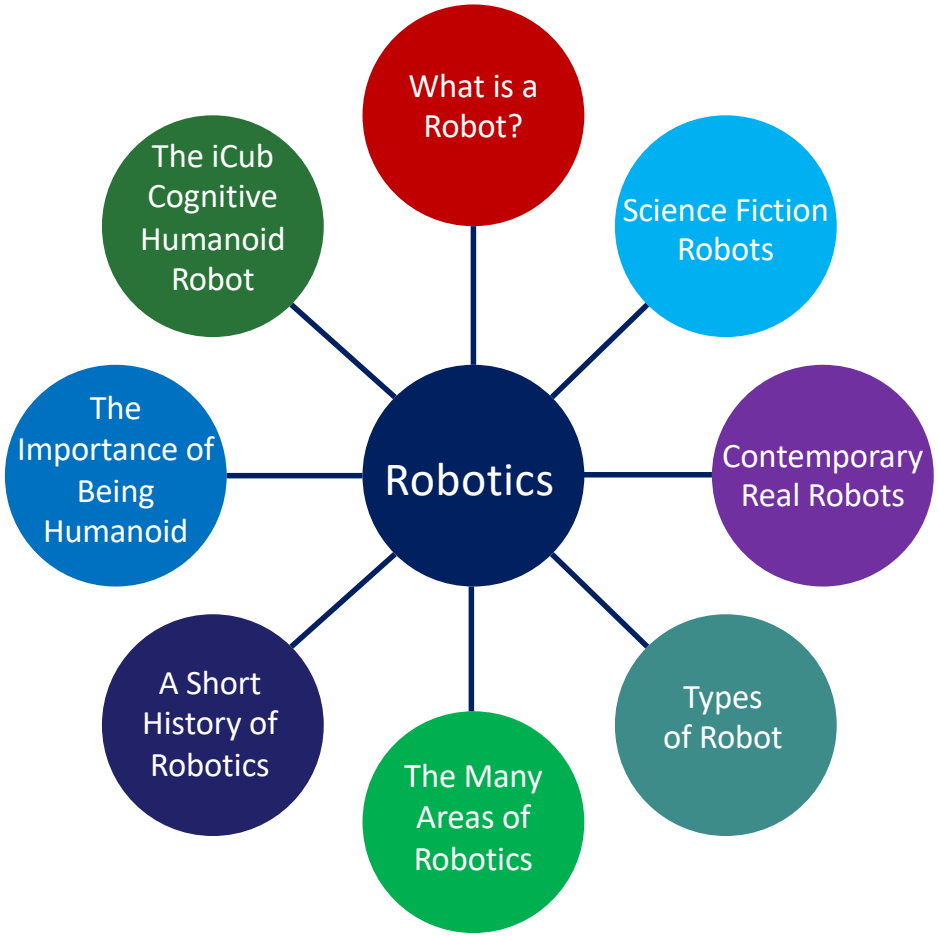
Course 04-800 G
Humanoid Robotics and Cognition

Guest Lecture

David Vernon
Carnegie Mellon University Africa

www.vernon.eu


What is a Robot?
The iCub Cognitive Humanoid Robot
Science Fiction Robots
The Importance of Being Humanoid
Robotics
Contemporary Real Robots
A Short History of Robotics
The Many Areas of Robotics
Types of Robot

What is a Robot?

What is a Robot?

"A robot is an autonomous system ← Not teleoperated (self-controlled & has controllers)

which exists in the physical world, ← Subject to the physical laws (has a physical body)

can sense its environment, ← Estimate the state of the world (uses sensors)

and can act on it ← Physically affect the world (uses actuators & effectors)

to achieve some goals" ← Purposeful, useful, possibly intelligent behaviour

M. Mataric, The Robotics Primer, MIT Press, 2007.

Science Fiction Robots

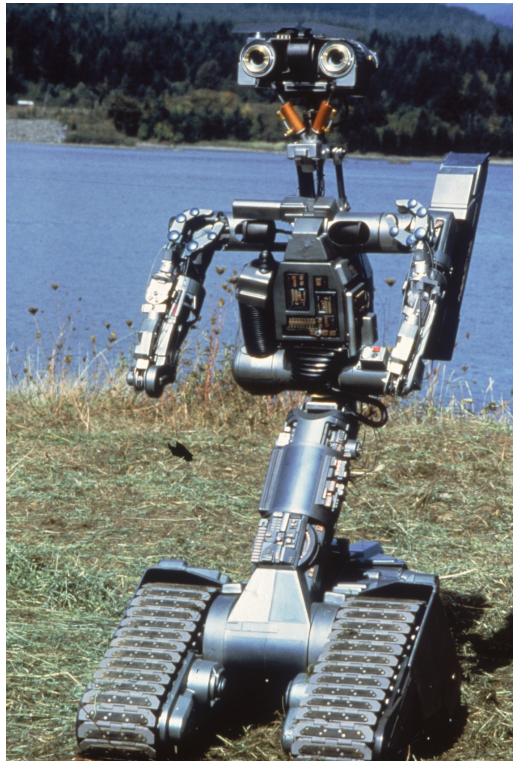
Science Fiction Robots

Robots feature prominently in the general public's perception of AI

This is due in part to the way they are portrayed in science fiction movies

Science Fiction Robots

From cute robots such as Johnny 5 in Short Circuit



Source: https://www.imdb.com/title/tt0091949/

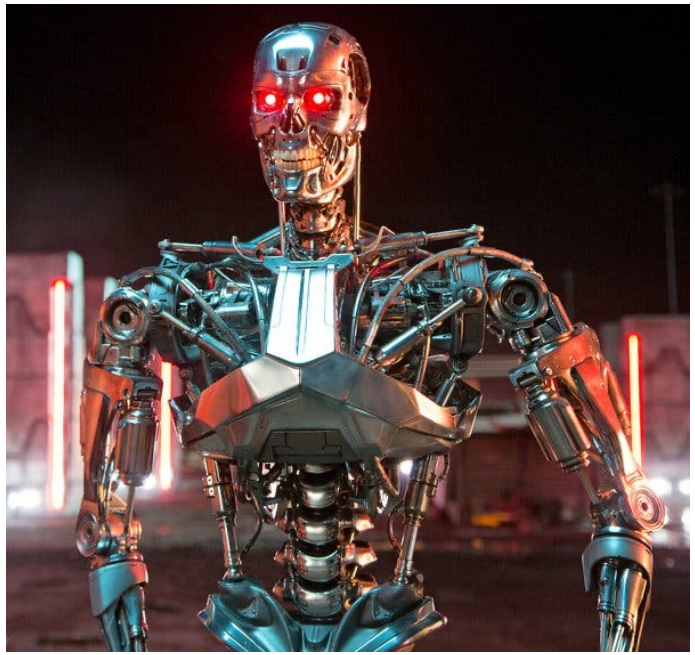
Science Fiction Robots

… and WALL·E

Source: https://pixar.fandom.com/wiki/WALL%E2%80%A2E_(character)

Science Fiction Robots

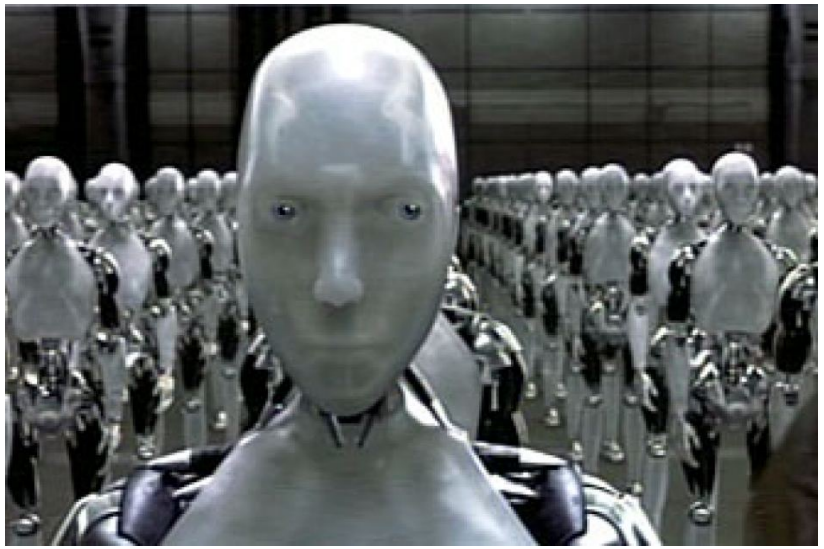
To more threatening robots such as the Skynet Terminator



Soource: https://www.nytimes.com/2015/05/26/science/darpa-robotics-challenge-terminator.html

Science Fiction Robots

Sonny in I, Robot



Source: https://www.abc.net.au/news/2004-07-21/i-robot-modern-interpretations-foresee-the-three/2012544?nw=0

Science Fiction Robots

... and Chappie

Source: https://www.abc.net.au/news/2004-07-21/i-robot-modern-interpretations-foresee-the-three/2012544?nw=0

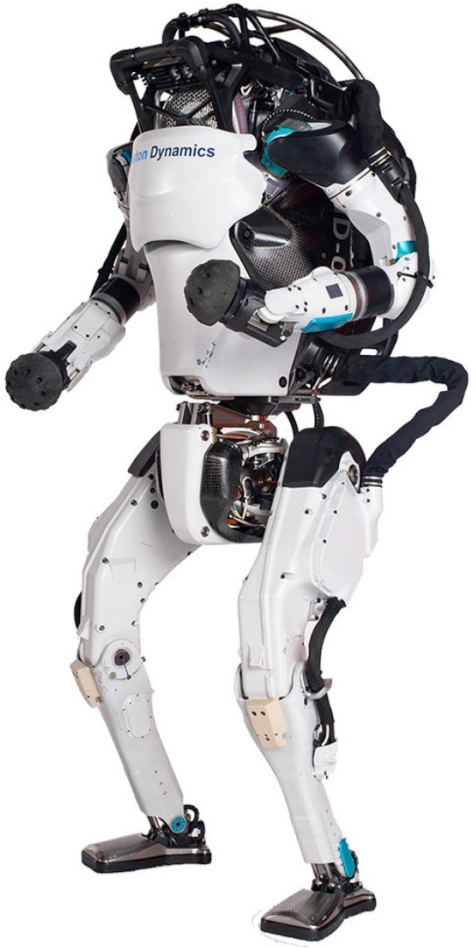
Contemporary Real Robots

There is a long way to go to match science fiction …

But impressive progress in mechatronics and control over the past ten years

Contemporary Real Robots

For example, consider the mobility displayed by Atlas from Boston Dynamics



Atlas

Atlas is the most agile humanoid in existence. It uses whole-body skills to move quickly and balance dynamically. It can lift and carry objects like boxes and crates, but its favorite tricks are running, jumping, and doing backflips.

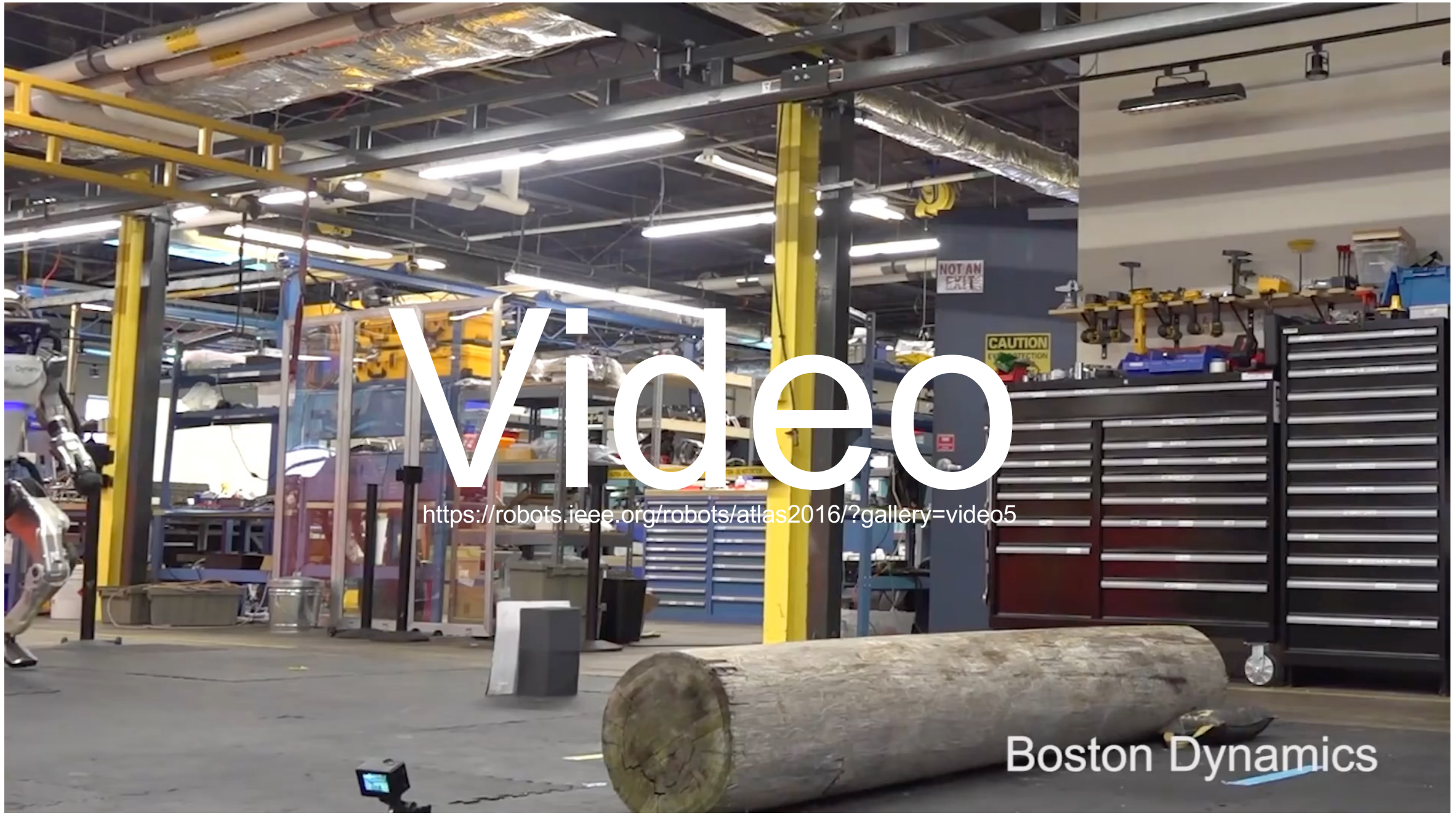
CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2016

TYPE
Humanoids, Industrial

Source: https://robots.ieee.org/robots/atlas2016/


Video
https://robots.ieee.org/robots/atlas2016/?gallery=video5
NOT AN EXIT
CAUTION
Boston Dynamics

Contemporary Real Robots

And Spot, also from Boston Dynamics

Spot

Spot is a compact, nimble four-legged robot that can trot around your office, home, or outdoors. It can map its environment, sense and avoid obstacles, climb stairs, and open doors. It can also fetch you a drink.

CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2016

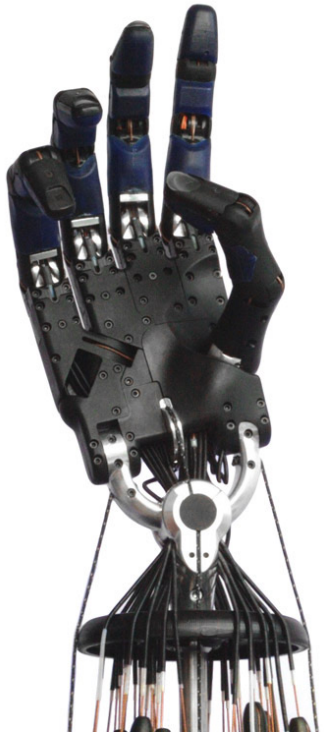
TYPE
Industrial, Research

Source: https://robots.ieee.org/robots/spotmini/


Video
https://robots.ieee.org/robots/spotmini/?gallery=video1

Science Fiction Robots vs. Contemporary Real Robots

Or the dexterity of the Shadow Hand



Shadow Hand

The Shadow Dexterous Hand is one of the most advanced robot hands in the world. It's designed to replicate as much of the functionality, dimensions, and range of motion of the human hand as possible.

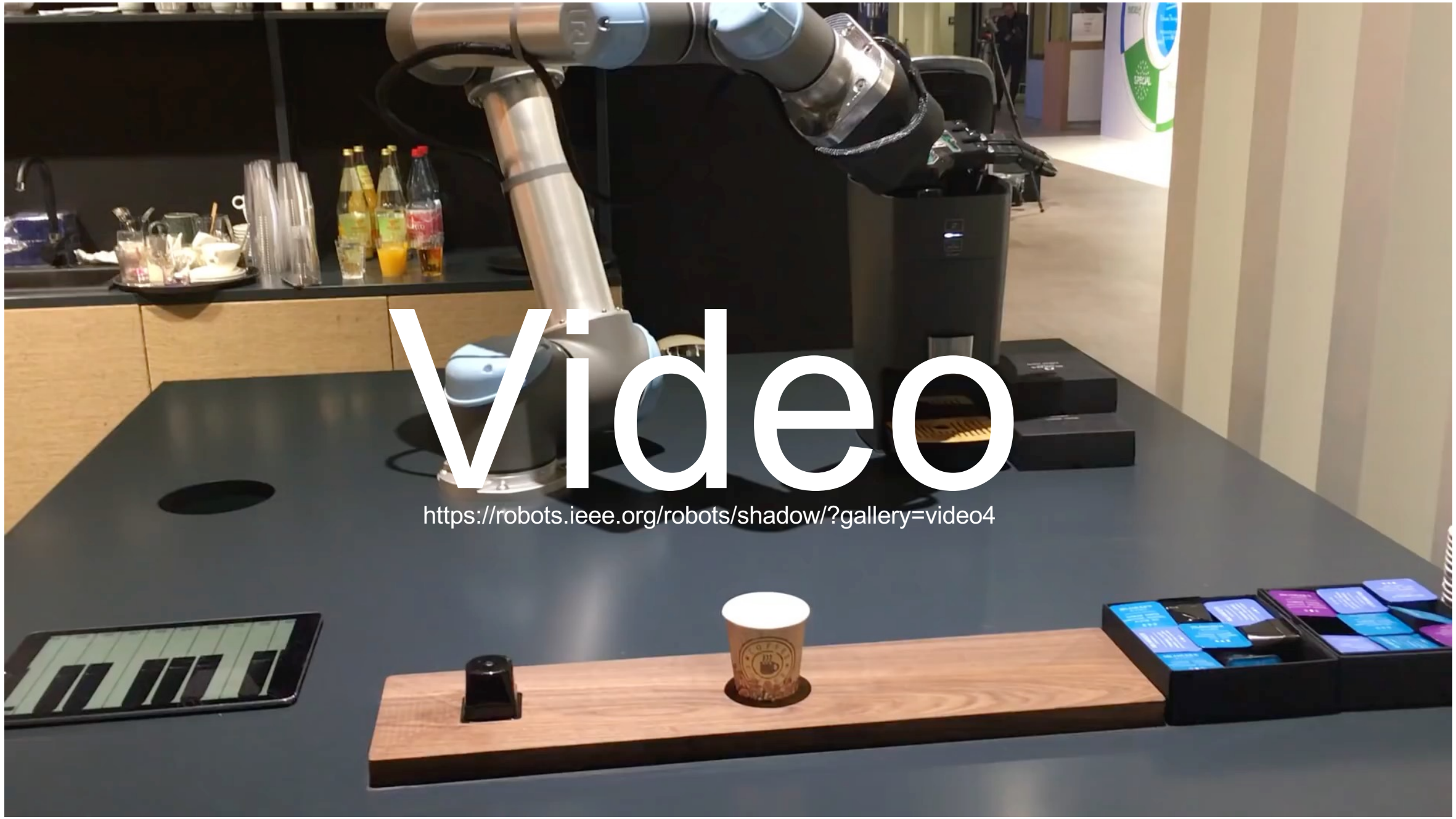
CREATOR
Shadow Robot Company

COUNTRY
United Kingdom

YEAR
2004

TYPE
Industrial, Telepresence, Research

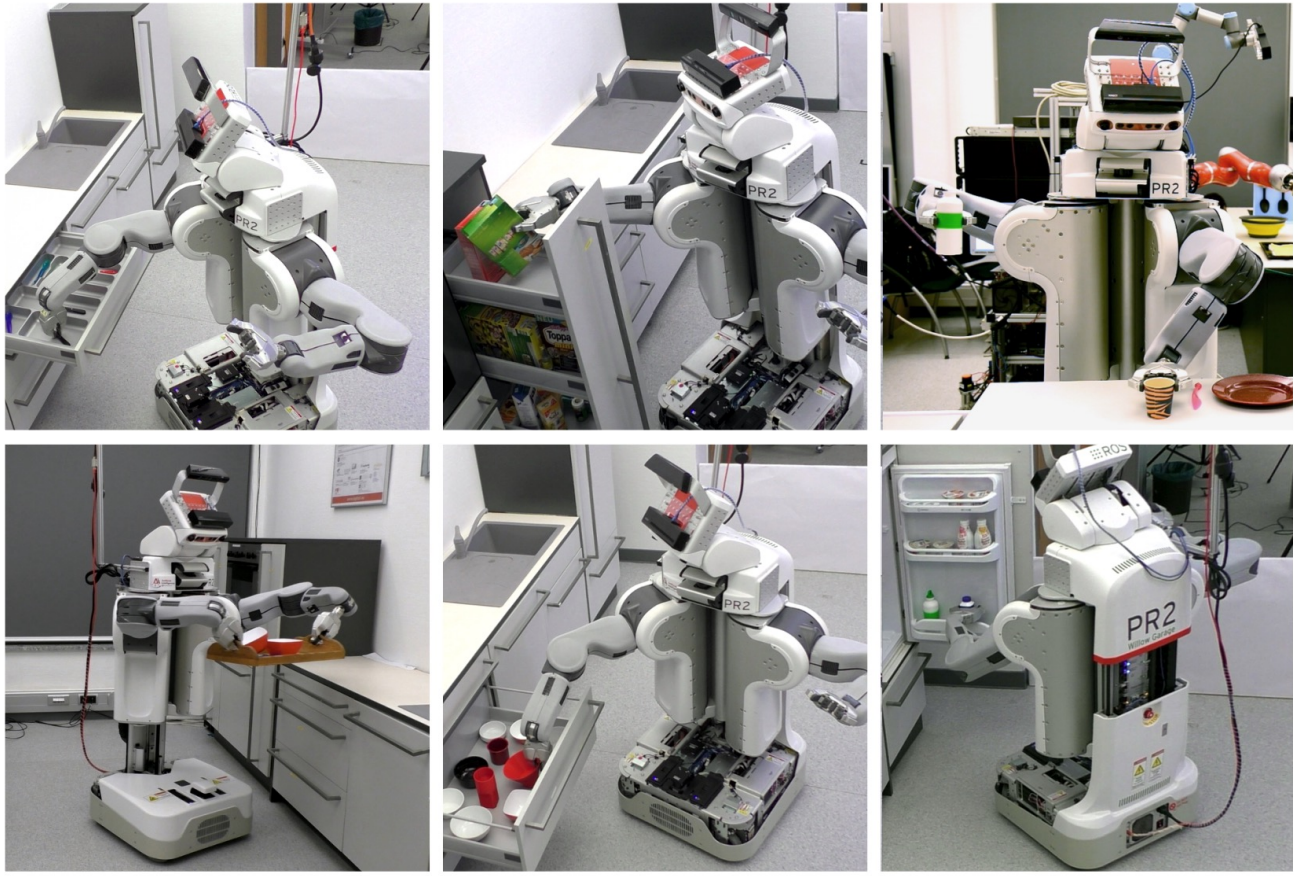
Source: https://robots.ieee.org/robots/shadow/


