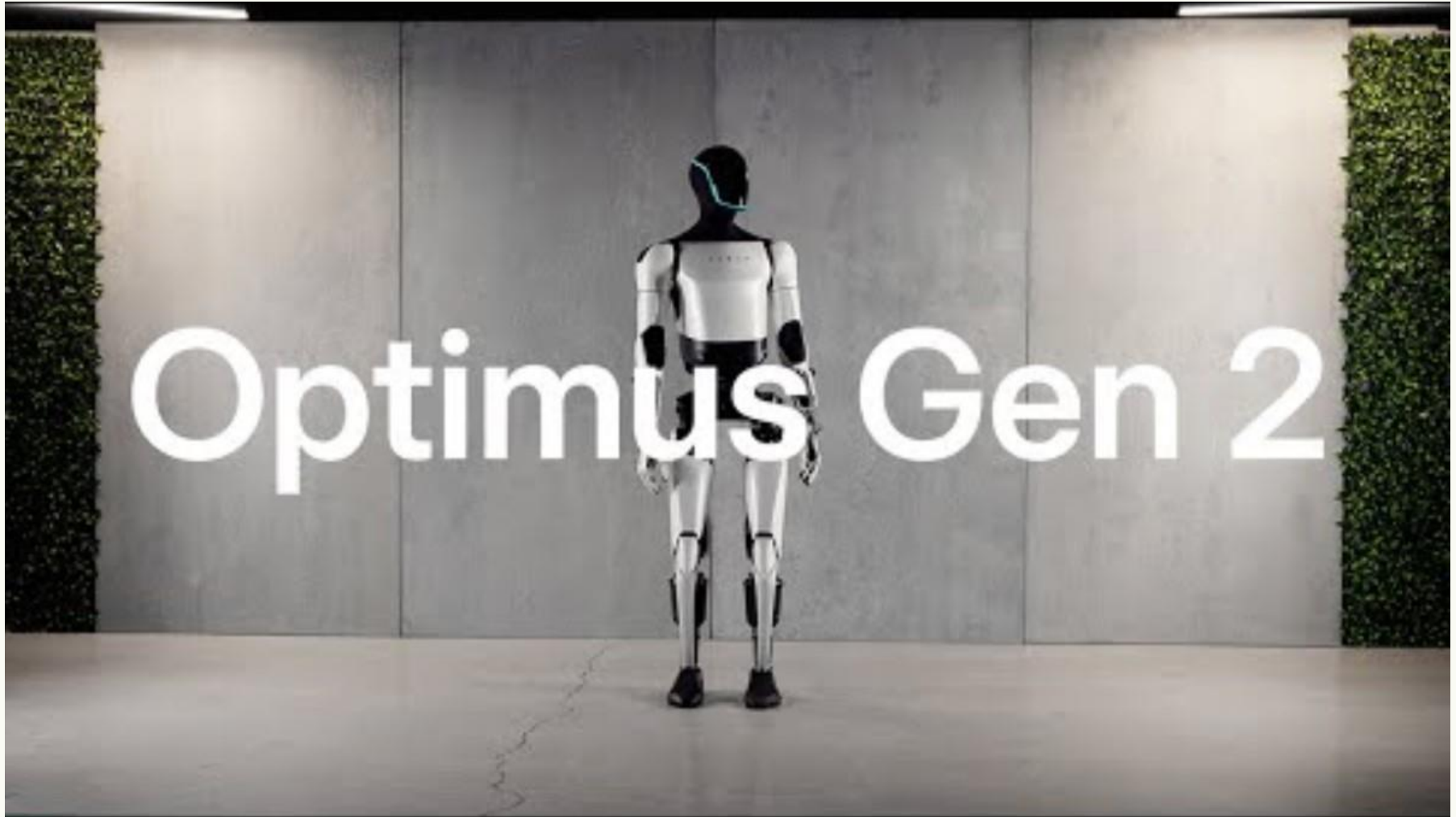
Published: 8:00am, 13 Aug, 2023 -

[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

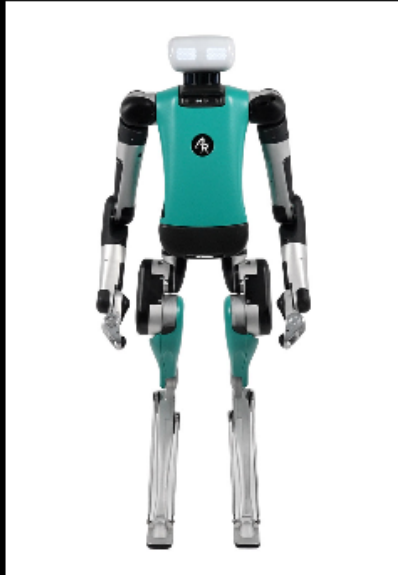


<https://youtu.be/cpraXaw7dyc?si=yNrfcVEh7xjLzFli>

# 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

Apptроник



Apptроник 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. Apptроник plans to field its robots in 10 pilot projects in 2024, with a full commercial release of Apollo in 2025.

