Artificial Intelligence and the Singularity

piero scaruffi

www.scaruffi.com

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"The person who says it cannot be done should not interrupt the person doing it" (Chinese proverb)

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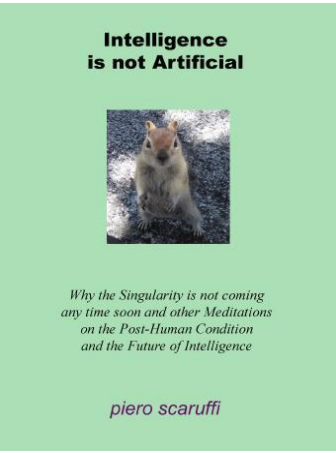

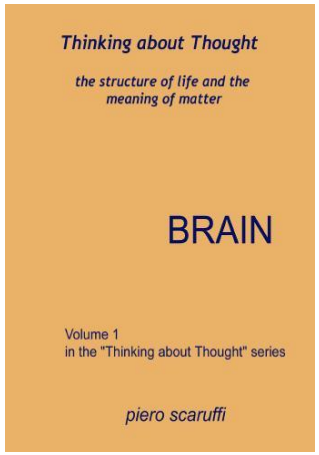

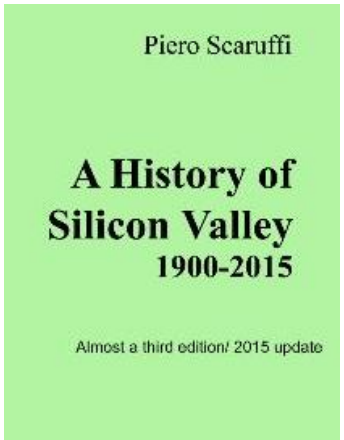

Olivetti AI Center, 1987

Piero Scaruffi

- Cultural Historian
- Cognitive Scientist
- Blogger
- Poet
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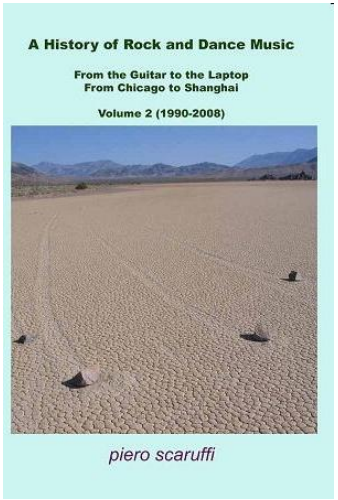
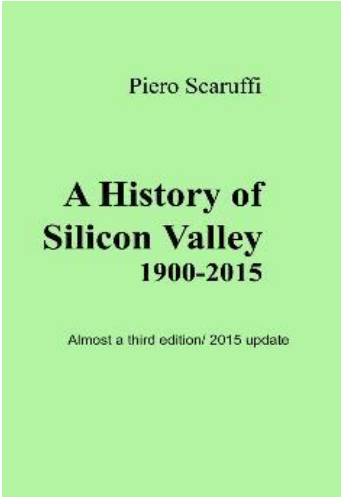
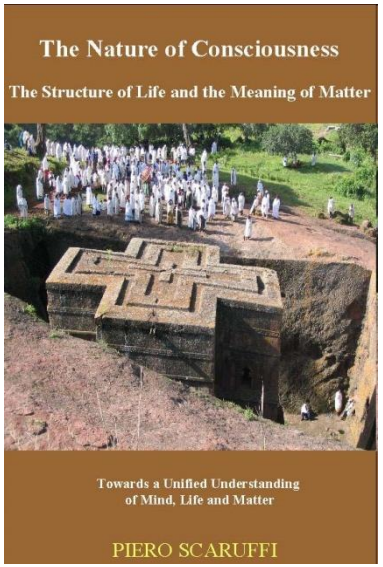
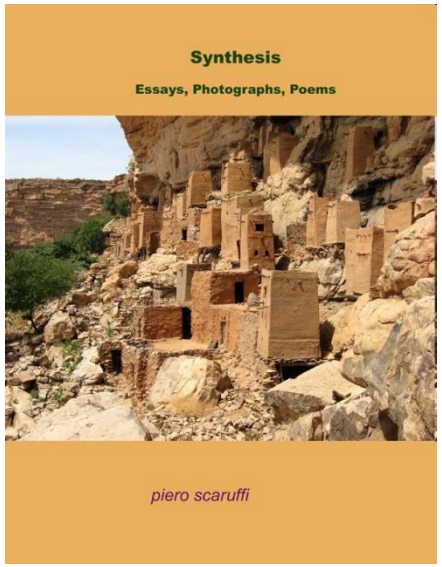




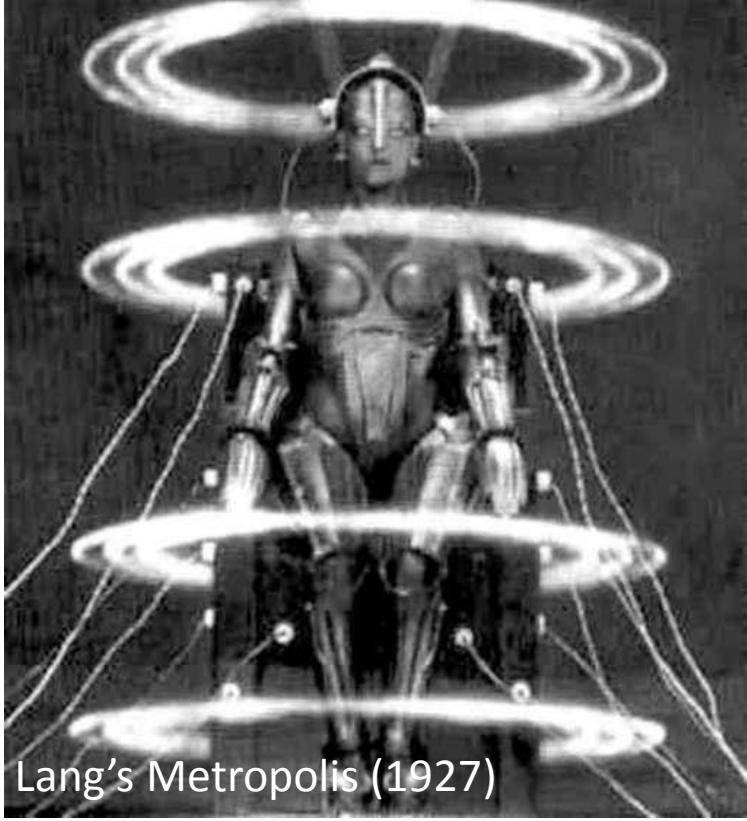




This is Part 4

- See http://www.scaruffi.com/singular for the index of this Powerpoint presentation and links to the other parts
  1. Classic A.I. - The Age of Expert Systems
  2. The A.I. Winter and the Return of Connectionism
  3. Theory: Knowledge-based Systems and Neural Networks
  4. Robots
  5. Bionics
  6. Singularity
  7. Critique
  8. The Future
  9. Applications
  10. Machine Art
  11. The Age of Deep Learning
  12. Natural Language Processing


A staging of Capek's play R.U.R. (1921)

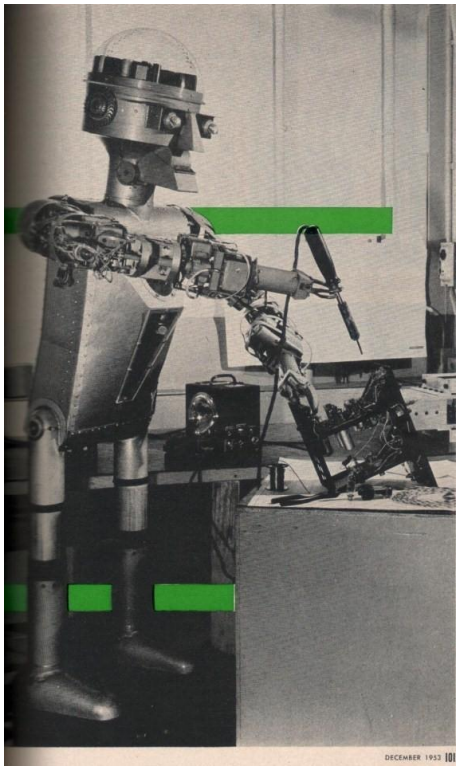

Lang's Metropolis (1927)

Robots

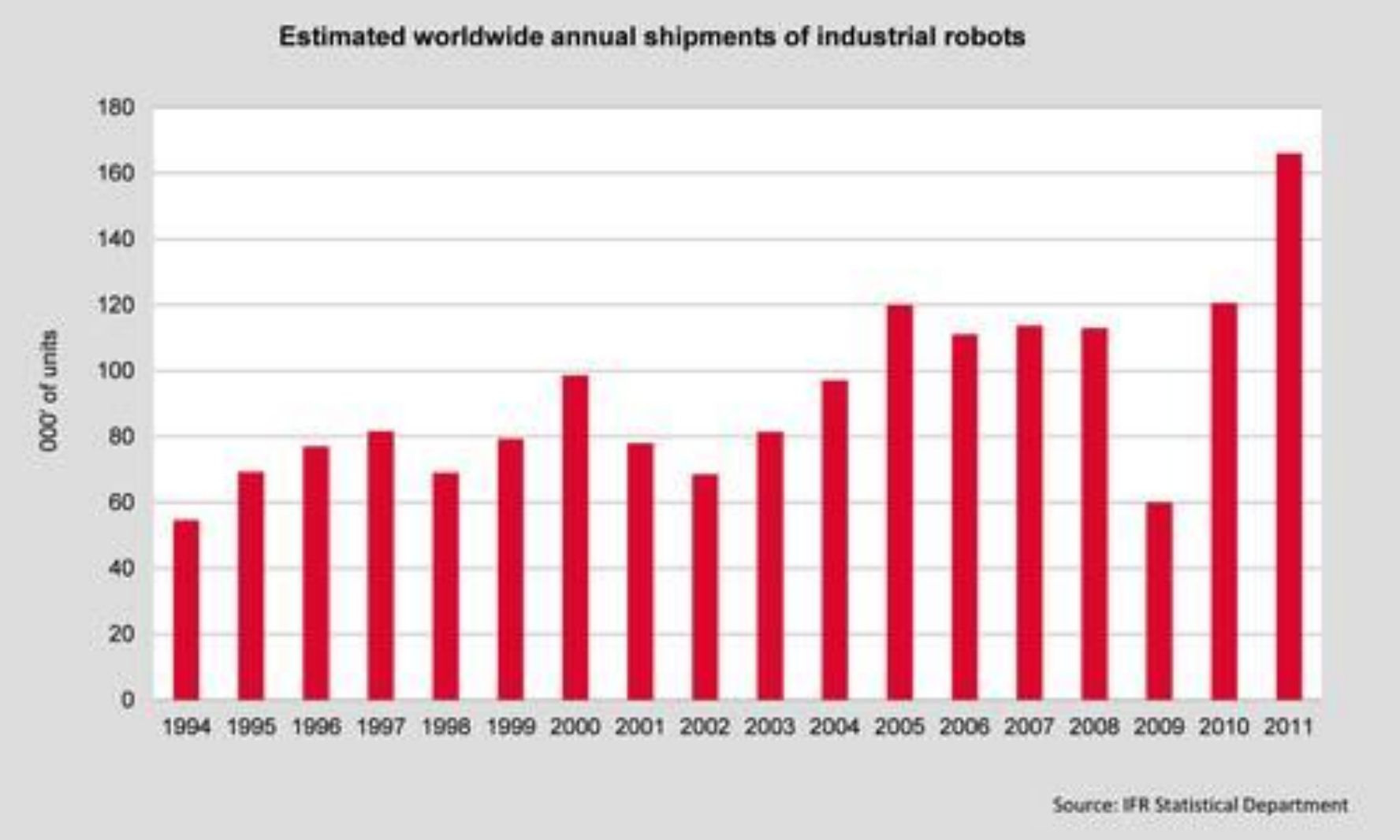

Chaplin's
"Modern Times"
(1930)

Robots

- Westinghouse’s Elektro (1939)
- Harvey Chapman's Garco (1953)



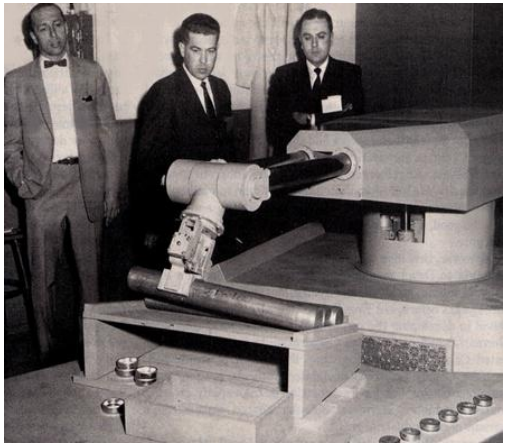
Robots


Estimated worldwide annual shipments of industrial robots
000' of units
180
160
140
120
100
80
60
40
20
0
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Source: IFR Statistical Department

