Robotics: Principles and Practice

Module 1: Introduction and Robot Components

Lecture 1: What is a robot? Types of robot. The many areas of robotics.

David Vernon
Carnegie Mellon University Africa

www.vernon.eu

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.

Types of Robot

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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!

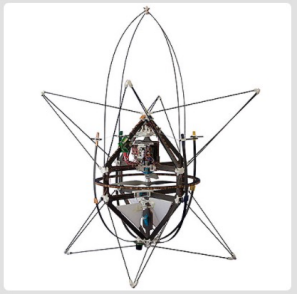
Type:
- Humanoids
- Consumer
- Drones
- Entertainment
- Education
- Research
- Medical
- Exoskeletons
- Disaster Response
- Service & Industrial
- Aerospace
- Underwater
- Military & Security
- Telepresence
- Self-Driving Cars


ACM-R5H


Adaptive Gripper

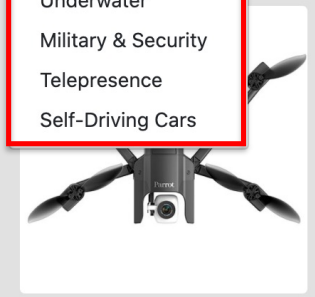

Aibo


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

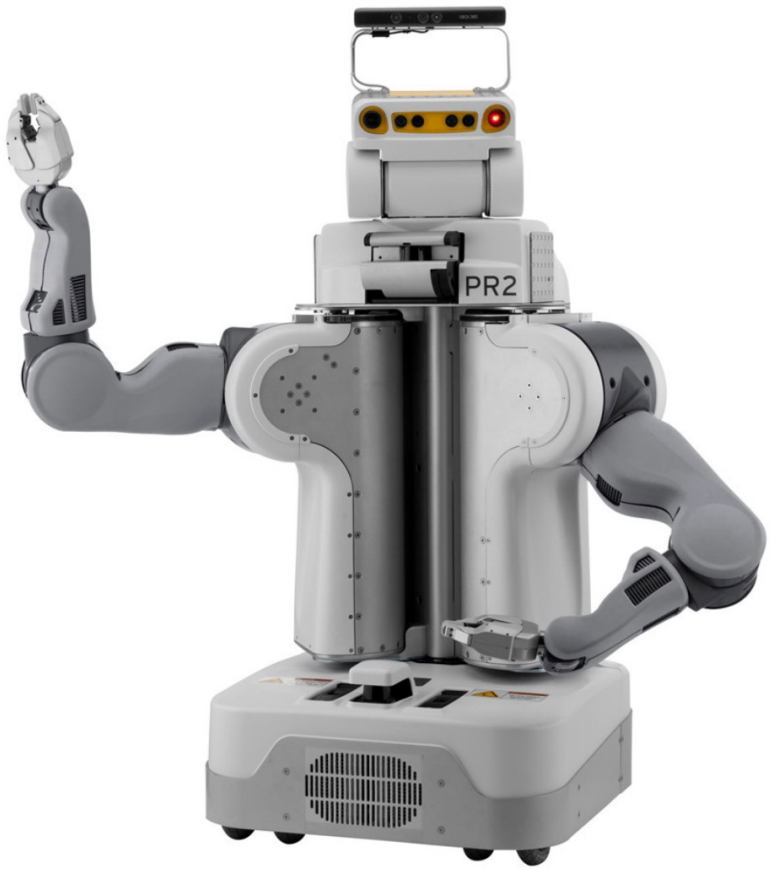
TYPE
Humanoids, Research

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

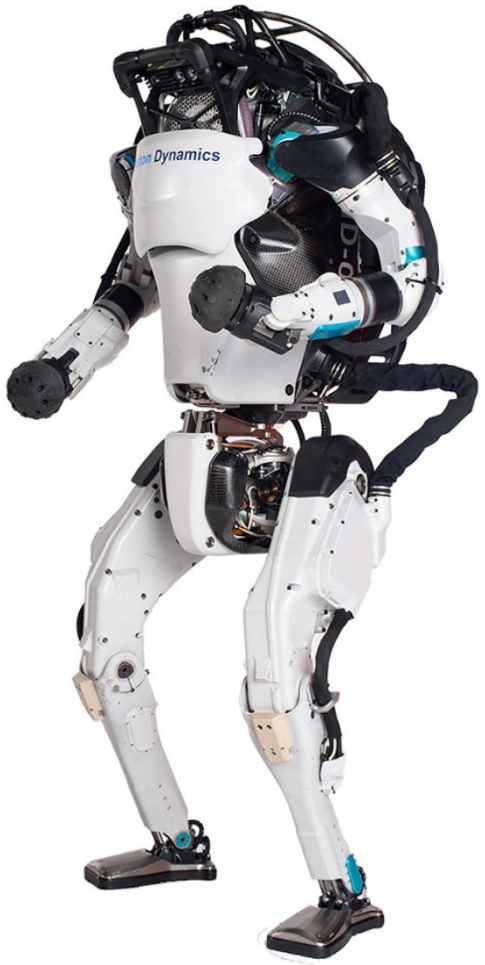
TYPE
Humanoids, Research

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.