## Neo

1X Technologies

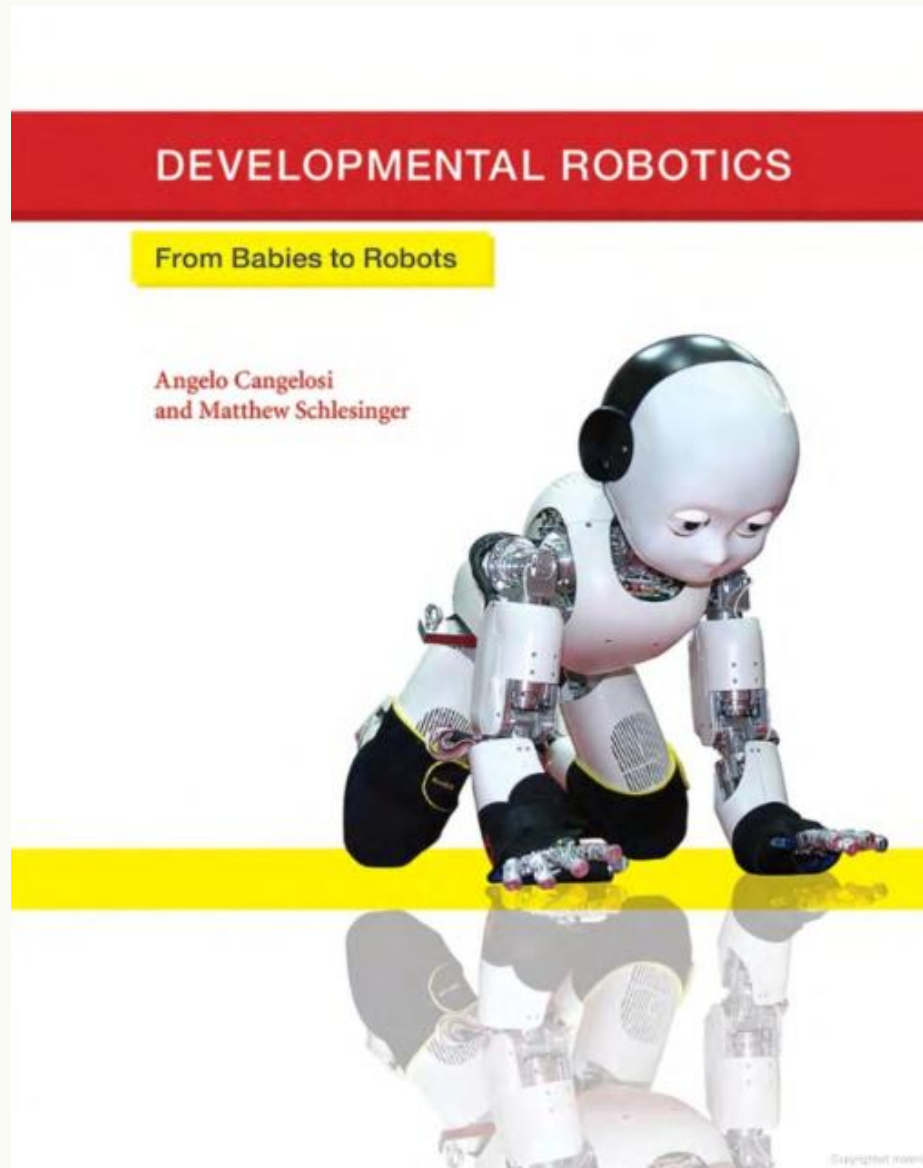


**1X’s** soft, tendon-based robot is designed to have very low inertia with the goal of building a robot that’s safe for humans to be around. The robot will weigh just 30 kilograms, with a carrying capacity of up to 20 kg. 1X, backed by OpenAI, hopes that Neo will become “an all-purpose android assistant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

IEEE Spectrum

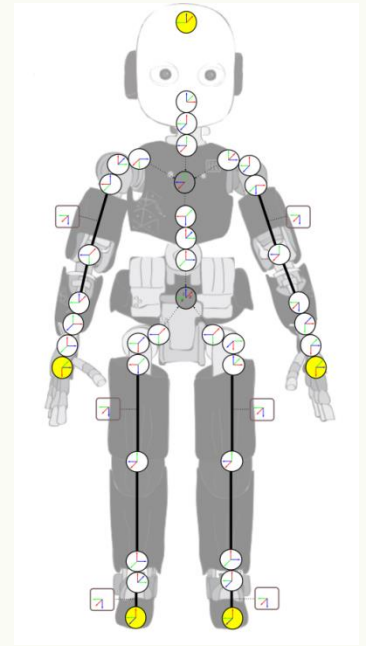