Robots

1959: Joseph Engelberger deploys the industrial robot Unimate at General Motors

1969: Stanford Research Institute's Shakey the Robot



Timeline

1973: Ichiro Kato's Wabot, the first anthropomorphic walking robot
1984: Valentino Breitenberg's “vehicles”
1986: Jaime Carbonell's Prodigy planner
1986: Rodney Brooks' "dumb" robots
1991: Shuuji Kajita's and Kazuo Tani's LIPM
1991: Jean-Claude Latombe's Randomized Path Planner
1993: Masayuki Inaba's remote-brained robots
1993: Tom Mitchell's Xavier robot
1994: Ernst Dickmanns' robot car
1997: The first RoboCup, the "Robot Soccer World Cup"
1997: NASA's Mars Pathfinder deployed on Mars the first roving robot, Sojourner
1998: Sebastian Thrun's Minerva and Pearl robots
1998: Steven LaValle's and James Kuffner's as the Rapidly-exploring Random Trees (RRT) planner
2000: Honda's Asimo, Sony's Qrio and Hirochika Inoue's H6
2001: Humanoid Robotics Project in Japan
2003: Klaus Loeffler's Johnnie
2005: Jun-ho Oh's Hubo
2005: Sebastian Thrun's robot car Stanley
2006: Willow Garage
2007: Stanford's Robot Operating System
2010: PR2 robot
2010: James Kuffner coins the term "cloud robotics"

Footstep Planning

Motion planning is hard

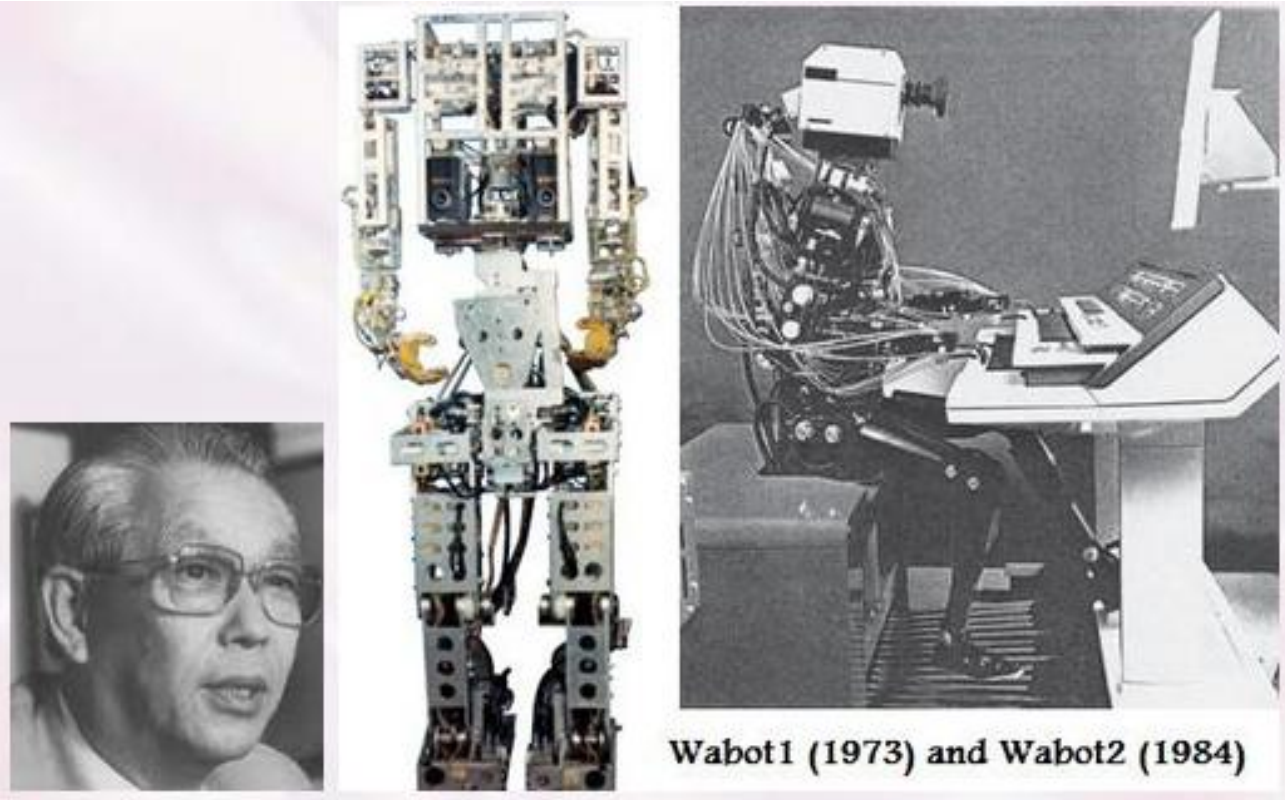
Lydia Kavraki

Problem	Complexity
Sofa Mover (3 DOF)	$O(n^{2+\varepsilon})$ not implemented
Piano Mover (6 DOF)	Polynomial – no practical algorithm known
n Disks in the Plane	NP-hard
n Link Planar Chain	PSPACE-Complete
Generalized Mover	PSPACE-Complete
Shortest Path for a Point in 3D	NP-hard
Curvature Constrained Point in 2D	NP-hard
Simplified Coulomb Friction	Undecidable

Robots

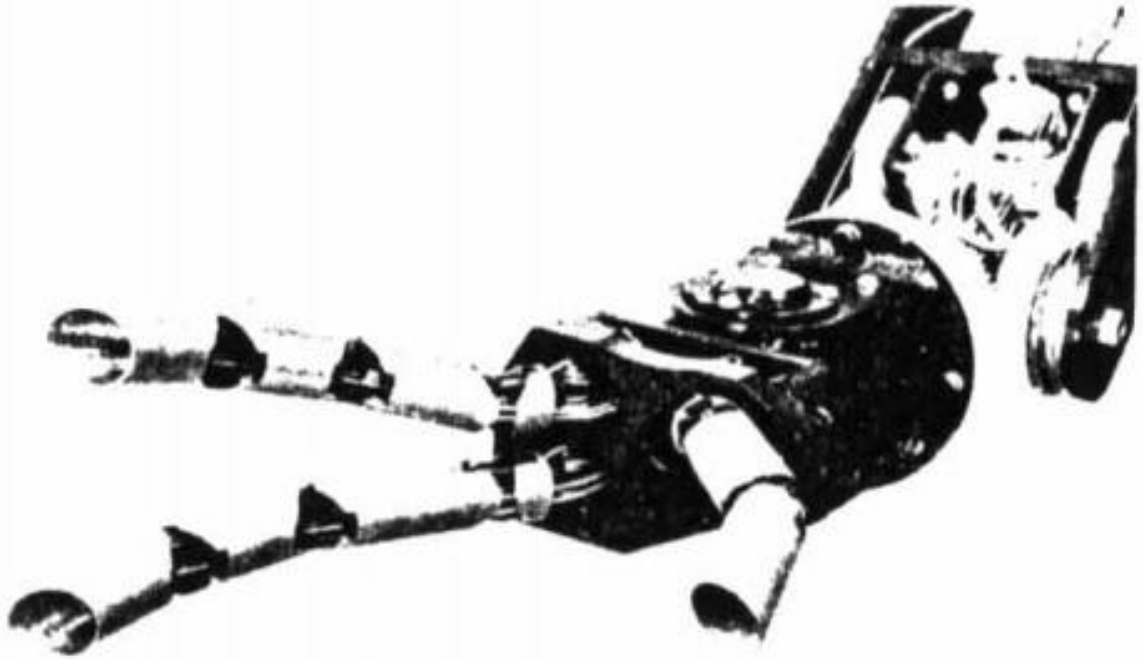
1969: Miomir Vukobratovic's ZMP method

1973: Ichiro Kato's Wabot, the first anthropomorphic walking robot



Robots

1979: Tokuji Okada's robotic hand with three fingers

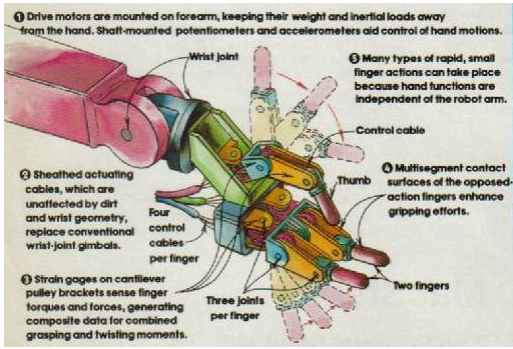


Okada's robotic hand
(1979)

Robots

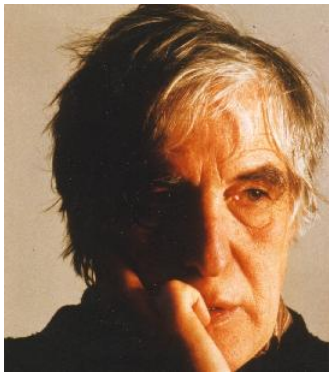
1981: Raoul Tubiana shows that the human hand has 22 degrees of freedom

1982: Kenneth Salisbury (Stanford) & Jet Propulsion Laboratory prove the minimum number of degrees of freedom required for grasping an object is 9

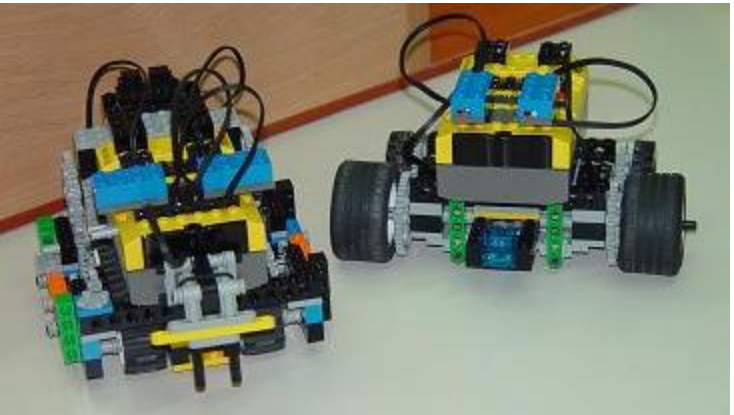


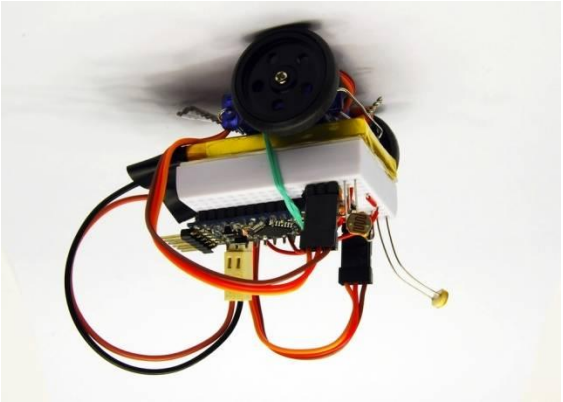
1984: Robotic hand by Stephen Jacobsen (Univ of Utah) & MIT

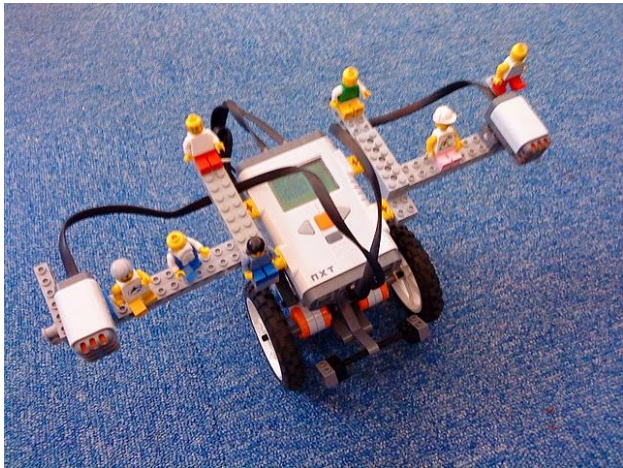
Robots



- Valentino Breitenberg's "vehicles" (1984)
  - Vehicle 1: a motor and a sensor
  - Vehicle 2: two motors and two sensors
  - Increase little by little the circuitry, and these vehicles seem to acquire not only new skills, but also a personality.