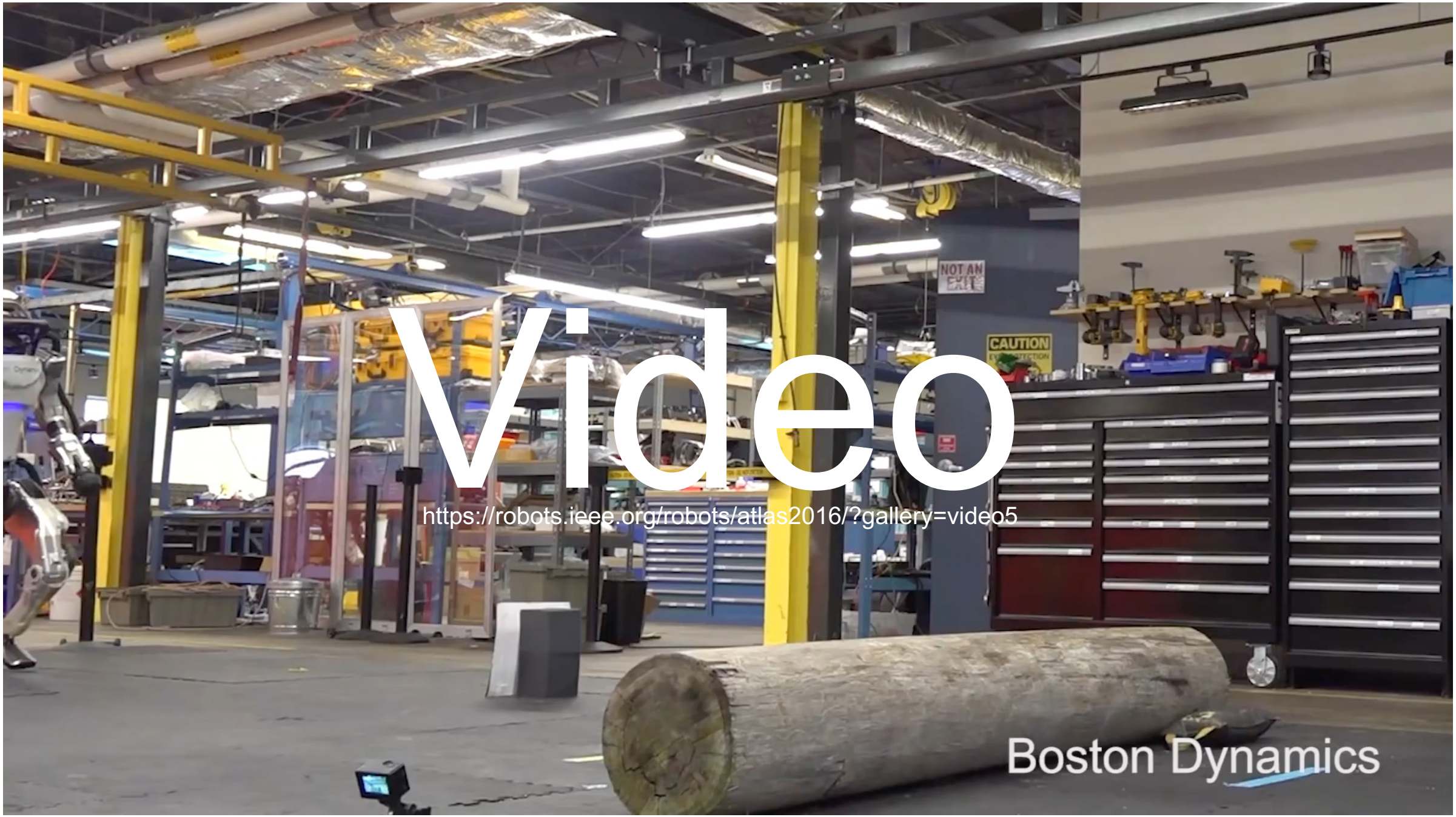
CREATOR
Boston Dynamics

COUNTRY
United States

YEAR
2016

TYPE
Humanoids, Industrial

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



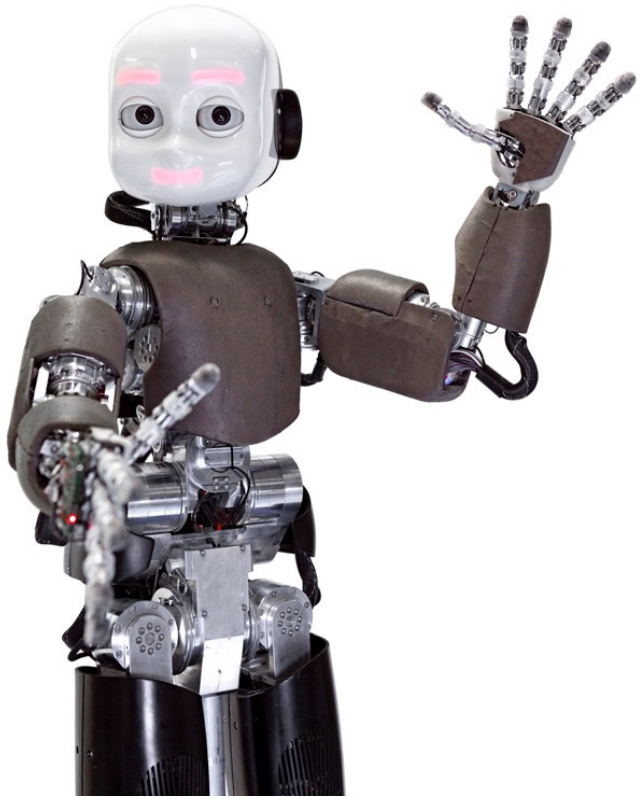
