Robotics: Principles and Practice

Module 1: Introduction and Robot Components

Lecture 5: Effectors

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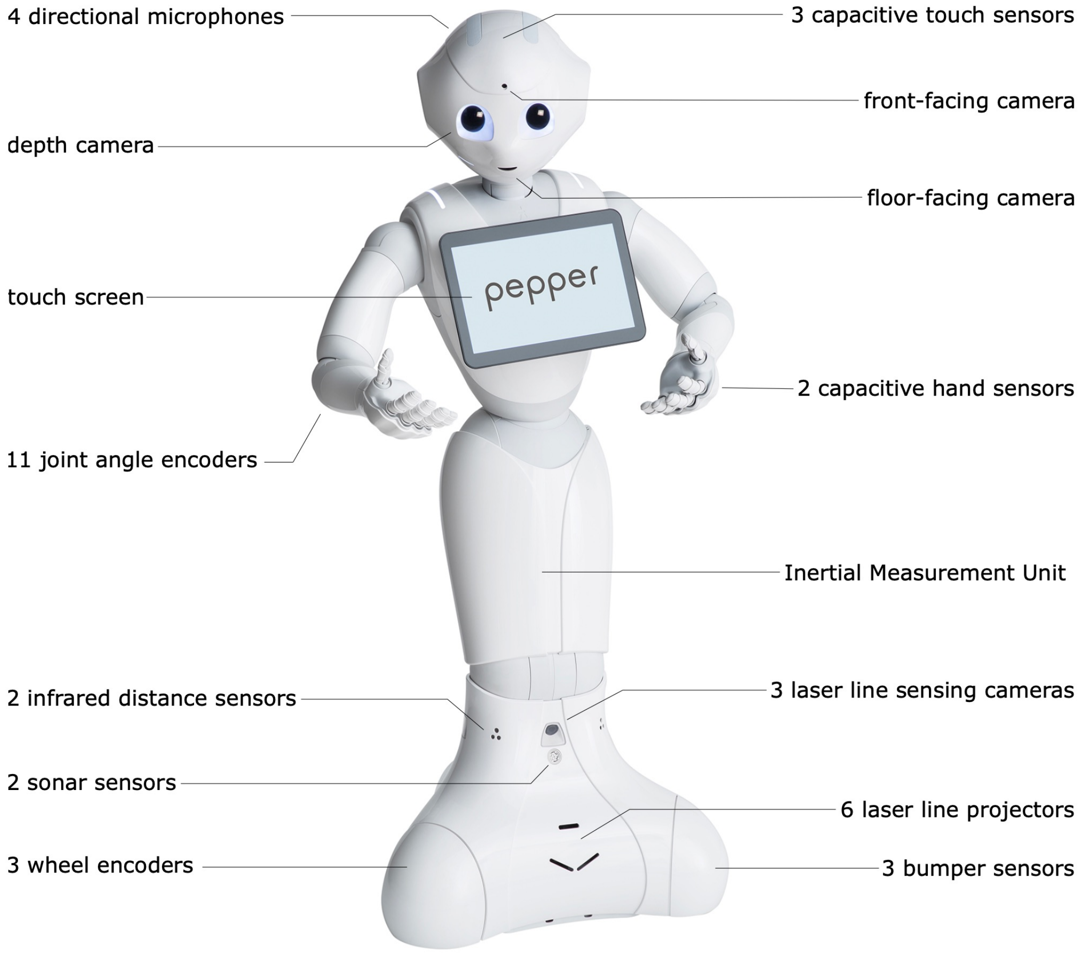
www.vernon.eu

Robot Components

- Physical embodiment
- Sensors — To perceive the environment
- Actuators
- Effectors