Robots

1986: Jaime Carbonell's Prodigy planner

1986: Rodney Brooks' "dumb" robots

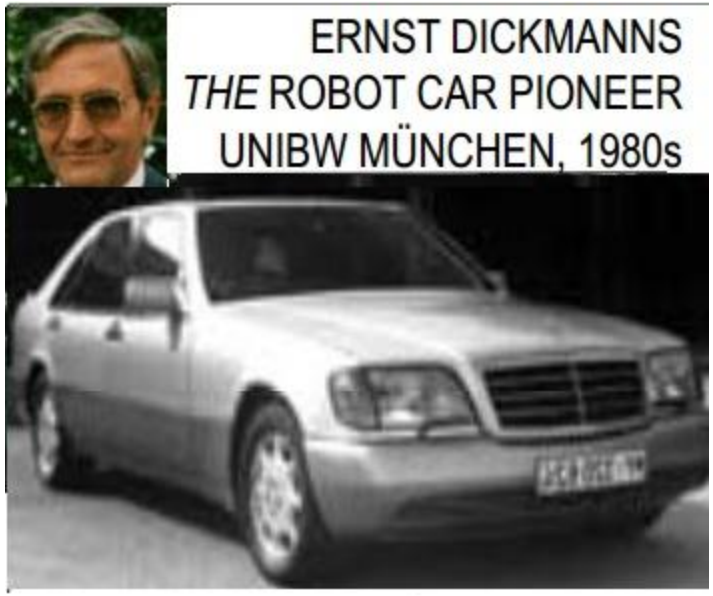
1991: Shuuji Kajita's and Kazuo Tani's LIPM

1991: Jean-Claude Latombe's Randomized Path Planner

1993: Masayuki Inaba's remote-brained robots

Robots

- Ernst Dickmanns' "robot car" (1986)



SELF-DRIVING CAR IN HIGHWAY TRAFFIC (1994)

1995: MUNICH TO DENMARK

Neural Networks

1988: Dean Pomerleau's Neural-based self-driving vehicle ALVINN

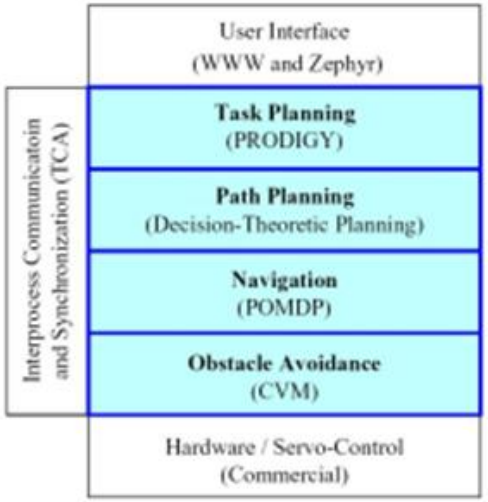
Robots

1993: Tom Mitchell's Xavier

Tom Mitchell

Joseph O'Sullivan / Sebastian Thrun

Reid Simmons / Manuela Veloso



Xavier

Robots

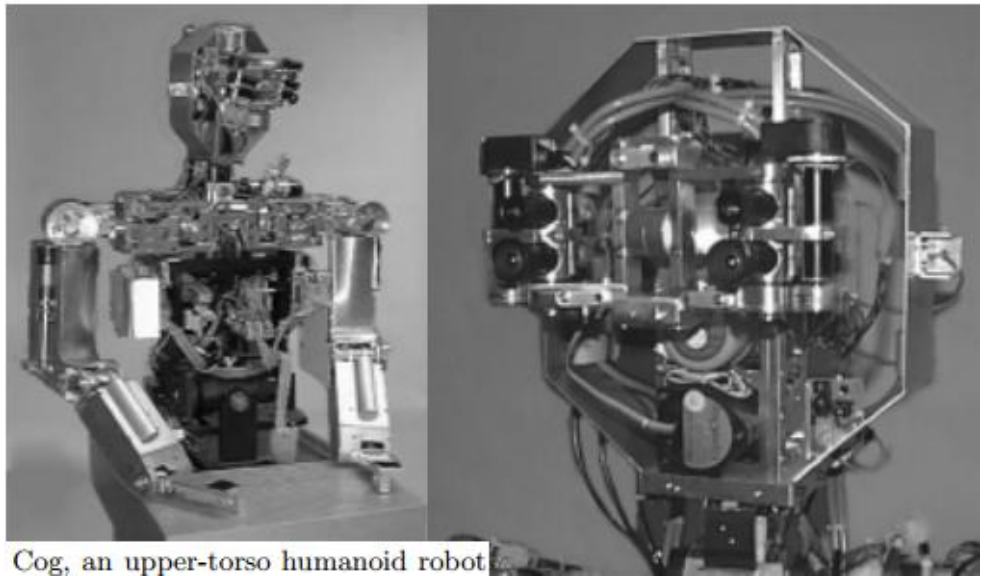
1993: Rodney Brooks' Cog

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
ARTIFICIAL INTELLIGENCE LABORATORY

A.I. Memo No. 1439 August, 1993

Building Brains for Bodies

Rodney A. Brooks and Lynn Andrea Stein



Cog, an upper-torso humanoid robot

Robots

1998: Sebastian Thrun's Minerva and Pearl

1998: Steven LaValle's and James Kuffner's Rapidly-exploring Random Trees (RRT) planner

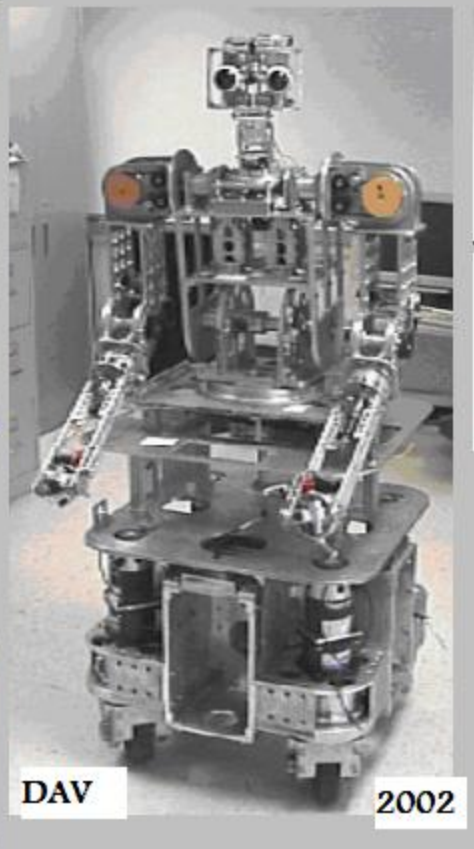
Photo by Brett W. Gould/The Washington Times

Robots

Developmental Robots

1998: Juyang Weng's SAIL

1998: Gerald Edelman's Darwin V



MICHIGAN STATE UNIVERSITY

UNIVERSITY OF CALIFORNIA SAN DIEGO

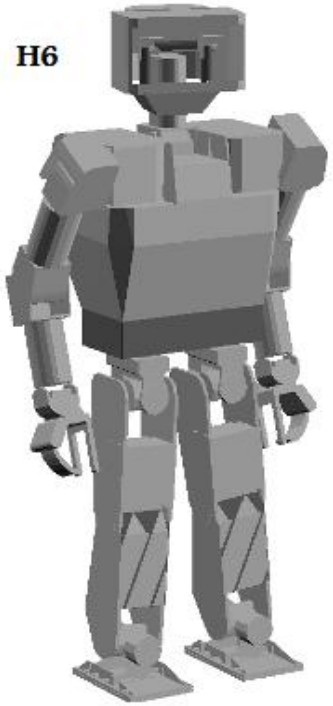
Walking Robots

2000:

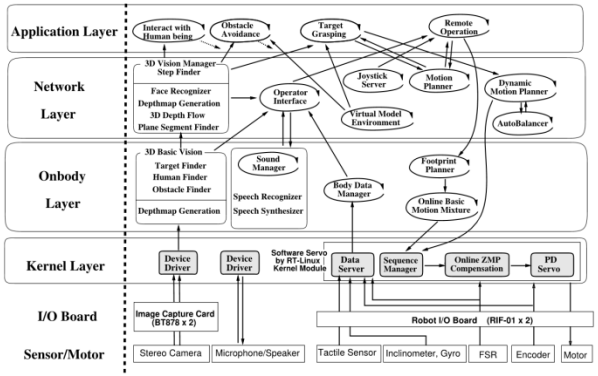
Hirochika Inoue's H6

Sony's Qrio

Honda's Asimo

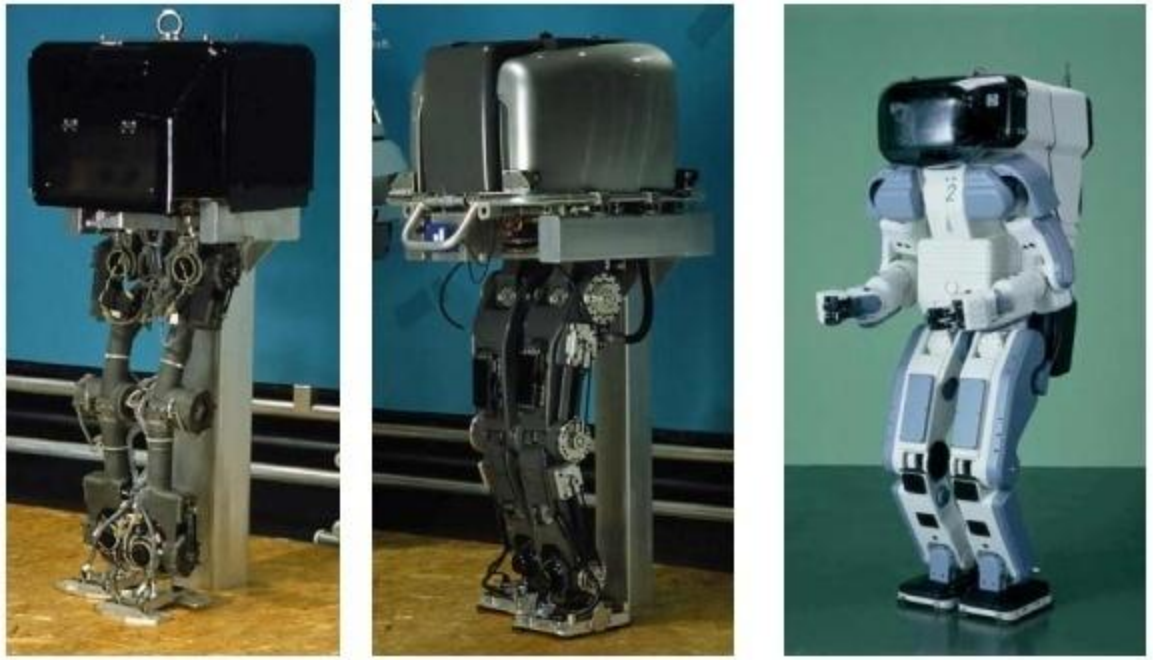


Asimo over the years



Walking Robots

Honda's Asimo



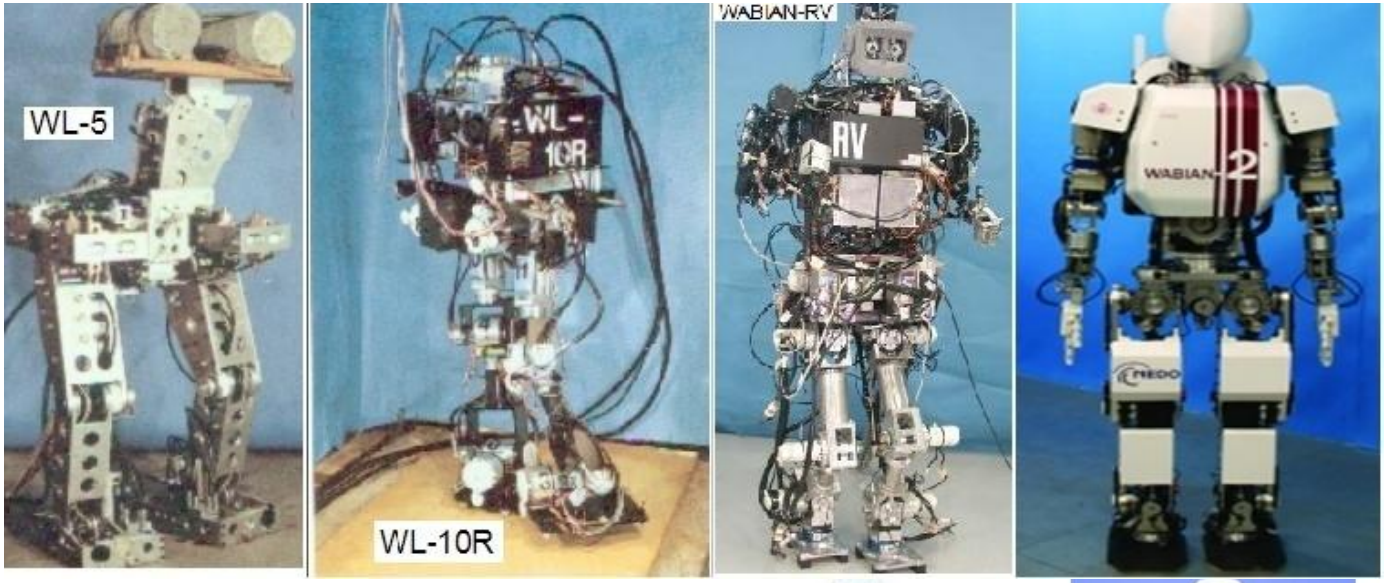
Evolution of robot models leading up to ASIMO