Video

https://robots.ieee.org/robots/atlas2016/?gallery=video5

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

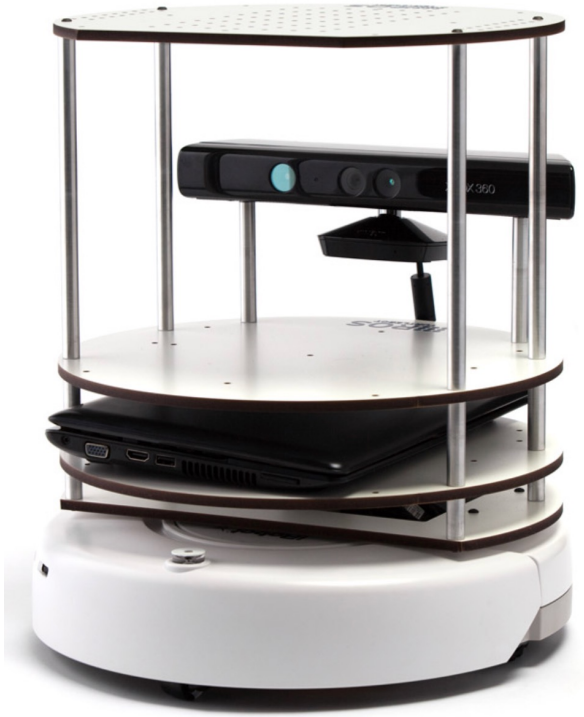
Source: https://robots.ieee.org/robots/roomba/