To take action

- Controllers — For autonomy

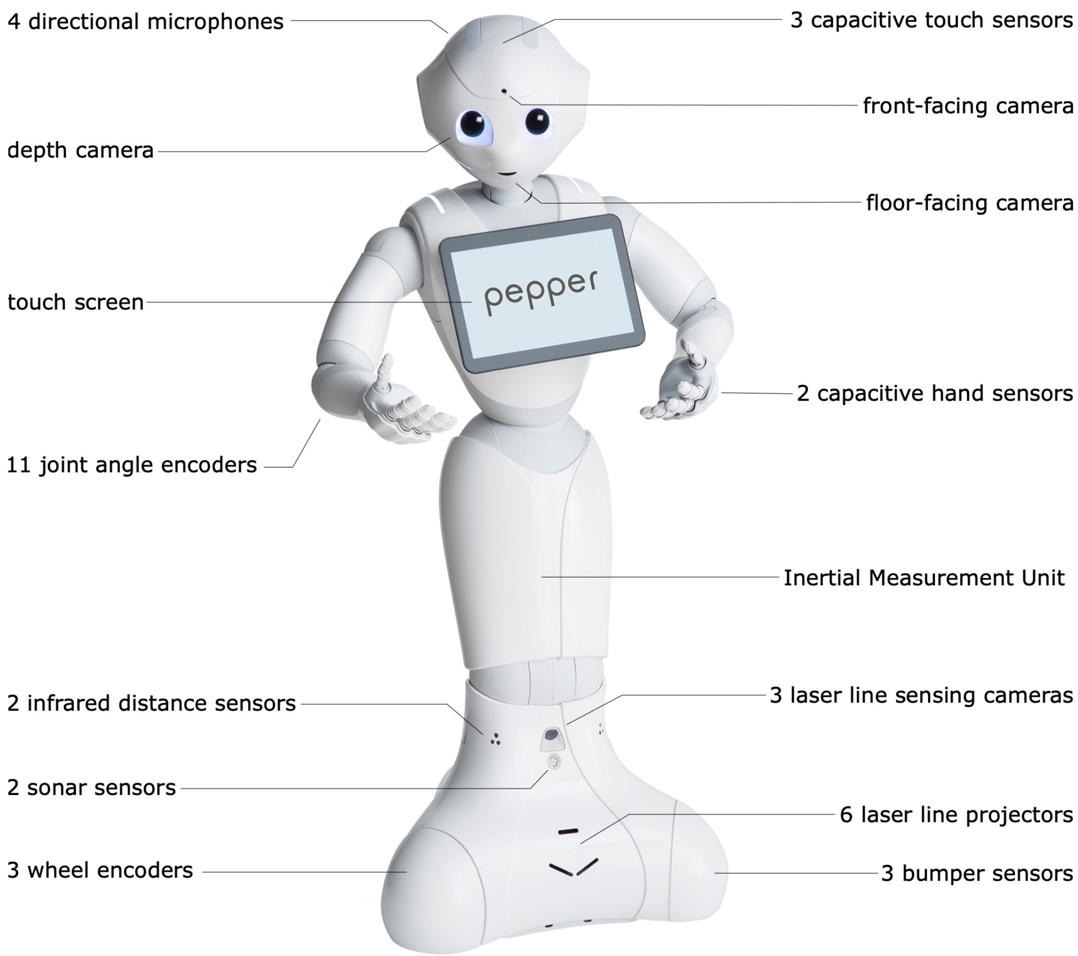


C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, S. Šabanović, Human-Robot Interaction – An Introduction, Cambridge University Press, 2020

Definition

"An effector is any device on a robot that has an effect (impact or influence) on the environment"

M. Mataric



C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, S. Šabanović, Human-Robot Interaction – An Introduction, Cambridge University Press, 2020

Effectors

Effectors for locomotion

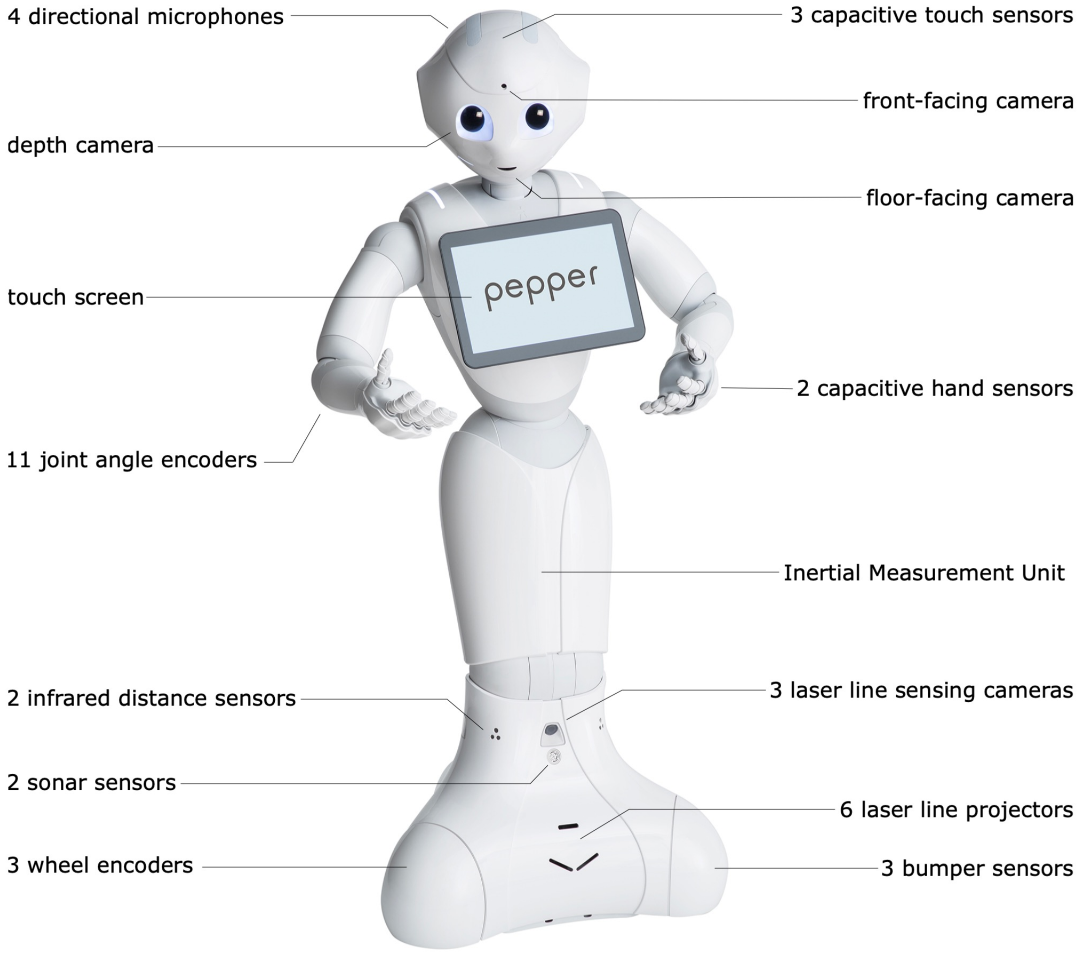
- Legs
- Wheels
- Tracks
- Wings
- Flippers

Effectors much be matched to the task the robot has to do and the environment in which it has to work

Effectors for manipulation

- Arms
- Hands
- Grippers
- Tools

Hands, Grippers, Tools: End-effectors



C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, S. Šabanović, Human-Robot Interaction – An Introduction, Cambridge University Press, 2020

Degrees of Freedom (DOF)