Video
https://robots.ieee.org/robots/shadow/?gallery=video4

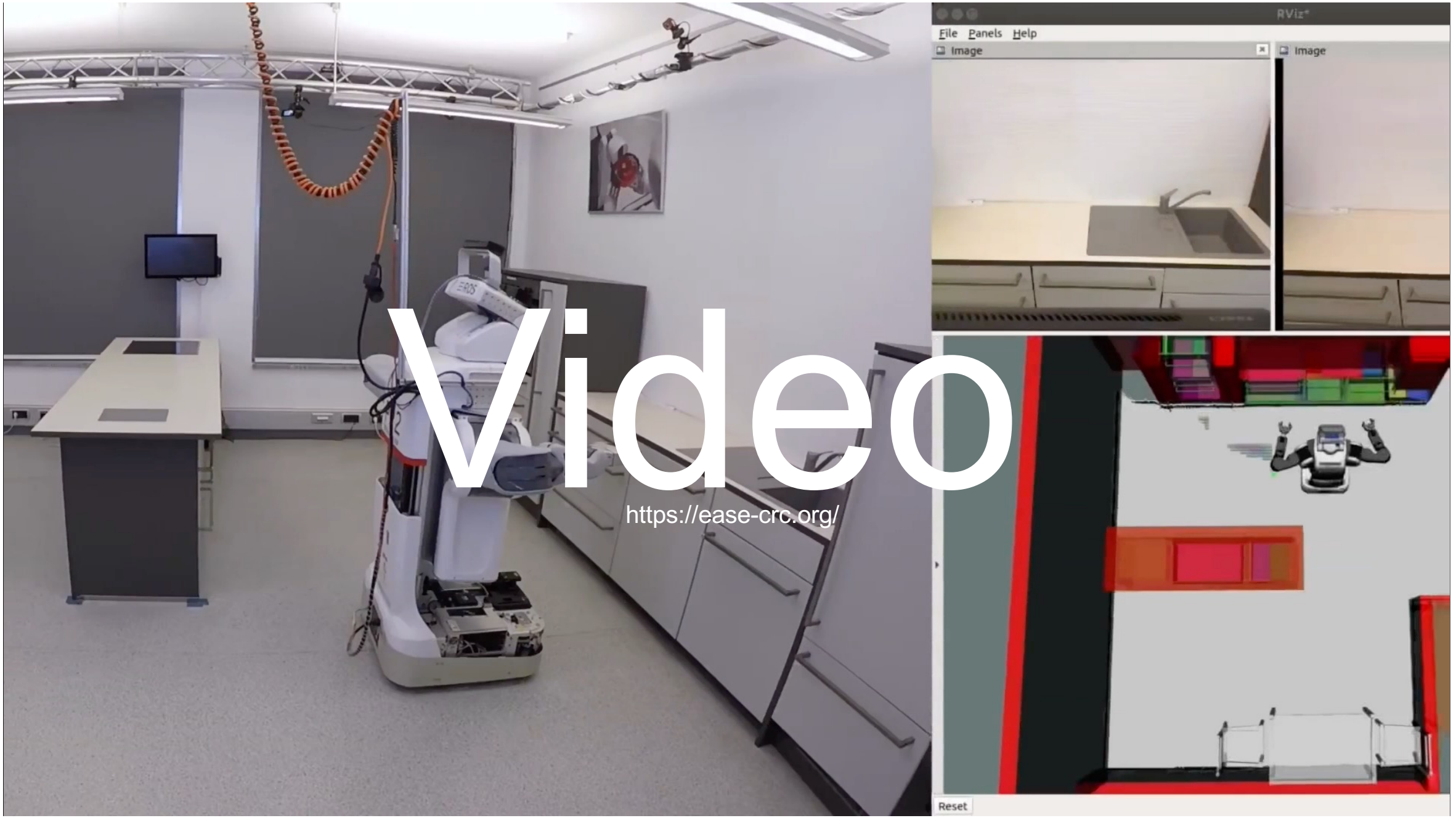
Science Fiction Robots vs. Contemporary Real Robots

There have also been recent advances in cognition-enabled robot manipulation in everyday activities

Such as setting a table, preparing a simple meal, and clearing up afterwards



Source: https://ease-crc.org/



Video

https://ease-crc.org/

Types of Robot

Join IEEE | IEEE.org | IEEE *Xplore* Digital Library | IEEE Standards | IEEE Spectrum | More Sites

ROBOTS YOUR GUIDE TO THE WORLD OF ROBOTICS

Home Robots News Play Learn

Source: https://robots.ieee.org/robots/

ALL ROBOTS | SORT ROBOTS | ROBOT RANKINGS

Name (A to Z) | Size (Smallest to Largest) | Date (Newest to Oldest) | Type | Country | Shuffle!

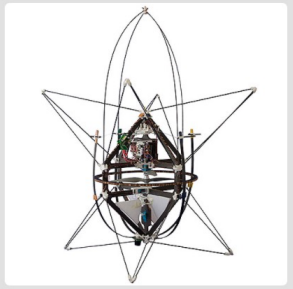
- Humanoids
- Consumer
- Drones
- Entertainment
- Education
- Research
- Medical
- Exoskeletons
- Disaster Response
- Service & Industrial
- Aerospace
- Underwater
- Military & Security
- Telepresence
- Self-Driving Cars


ACM-R5H


Adaptive Gripper

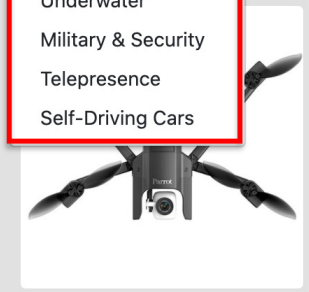

Aibo


AILA


AirBurr


Albert Hubo


AlphaDog


Anafi


Anki Drive

Types of Robot

Humanoids

Research

Armar

Armar is a robot created to be a helper in industrial environments. Its humanoid form lets it use human tools like power drills and hammers. Earlier versions were home helpers that could clean tables and load the dishwasher.

CREATOR
Karlsruhe Institute of Technology

COUNTRY
Germany

YEAR
2017

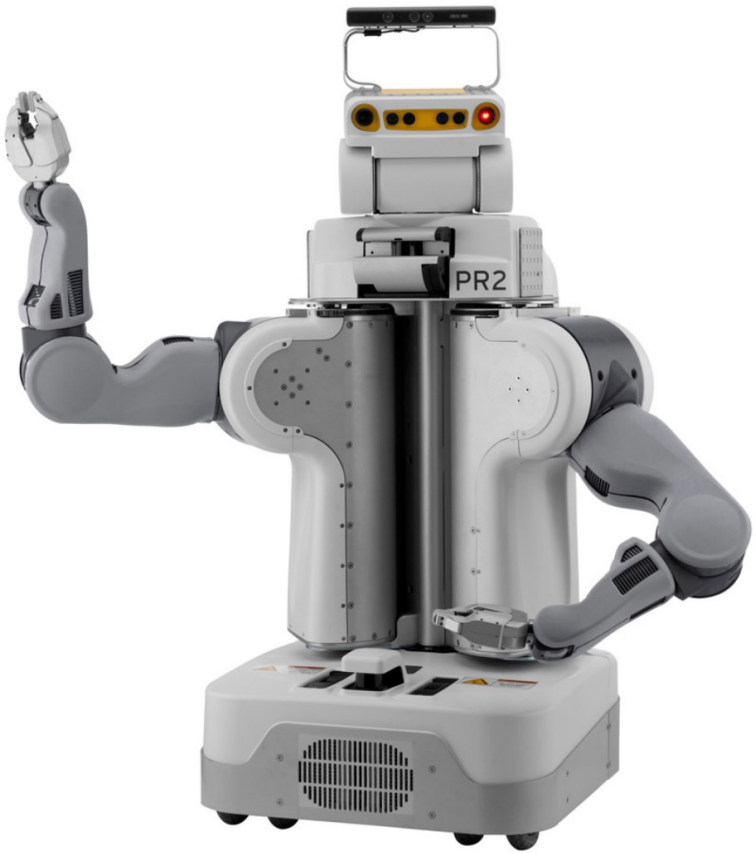
TYPE
Humanoids, Research

Source: https://robots.ieee.org/robots/armar/

Types of Robot

Humanoids

Research



PR2

The PR2 is one of the most advanced research robots ever built. Its powerful hardware and software systems let it do things like clean up tables, fold towels, and fetch you drinks from the fridge.

CREATOR
Willow Garage

COUNTRY
United States

YEAR
2010

TYPE
Research, Humanoids

Source: https://robots.ieee.org/robots/pr2/

Types of Robot

Humanoids

Consumer

Entertainment

Pepper

Pepper is a friendly humanoid designed to be a companion in the home and help customers at retail stores. It talks, gesticulates, and seems determined to make everyone smile.

CREATOR
SoftBank Robotics
(originally created by Aldebaran Robotics, acquired by SoftBank in 2015)

COUNTRY
Japan

YEAR
2014

TYPE
Humanoids, Consumer, Entertainment

Source: https://robots.ieee.org/robots/pepper/

Types of Robot

Humanoids

Research

Education

Nao

Nao is a small humanoid robot designed to interact with people. It's packed with sensors (and character) and it can walk, dance, speak, and recognize faces and objects. Now in its sixth generation, it is used in research, education, and healthcare all over the world.

CREATOR
SoftBank Robotics
(originally created by Aldebaran Robotics, acquired by SoftBank in 2015)

COUNTRY
France

YEAR
2008

TYPE
Humanoids, Research, Education

Source: https://robots.ieee.org/robots/nao/

Types of Robot

Humanoids

Research

HRP-4

HRP-4 is one of the world's most advanced humanoids, the culmination of a decade of R&D. It's designed to collaborate with humans and can perform remarkably natural, human-like movements.

CREATOR
Kawada Industries and AIST

COUNTRY
Japan

YEAR
2010

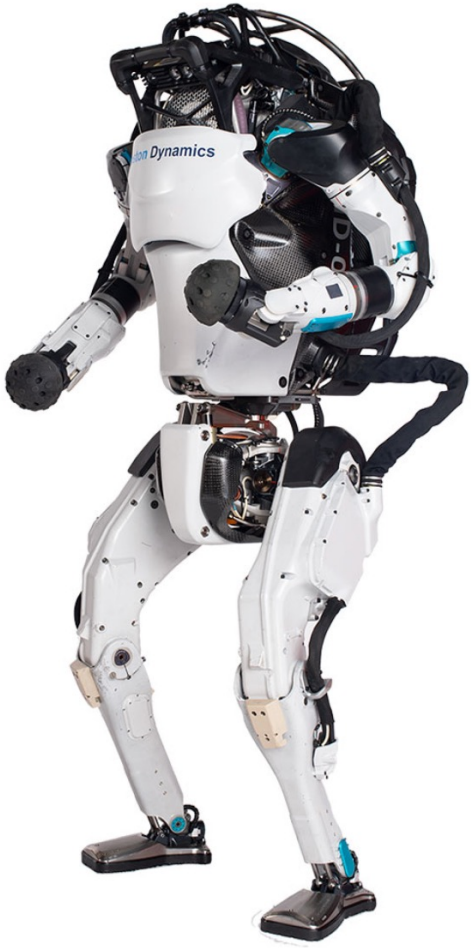
TYPE
Humanoids, Research

Source: https://robots.ieee.org/robots/hrp4/

Types of Robot

Humanoids

Industrial



Atlas

Atlas is the most agile humanoid in existence. It uses whole-body skills to move quickly and balance dynamically. It can lift and carry objects like boxes and crates, but its favorite tricks are running, jumping, and doing backflips.

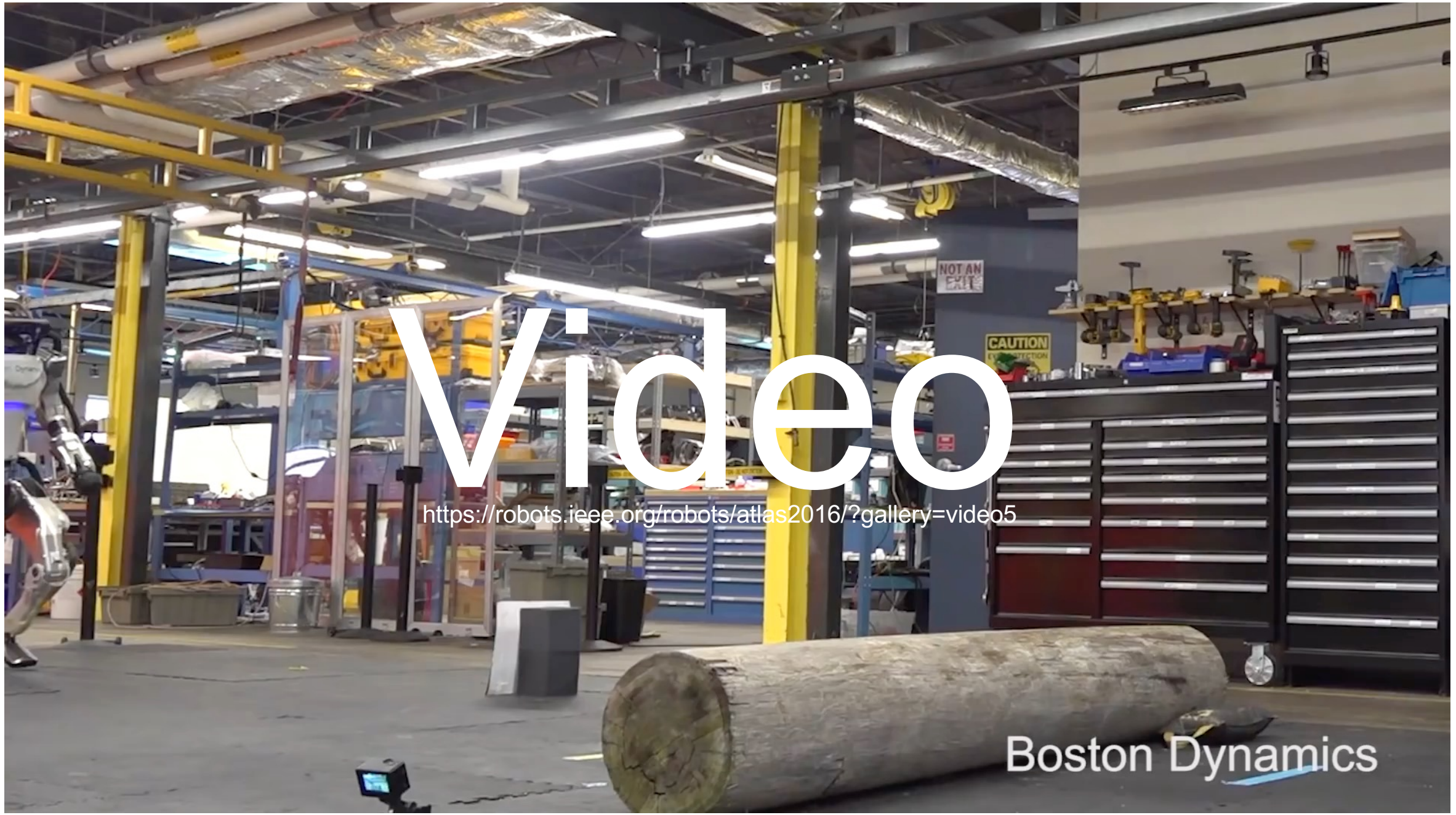
CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2016

TYPE
Humanoids, Industrial

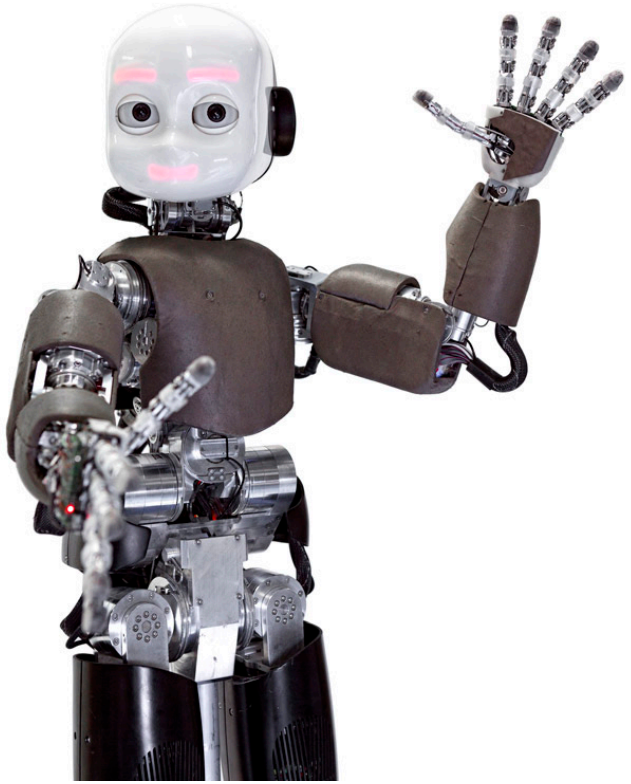
Source: https://robots.ieee.org/robots/atlas2016/


Video
https://robots.ieee.org/robots/atlas2016/?gallery=video5
NOT AN EXIT
CAUTION
Boston Dynamics

Types of Robot

Humanoids

Research



iCub

iCub is a child-size humanoid robot capable of crawling, grasping objects, and interacting with people. It's designed as an open source platform for research in robotics, AI, and cognitive science.

CREATOR
RoboCub Consortium and IIT

COUNTRY
Italy

YEAR
2004

TYPE
Humanoids, Research

Source: https://robots.ieee.org/robots/icub/

Video

https://robots.ieee.org/robots/icub/?gallery=video1

Types of Robot

Consumer

Roomba

Roomba is an autonomous vacuum and one of the most popular consumer robots in existence. It navigates around clutter and under furniture cleaning your floors, and returns to its charging dock when finished.

CREATOR
iRobot

COUNTRY
United States

YEAR
2002

TYPE
Consumer

Source: https://robots.ieee.org/robots/roomba/

Video

https://robots.ieee.org/robots/roomba/?gallery=video2

Types of Robot

Education

Roomba

Roomba is an autonomous vacuum and one of the most popular consumer robots in existence. It navigates around clutter and under furniture cleaning your floors, and returns to its charging dock when finished.

CREATOR
iRobot

COUNTRY
United States

YEAR
2002

TYPE
Consumer

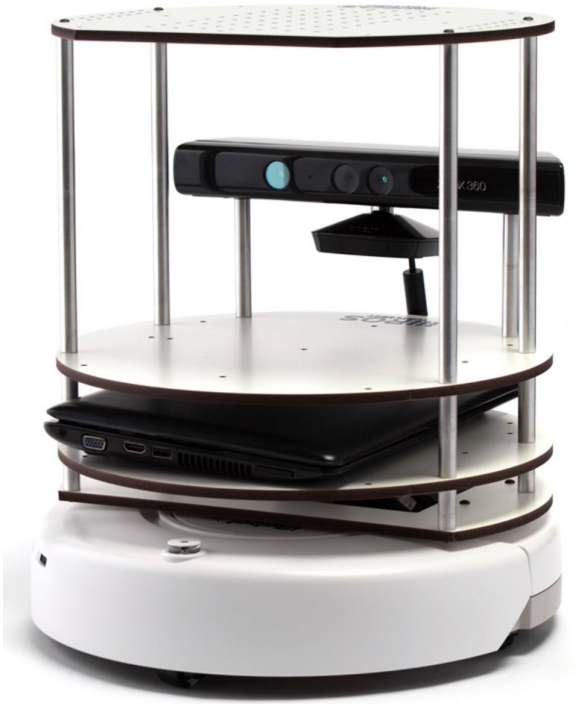
Source: https://robots.ieee.org/robots/roomba/

Types of Robot

Consumer

Research

Education



TurtleBot

TurtleBot is a low-cost personal robot designed for hobbyists and researchers. It's open source, runs the ROS operating system, and combines a netbook with a Kinect 3D sensor and a mobile base.

CREATOR
Willow Garage

COUNTRY
United States

YEAR
2011

TYPE
Consumer, Research, Education

Source: https://robots.ieee.org/robots/turtlebot/

Video

https://robots.ieee.org/robots/turtlebot/?gallery=video1

Types of Robot

Drones

Military & Security

Global Hawk

The Global Hawk is an unmanned aerial vehicle that's used for high-altitude, long-duration surveillance. You tell it what to do, and it can take off, fly, spy, and return without any human input.