"E2": Model in 1989 "E6": Model 1993 "P2": The first humanoid 1996 robot Honda unveiled

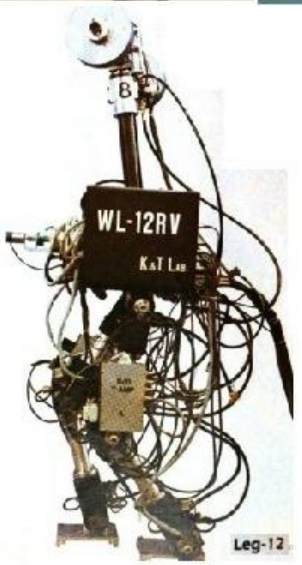
Takenaka

Walking Robots

Atsuo Takanishi



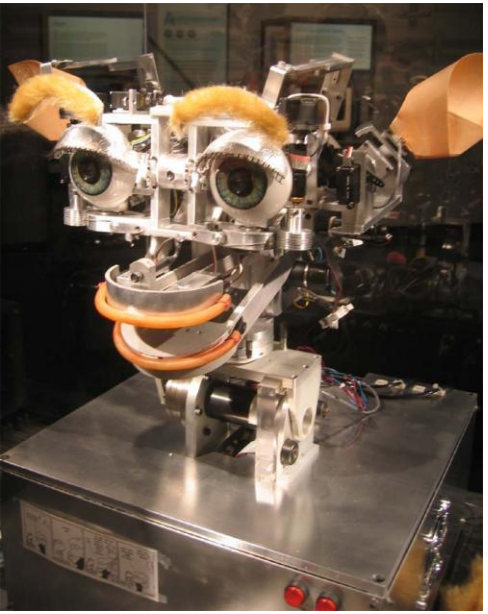
1971: WL-5
1983: WL-10R
1985: Leg-11
1996: Wabian
2006: Wabian-2R



Robots

2000: Cynthia Breazeal's emotional robot, "Kismet"

2003: Hiroshi Ishiguro's Actroid, a young woman



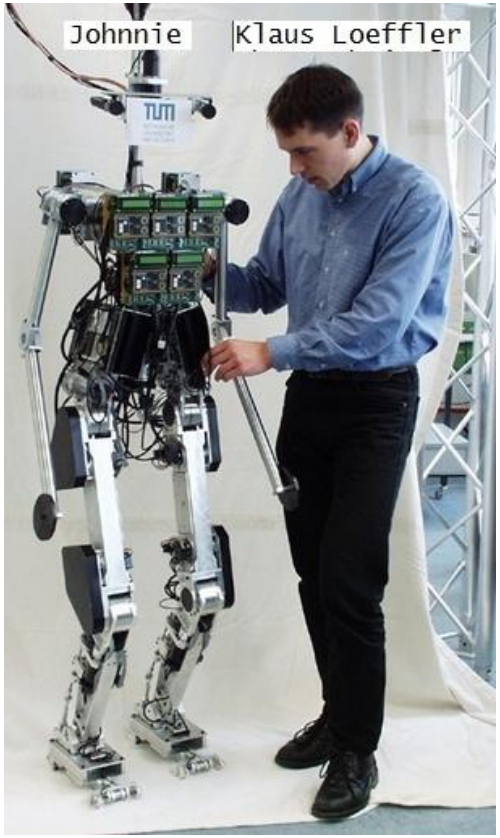
Which is the robot?

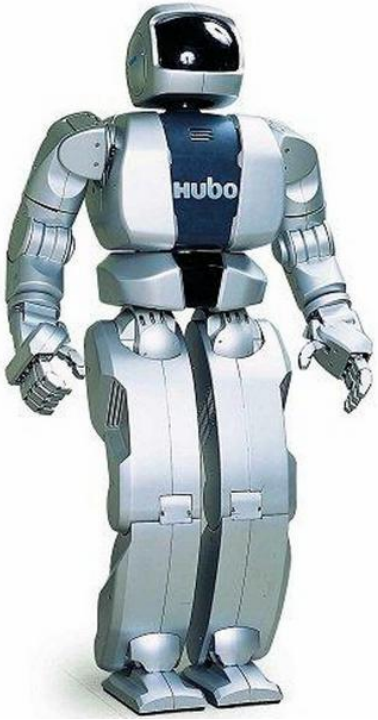
Robots

2003: Klaus Loeffler’s Johnnie

2005: Jun-ho Oh's Hubo

2005: Sebastian Thrun’s robot car Stanley





Robots

Special purpose robots:

2001: NEC PaPeRo (a social robot targeting children)

2007: RobotCub Consortium agreement, the iCub (for research in embodied cognition)

2008: Aldebaran Robotics' Nao (for research and education)

2010: NASA's Robonaut-2 (for exploration)

Robots

General-purpose robots:

2006: Willow Garage

2007: Stanford’s Robot Operating System

2010: PR2 robot

2012: Open Source Robotics Foundation

Robots

Domestic robots:

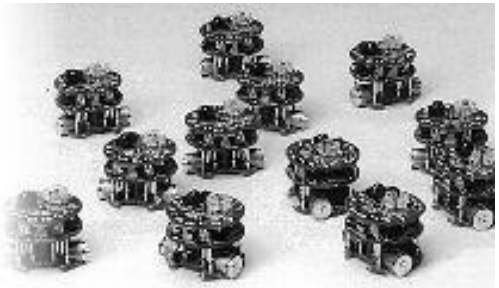
2005: Toyota's Partner (designed for assistance and elderly care applications)

2007: Toyota's nursebot Robina

2015: Univ of Hamburg's robot

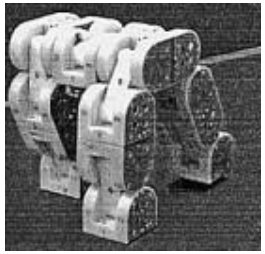
2015: Hanson Robotics' Sophia

Robots



Modular self-configuring robots

- Toshio Fukuda’s CEBOT (Japan, 1988)
- Satoshi Murata's M-TRAN (Japan, 1999)
- Daniela Rus’ M-blocks (MIT, 2010)



Robots

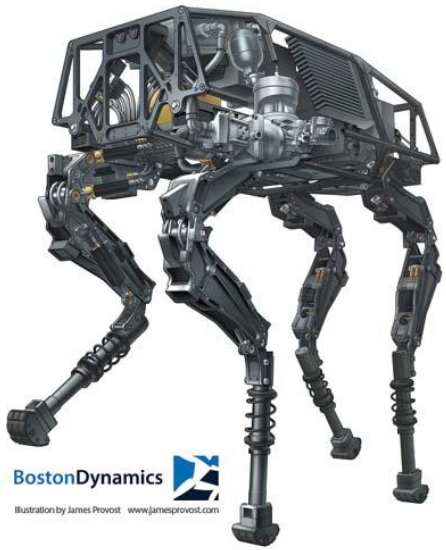
2005: Boston Dynamics' quadruped robot "BigDog“

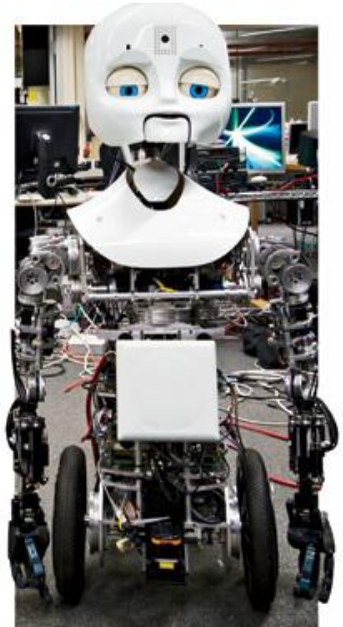
2008: Nexi (MIT Media Lab), a mobile-dexterous-social robot

2010: Lola Canamero's Nao, a robot that can show its emotions

2011: Osamu Hasegawa's SOINN-based robot that learns functions it was not programmed to do

2012: Rodney Brooks' hand programmable robot "Baxter"





Robots

Google buys Boston Dynamics, maker of spectacular and terrifying robots

Dec 14, 2013,

Google's Andy Rubin Pursues 'Replicant' Robots

Dec 04, 2013

Jun. 9, 2017,

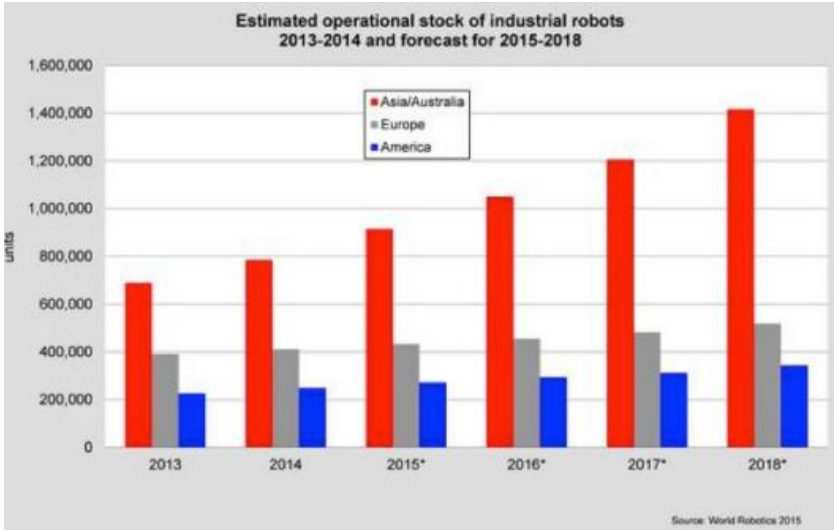
Softbank just bought Google's robotics division to help secure its ambitious vision for the future

Robots

- Darpa Challenge 2015

Industrial Robots

- Asia holds the leadership in industrial robots: in 2014 Asia bought 139,300 industrial robots (more than half the world's total), +41%, of which
  - 57,096 in China (+41%)
  - 29,300 in Japan (+17%)
  - 24,700 in Korea (+16%)
  - 6,900 in Taiwan (+27%)
  - compared with
    - 26,200 in the USA (+11%)
    - 20,100 in Germany (10%)
    - 6,200 in Italy (+32%)
    - Very small numbers in the rest of Europe



The most complex robot

DARPA DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Aircrew Labor In-Cockpit Automation System (ALIAS)

Robots

- Toys: most robots are an evolution of Pinocchio, not of Shakey

Domestic Robots

- Research and Markets estimates that the personal robotics industry could be worth as much as $34 billion by 2022
- Luna (2011)
- Jibo (2014)

Domestic Robots

Domestic Robots

- The robot that follows you

Domestic Robots

- Robots with an evolving personality

Sandy Spangler talking about Cozmo (2018)