# Baby humanoid robots



# The iCub humanoid (2004 – now)

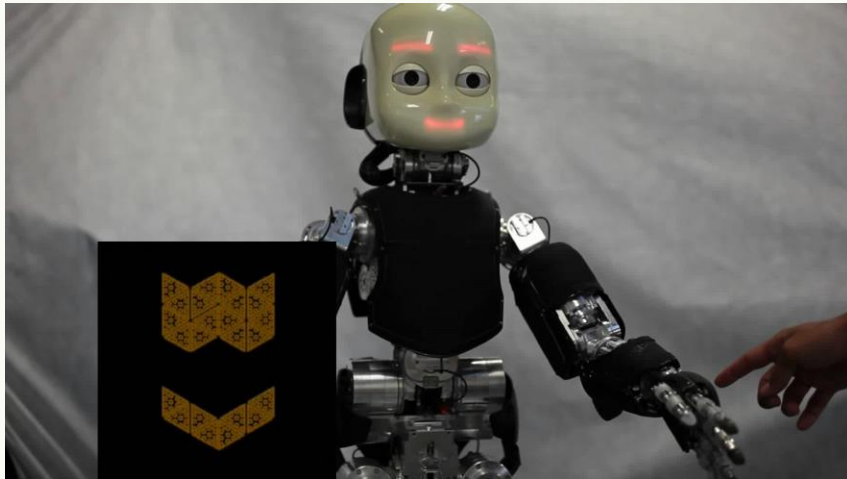
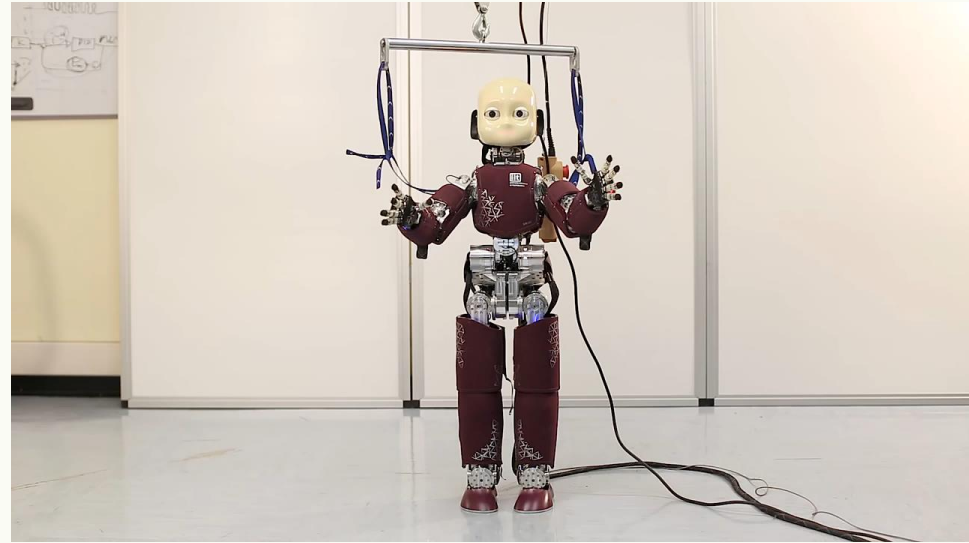
- Size of a 4 year old child
- Motor / proprioception (joint angles)
  - 53 DOF
- **Tactile information**
  - cca 4000 pressure-sensitive tactile elements (taxels) on the whole body
- Vision
  - 2 standard cameras in biomimetic DOF setup (pan, tilt, vergence)
- Force/torque sensors
- Inertial sensors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