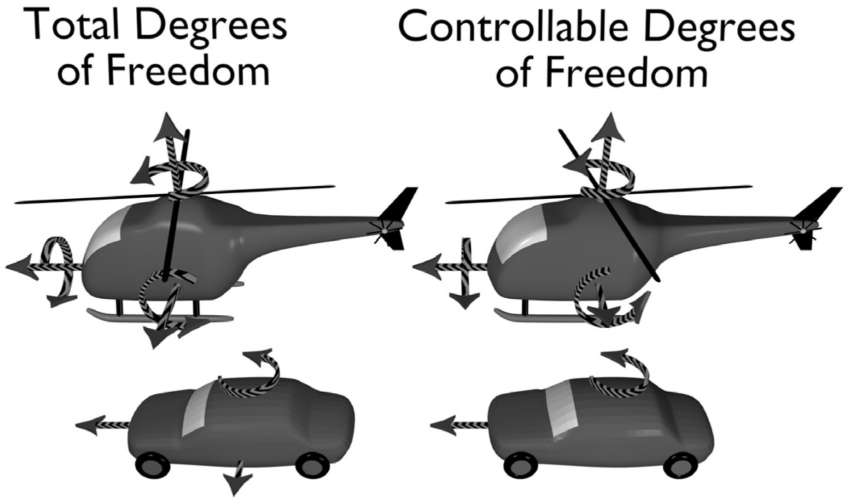
- The minimum number of coordinates required to completely specify the motion of a mechanical system
- Determines what poses (positions and orientations) the robot can achieve
- Determines how it can move

Degrees of Freedom (DOF)

- It requires six degrees of freedom to position and orient a body in space
  - Three translational degrees of freedom
  - Three rotational degrees of freedom
- The position and orientation of a body is referred to as its pose
- Much more on pose specification later in the course

Degrees of Freedom (DOF)

- A flying helicopter has six degrees of freedom
  - Three translational & three rotational
- A car or bicycle moving on a plane has three degrees of freedom
  - Two translational and one rotational
  - But only two are controllable
    - Forward velocity
    - Rotation about the vertical axis



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

Degrees of Freedom (DOF)

$TDOF$: total degrees of freedom

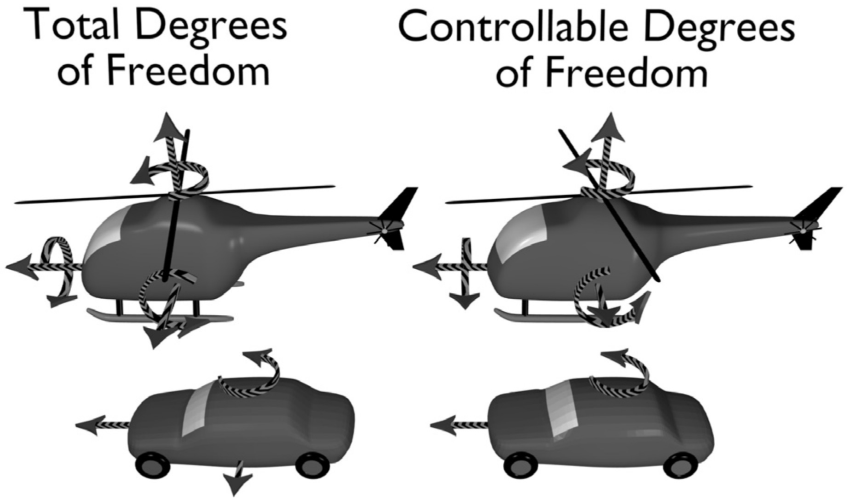
$CDOF$: controllable degrees of freedom

Holonomic robot: $CDOF = TDOF$

Non-holonomic robot: $CDOF < TDOF$

Redundant robot: $CDOF > TDOF$

(We'll cover a more technical explanation of non-holonomic robots later in the course)



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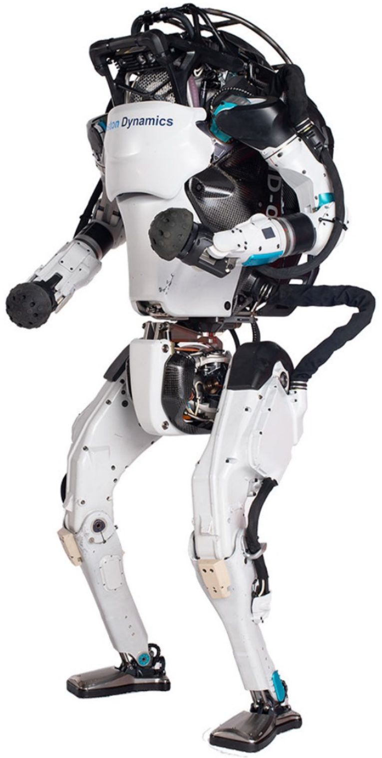