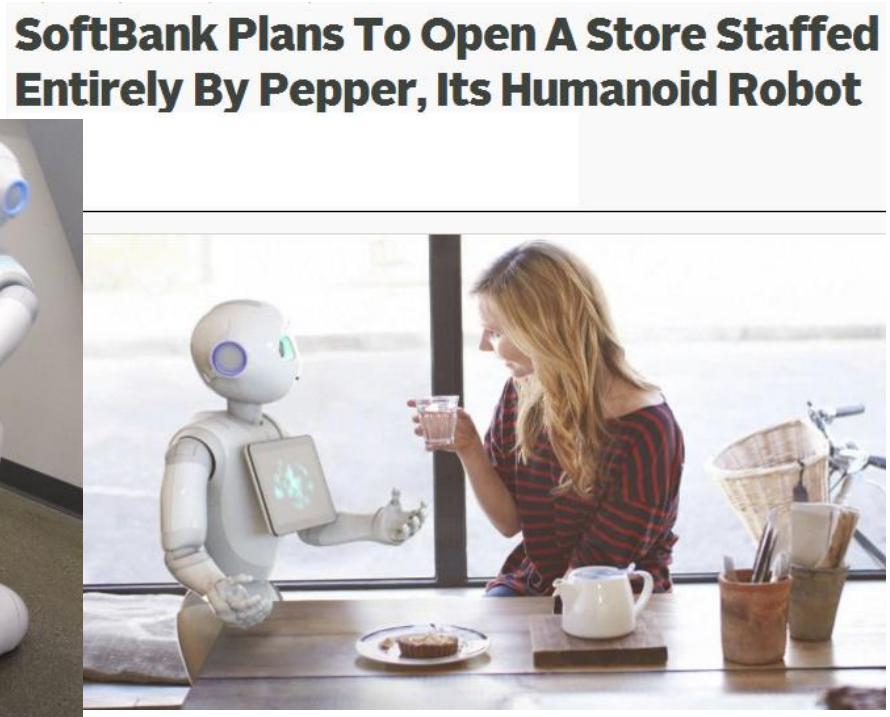
Domestic Robots

Robots

- Consumer robots: cheap, unstructured environment
- Industrial robots: expensive, precise, structured environment
- Service robots: midprice, somewhat structured environment

Customer-service Robots

- Robots for the service industry
  - Pepper (Japan, 2014)
  - Savioke (Sunnyvale, 2013)



Customer-service Robots

Knightscope's K5 robot security guard at the Stanford Shopping Center (2016)
Savioke's robot concierge Botlr at the Aloft hotel in Cupertino (2016)
Simbe's robot clerk Tally at a Target store in San Francisco (2016)

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Robots

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SINGAPORE

Robo Librarian Tracks Down Misplaced Books

Smart Tissue Autonomous Robot
(Peter Kim , Washington, 2016)

Children's National

Robots

- Shopping Robots: an evolution of the shopping cart





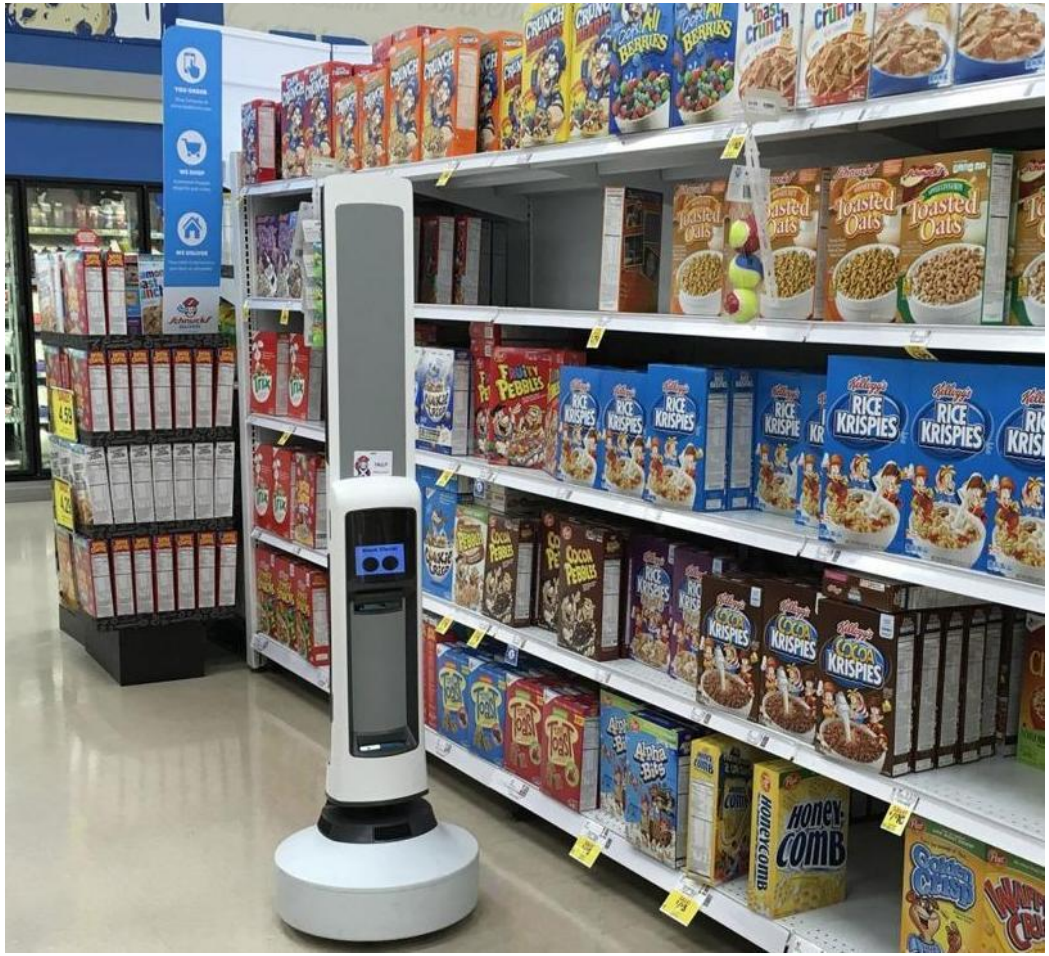






Robots

- Inventory Robots



Simbe

Robots

- Delivery Robots

Starship

Robots

- Domestic Robots

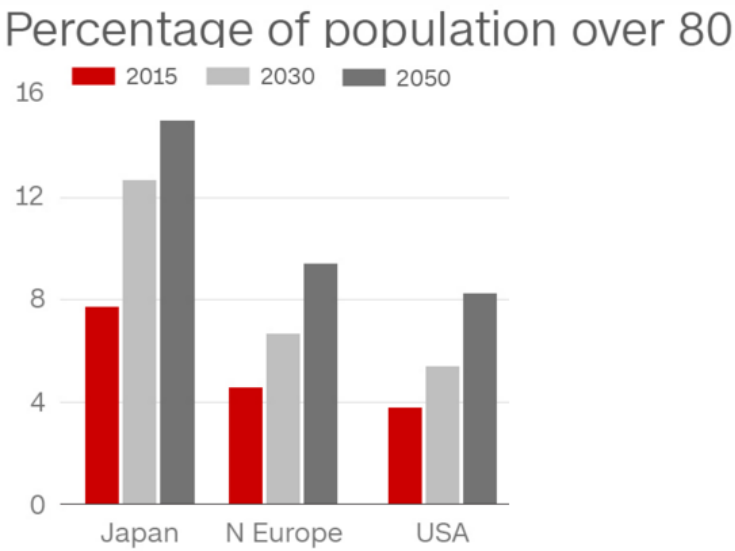

The robotic chef - Moley Robotics

Robots

- Peanut Robotics (Berkeley, 2018)

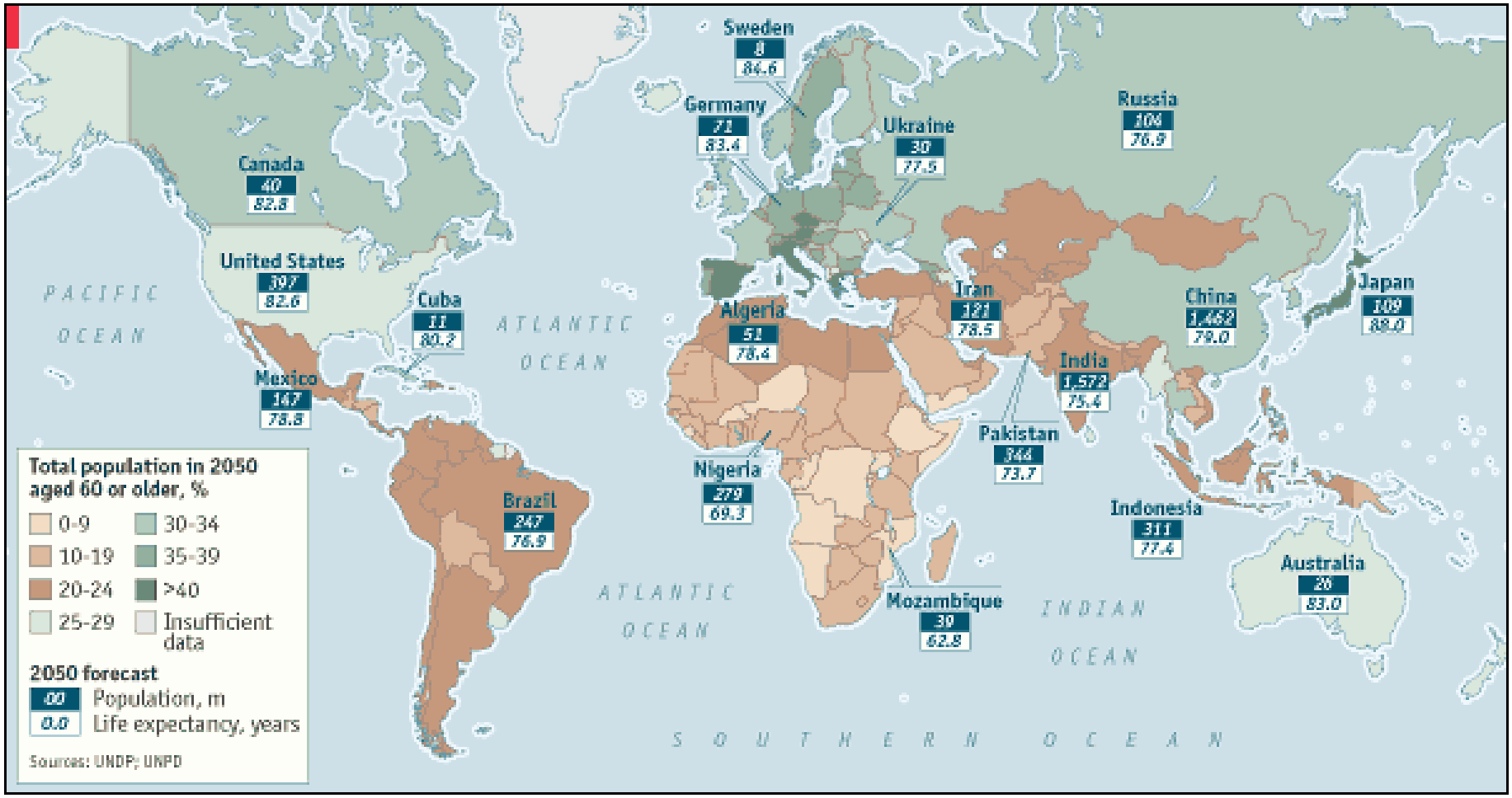
Robots

- Robots for an aging society (social companion robots)



Robots

- Robots for an aging society



Robots

- Domestic Robots

Toyota Partner Robot
HSR (Human Support Robot)