# iCub (videos)

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

<https://youtu.be/UPQLcE1vwAQ>



<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

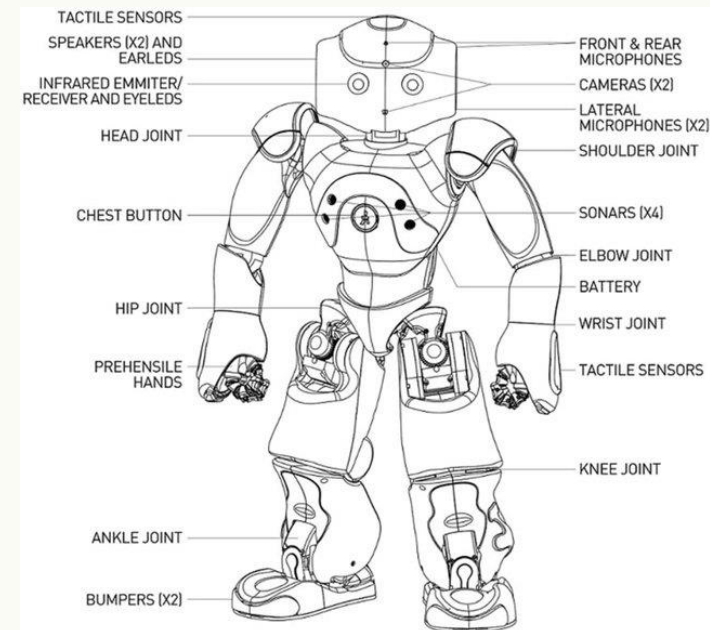
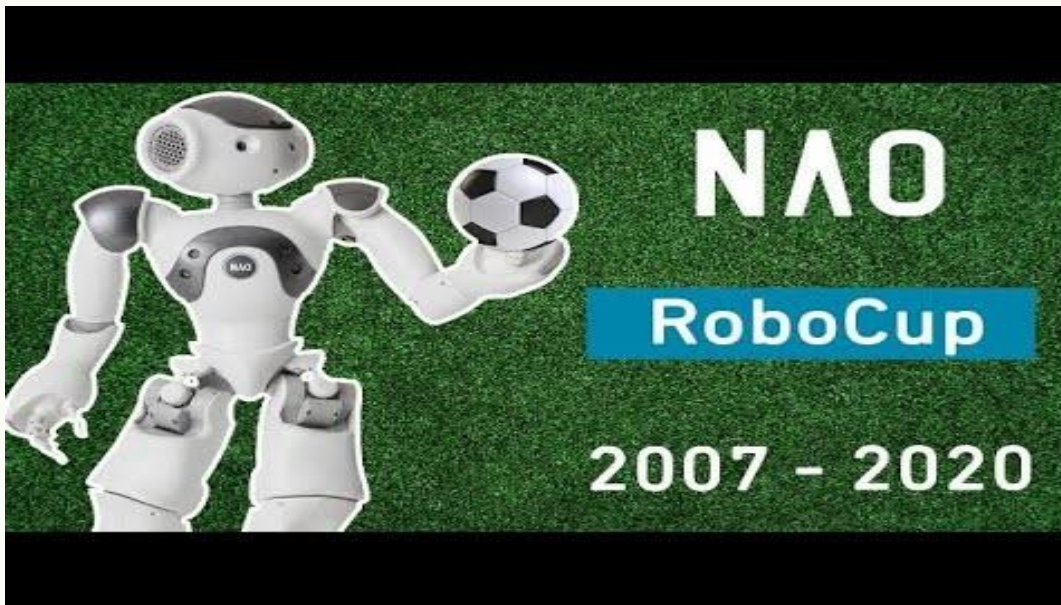