CREATOR
Northrop Grumman

COUNTRY
United States

YEAR
2001

TYPE
Aerospace, Military & Security, Drones

Source: https://robots.ieee.org/robots/globalhawk/

Types of Robot

Drones

Medical

Zipline

Zipline is an autonomous fixed-wing aircraft drone used to carry blood and medicine from a distribution center to wherever it's needed. It can launch within minutes, and travel in any weather.

CREATOR
Zipline

COUNTRY
United States

YEAR
2016

TYPE
Drones, Medical

Source: https://robots.ieee.org/robots/zipline/


Video
http://www.vernon.eu/videos/Zipline_hero.mp4
zipline


Video
https://www.youtube.com/watch?v=QWgIZKVP26c

Video

http://www.vernon.eu/videos/Zipline_drop.mp4

Types of Robot

Entertainment

Consumer

Aibo

Aibo is a friendly robotic dog whose personality and behavior evolves over time. It can recognize its owner's face, detect smiles and words of praise, and learn new tricks. And of course, it loves to be petted.

CREATOR
Sony

COUNTRY
Japan

YEAR
2018

TYPE
Consumer, Entertainment

Source: https://robots.ieee.org/robots/aibo2018/

Video

https://www.youtube.com/watch?v=5ifwGc-0mAY

Types of Robot

Industrial

Picker Robots

Picker Robots are mobile machines designed to autonomously retrieve and carry products in a warehouse. The robots are directed through AI-powered software that identifies the most efficient paths for them to pick, replenish, return, and count goods.

CREATOR
inVia Robotics

COUNTRY
United States

YEAR
2015

TYPE
Industrial

Source: https://robots.ieee.org/robots/invia/


Video
https://robots.ieee.org/robots/invia/?gallery=video5

Types of Robot

Industrial

Freight

Freight is an autonomous mobile base for use in warehouses to transport materials from point A to point B. The robot platforms come in three zippy flavors – 100, 500 and 1500, all of which represent the payload it can handle in kilograms.

CREATOR
Fetch Robotics

COUNTRY
United States

YEAR
2014

TYPE
Industrial

Source: https://robots.ieee.org/robots/freight/

Types of Robot

Industrial

Sawyer

Sawyer is an industrial collaborative robot designed to help out with manufacturing tasks and work alongside humans. You can teach it new tasks by demonstrating what to do using the robot's own arm.

CREATOR
Rethink Robotics

COUNTRY
United States 🇺🇸

YEAR
2015

TYPE
Industrial

Source: https://robots.ieee.org/robots/sawyer/


Video
https://robots.ieee.org/robots/sawyer/?gallery=video1

Types of Robot

Industrial

Meca500

Meca500 is the world's smallest, most compact six-axis industrial robot arm. It's also one of the most precise. And with an embedded controller it can easily be transported and set up in confined spaces.

CREATOR
Mecademic

COUNTRY
Canada

YEAR
2015

TYPE
Industrial

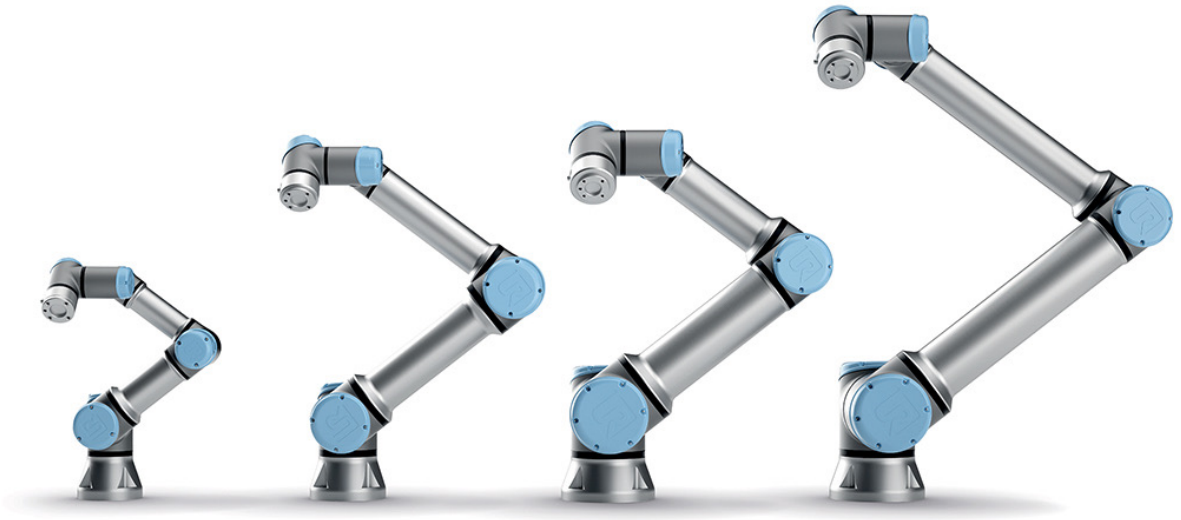
Source: https://robots.ieee.org/robots/meca/

Video

https://robots.ieee.org/robots/meca500/?gallery=video1

Types of Robot

Industrial



UR

Universal Robots cobots are versatile, lightweight collaborative robotic arms designed to work safely alongside humans. Users program it through an intuitive touch-screen interface and by positioning the robot with their hands.

CREATOR
Universal Robots

COUNTRY
Denmark

YEAR
2008

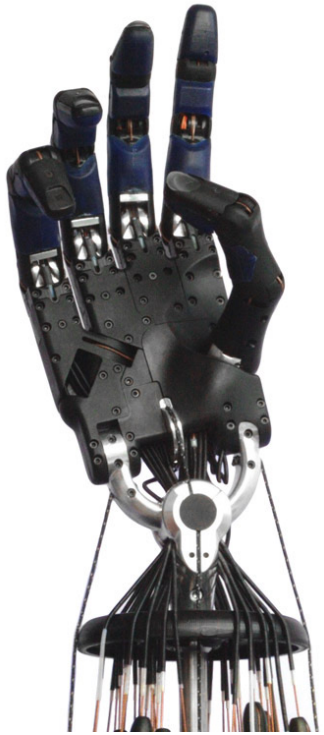
TYPE
Industrial

Source: https://robots.ieee.org/robots/ur/

Types of Robot

Research

Industrial



Shadow Hand

The Shadow Dexterous Hand is one of the most advanced robot hands in the world. It's designed to replicate as much of the functionality, dimensions, and range of motion of the human hand as possible.

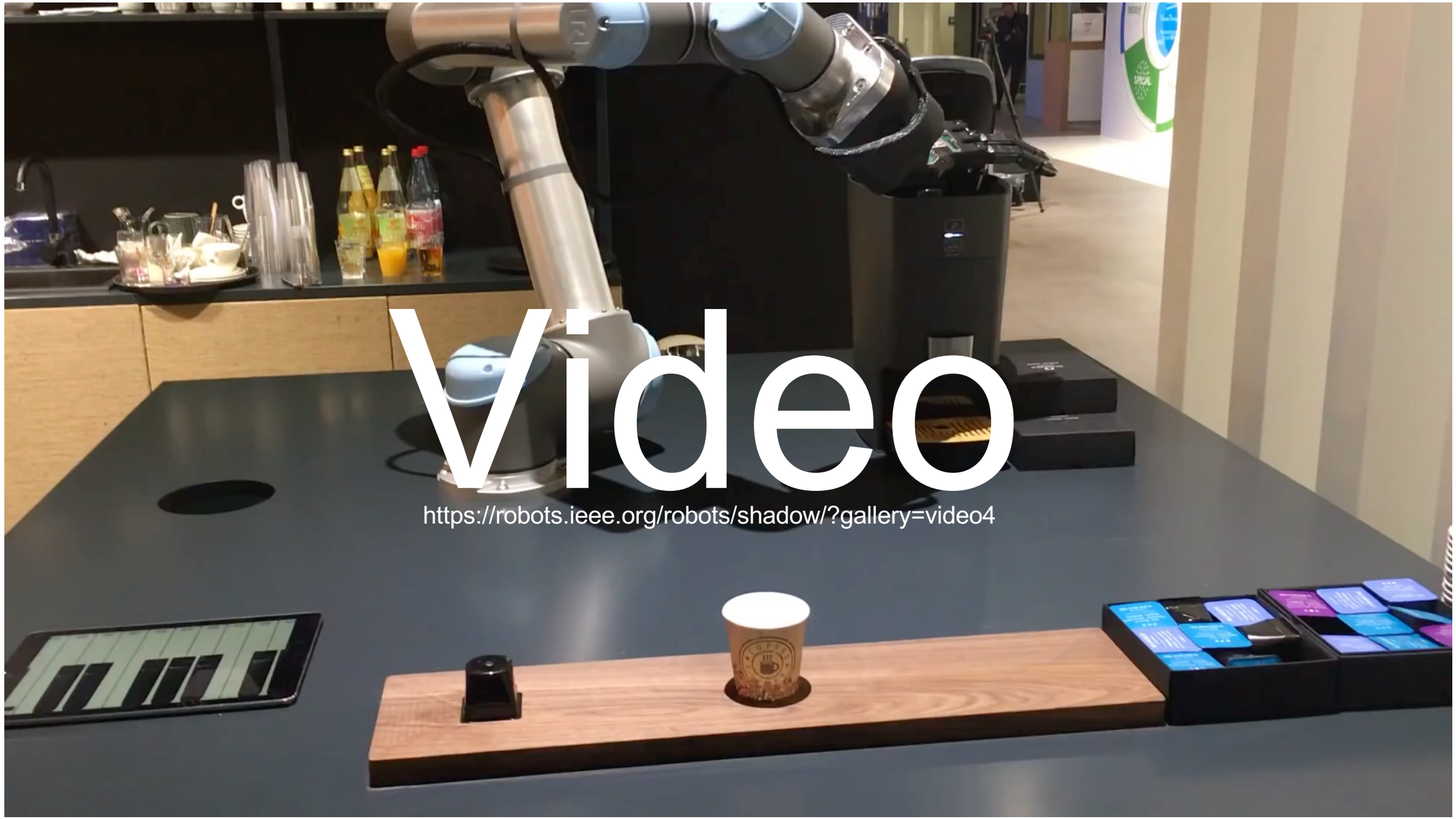
CREATOR
Shadow Robot Company

COUNTRY
United Kingdom

YEAR
2004

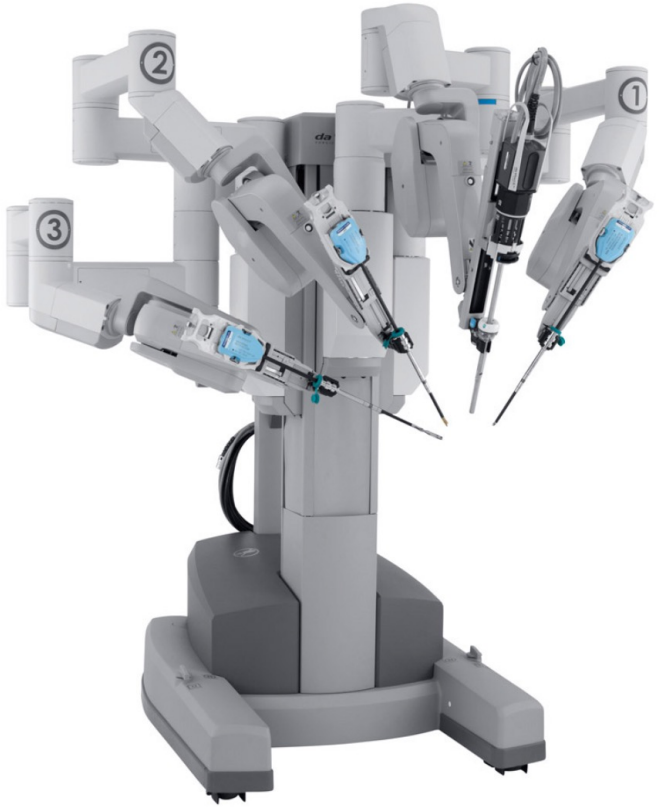
TYPE
Industrial, Telepresence, Research

Source: https://robots.ieee.org/robots/shadow/


Video
https://robots.ieee.org/robots/shadow/?gallery=video4

Types of Robot

Medical



Da Vinci

The da Vinci is a surgical robot designed for minimally invasive procedures. It has four arms equipped with surgical instruments and cameras that a physician controls remotely from a console.

CREATOR
Intuitive Surgical

COUNTRY
United States

YEAR
1999

TYPE
Medical

Source: https://robots.ieee.org/robots/davinci/

THE DA VINCI SURGICAL SYSTEM

SURGEON SIDE

1. High Resolution Stereo Viewers (HRSVs)
2. Master Tool Manipulators (MTMs)
3. Foot pedal tray

PATIENT SIDE

1. Patient Side Manipulators (PSMs)
2. Endoscopic Camera Manipulator (ECM)
3. Vision Cart

Patient Side Manipulators: robotic arms teleoperated by the Master Tool Manipulators, they mount the surgical tools.

Endoscopic Camera Manipulator: robotic arm that is also teleoperated by the Master Tool Manipulators, it holds the endoscope.


Video
https://www.youtube.com/watch?v=961E6Nx9Pok

Types of Robot

Consumer

Telepresence

Beam

Beam is a telepresence robotic system that can "teleport" you to a remote location, allowing you to move around and interact with people. It is easy to drive and has a large display to improve face-to-face, or screen-to-face, communication.

CREATOR
Suitable Technologies

COUNTRY
United States

YEAR
2011

TYPE
Telepresence, Consumer

Source: https://robots.ieee.org/robots/beam/

Types of Robot

Autonomous Vehicle Research

Boss

Boss is the world's smartest Chevy Tahoe. In 2007, it won the DARPA Urban Challenge for autonomous vehicles, taking home a $2 million prize for not breaking any traffic laws or running anyone over.

CREATOR
Carnegie Mellon University

COUNTRY
United States

YEAR
2007

TYPE
Autonomous Vehicle, Research

Source: https://robots.ieee.org/robots/boss/

Types of Robot

Autonomous Vehicle Research

Google Self-Driving Car

Google's self-driving car is a modified Toyota Prius that can autonomously drive in city traffic and on highways. The goal is developing technology to reduce traffic accidents and increase road efficiency.

CREATOR
Google

COUNTRY
United States

YEAR
2010

TYPE
Autonomous Vehicle, Research

Source: https://robots.ieee.org/robots/beam/

Types of Robot

Industrial

Research

Disaster Response

ANYmal

ANYmal is a rugged, autonomous four-legged robot designed for inspection and manipulation tasks. It uses sensors to scan the terrain and avoid obstacles, and can operate in rain, snow, wind, waterlogged rooms, and dusty environments.

CREATOR
ETH Zurich and ANYbotics

COUNTRY
Switzerland

YEAR
2016

TYPE
Industrial, Research, Disaster Response

Source: https://robots.ieee.org/robots/anymal/

Types of Robot

Industrial

Research

Spot

Spot is a compact, nimble four-legged robot that can trot around your office, home, or outdoors. It can map its environment, sense and avoid obstacles, climb stairs, and open doors. It can also fetch you a drink.

CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2016

TYPE
Industrial, Research

Source: https://robots.ieee.org/robots/spotmini/


Video
https://robots.ieee.org/robots/spotmini/?gallery=video1

Types of Robot

Military & Security

Research

AlphaDog

AlphaDog is a quadruped robot the size of a mule (a big, mean mule). It's powered by a hydraulic actuation system and is designed to assist soldiers in carrying heavy gear over rough terrain.

CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2011

TYPE
Military & Security, Research

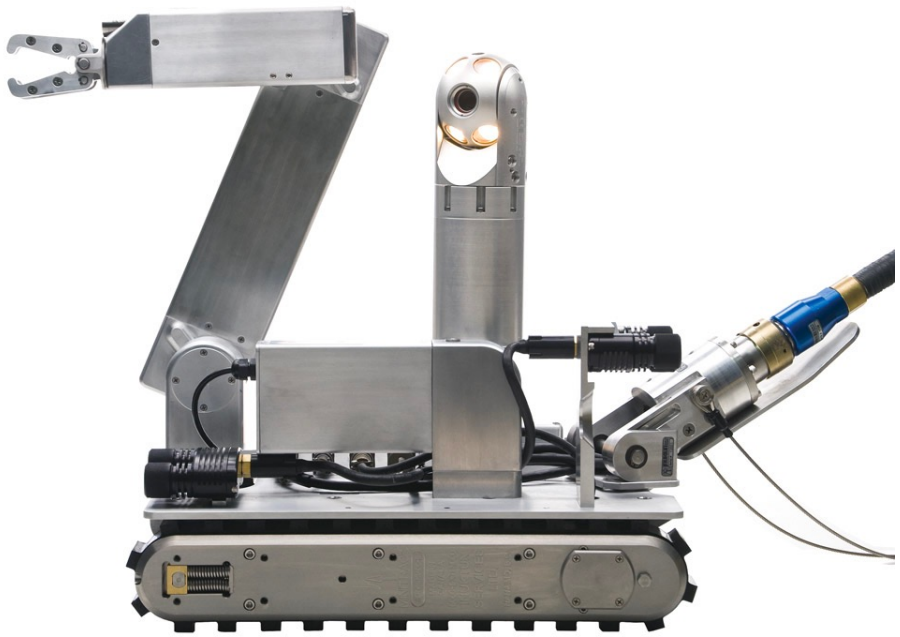
Source: https://robots.ieee.org/robots/alphadog/

Types of Robot

Industrial

Military & Security

Disaster Response



Versatrax

Versatrax 450 TTC is a mobile robot designed for hazardous environments. It allows users to locate, inspect, and safely remove dangerous materials from any site faster than by conventional means.

CREATOR
Inuktun Services

COUNTRY
Canada

YEAR
2012

TYPE
Industrial, Military & Security, Disaster Response

Source: https://robots.ieee.org/robots/inuktun/

Types of Robot

Military & Security

Disaster Response

Kobra

Kobra is a rugged, remote control robot designed to search for explosives and carry out reconnaissance missions. It rolls on tank-like treads, and its manipulator arm can lift heavy payloads.

CREATOR
Endeavor Robotics
(Originally created by iRobot)

COUNTRY
United States

YEAR
2011

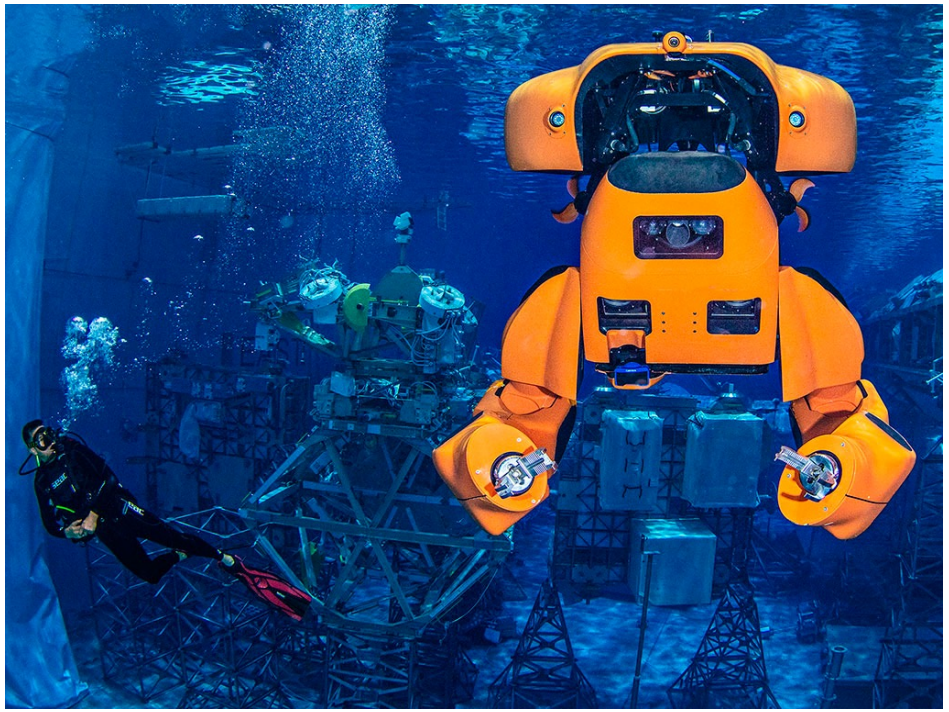
TYPE
Military & Security, Disaster Response

Source: https://robots.ieee.org/robots/kobra/

Types of Robot

Underwater

Industrial



Aquanaut

Aquanaut is an unmanned underwater vehicle that can transform itself from a nimble submarine designed for long-distance cruising into a half-humanoid robot capable of carrying out complex manipulation tasks. It can inspect subsea oil and gas infrastructure, operate valves, and use tools.

CREATOR
Houston Mechatronics Inc.

COUNTRY
United States

YEAR
2019

TYPE
Underwater, Industrial

Source: https://robots.ieee.org/robots/aquanaut/

Types of Robot

Research

Salamandra robotica II

Salamandra robotica II is an amphibious robot inspired by the salamander's anatomy and nervous system. It's used to study robot locomotion and test neurobiological models in real environments.