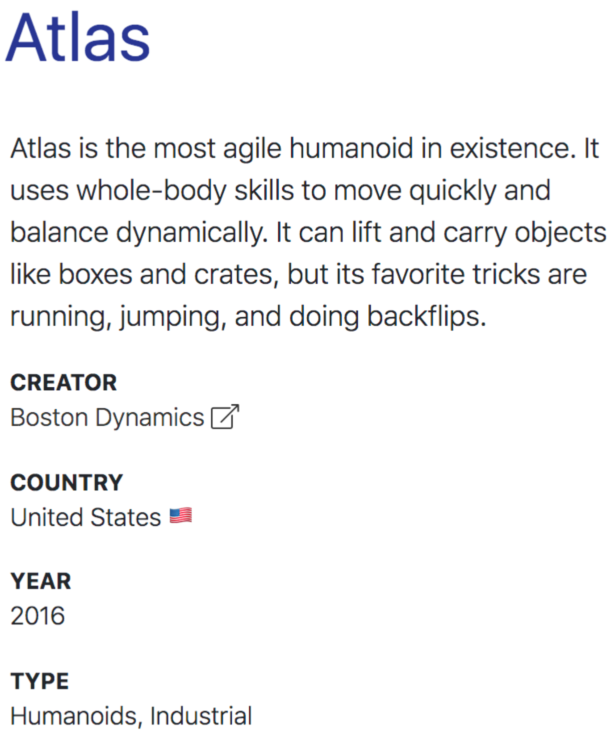

Atlas

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/

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End-effectors

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/

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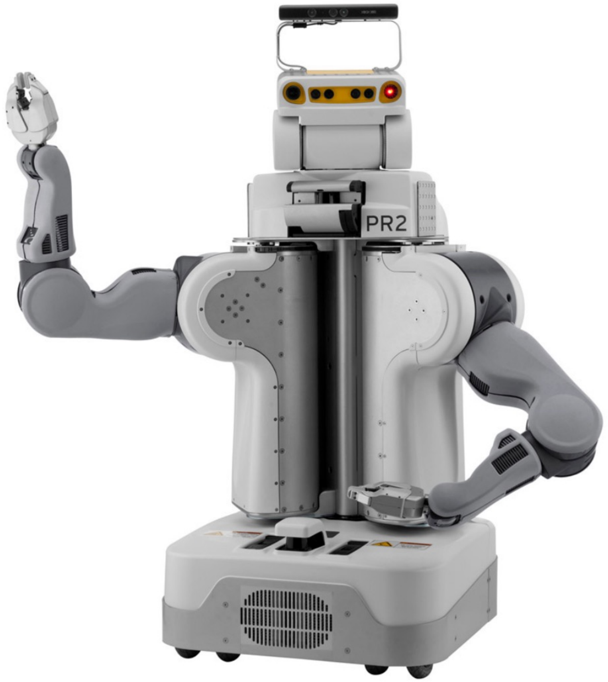
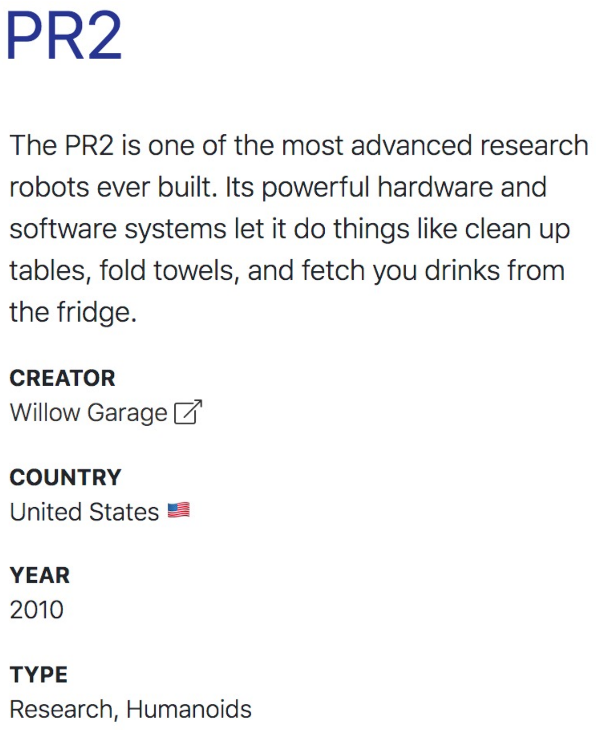