Robina

medical and nursing care

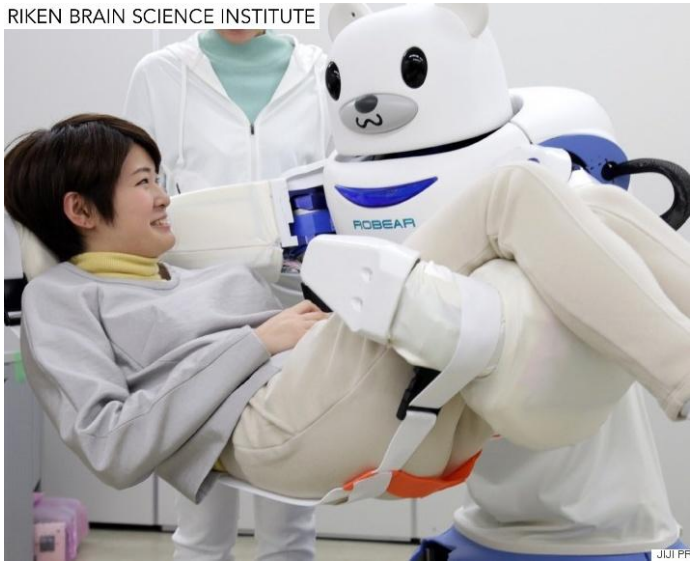
Robots

Warehouse helpers

- Amazon's Kiva
- Fetch
- Magazino's Toru

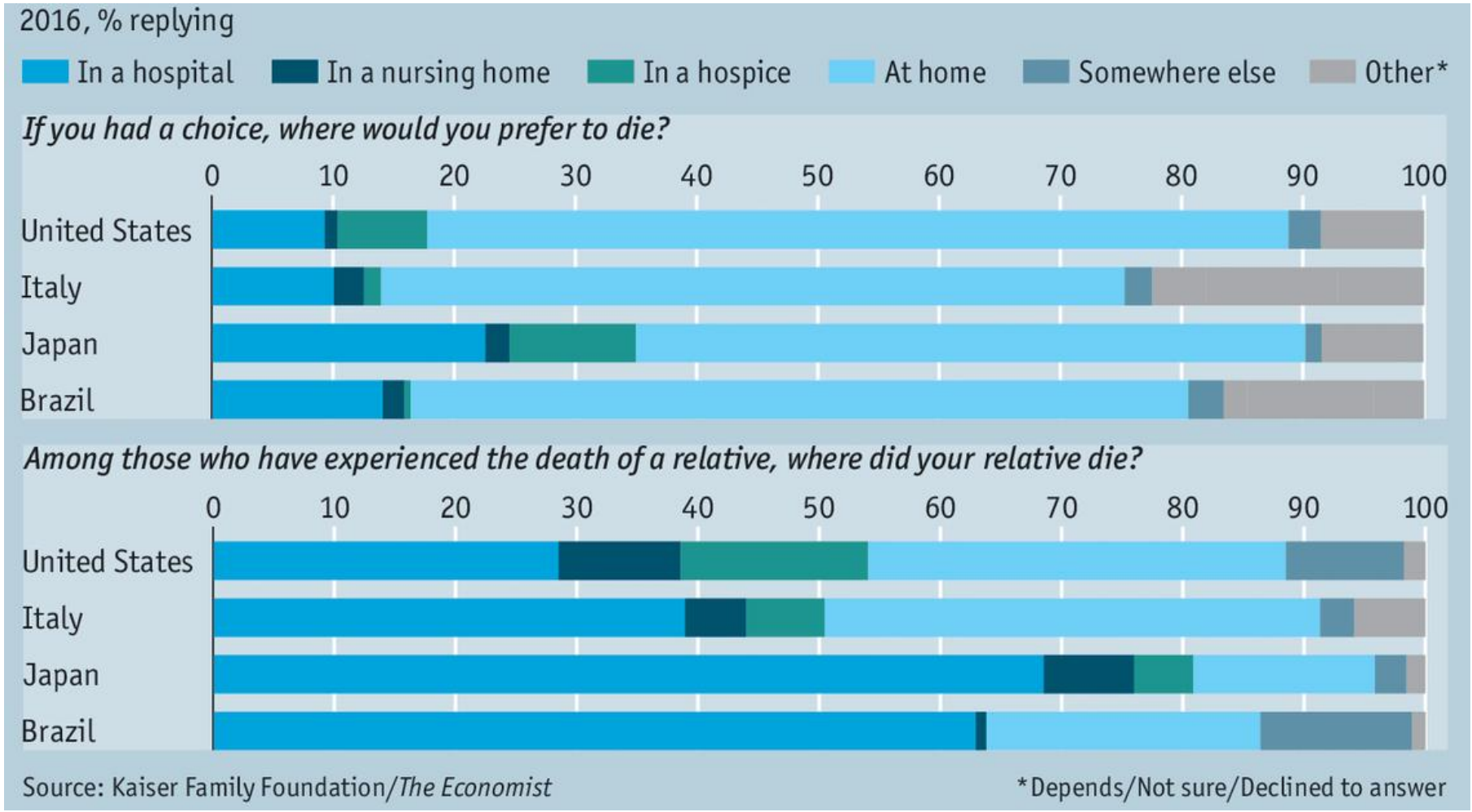
Robots

- Robots for an aging society (social companion robots)
  - Mobiserv “social companion robot” that encourages the elderly to eat healthily and exercise (Europe, 2013)
  - Paro the cuddly seal robot (USA, 2014)
  - RoBear robot nurse (Japan, 2015)
  - RoboCoach (Singapore, 2015)



Robots

- Robots for an aging society



Robots

- Robots for an aging society: exoskeletons
  - Bleex (UC Berkeley, 2000)
  - ReWalk (Amit Goffer)
  - ExoWorks/Ekso Bionics (UC Berkeley spinoff, Homayoon Kazerooni)
  - Suitx (UC Berkeley spinoff)
  - Superflex (SRI spinoff)

ReWalk™ More Than Walking.

ekso BIONICS®

SUITX

SRI International Spins Off Superflex, Inc. to Help People Achieve Their Physical Potential

April 21, 2016

Robots

- Robots for an aging society
  - More than 1 million people in the USA require daily physical assistance to get dressed because of injury, disease and old age
  - Solution: a robot that learns to dress people (Zackory Erickson @ Georgia Institute of Technology, 2018)

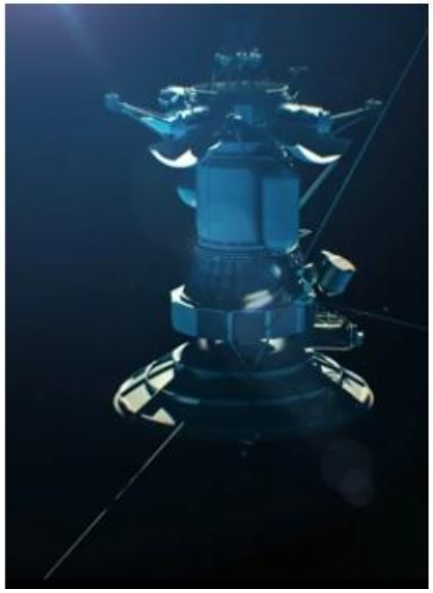
Robots

- Robots for dangerous jobs (explosives, radioactive areas, other planets)

Robots

- Robots for dangerous jobs (explosives, radioactive areas, other planets)

Fukushima disaster: The robots going where no human can



Robots

- Robots for dangerous jobs: assisting infectious patients in hospitals

E&T ENGINEERING AND TECHNOLOGY

Published Wednesday, January 29, 2020

Amid the coronavirus outbreak, robots are being deployed in an afflicted Chinese city to tend to people under quarantine.

Robots

- Robots for dangerous jobs (explosives, radioactive areas, other planets)
  - UCL's Cisbot to maintain gas pipelines

ULC | PIPELINE ROBOTICS

Robots

- Domestic Robots

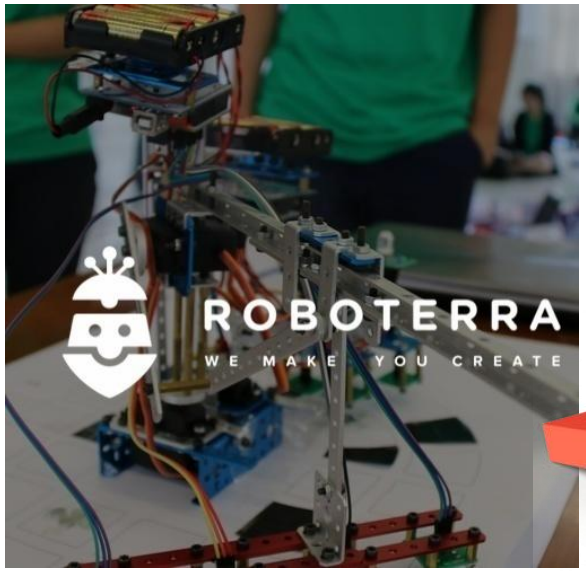
Toyota Partner Robot
HSR (Human Support Robot)

2012

2007

Educational Robots

- Robots for education
  - Roboterra



Bay Area robotics

- Willow Garage: Savioke; Suitable Technologies; Fetch Robotics; Redwood Robotics; Simbe; etc.
- SRI: Grabit, Intuitive Surgical.
- Otherlab: Pneubotics

Cobots

Ed Colgate and Michael Peshkin

- A brief history:
- 1996: Michael Peshkin and Ed Colgate (Northwestern Univ) design "intelligent assist devices“ for Prasad Akella's team at General Motors
- 1997: Peshkin and Colgate found Cobotics/ CoMoCo
- 2004: KUKA’s LBR 3
- 2008: Universal Robots’ UR5
- 2012: Rethink Robotics’ Baxter

UR5 collaborative robot arm

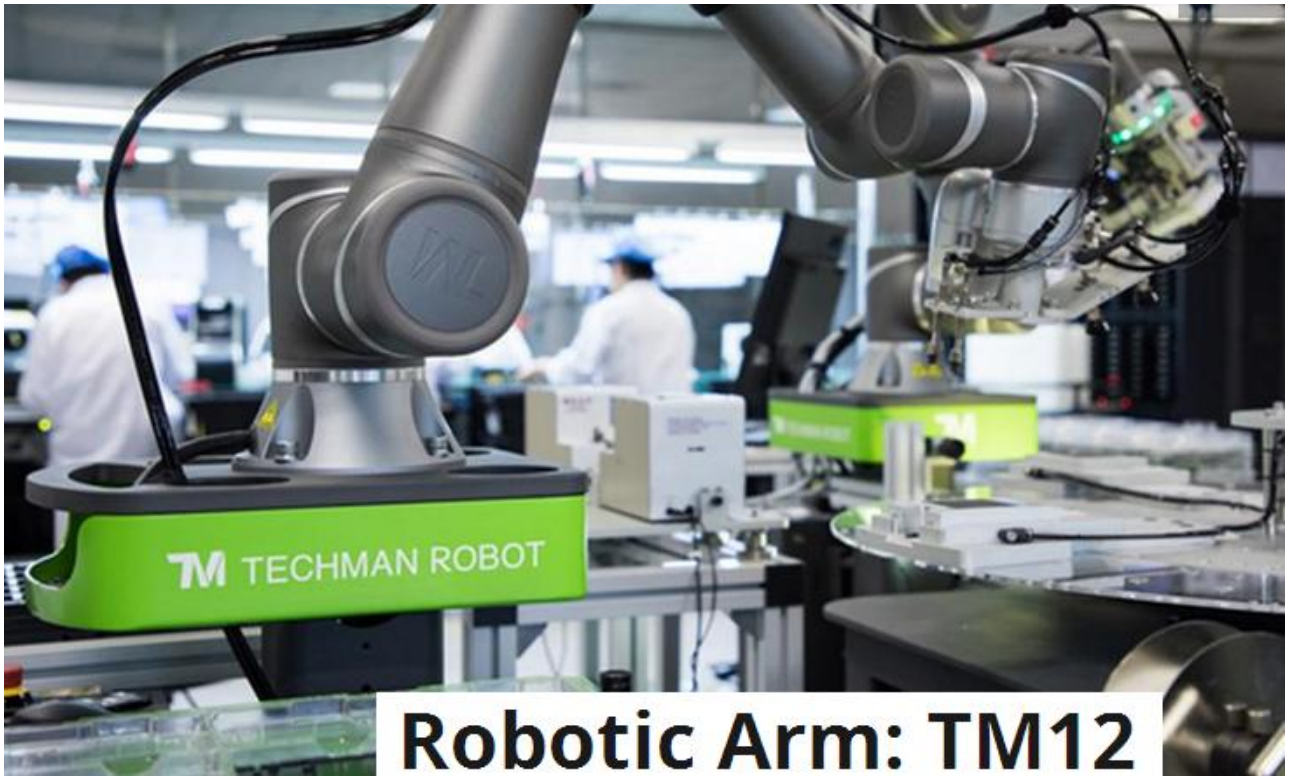
Rethink Robotics
Baxter

Cobots

- 2019: UC Berkeley's Blue (Pieter Abbeel)