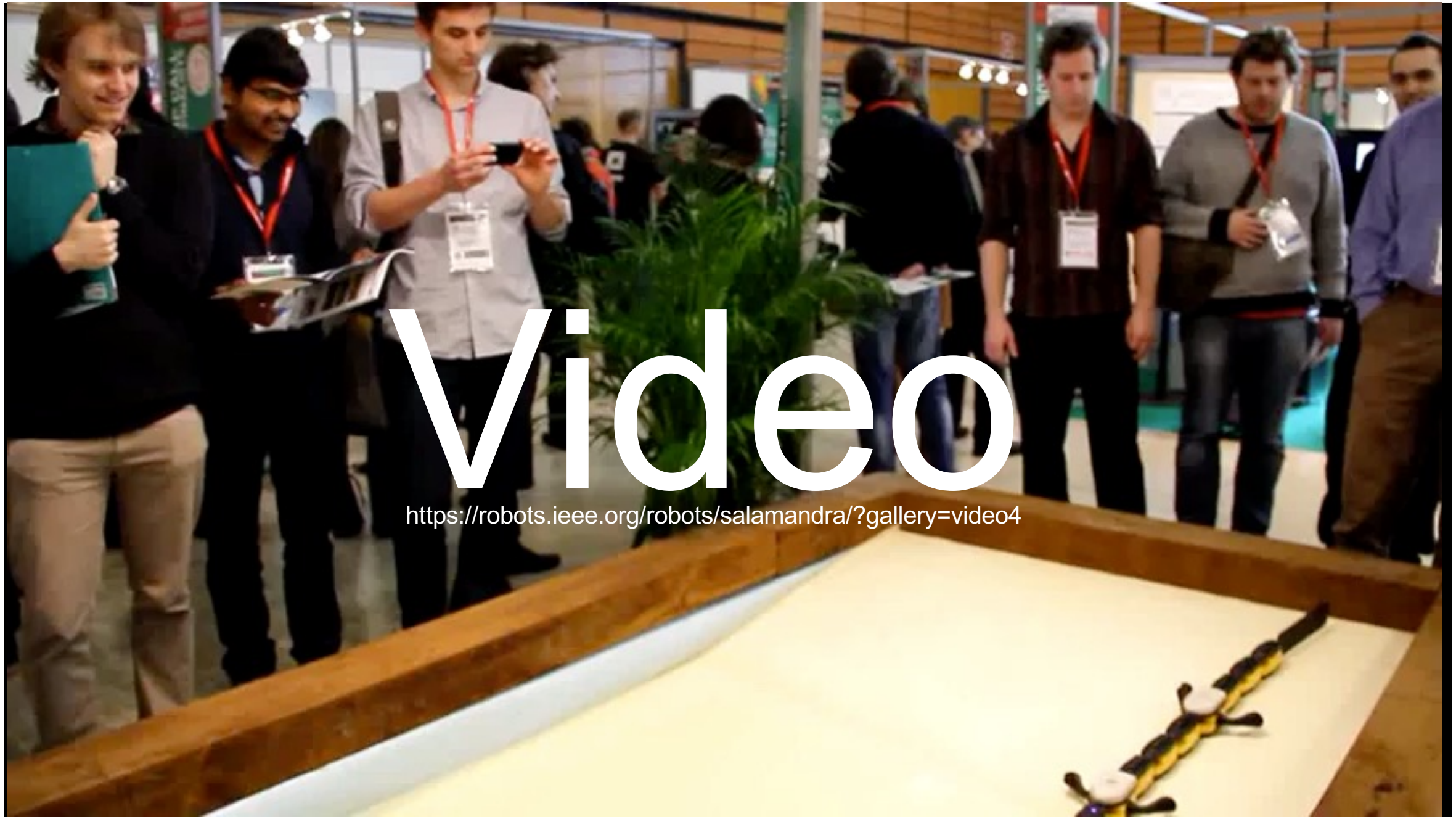
CREATOR
Biorobotics Laboratory at EPFL

COUNTRY
Switzerland

YEAR
2012

TYPE
Research

Source: https://robots.ieee.org/robots/salamandra/


Video
https://robots.ieee.org/robots/salamandra/?gallery=video4

The Many Areas of Robotics

The Many Areas of Robotics

Technical Committees

Aerial Robotics and Unmanned Aerial Vehicles
Agricultural Robotics and Automation
Algorithms for Planning and Control of Robot Motion
Automation in Health Care Management
Automation in Logistics

Autonomous Ground Vehicles and Intelligent Transportation Systems
Bio Robotics
Cognitive Robotics
Collaborative Automation for Flexible Manufacturing
Computer & Robot Vision

Cyborg & Bionic Systems
Digital Manufacturing and Human-Centered Automation
Energy, Environment, and Safety Issues in Robotics and Automation
Haptics
Human Movement Understanding

Human-Robot Interaction & Coordination
Humanoid Robotics
Marine Robotics
Mechanisms and Design
Micro/Nano Robotics and Automation

Mobile Manipulation
Model-Based Optimization for Robotics
Multi-Robot Systems
Neuro-Robotics Systems
Performance Evaluation & Benchmarking of Robotic and Automation Systems

Rehabilitation and Assistive Robotics
RoboCup
Robot Ethics
Robot Learning
Robotic Hands, Grasping and Manipulation

Robotics and Automation in Nuclear Facilities
Robotics Research for Practicality
Safety, Security and Rescue Robotics
Semiconductor Manufacturing Automation
Smart Buildings

Soft Robotics
Software Engineering for Robotics and Automation
Space Robotics
Surgical Robotics
Sustainable Production Automation

Telerobotics

Verification of Autonomous Systems
Wearable Robotics
Whole-Body Control

https://www.ieee-ras.org/technical-committees

A Short History of Robotics

History of Robotics

- The word robot was popularized by the Czech playwright Karel Capek

  pronounced Kha-rel Cha-pek

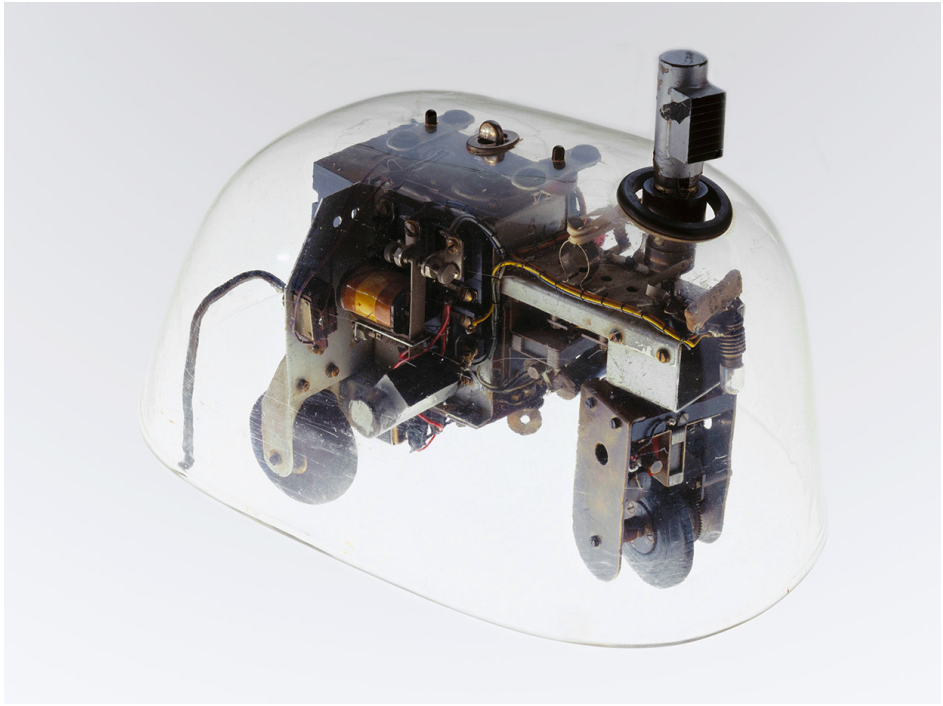
  in his 1921 play Rossum's Universal Robots (R.U.R.).

- It resulted from combining the Czech words rabota, meaning "obligatory work" and robotnik, meaning "serf"

History of Robotics

W. Grey Walter's Tortoises (1950)

- Neurophysiologist W. Grey Walter built his cybernetic tortoises to understand the functions of the brain
  - Elmer and Elsie
- Part of the emerging field of cybernetics
  - The field's founder, Norbert Wiener, defined cybernetics as "the scientific study of control and communication in the animal and the machine."

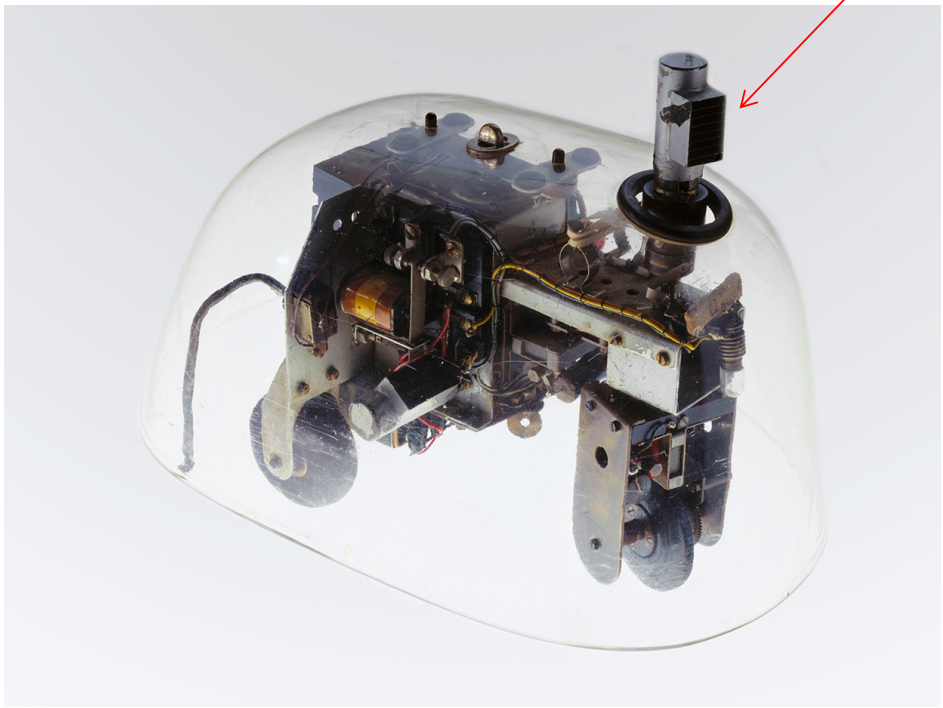


Meet the Roomba's Ancestor: The Cybernetic Tortoise, IEEE Spectrum, 2020
https://spectrum.ieee.org/tech-history/space-age/meet-roombas-ancestor-cybernetic-tortoise

History of Robotics

W. Grey Walter's Tortoises (1950)

- "With just a photocell, a touch sensor, and two vacuum tubes, the robo-tortoise mimicked the way real animals move"



Meet the Roomba's Ancestor: The Cybernetic Tortoise, IEEE Spectrum, 2020
https://spectrum.ieee.org/tech-history/space-age/meet-roombas-ancestor-cybernetic-tortoise

History of Robotics

Claude Shannon's Mouse (1950)

- This was one of the world's first examples of machine learning: a robotic maze-solving mouse known as Theseus

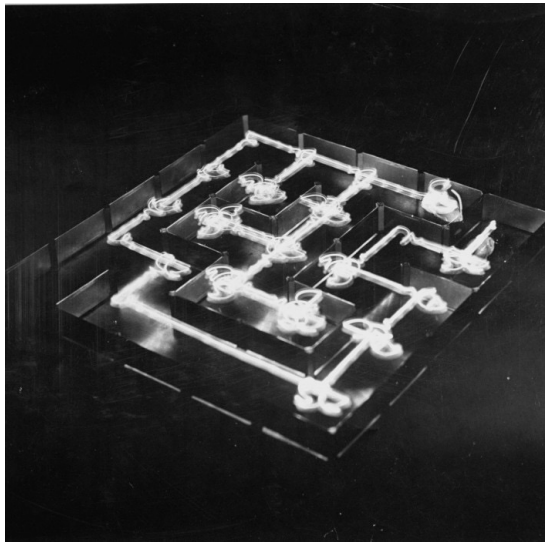
https://www.technologyreview.com/2018/12/19/138508/mighty-mouse/

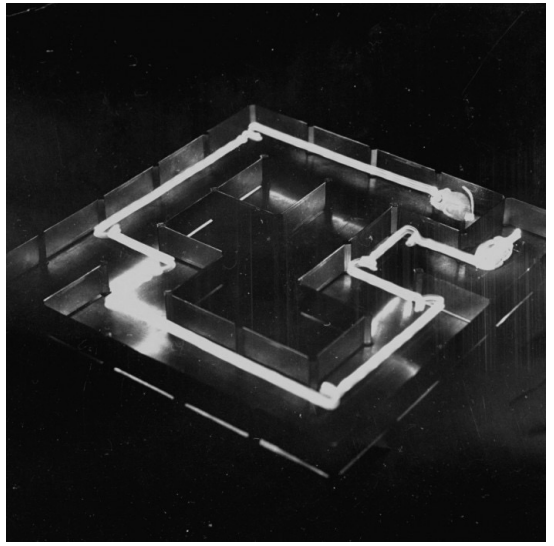
History of Robotics

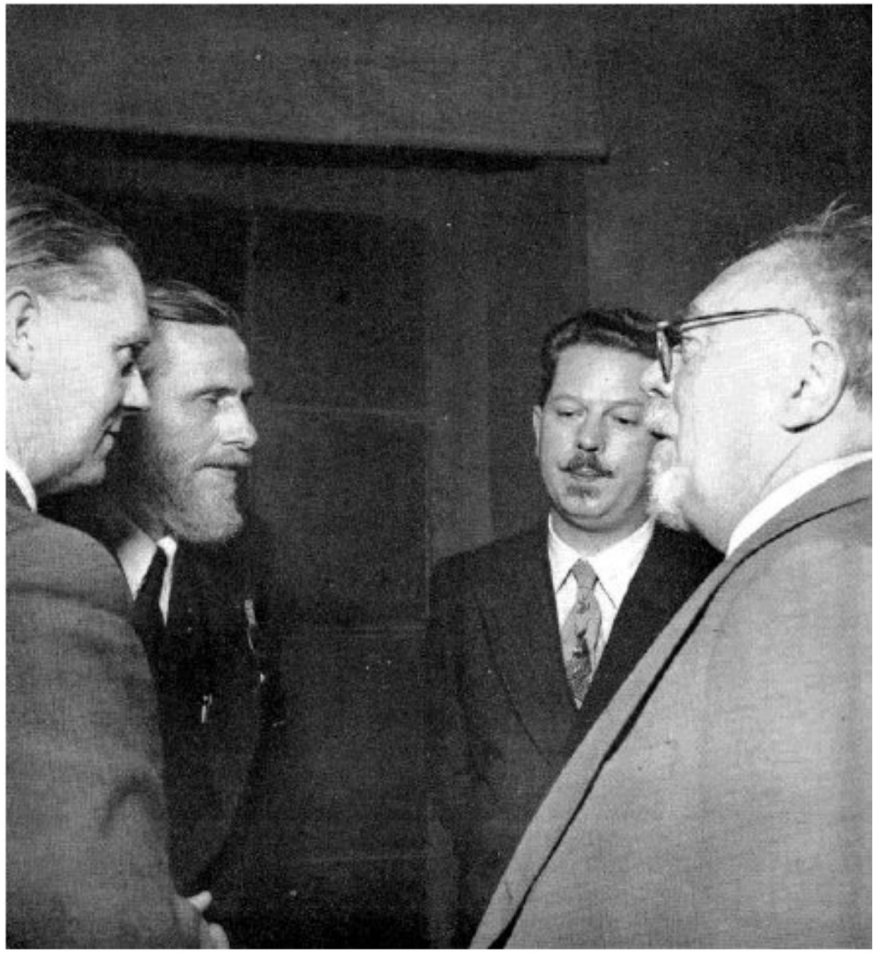
Claude Shannon's Mouse

"These photos, published in Life magazine in 1952, show the path Theseus took while learning a maze pattern and the direct path taken on its second trip through the same maze"

https://www.technologyreview.com/2018/12/19/138508/mighty-mouse/







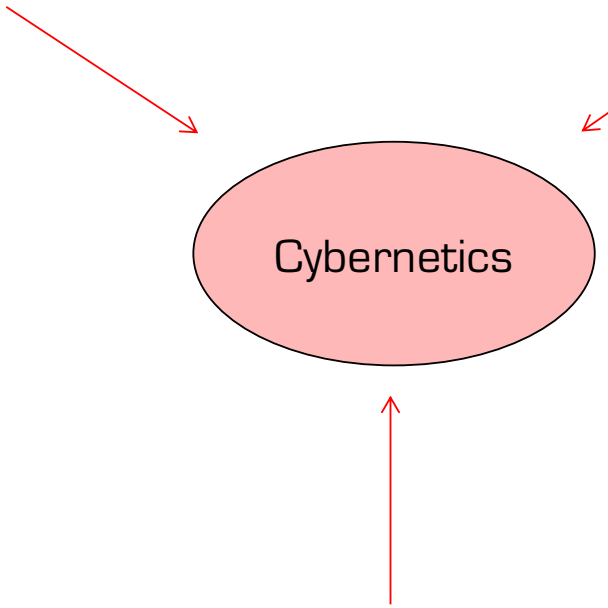
W. Ross Ashby, Warren McCulloch, Grey Walter, Norbert Wiener
at the 1951 Congress on Cybernetics, Paris

https://www.researchgate.net/publication/287293010_Warren_McCulloch_and_the_British_Cyberneticians/figures?lo=1

N. Wiener
Cybernetics: or the Control and Communication in the Animal and the Machine, 1948.

(κυβερνητης or kybernetes: steersman)

W. Ross Ashby
Design for a Brain, first edition, 1952 ... 1956, 1960.
Introduction to Cybernetics, 1957

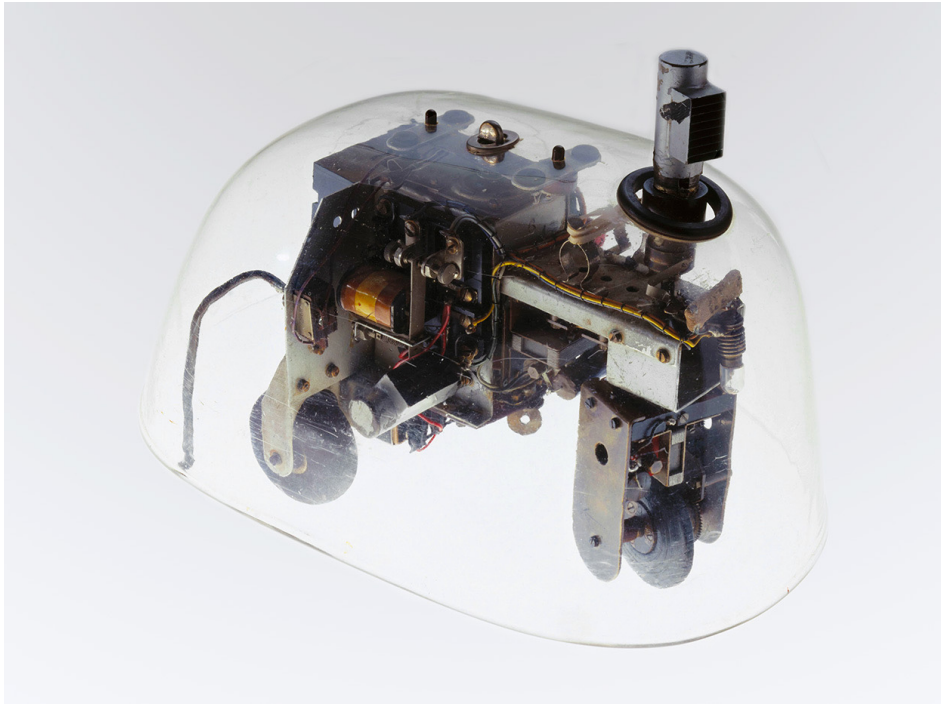


Walter McCulloch
W. S. McCulloch and W. Pitts "A logical calculus of ideas immanent in nervous activity". Bulletin of Mathematical Biophysics 5:115–133, 1943

History of Robotics

Both Walter's and Shannon's robots built on behaviorist psychology

- using associative and reinforcement learning in relatively simple neural networks
- rather than focussing on internal models and symbolic computation
- Precursor to reactive and behaviour-based robotics (more on this later when we discuss paradigms of robotics)



Meet the Roomba's Ancestor: The Cybernetic Tortoise, IEEE Spectrum, 2020
https://spectrum.ieee.org/tech-history/space-age/meet-roombas-ancestor-cybernetic-tortoise

History of Robotics

Shakey (1966 – 1972)

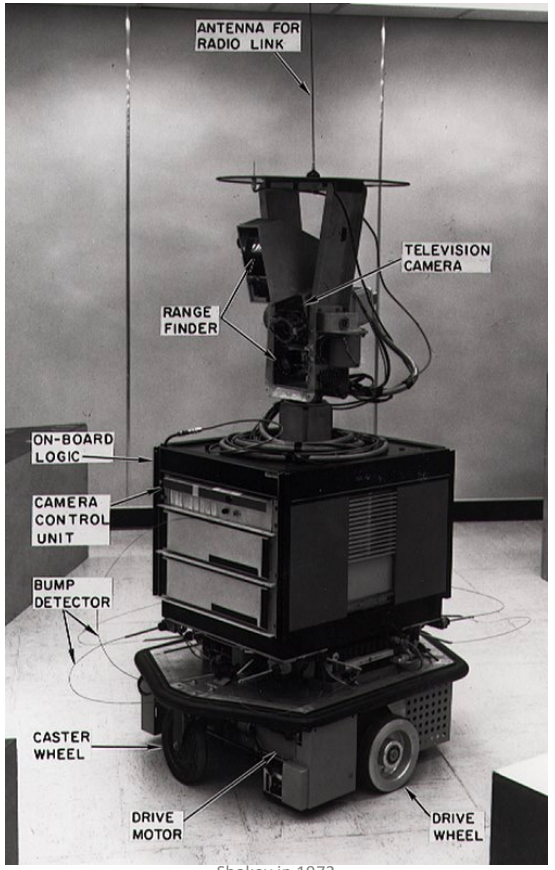
- "Shakey" was the first mobile robot with the ability to perceive and reason about its surroundings and its actions
- Developed at the Artificial Intelligence Center of Stanford Research Institute (now called SRI International)
- Charles Rosen, Nils Nilsson, Alfred Brain, Sven Wahlstrom, Bertram Raphael, Richard Duda, Peter Hart, Richard Fikes, Richard Waldinger, Thomas Garvey, Jay Tenenbaum, Helen Chan Wolf and Michael Wilber

https://www.sri.com/hoi/shakey-the-robot/

History of Robotics

Shakey built on computationalist (cognitivist) psychology and symbolic AI

- Programming was primarily done in LISP
- Using the Stanford Research Institute Problem Solver (STRIPS) planner
- The first robot that was a logical, goal-based agent
- Precursor to hierarchical "sense-plan-act" robotics (more on this later when we discuss paradigms of robotics)