PR2

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

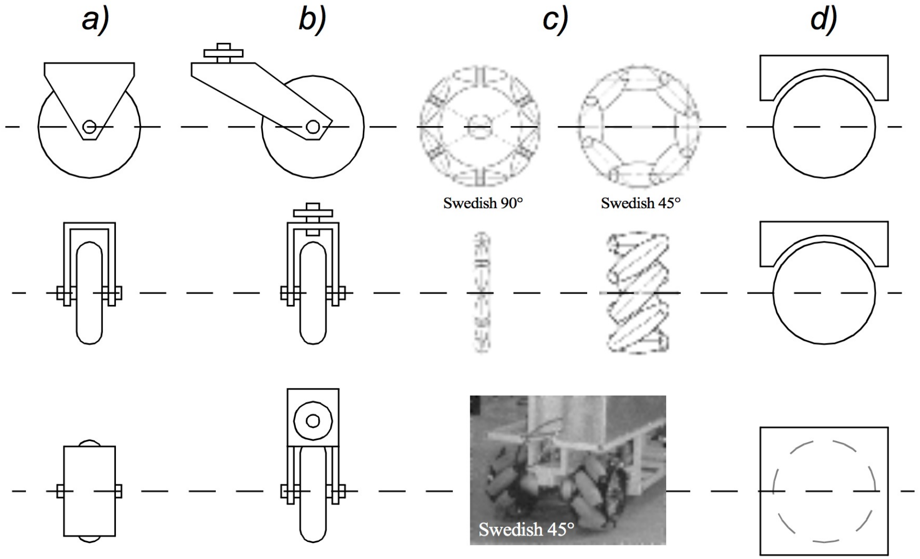
COUNTRY
United States 🇺🇸

YEAR
2010

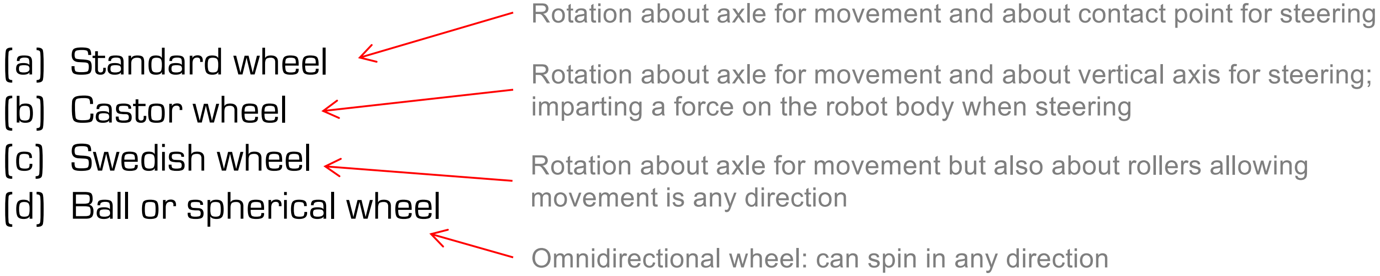
TYPE
Research, Humanoids

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

Wheels



Source: R. Siegwart and I. R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, MIT Press, 2004



(a) Standard wheel

(b) Castor wheel

(c) Swedish wheel

(d) Ball or spherical wheel

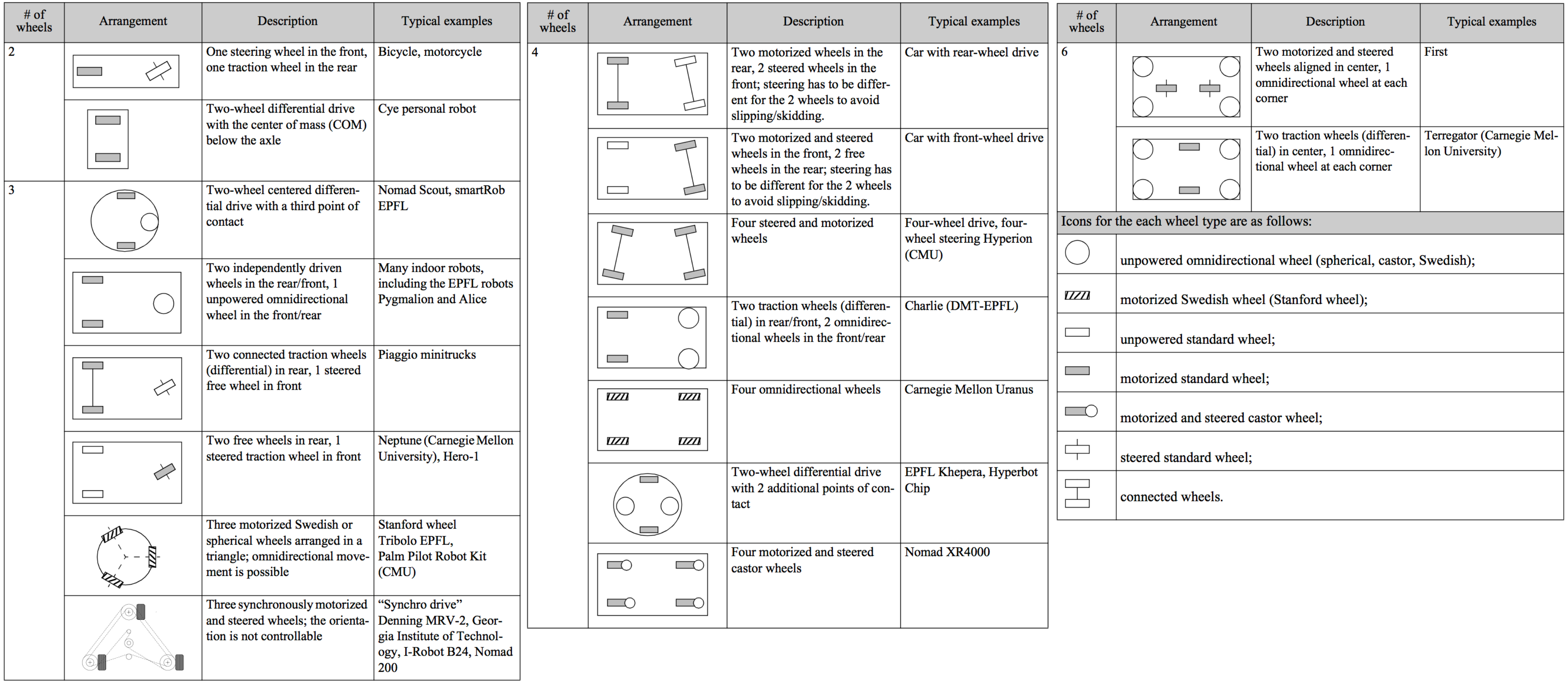
Rotation about axle for movement and about contact point for steering

Rotation about axle for movement and about vertical axis for steering; imparting a force on the robot body when steering

Rotation about axle for movement but also about rollers allowing movement is any direction