Cobots

- 2019: Techman's TM12

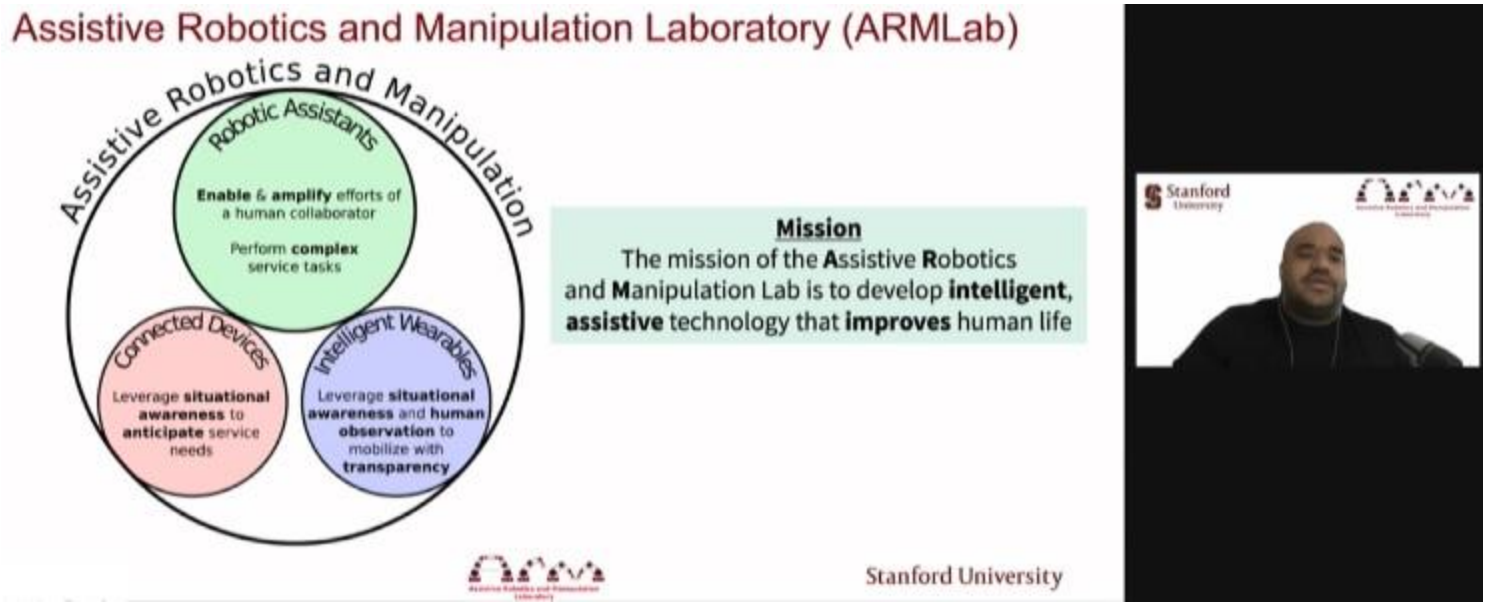


Cobots

- The evolution of robotics
  - 1960-90s Automation (eg, robotic arm)
  - 1990s-00s Autonomy (eg self-driving car)
  - 2010s Augmentation (eg cobot)

Cobots

- Human-robot collaboration
  - The robot must have a model of the human collaborator
  - Monroe Kennedy's ARMLab at Stanford



Cobots

- Human-robot collaboration
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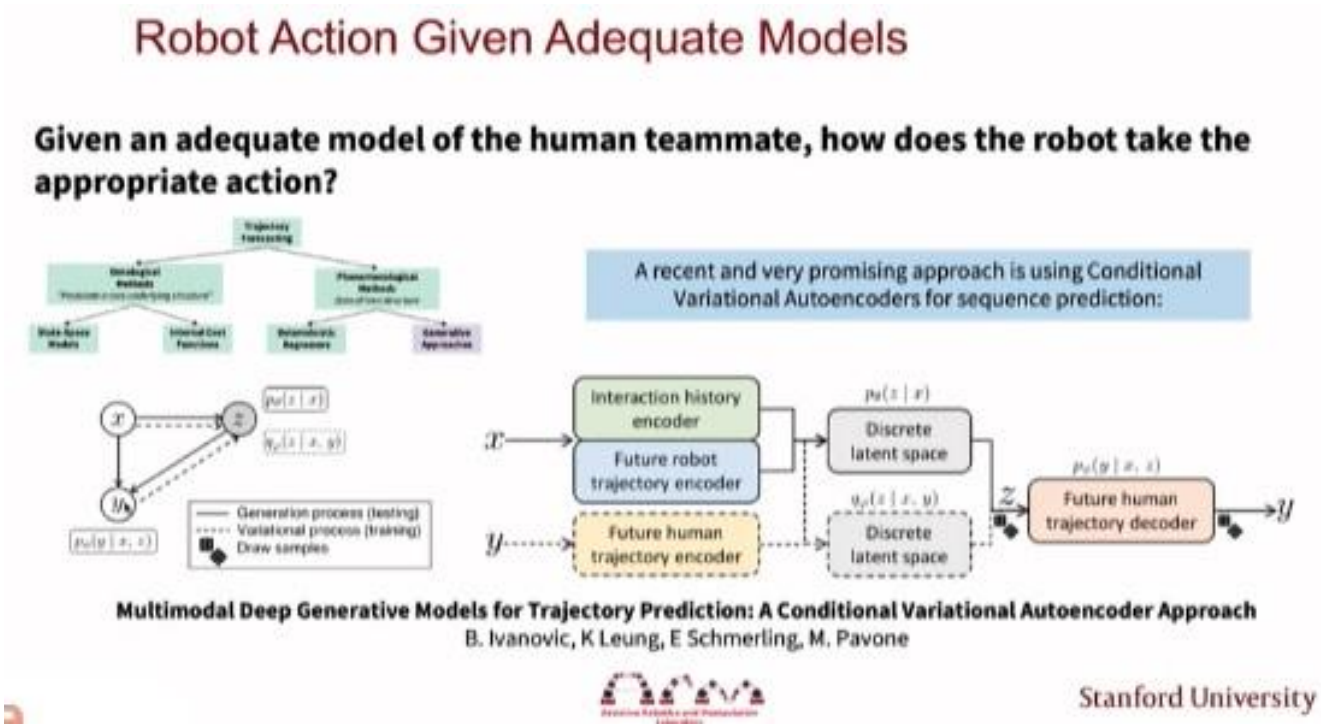
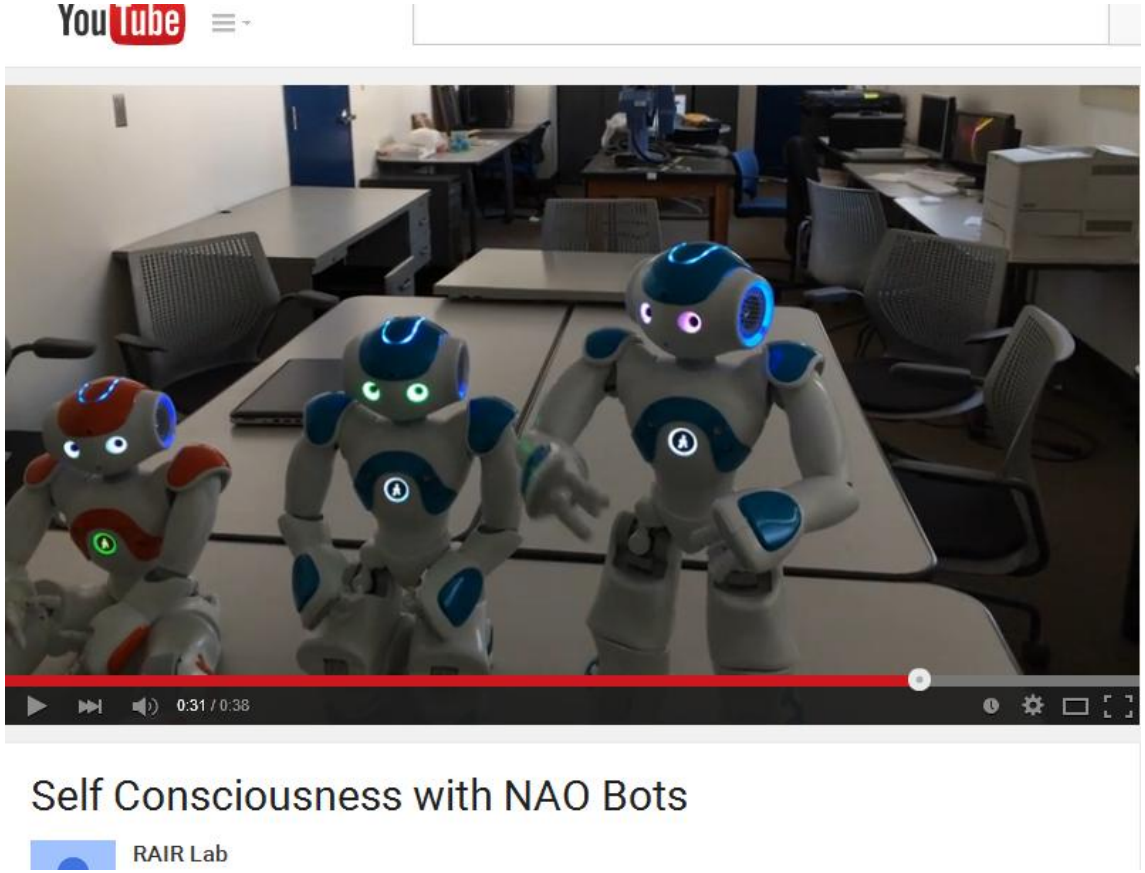


Bay Area robotics

- Pneubotics: metal-less "soft" robots (capable, for example, of handling food).

Robots

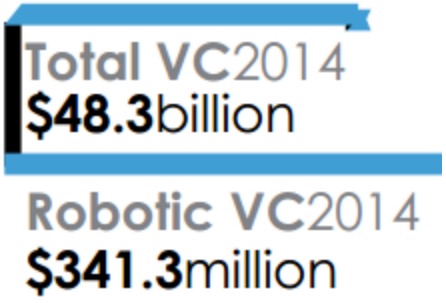
2015: Selma Bringsjord's robot solves the "wise men" riddle



Robots

2015: $1 billion investment in robotics in the USA, of which 3/4th in the Bay Area

2015: Toyota Research Institute (TRI), with a $1 billion 5-year budget, headed by former DARPA executive Gill Pratt and based at Stanford and MIT



Robots

Future applications:

- Surgery (Intuitive Surgical, Verb Surgical)
- Cars
- Agriculture
- Mining
- Exoskeleton
- Older care
- Cleaning
- Inspection
- Underwater

Robots

Applications:

Surgery

DaVinci surgeon assistant
(Intuitive Surgical, 2000)

INTUITIVE SURGICAL®

Verb Surgical: Google +
Johnson & Johnson (2015)

VERB SURGICAL

WIRED

DAVEY ALBA BUSINESS 12.10.15 6:15 PM

GOOGLE'S VERILY IS SPINNING OFF 'VERB,' A SECRETIVE ROBOT-SURGERY STARTUP

Smart Tissue Autonomous Robot
(Peter Kim , Washington, 2016)

Children's National™

Robots

Applications:

Surgery

Artas

Medtech

Medrobotics

Mako surgical robots

Robots

Applications:

Dental Surgery

Chinese robot dentist is first to fit implants in patient's mouth without any human involvement

Xian
Sep 2017

Robots

Applications:

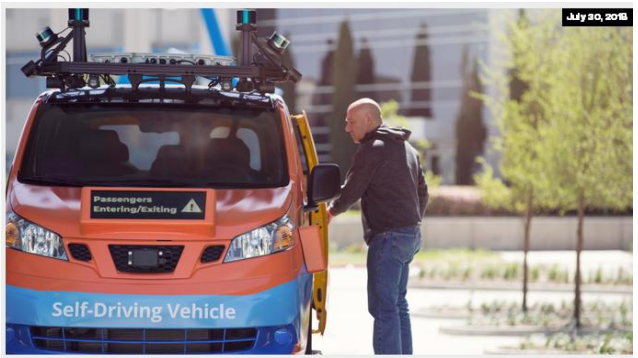
Self-driving car

Google Autonomous Car Spinoff Waymo Builds Town As Test Track

Robots

Applications:

Self-driving car



Drive.ai's autonomous vehicle pilot program launches today

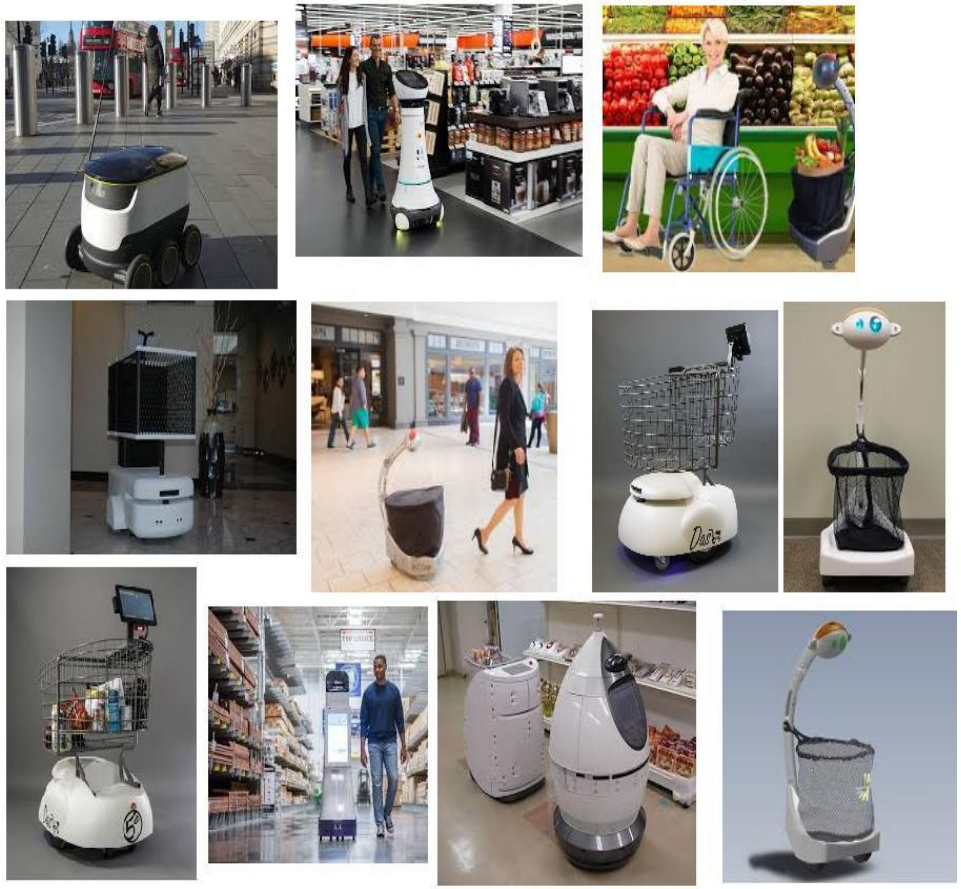
The company's self-driving cars are taking to the streets in Frisco, Texas