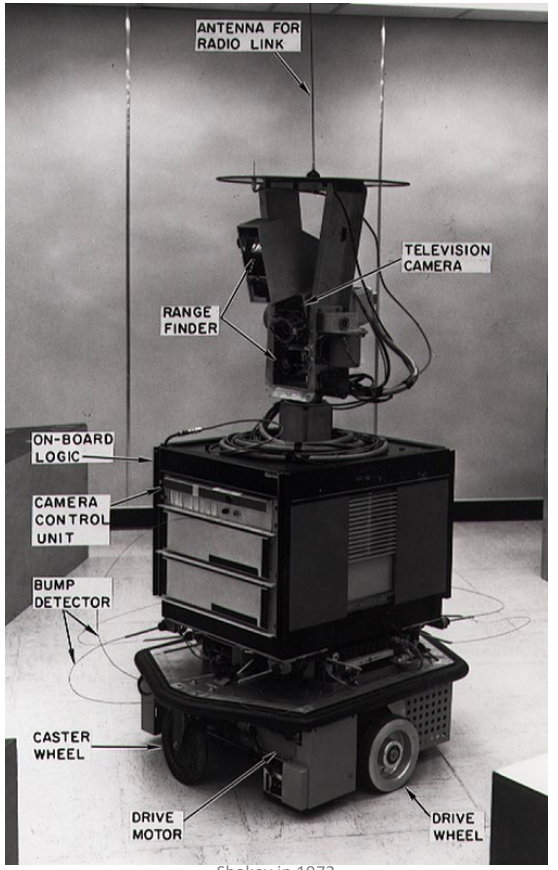


Shakey in 1972
https://en.wikipedia.org/wiki/Shakey_the_robot

History of Robotics

Some research results

- The A* search algorithm
- The Hough transform
- The visibility graph method
- Major impact on the development of robotics & AI (and computer science, generally)



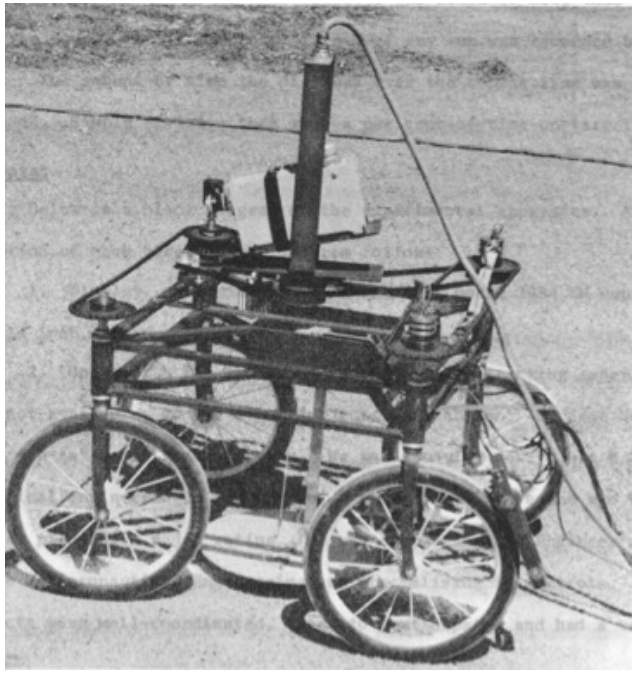
Shakey in 1972
https://en.wikipedia.org/wiki/Shakey_the_robot

History of Robotics

Stanford Cart (1960 - 1980)

James Adams
Stanford University

https://web.stanford.edu/~learnest/sail/oldcart.html



Stanford Cart with cable, 1961

https://web.stanford.edu/~learnest/sail/oldcart.html

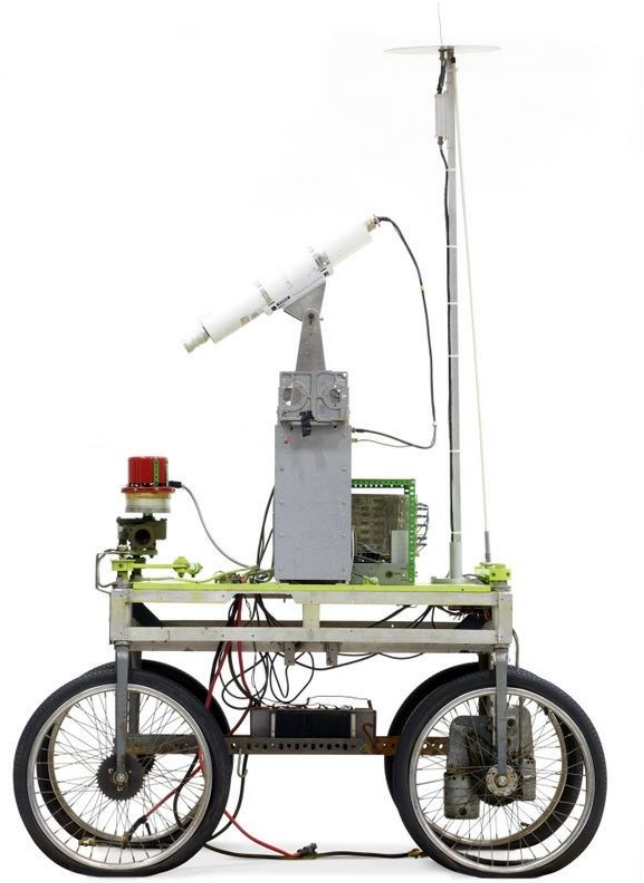
History of Robotics

Stanford Cart (1961 - 1980)

Hans Moravec

Stanford Artificial Intelligence Laboratory SAIL

- Sensors
  - Stereo vision (camera on a slider)
- Speed
  - ~1 meter per 10-15 minutes
  - Full run: 5 hours
- Accomplishments:
  - Successfully navigated 20 meter courses, avoiding obstacles using visual sensing
  - Used graph search to find shortest path



Stanford Cart 1980
© Mark Richards

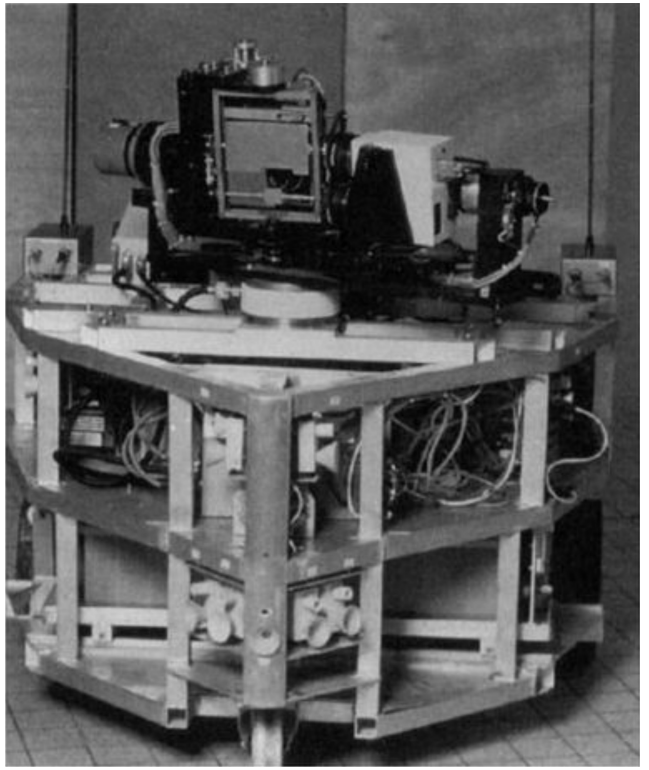
https://www.computerhistory.org/revolution/artificial-intelligence-robotics/13/293/1277

History of Robotics

HILARE (late 1970s)

LAAS Lab
Laboratoire d'Analyse et D'Architecture des Systemes,
Toulouse, France

- Sensors
  - Video camera
  - 14 sonar sensors
  - Laser range finder
- Actuators
  - Three wheels: two actuated, one caster
- Weight
  - 400 kg



https://slideplayer.com/slide/11973896/

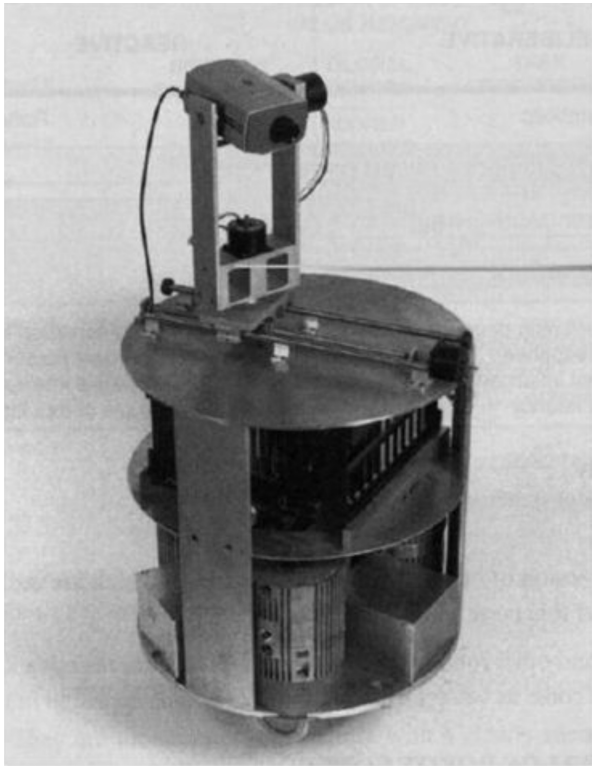
History of Robotics

Rover (1983)

Hans Moravec

Carnegie Mellon University

- Follow-on from the Stanford Cart
- Sensors
  - Video camera with pan and tilt
  - Sonar
  - Infrared
- Actuators
  - Three independently powered wheels
- Accomplishments: set the stage for behavior-based robotics



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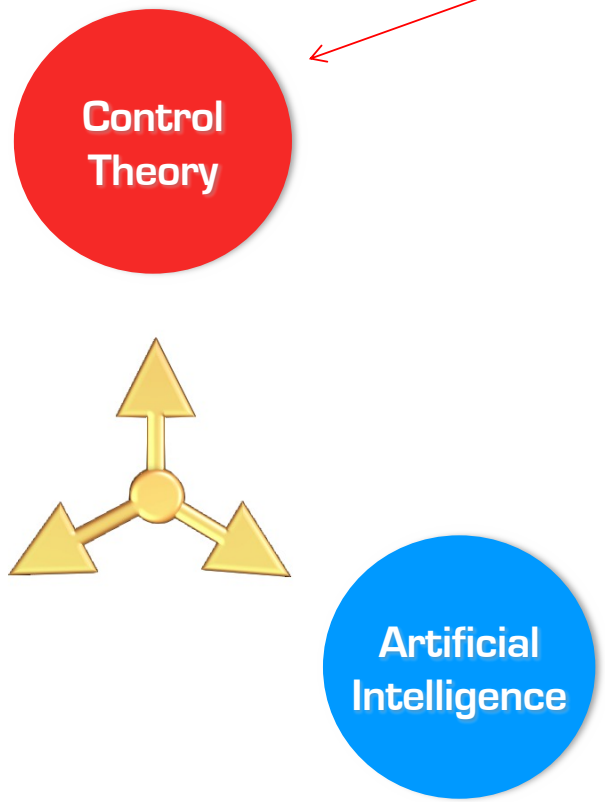
Robotics

"The mathematics of controlling machines"



"The integration of sensing, action, and the environment"

"The mechanisms for planning and reasoning"

M. Mataric, The Robotics Primer, MIT Press, 2007; Chapter 2, p. 17.

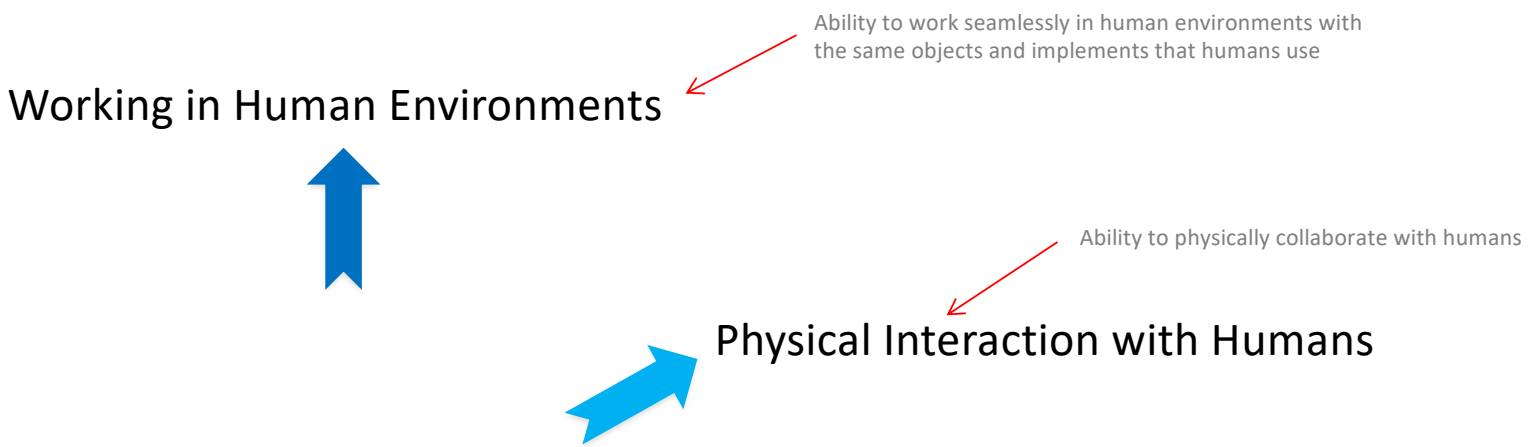
The Importance of Being Humanoid

Six Ways Humanoid Robots Are Special

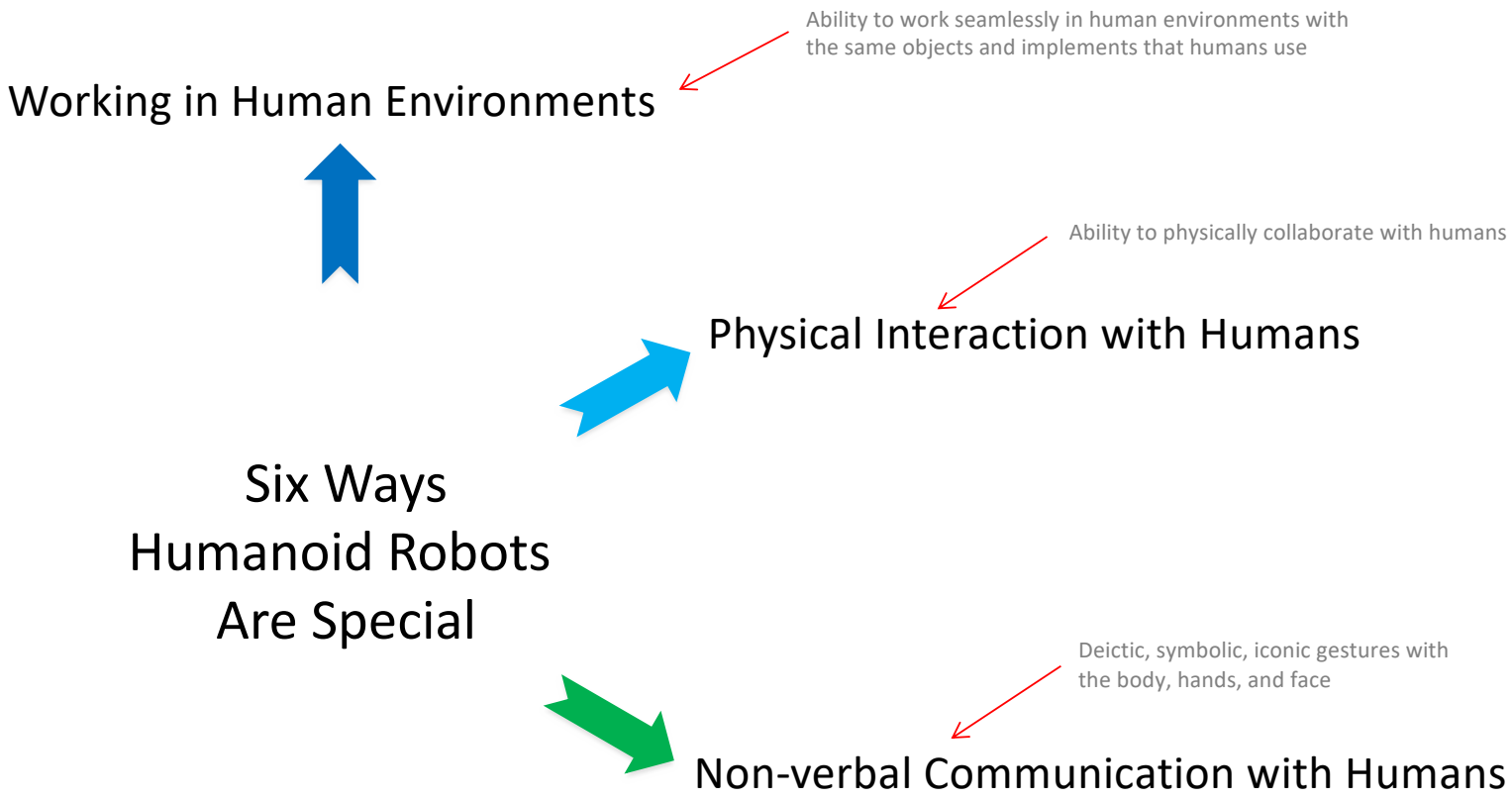
Working in Human Environments

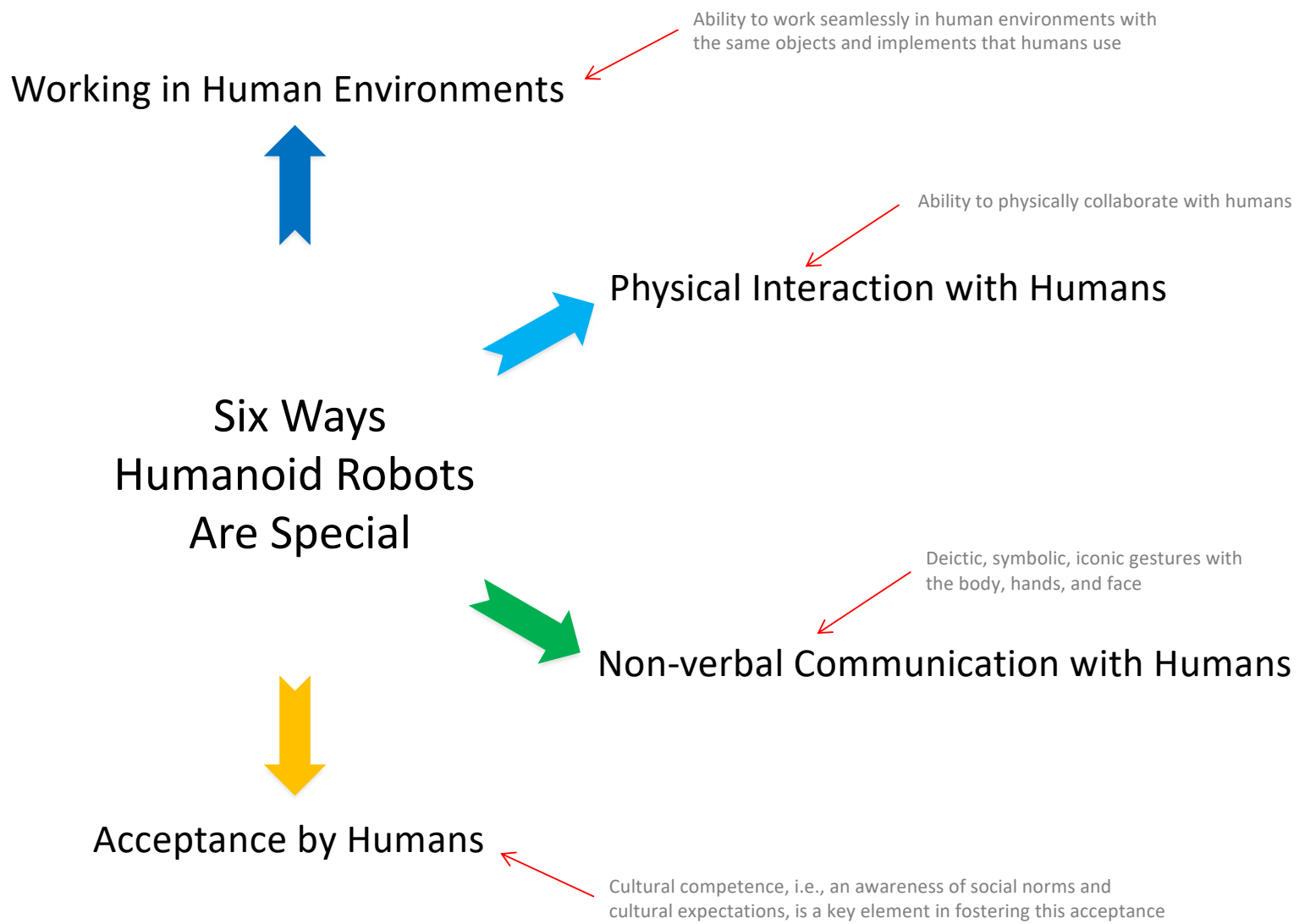
Ability to work seamlessly in human environments with the same objects and implements that humans use

Six Ways Humanoid Robots Are Special



Six Ways Humanoid Robots Are Special


Working in Human Environments
Ability to work seamlessly in human environments with the same objects and implements that humans use
Physical Interaction with Humans
Ability to physically collaborate with humans
Six Ways Humanoid Robots Are Special
Non-verbal Communication with Humans
Deictic, symbolic, iconic gestures with the body, hands, and face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Cultural competence, i.e., an awareness of social norms and cultural expectations, is a key element in fostering this acceptance

Six Ways Humanoid Robots Are Special

Working in Human Environments

Ability to work seamlessly in human environments with the same objects and implements that humans use