image courtesy of [Softbank robotics](https://www.softbankrobotics.com)

<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

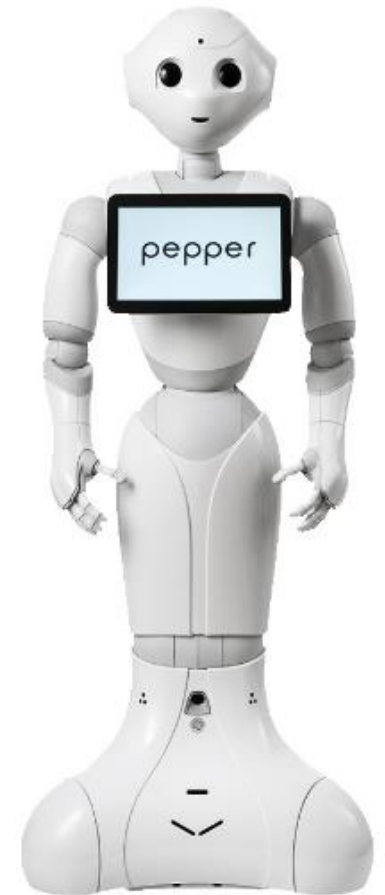
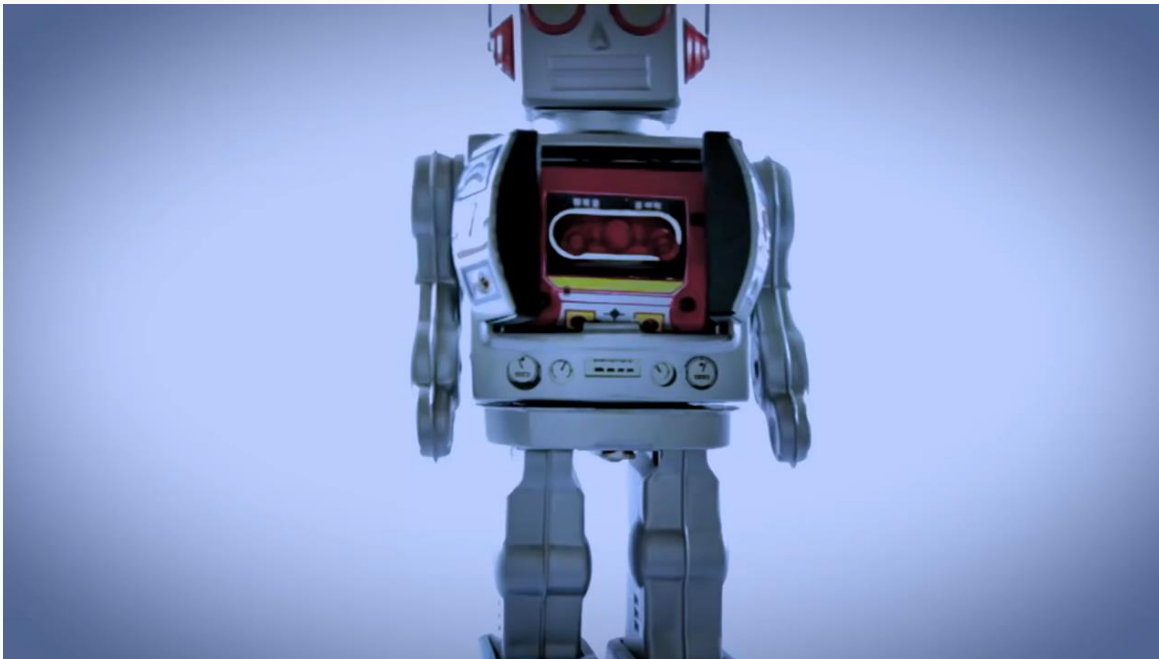
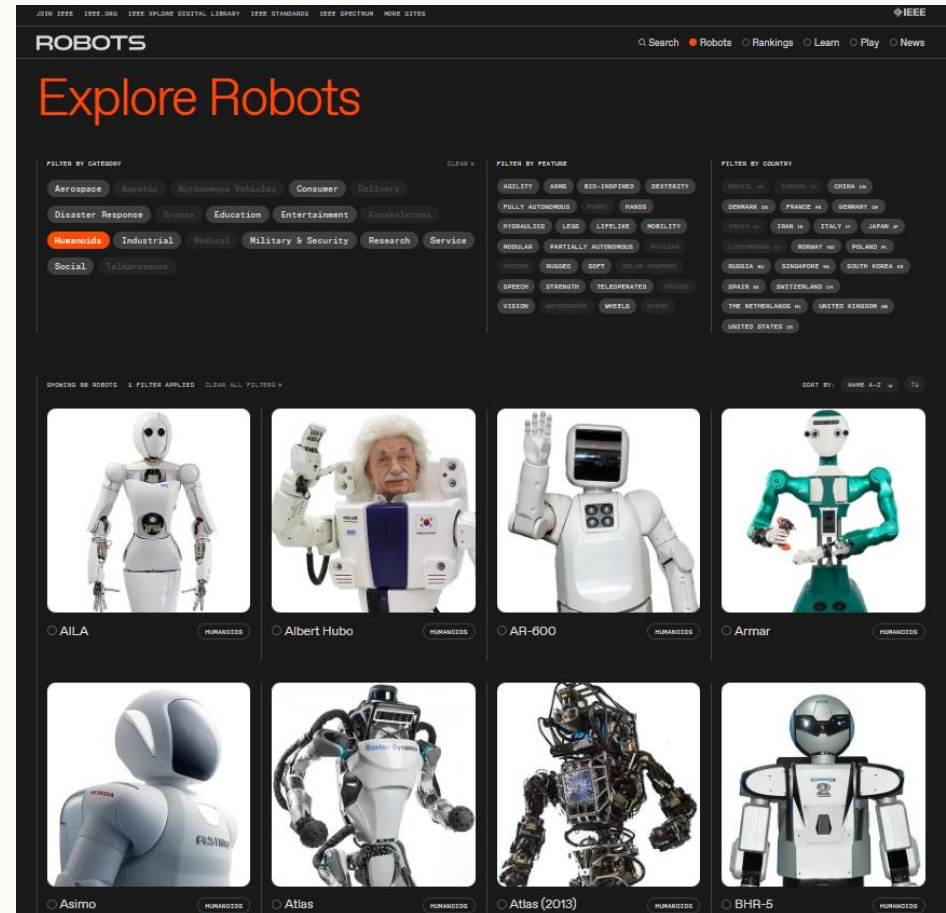


image courtesy of [IEEE robots](#)

<https://youtu.be/oDeQC1krLvc>

# 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/>