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=QWglZKVP26c

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

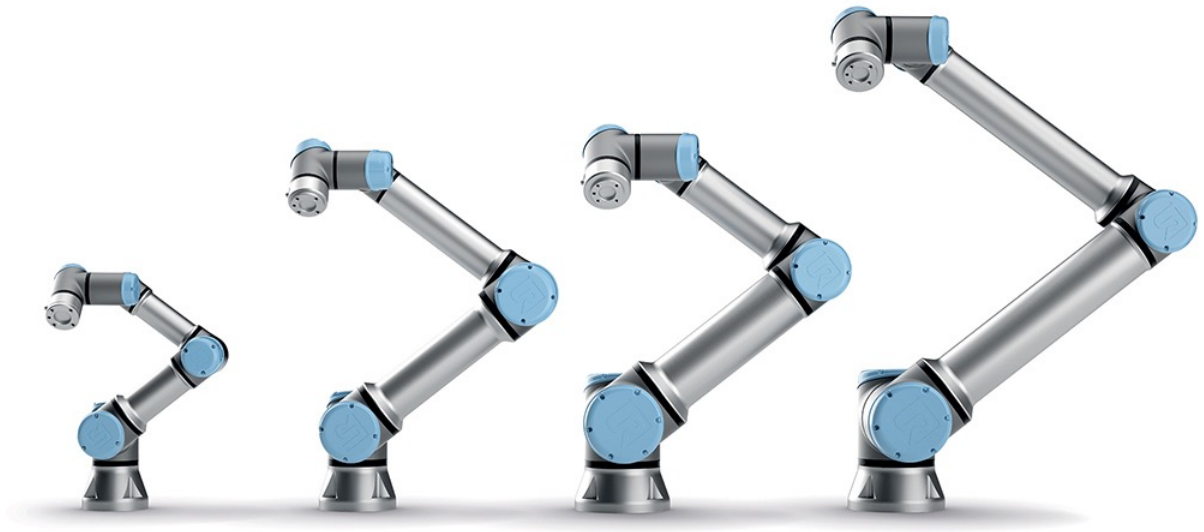
Source: https://robots.ieee.org/robots/meca/

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.