Omnidirectional wheel: can spin in any direction

Wheels



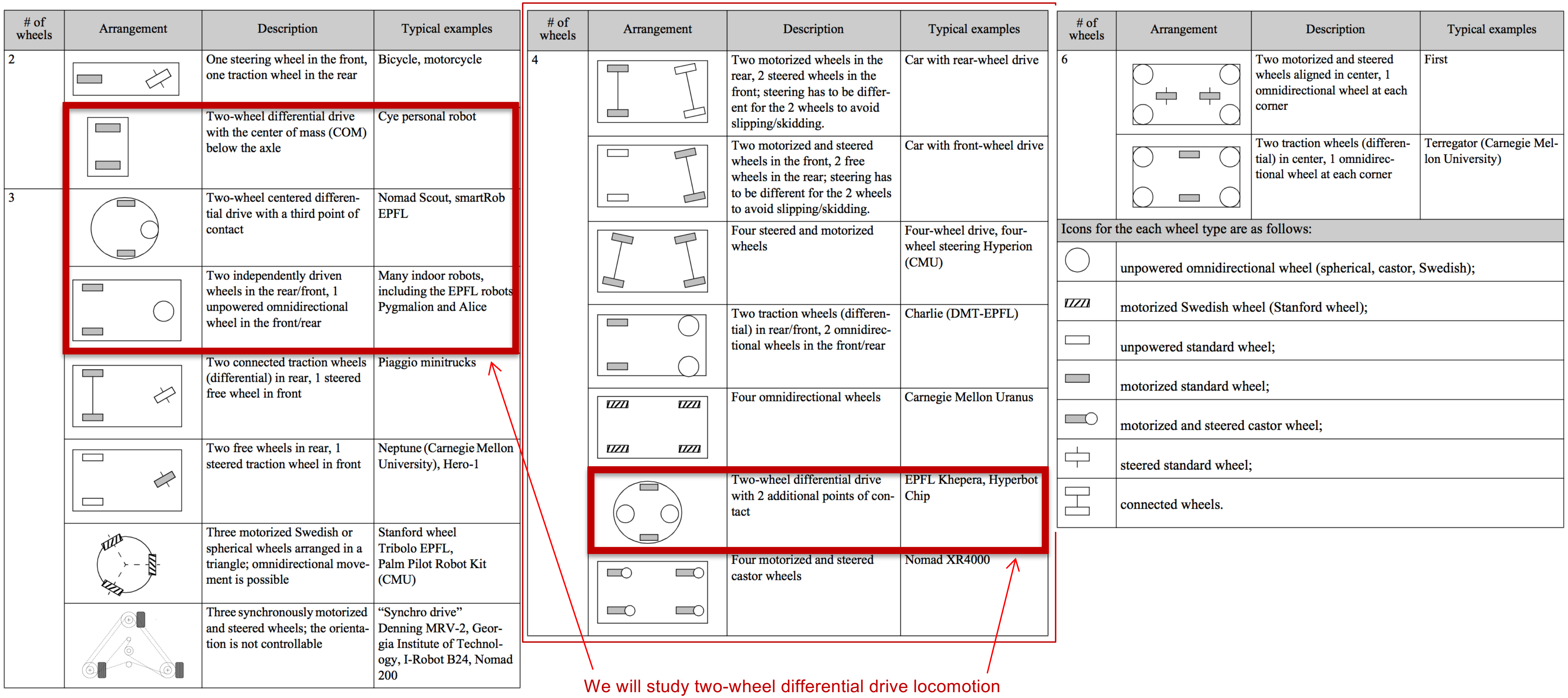
# of wheels	Arrangement	Description	Typical examples
2		One steering wheel in the front, one traction wheel in the rear	Bicycle, motorcycle
		Two-wheel differential drive with the center of mass (COM) below the axle	Cye personal robot
3		Two-wheel centered differential drive with a third point of contact	Nomad Scout, smartRob EPFL
		Two independently driven wheels in the rear/front, 1 unpowered omnidirectional wheel in the front/rear	Many indoor robots, including the EPFL robots Pygmalion and Alice
		Two connected traction wheels (differential) in rear, 1 steered free wheel in front	Piaggio minitrucks
		Two free wheels in rear, 1 steered traction wheel in front	Neptune (Carnegie Mellon University), Hero-1
		Three motorized Swedish or spherical wheels arranged in a triangle; omnidirectional movement is possible	Stanford wheel Tribolo EPFL, Palm Pilot Robot Kit (CMU)
		Three synchronously motorized and steered wheels; the orientation is not controllable	"Synchro drive" Denning MRV-2, Georgia Institute of Technology, I-Robot B24, Nomad 200
4		Two motorized wheels in the rear, 2 steered wheels in the front; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with rear-wheel drive
		Two motorized and steered wheels in the front, 2 free wheels in the rear; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with front-wheel drive
		Four steered and motorized wheels	Four-wheel drive, four-wheel steering Hyperion (CMU)
		Two traction wheels (differential) in rear/front, 2 omnidirectional wheels in the front/rear	Charlie (DMT-EPFL)
		Four omnidirectional wheels	Carnegie Mellon Uranus
		Two-wheel differential drive with 2 additional points of contact	EPFL Khepera, Hyperbot Chip
		Four motorized and steered castor wheels	Nomad XR4000
6		Two motorized and steered wheels aligned in center, 1 omnidirectional wheel at each corner	First
		Two traction wheels (differential) in center, 1 omnidirectional wheel at each corner	Terregator (Carnegie Mellon University)

Icons for the each wheel type are as follows:

○	unpowered omnidirectional wheel (spherical, castor, Swedish);
▨	motorized Swedish wheel (Stanford wheel);
▭	unpowered standard wheel;
▬	motorized standard wheel;
▬○	motorized and steered castor wheel;
┿	steered standard wheel;
⌶	connected wheels.

Source: R. Siegwart and I. R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, MIT Press, 2004

Wheels



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		Three synchronously motorized and steered wheels; the orientation is not controllable	"Synchro drive" Denning MRV-2, Georgia Institute of Technology, I-Robot B24, Nomad 200

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		Two motorized and steered wheels in the front, 2 free wheels in the rear; steering has to be different for the 2 wheels to avoid slipping/skidding.	Car with front-wheel drive
		Four steered and motorized wheels	Four-wheel drive, four-wheel steering Hyperion (CMU)
		Two traction wheels (differential) in rear/front, 2 omnidirectional wheels in the front/rear	Charlie (DMT-EPFL)
		Four omnidirectional wheels	Carnegie Mellon Uranus
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		Four motorized and steered castor wheels	Nomad XR4000

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▬	motorized standard wheel;
▬○	motorized and steered castor wheel;
╪	steered standard wheel;
⌶	connected wheels.