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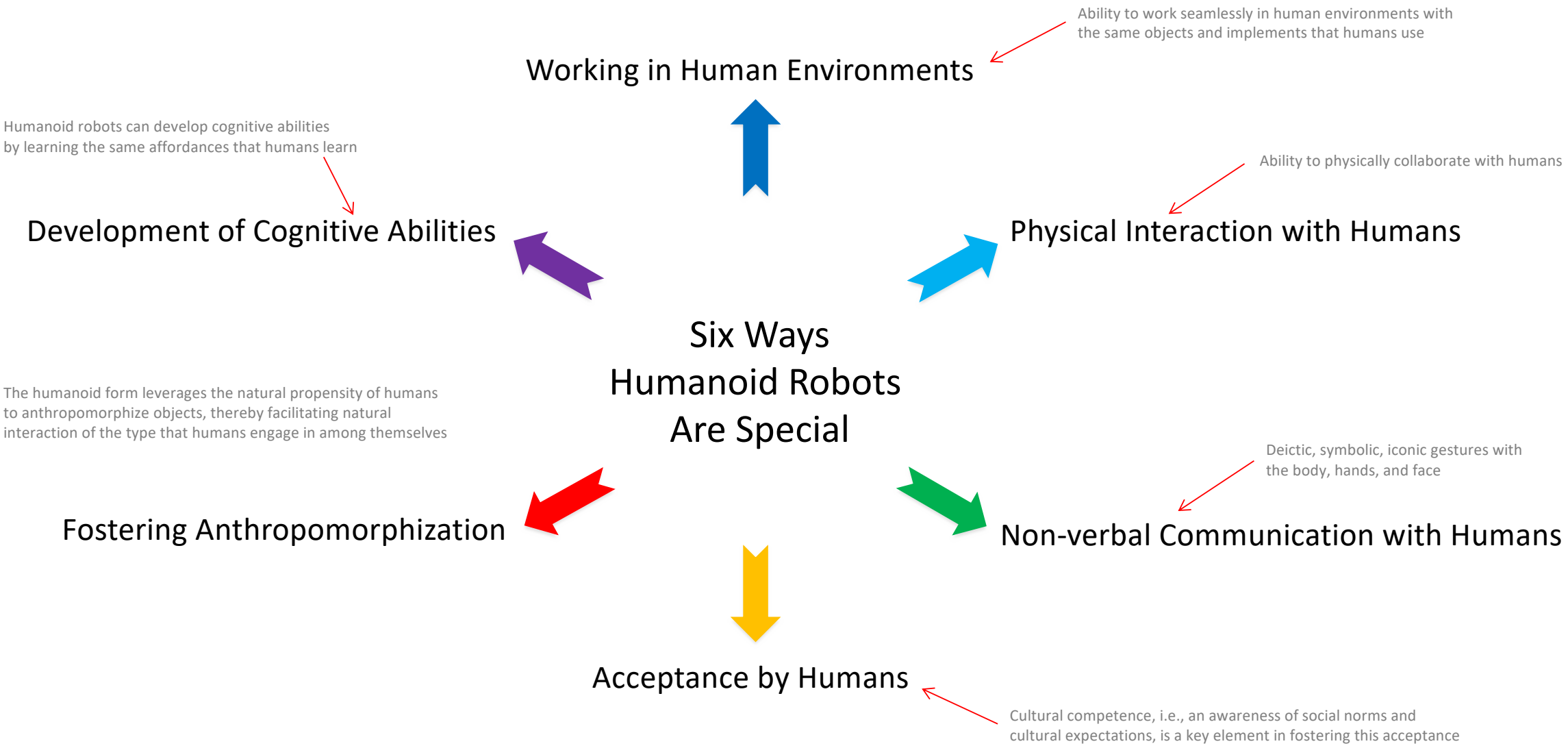
Fostering Anthropomorphization

The humanoid form leverages the natural propensity of humans to anthropomorphize objects, thereby facilitating natural interaction of the type that humans engage in among themselves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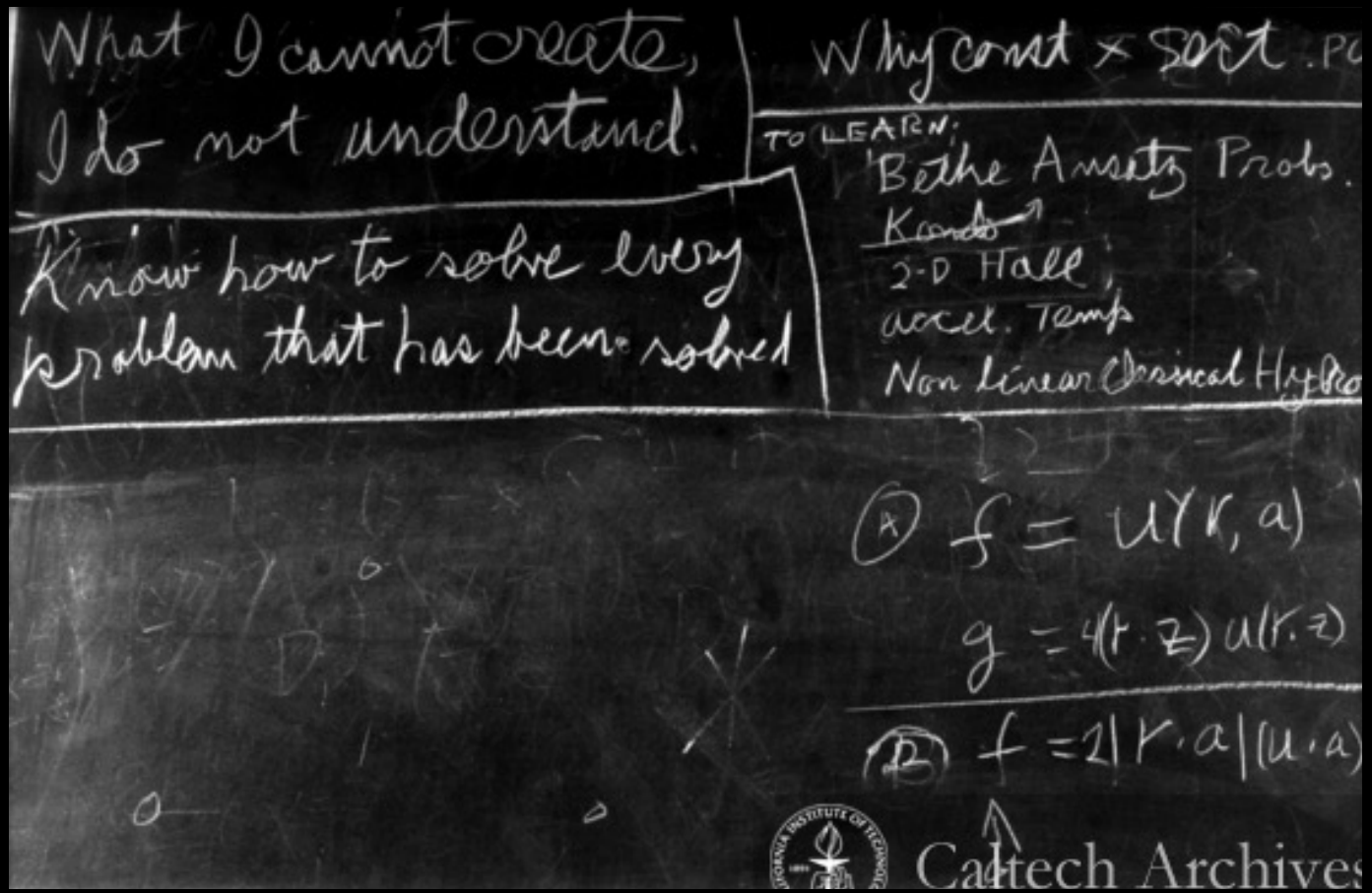
Development of Cognitive Abilities
Humanoid robots can develop cognitive abilities by learning the same affordances that humans learn

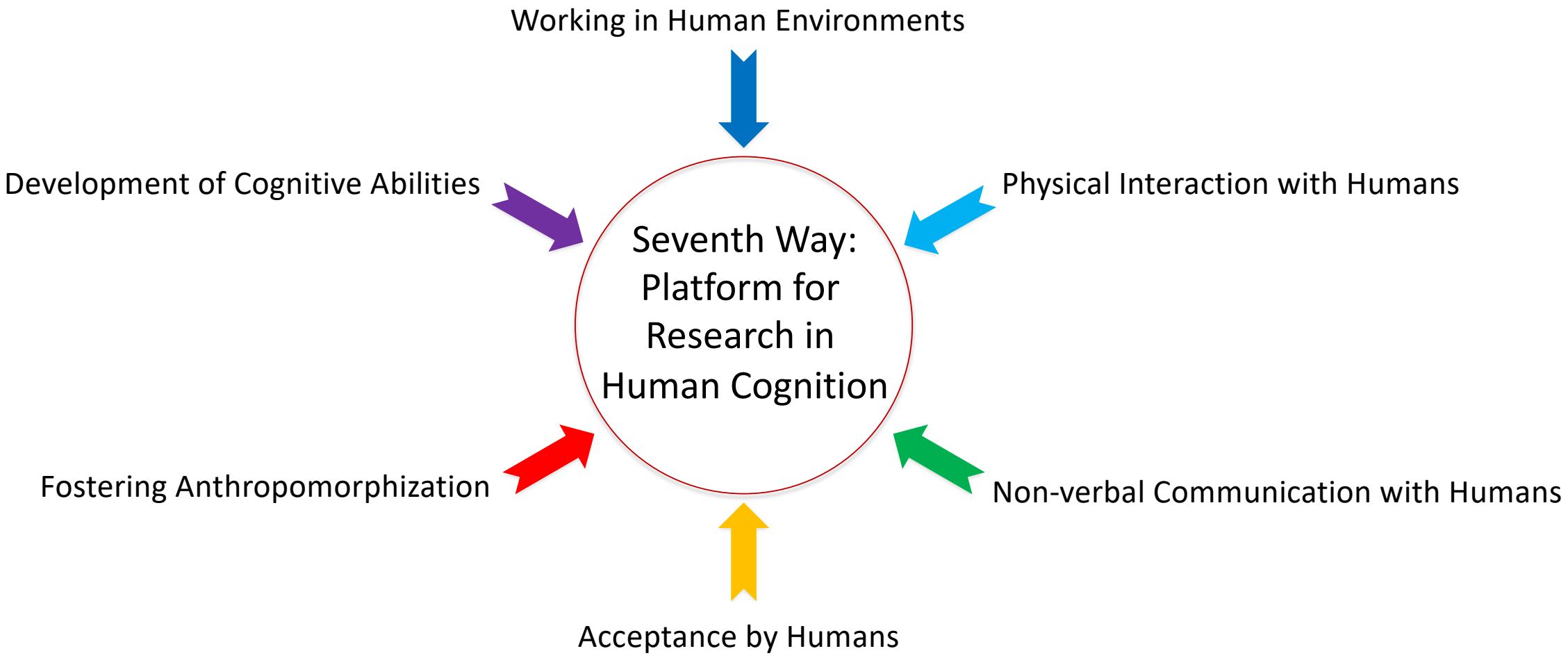
Two reasons people study artificial cognitive systems
& build cognitive robots

1. They want smart systems

2. They want to study cognition



Richard Feynman


Working in Human Environments
Development of Cognitive Abilities
Physical Interaction with Humans
Seventh Way: Platform for Research in Human Cognition
Fostering Anthropomorphization
Non-verbal Communication with Humans
Acceptance by Humans

The iCub Cognitive Humanoid Robot

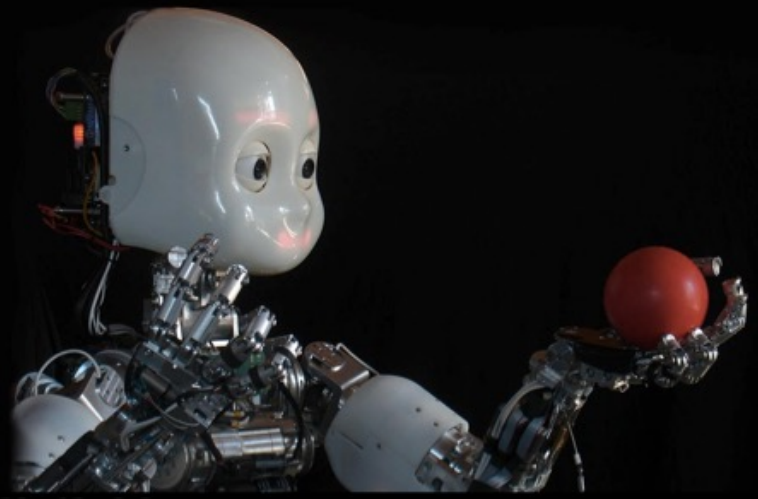
iCub.org

an open source cognitive humanoid robotic platform

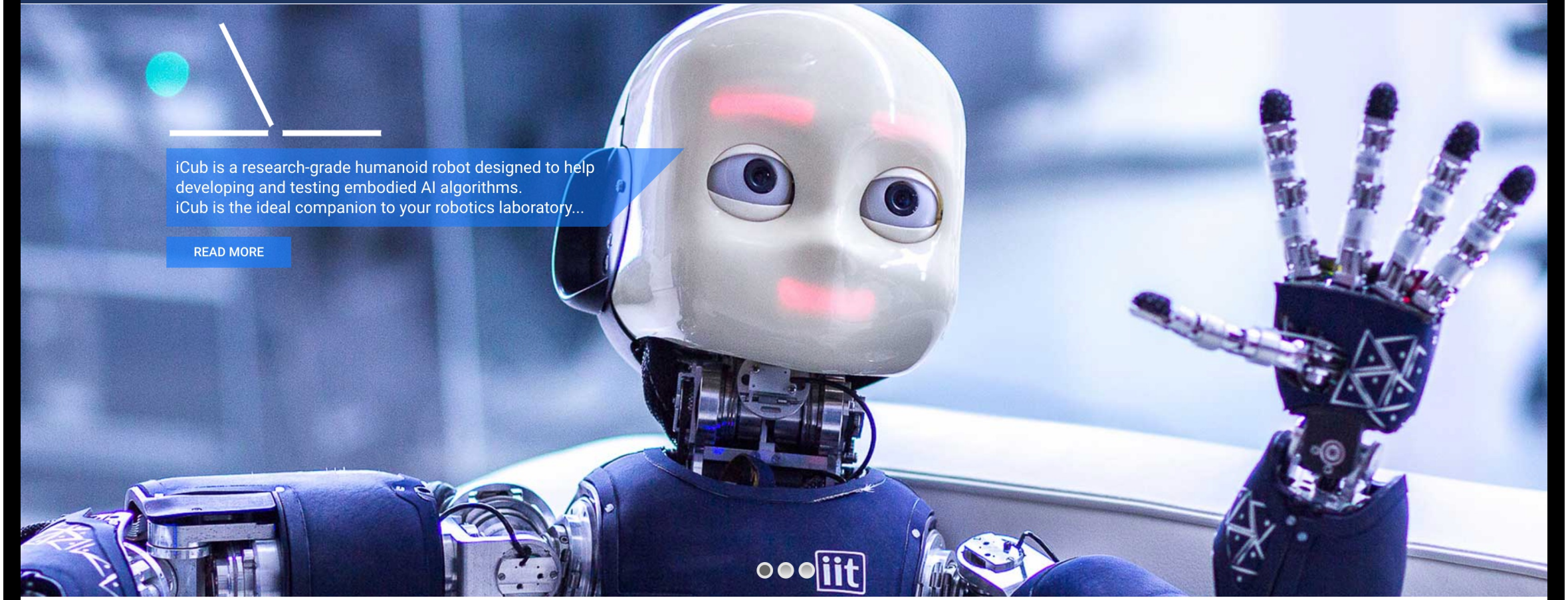
Cogsys Cognitive Systems

Funded by The European Commission, Project IST-004370, RobotCub, under Strategic Objective 2.3.2.4: Cognitive Systems

RobotCub

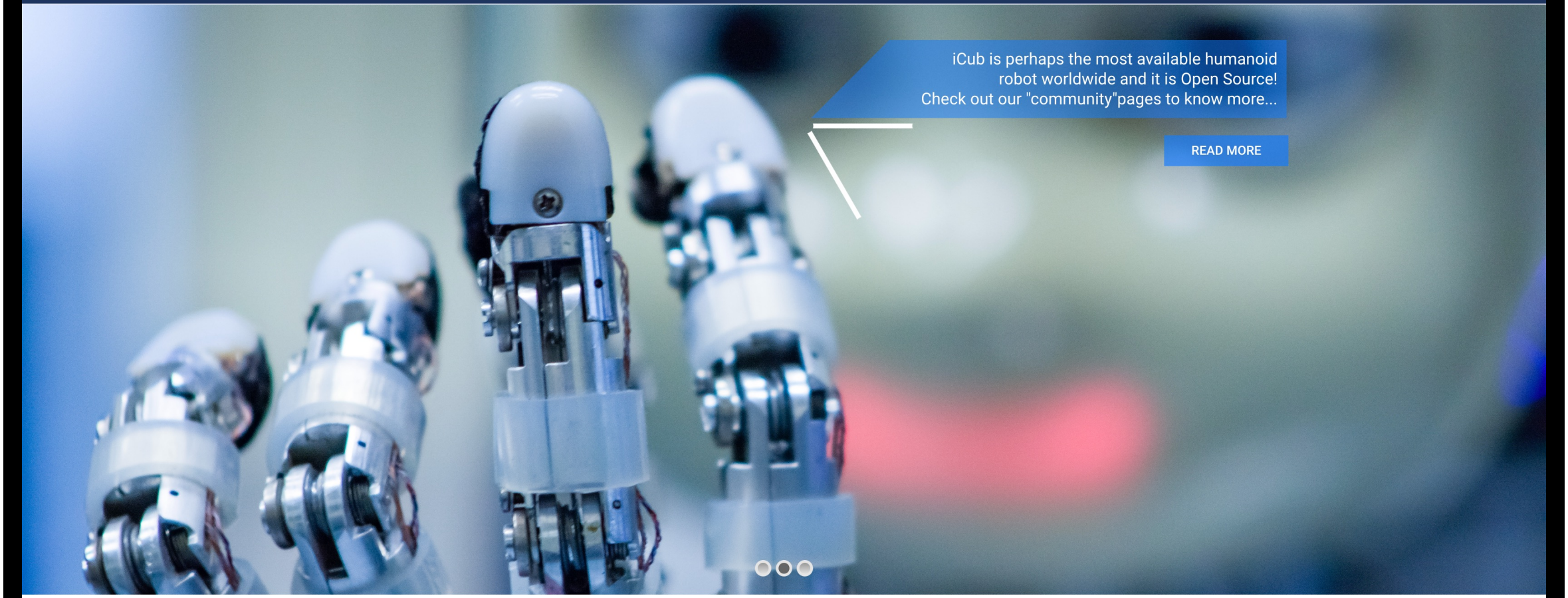


Funded by The European Commission, Project IST-004370, RobotCub, Strategic Objective 2.3.2.4: Cognitive Systems
www.icub.eu



iCub

iCub is a research-grade humanoid robot designed to help developing and testing embodied AI algorithms. iCub is the ideal companion to your robotics laboratory. The iCub Project blends results from various IIT Research Lines by applying the principles of systems engineering and by seeking worldwide collaboration opportunities. Not less importantly, the iCub team is active in several industrial partnerships. The iCub Project represents one of IIT's thrusts in the transfer of robotics technologies to industrial exploitation.