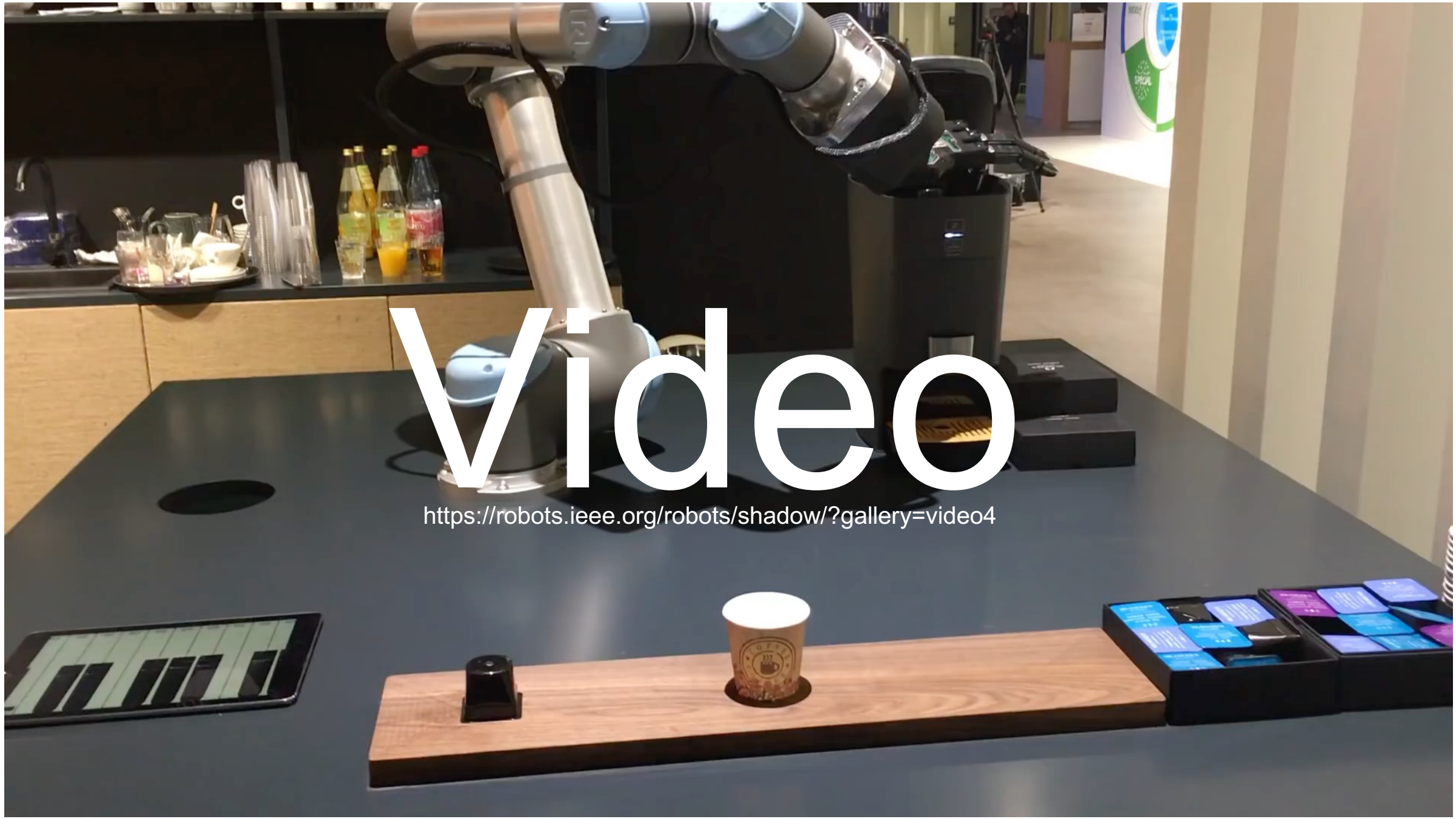
CREATOR
Shadow Robot Company

COUNTRY
United Kingdom

YEAR
2004

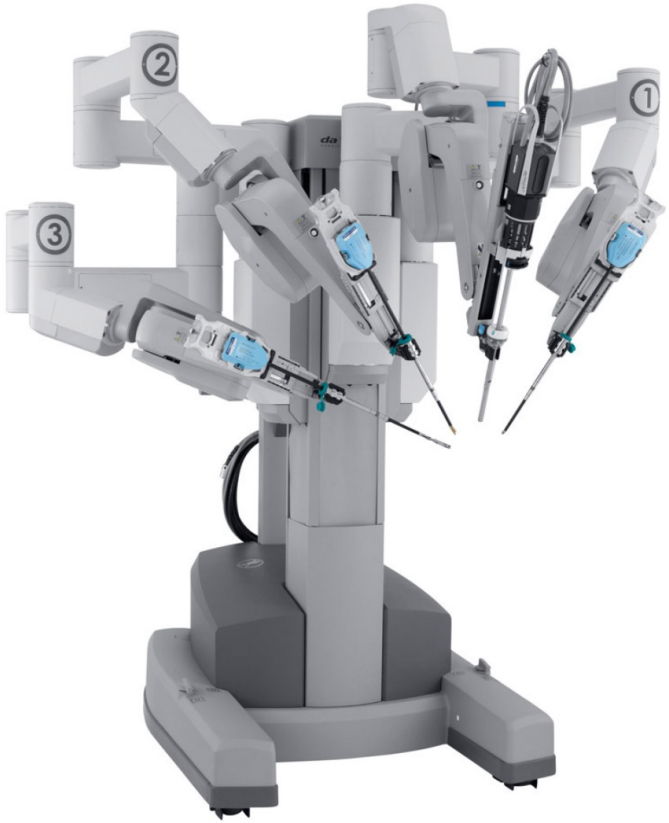
TYPE
Industrial, Telepresence, Research

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

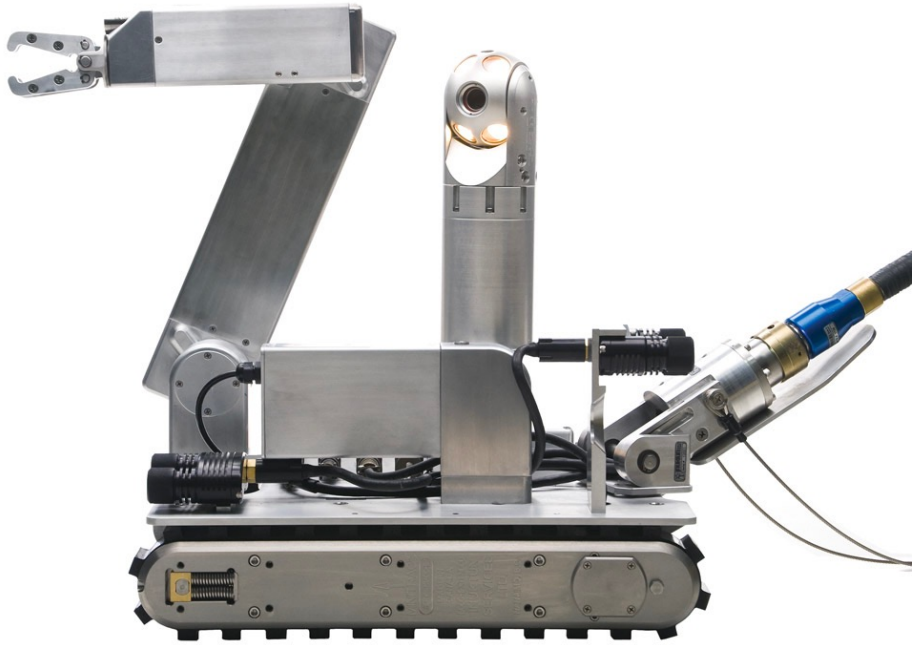