We will study two-wheel differential drive locomotion

Source: R. Siegwart and I. R. Nourbakhsh, *Introduction to Autonomous Mobile Robots*, MIT Press, 2004

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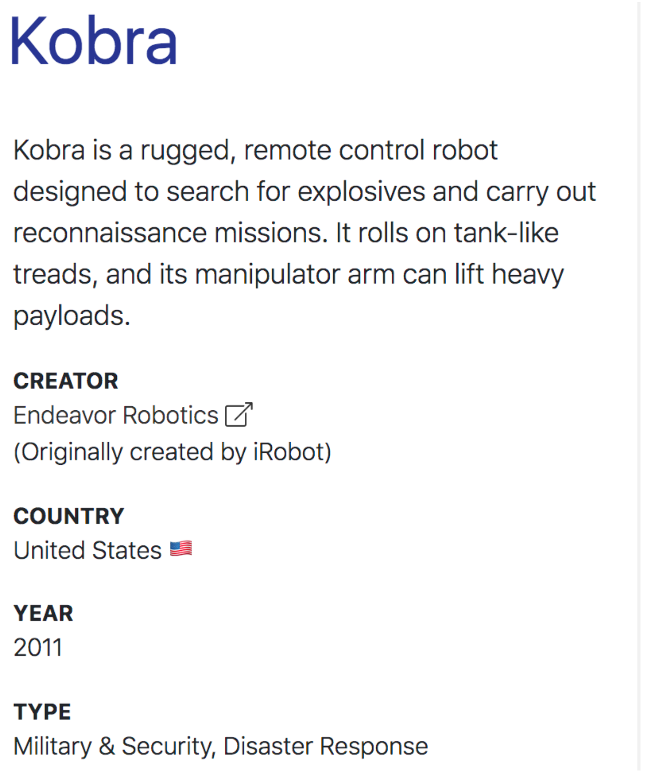
End-effectors



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/

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Hands, Grippers, Tools } End-effectors

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/

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Hands, Grippers, Tools: End-effectors

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/

Effectors

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End-effectors

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CREATOR
Willow Garage

COUNTRY
United States 🇺🇸

YEAR
2010

TYPE
Research, Humanoids

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

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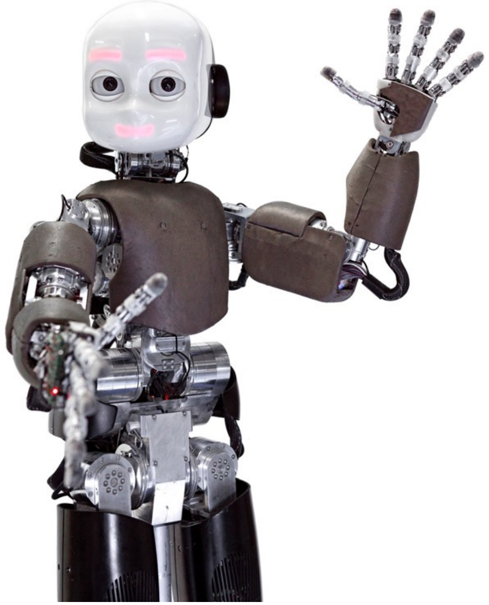

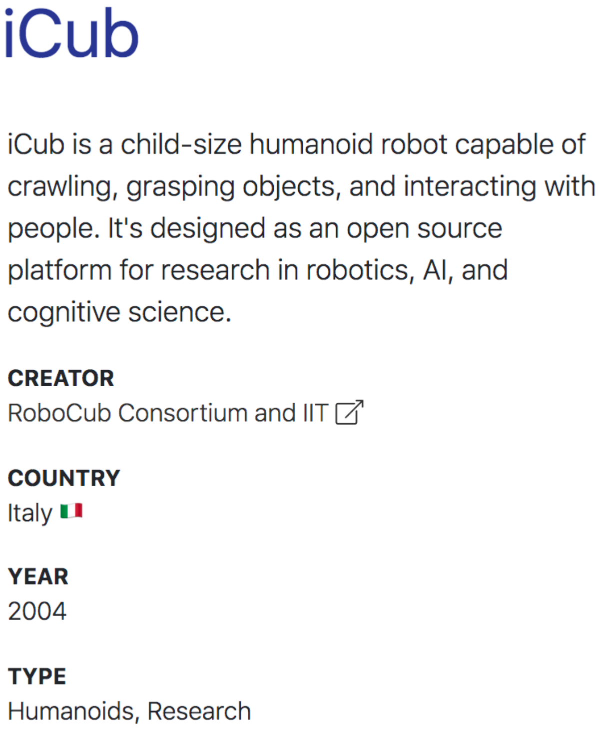

iCub

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/

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End-effectors

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/davinci/

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Effectors for locomotion

- Legs
- Wheels
- Tracks
- Wings
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- Arms
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- Tools

End-effectors

Two-finger gripper

C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, S. Šabanović, Human-Robot Interaction – An Introduction, Cambridge University Press, 2020