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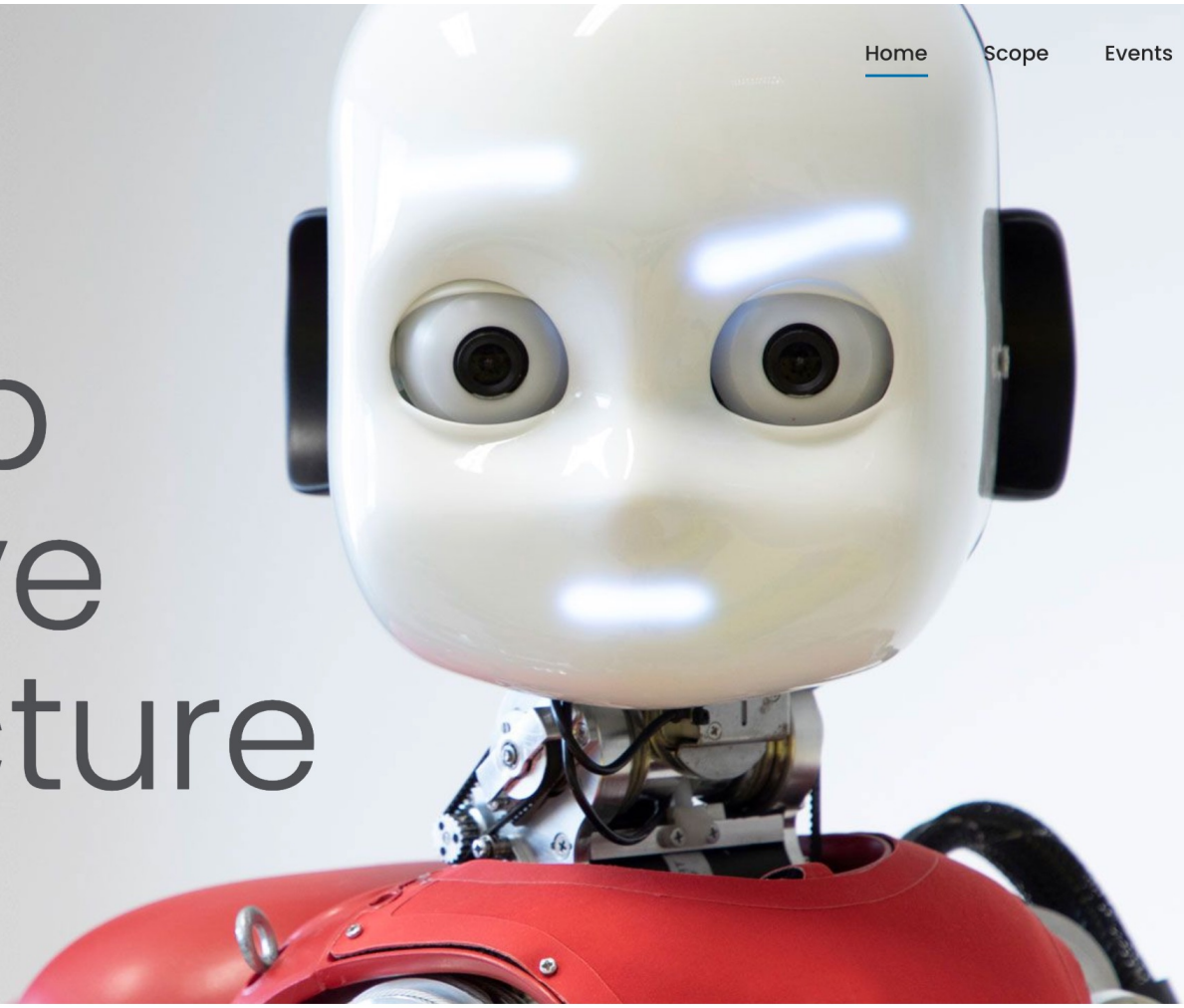
ISTITUTO ITALIANO
DI TECNOLOGIA
THE ICUB COGNITIVE
ARCHITECTURE

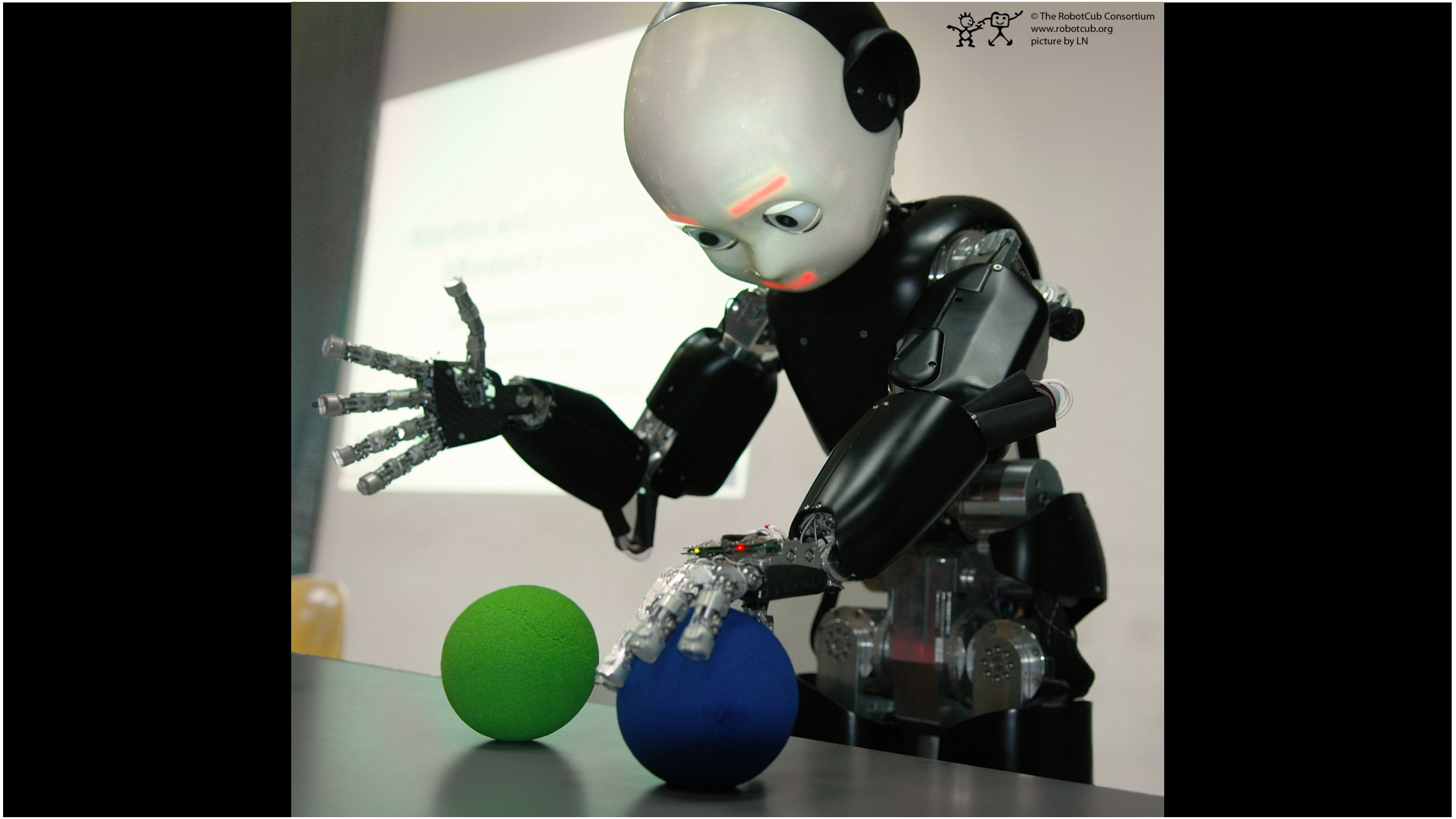
Home Scope Events Contact

iCog.

The iCub Cognitive Architecture

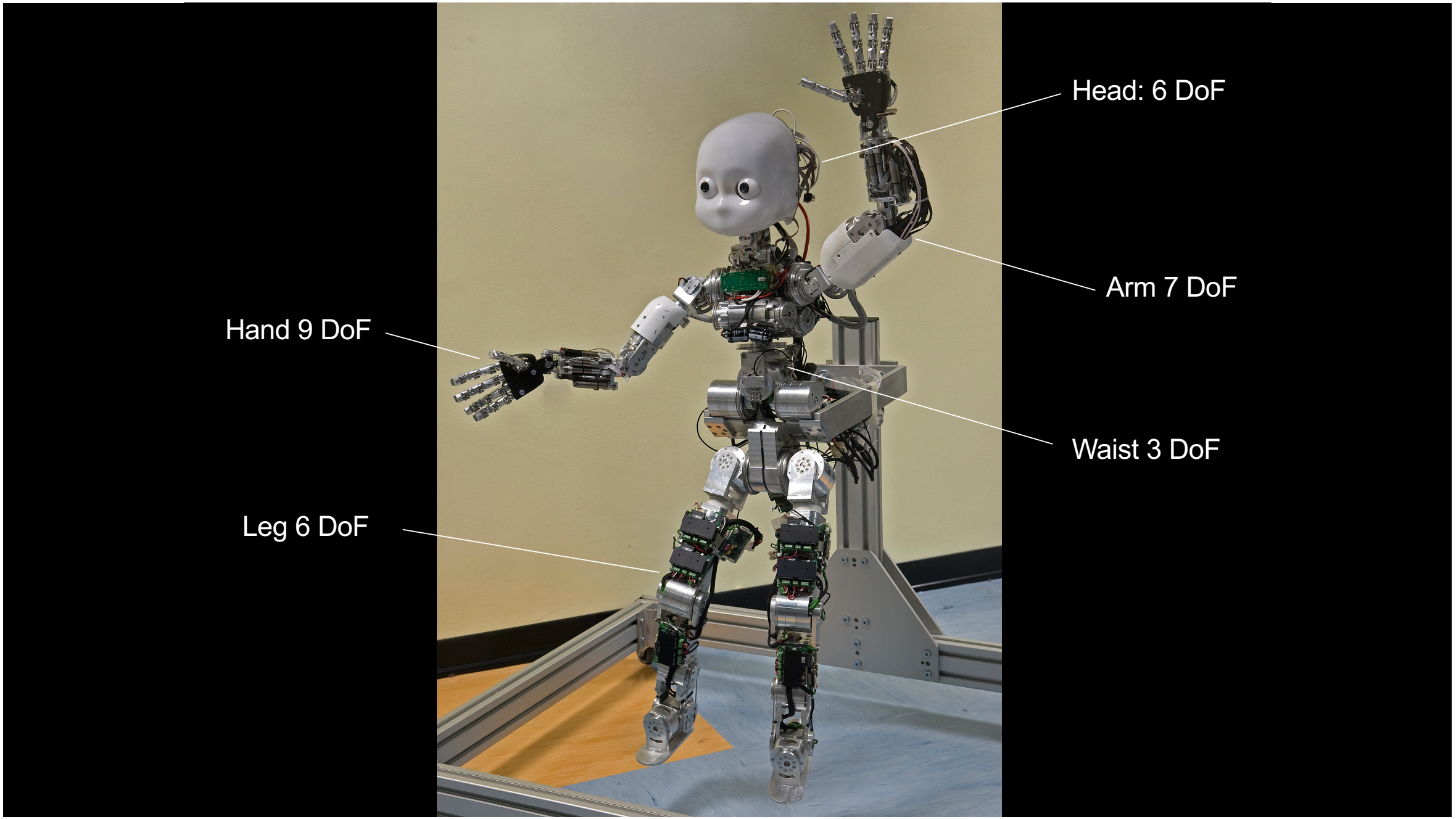


iCog is an open source initiative started at IIT with the goal of advancing our knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system such as the iCub humanoid robot.


© The RobotCub Consortium
www.robotcub.org
picture by LN

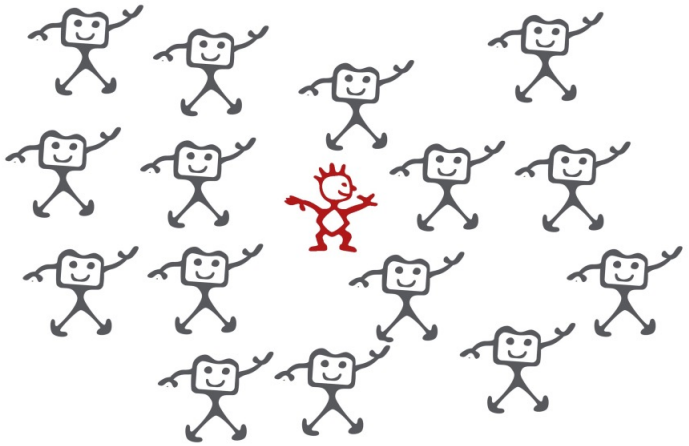

© the RobotCub Consortium www.RobotCub.org


RobotCub.org
General Meeting
Estoril, Portugal, March 17-19 2005

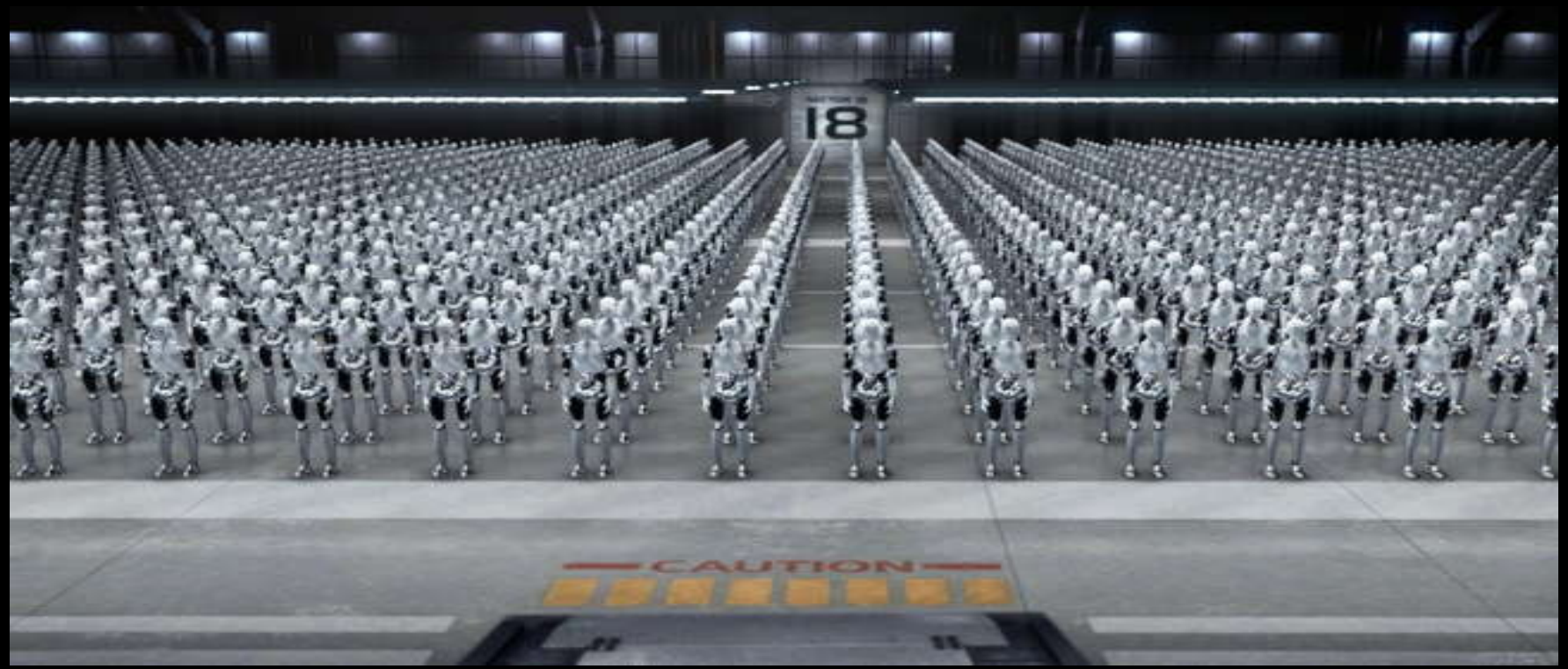

Head: 6 DoF
Arm 7 DoF
Hand 9 DoF
Waist 3 DoF
Leg 6 DoF

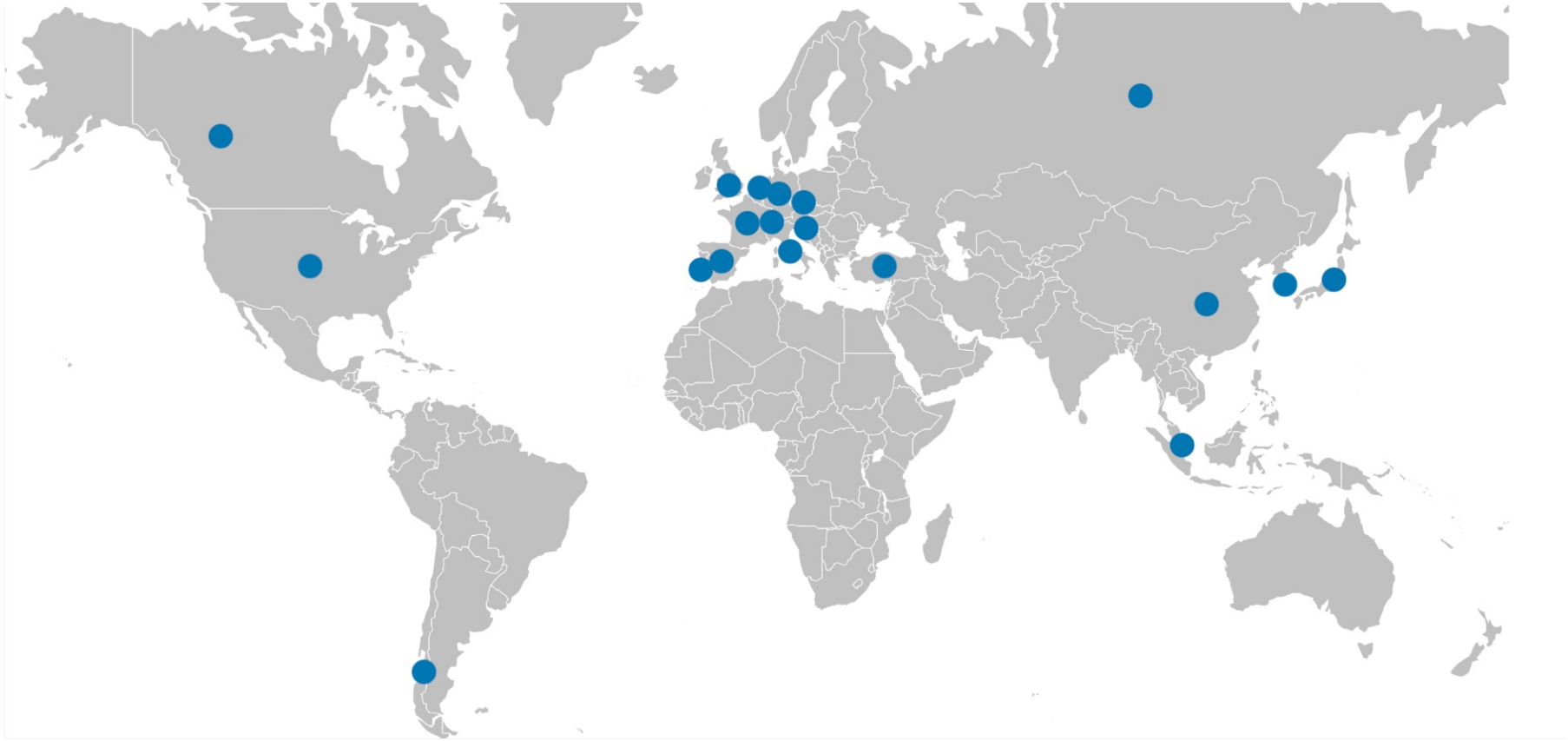
iCub production





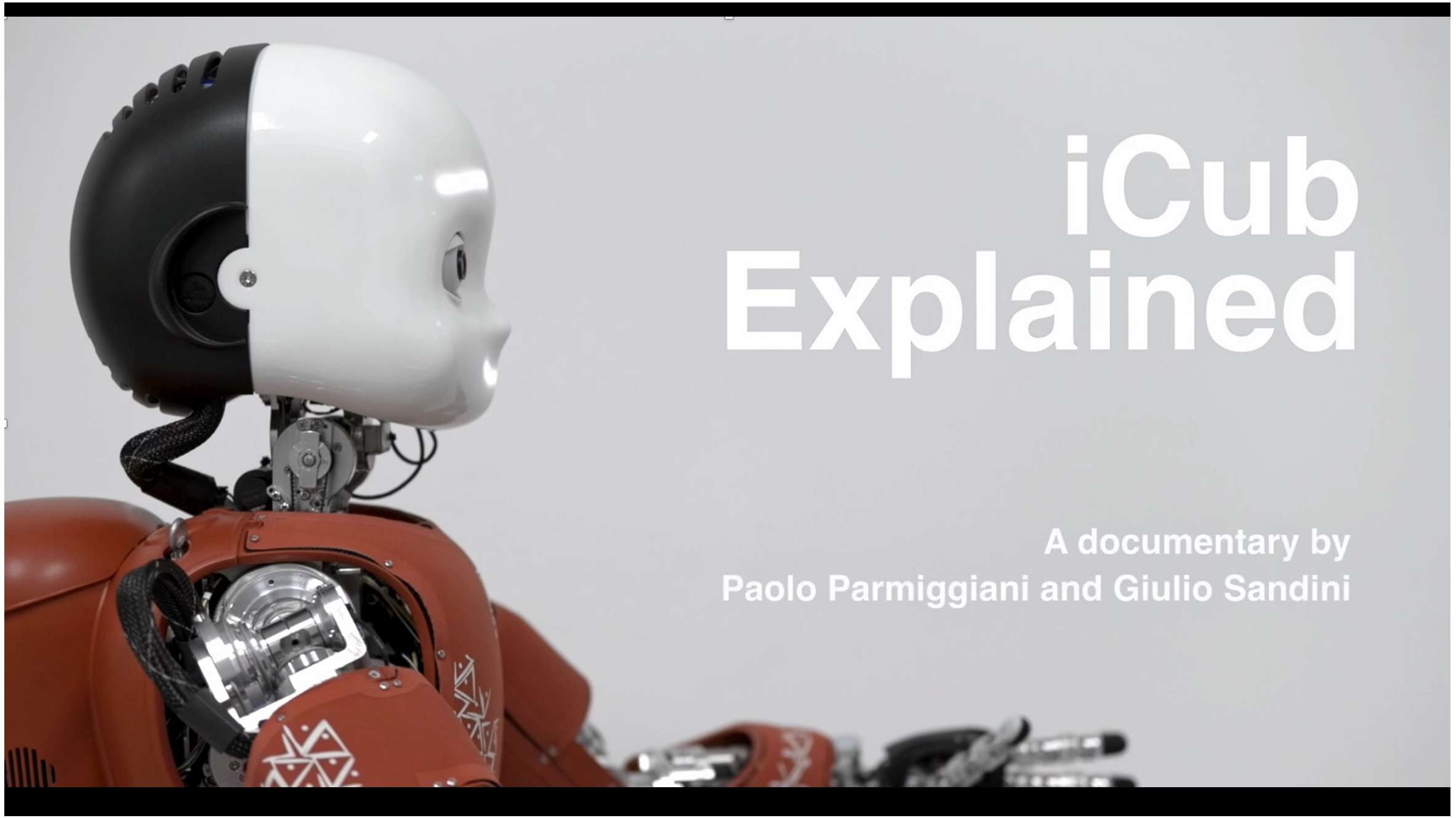
42 iCubs so far ...


18
CAUTION



https://infogram.com/copy-icub-map-1h9j6qgelxw054g?live

iCub.org


iCub
Explained
A documentary by
Paolo Parmiggiani and Giulio Sandini

What is Cognition?