Source: https://robots.ieee.org/robots/alphadog/

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

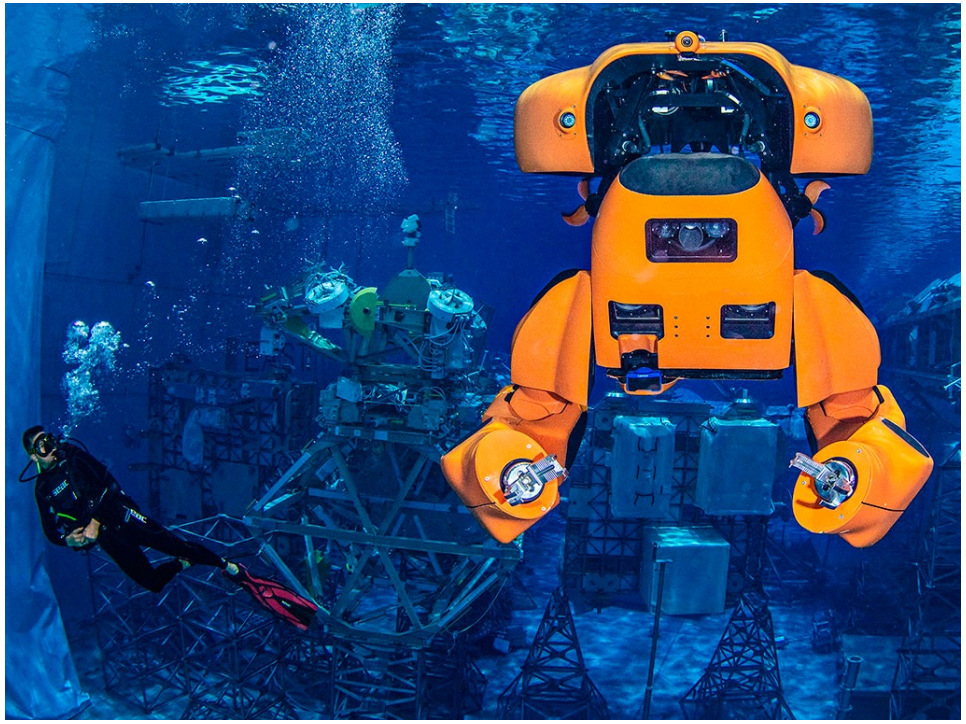
TYPE
Military & Security, Disaster Response

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.