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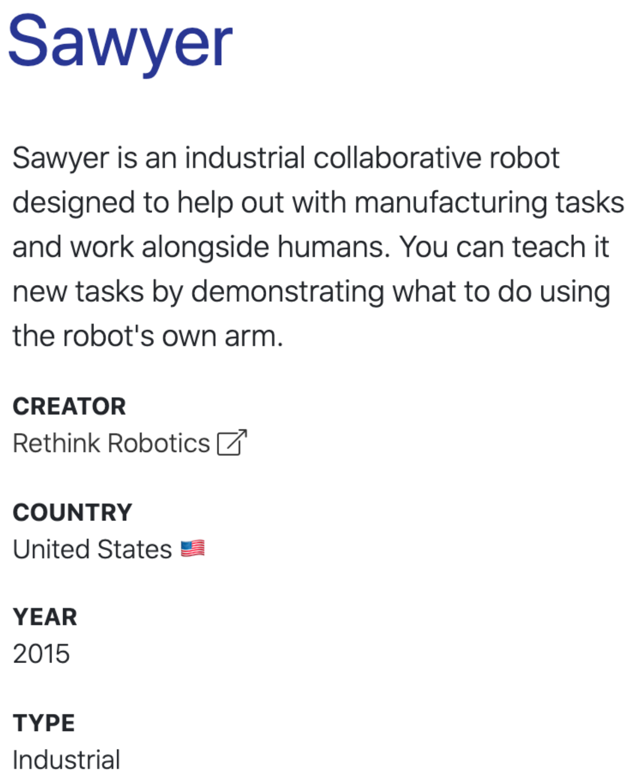

Sawyer

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/

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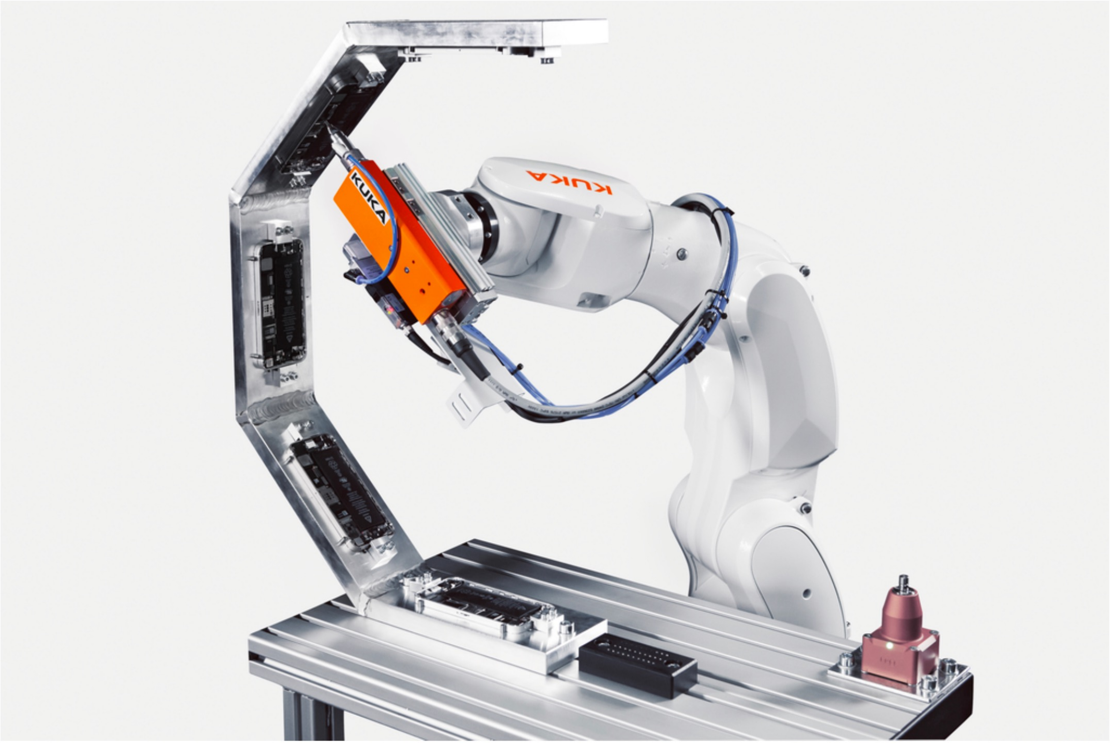

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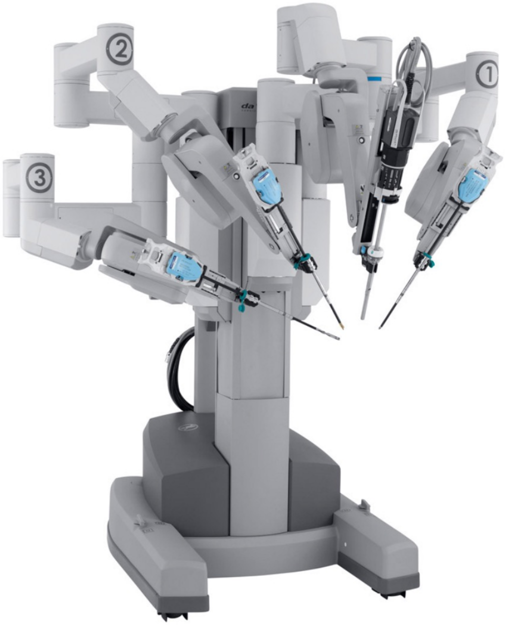

Da Vinci

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/

Reading

C. Bartneck, T. Belpaeme, F. Eyssel, T. Kanda, M. Keijsers, S. Šabanović, Human-Robot Interaction – An Introduction, Cambridge University Press, 2020. Chapter 3: How a Robot Works.

https://www.human-robot-interaction.org/download/170/

M. Mataric, The Robotics Primer, MIT Press, 2007. Chapters 5 and 6.