"Cognition is the process by which an autonomous system

perceives its environment,

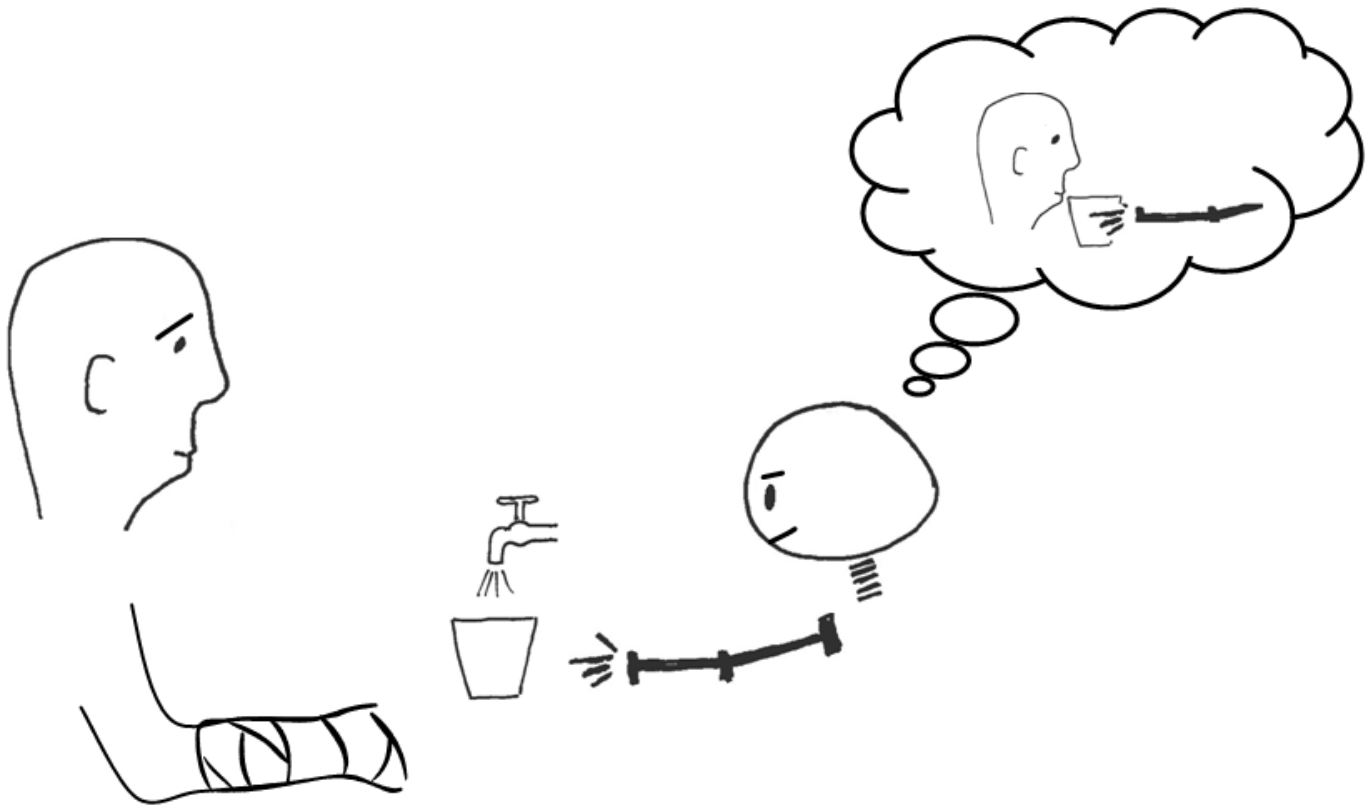
learns from experience,

anticipates the outcome of events,

acts to pursue goals, and

adapts to changing circumstances."

D. Vernon, Artificial Cognitive Systems – A Primer, MIT Press, 2014

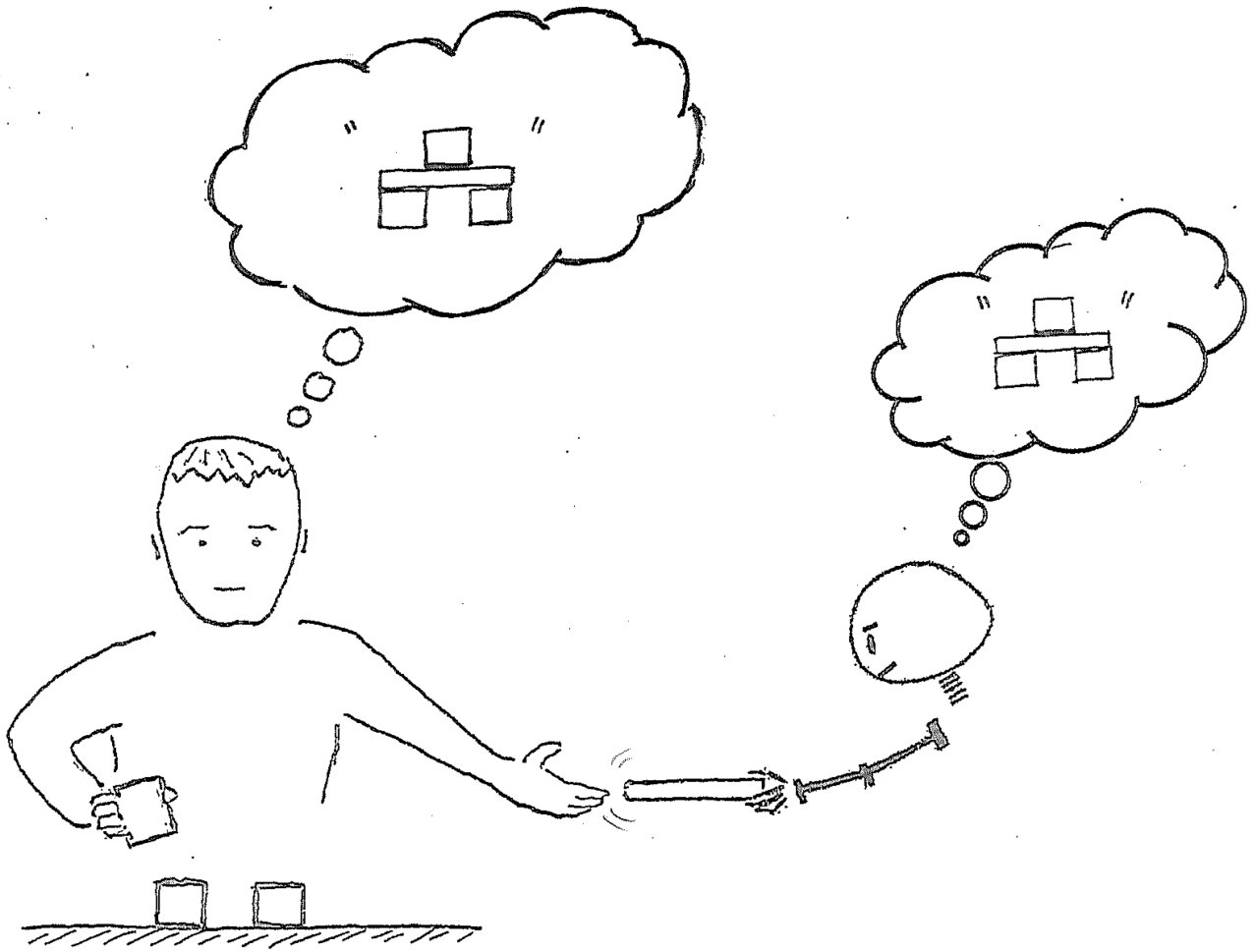


The Future

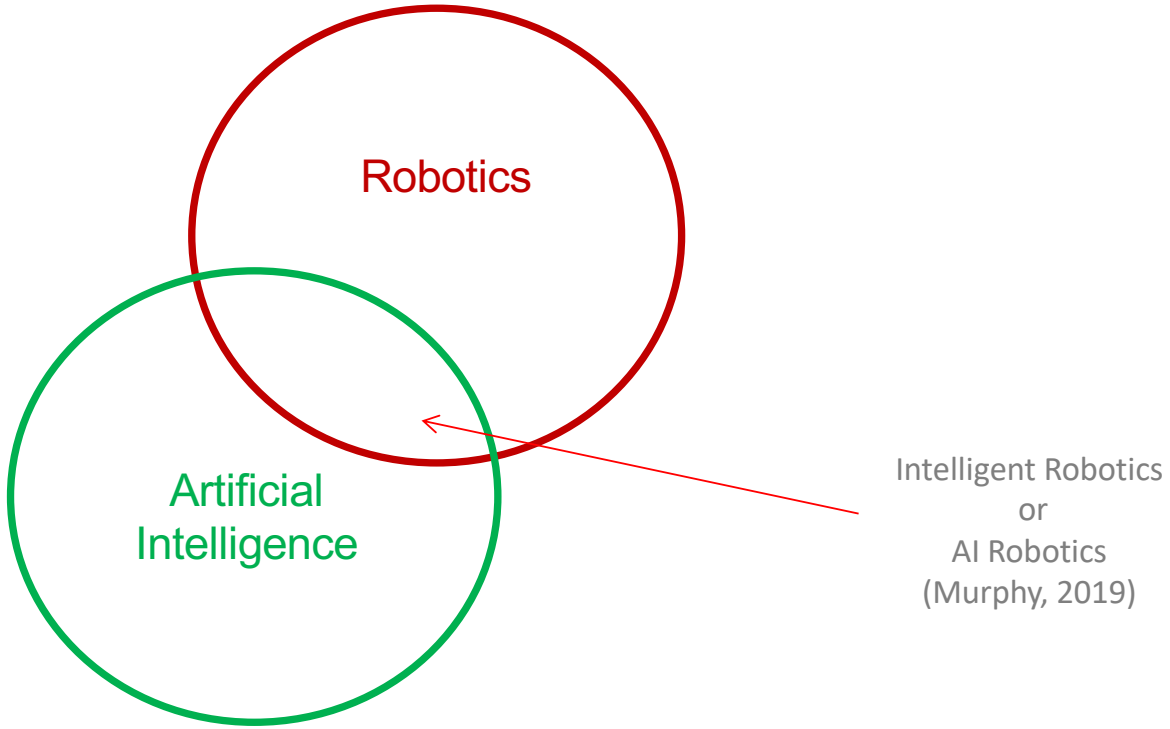
A cognitive system continually predicts

the need for actions
(self and others)

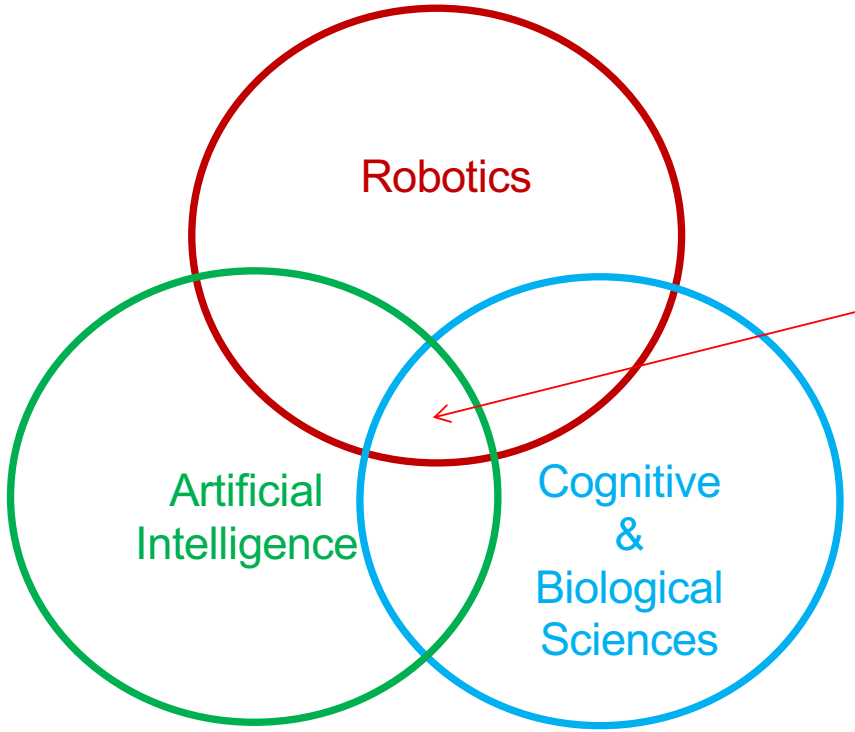
the outcome of those actions



Robotics, AI, and Cognition



Robotics, AI, and Cognition



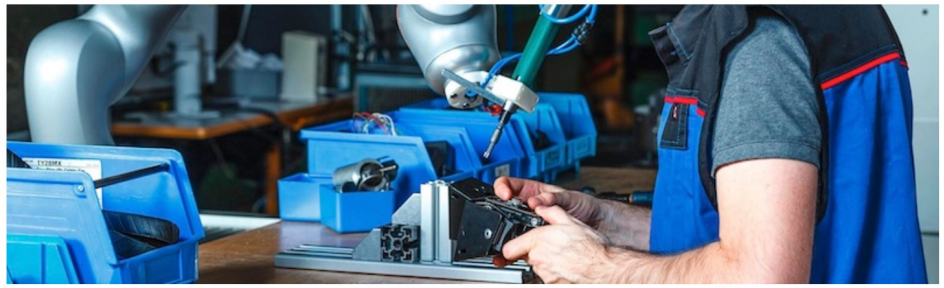
Cognitive Robotics:

Perception
Attention
Action selection
Memory,
Learning
Reasoning
Metacognition
Prospection

(Vernon, 2022)

Scope

There is growing need for robots that can interact safely with people in everyday situations. These robots have to be able to anticipate the effects of their own actions as well as the actions and needs of the people around them.



(Image courtesy of Fraunhofer IPA)

To achieve this, two streams of research need to merge, one concerned with physical systems specifically designed to interact with unconstrained environments and another focussing on control architectures that explicitly take into account the need to acquire and use experience.

The merging of these two areas has brought about the field of *Cognitive Robotics*. This is a multi-disciplinary science that draws on research in adaptive robotics as well as cognitive science and artificial intelligence, and often exploits models based on biological cognition.

Cognitive robots achieve their goals by perceiving their environment, paying attention to the events that matter, planning what to do, anticipating the outcome of their actions and the actions of other agents, and learning from the resultant interaction. They deal with the inherent uncertainty of natural environments by continually learning, reasoning, and sharing their knowledge.

Committee News

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FOUNDING DATE

19 September 2014

Reading

D. Vernon, "Robotics and Artificial Intelligence in Africa", IEEE Robotics & Automation Magazine, Vol. 26, No. 4, pp. 131-135, December 2019.

http://vernon.eu/publications/19_Vernon_RAM.pdf

M. Mataric, The Robotics Primer, MIT Press, 2007. Chapter 1 and 2.

Robotics and Artificial Intelligence in Africa

By David Vernon

Artificial intelligence (AI) provides many opportunities for social and economic empowerment in developing countries. However, when one thinks of Africa, robotics does not spring immediately to mind as the most relevant application of AI, considering that the continent typically has high unemployment and fast-growing populations. Nevertheless, some countries in Africa have embraced robotics on the basis that it has an important role to play in their economic development. In this article, we explore this role and the ways in which Africa can best exploit the opportunities afforded by intelligent automation and robotics. It also highlights strategies to offset the threats posed by global factors, such as premature deindustrialization.

The Growing Impact of AI in Africa

There is an increasing awareness of the positive impact that AI will have on developing countries, including sub-Saharan Africa, in sectors such as agriculture, health care, and public and financial services [1]. AI has the potential to drive economic growth, development, and democratization, thereby reducing poverty, increasing education, supporting health-care delivery, increasing food production, expanding the capacity of the existing road infrastructure by increasing traffic flows, improving public services, and bettering the quality of life for people with disabilities [2]. AI can empower workers at all skill levels to be more competitive [3], [4]. Specifically, it can be used to augment and enhance human skills—not to replace or displace humans—and to do so at all levels, enabling average and low-skill workers to fit better in high-performance environments and take on more complex responsibilities.

Africa's biggest economic challenge is to equip large sections of its economy with average workers who are primed to perform tasks far better than most employees are currently managing to do. In South Africa, approximately 31% of employers cannot fill their vacancies [4]. AI will make technology easier to adopt and harness [1], [4]. In the health-care sector, AI helps address the shortage of doctors through telemedicine and access to medical supplies through drone deliveries [5]. In agriculture, AI (including machine learning, remote sensing, and data analytics) has the potential to improve productivity and efficiency at all stages of the value chain, enabling small-holder farmers to increase their income through higher crop yields and greater price control, detect and precisely treat pests and diseases, monitor soil conditions and target fertilizer applications, create virtual cooperatives to aggregate crop yields, broker better prices, and exploit economies of scale. Internet of Things (IoT) platforms may offer cost-effective ways to achieve those benefits [6]. For example, Microsoft is applying its Farmbeats platform [7] in developing countries by lowering the cost associated with densely deploying sensors, exploiting sparsely distributed sensors and aerial imagery to generate precision maps, and replacing expensive drones with smartphones attached to hand-carried, low-cost, tethered helium balloons [8].

Premature Deindustrialization

On the downside, factory and call-center work will slow as tasks are replaced by AI-enabled automation, including robots, which will add pressure to unemployment rates that are already high in developing countries, including those in Africa [5]. This will be exacerbated by growing populations, reducing opportunities still further. Africa's population is large and expanding fast: most of its people are young and urban with a median age of 19.5 years, compared to Germany (47.1), the United States (38.1), and China (37.7), and the youth population is set to reach 225 million by 2055 [5]. Kenya, Nigeria, and South Africa, for example, are projected to have approximately 5.5%, 8.5%, and 12.5%, respectively, of their workforce displaced by automation [9]. A report by the Oxford Martin School at the University of Oxford, United Kingdom, and Citigroup, New York, summarizes the situation in Africa in stark terms [10]:

> In most of sub-Saharan Africa, the manufacturing share of output has persistently declined over the past 25 years. The share of jobs in manufacturing is even smaller: just over 6% of all jobs. This figure barely changed over the course of the three decades

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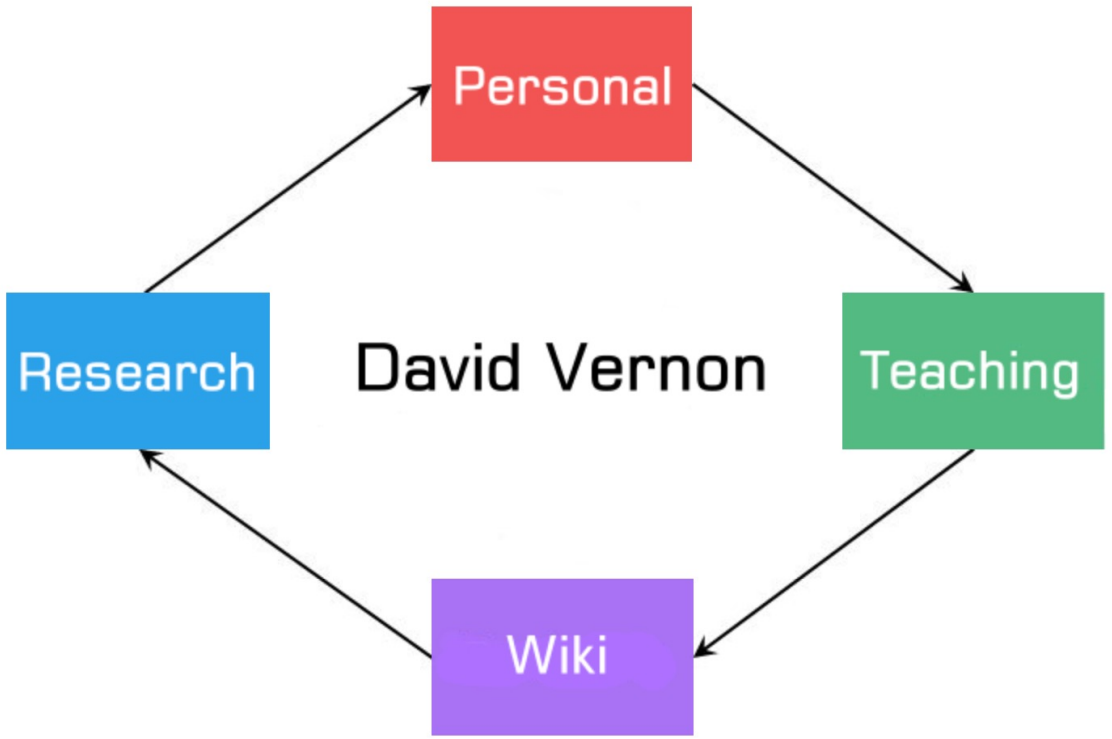
Videos

Atlas (0:30):	https://robots.ieee.org/robots/atlas2016/?gallery=video5
iCub (2:40)	https://robots.ieee.org/robots/icub/?gallery=video1
Roomba (1:30)	https://robots.ieee.org/robots/roomba/?gallery=video2
Turtlebot (1:30)	https://robots.ieee.org/robots/turtlebot/?gallery=video1
Zipline (0:06)	http://www.vernon.eu/videos/Zipline_hero.mp4
Zipline (1:09)	https://www.youtube.com/watch?v=QWglZKVP26c
Zipline (0:15)	http://www.vernon.eu/videos/Zipline_drop.mp4
Zipline (11:44)	https://www.youtube.com/watch?v=jEbRVNxL44c
Picker Robots (0:15)	https://robots.ieee.org/robots/invia/?gallery=video5
Sawyer (0:30)	https://robots.ieee.org/robots/sawyer/?gallery=video1
Meca (1:15)	https://robots.ieee.org/robots/meca500/?gallery=video1
Shadow Hand (3:00)	https://robots.ieee.org/robots/shadow/?gallery=video4
Spot (2:00)	https://robots.ieee.org/robots/spotmini/?gallery=video1
Salamandra (0:43)	https://robots.ieee.org/robots/salamandra/?gallery=video4
iCub Explained (32:10)	https://www.youtube.com/watch?v=W3gIV81GYm4



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David Vernon's Wiki

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My website

AI, Machine Learning, and Robotics in Africa [edit]

A collection of links mapping out the many aspects of AI, ML, and robotics in Africa

AI in Europe [edit]

A collection of links that map Europe's strategy for research, development, and innovation in human-centric, sustainable, secure, inclusive, and trustworthy AI

Teaching [edit]

Support material for some of the courses on my main website.

Applied Computer Vision
Artificial Cognitive Systems
Cognitive Robotics
Principles of Computer Programming code snippets
Robotics: Principles and Practice

Research [edit]

Research Activities
The CINDY Cognitive Architecture (legacy project)

Talks and Presentations [edit]

Talks and Presentations

Diversity, Equity, and Inclusion [edit]

Unpacking Diversity, Equity, and Inclusion

Links [edit]

A collection of links to resources on many topics of personal interest