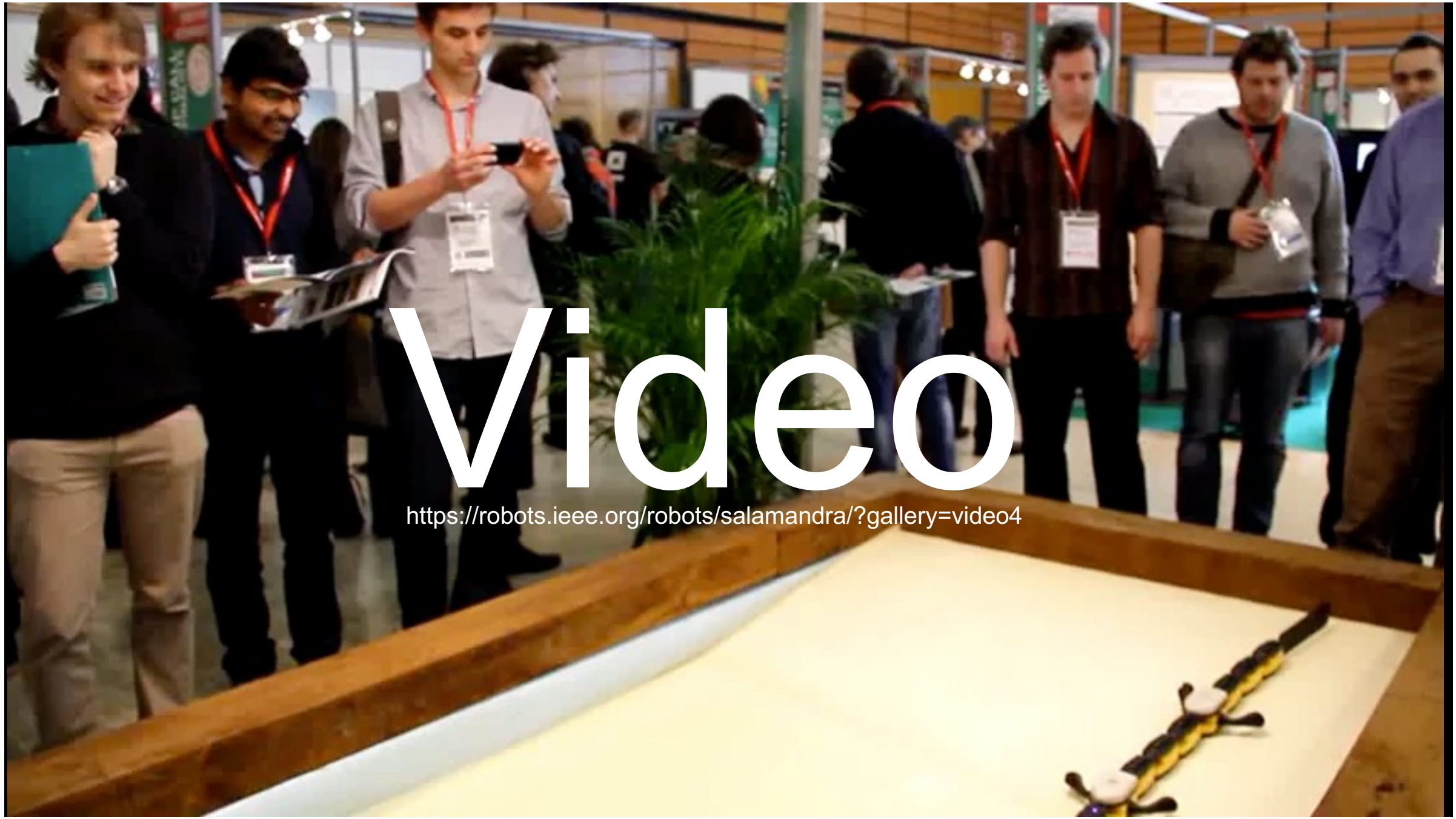
CREATOR
Biorobotics Laboratory at EPFL

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

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

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.

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

Digital Object Identifier 10.1109/MRA.2019.2946107
Date of current version: 11 December 2019

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