August 23, 2017 Walmart TODAY

Walmart, Google Partner to Make Shopping Even Easier – Here's How

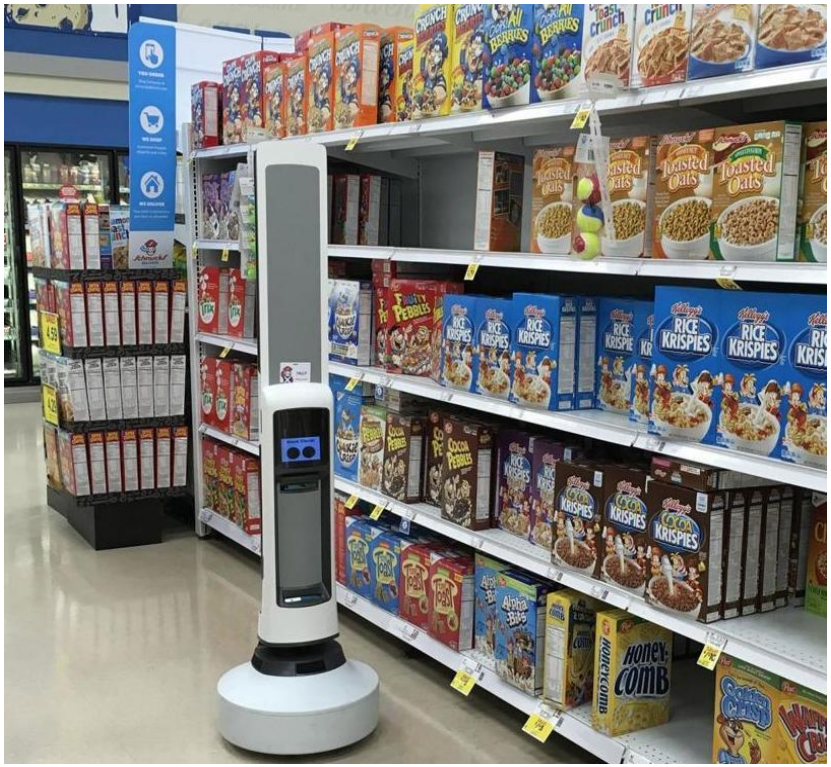
What is a Robot?

Shopping robots an evolution of the shopping cart



What is a Robot?

Inventory robots



Simbe

REUTERS

OCTOBER 26, 2017 / 7:29 PM / 9 MONTHS AGO

Wal-Mart's new robots scan shelves to restock items faster

Forbes

Walmart's Robots Are No Replacement For Humans

What is a Robot?

Delivery robots

Starship

Robomarts

CURBED
SAN FRANCISCO

SAN FRANCISCO | NEWS | TECH

San Francisco bans robots from most sidewalks

Delivery drones permitted only in low-foot traffic zones after Tuesday vote

By Adam Brinklow | Dec 6, 2017, 3:16pm PST

What is a Robot?

Smart suitcase

Forwardx's CX-.

Travelmate

ts

Modobag

What is a Robot?

Warehouse robots

Fetch

Amazon's Kiva

Magazino's Toru

What is a Robot?

CES 2018

Aeolus Robotics

Segway Loomo

Amy Robotics

Qihan Sanbot El

EQL Qubi

Robots

Trends

- nanorobots for eye surgery
- microrobots for construction
- soft robots for food handling, quasi-organic robots with flexible actuators (Pneubots)

Case study: Japan

Takayama Festival of Mechanical Puppets

Case study: Japan

- Bunraku/ puppet theater (~1650)
- "*Automated mechanisms, or karakuri, were originally separate from the puppets, used only in stage machinery or in robot dolls that performed between acts. But the machinery eventually found its way into the bodies of the puppets*" (Chris Bolton)

Case study: Japan

- Robots in comic books (mangas)
  - Gajo Sakamoto's "Tanku Tankuro" (1934)
  - Osamu Tezuka's "Tetsuwan Atomu/ Astro Boy" (1951)
  - Mitsuteru Yokoyama's "Tetsujin 28go/ Iron Man No 28" (1956) and "Jaianto Robo/ Giant Robot" (1967)
  - Hiroshi Fujimoto and Motoo Abiko's cat robot "Doraemon" (1969)
  - Go Nagai's drivable robot "Mazinger Z" (1972)
  - Akira Toriyama's girl robot "Dokuta Suranpu/ Dr Slump" (1980)

Case study: Japan

- Mangas about cyborgs
  - Kazumasa Hirai's and Jiro Kuwata's "Eitoman/ 8 Man" (1963)
  - Shotaro Ishinomori's "Cyborg 009" (1964).

Case study: Japan

- Robots on television
- Anime/cartoons
  - Yoshiyuki Tomino's "Yusha Raidin/ Brave Raideen" (1975), "Voltes V" (1977) and "Gandamu" (1979)
- Special-effects live-action shows (tokusatsu)
  - Shotaro Ishinomori's "Kamen Rider" (1971), "Jinzo Ningen Kikaida/ Android Kikaider" (1972), "Robotto Keiji/ Robot Detective" (1973) and "Ganbare Robocon" (1974).

Case study: Japan

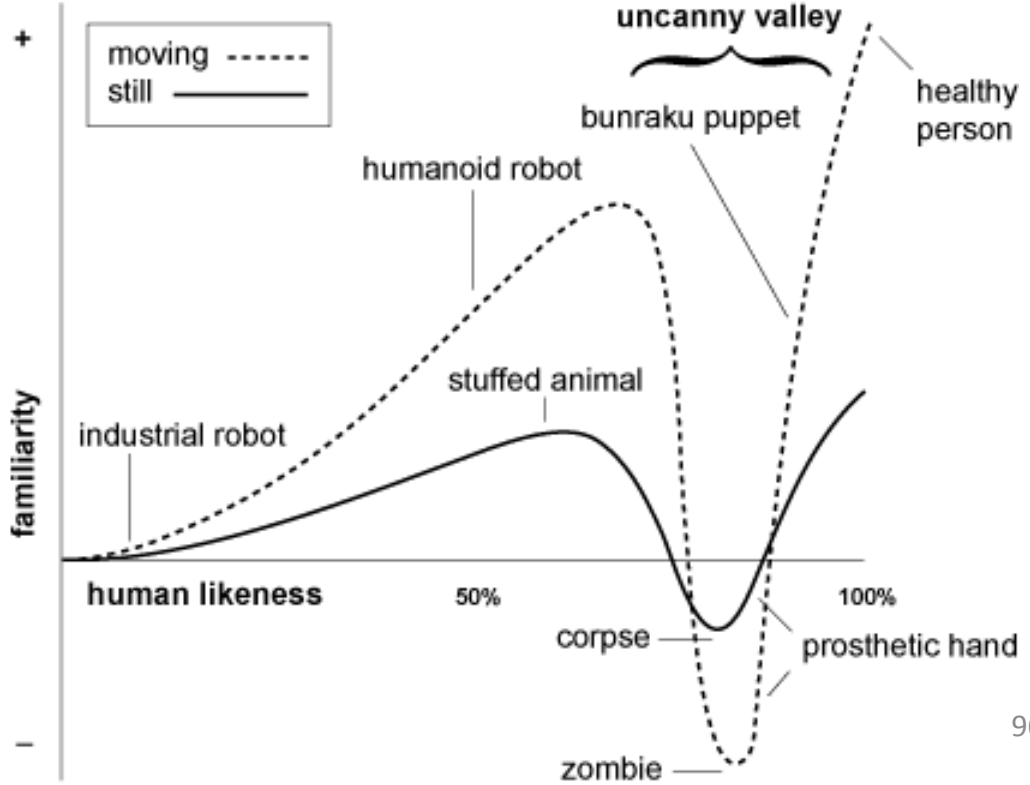
- Oriza Hirata's robot theater

"I, Worker" (2008)

"Sayonara" (2010)

Case study: Japan

- The uncanny valley
  - Ernst Jentsch: “On the Psychology of the Uncanny” (1906)
  - Masahiro Mori: “The Uncanny Valley” (1970)

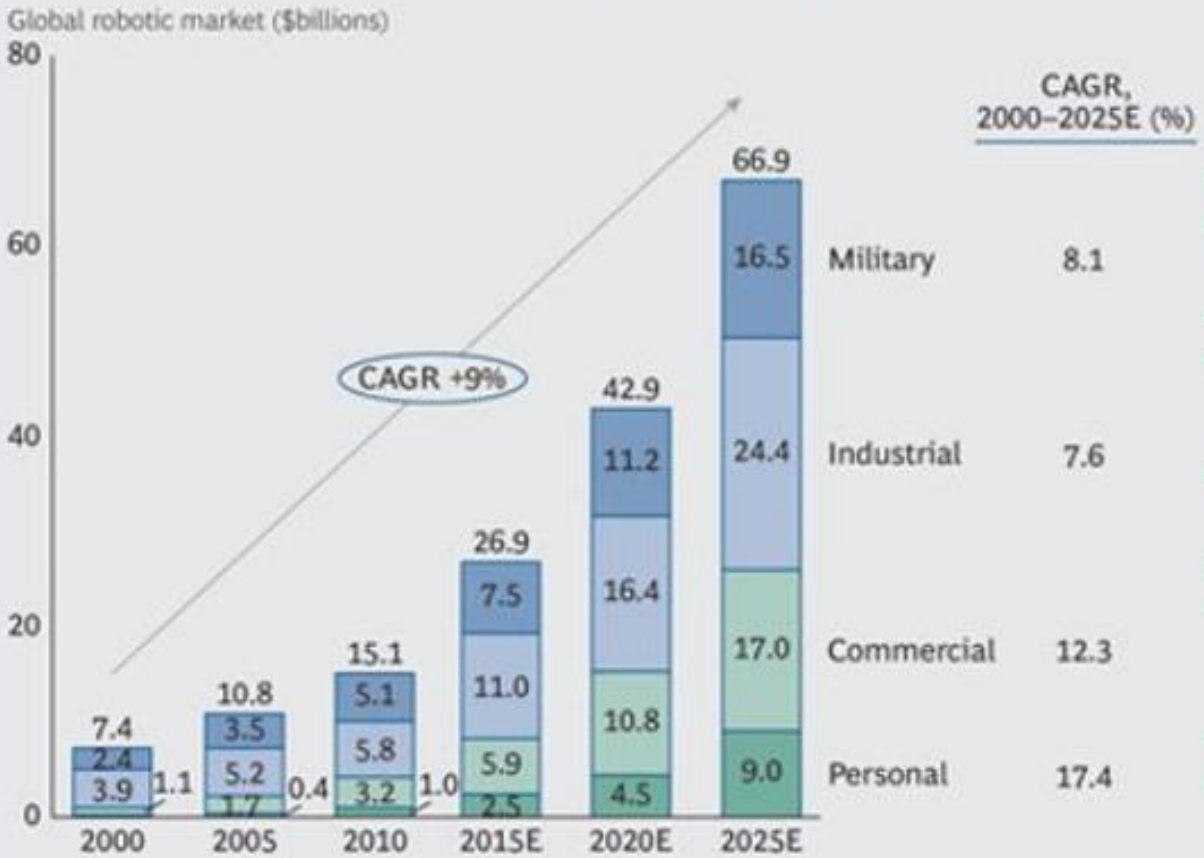


Case study: Japan

- The uncanny valley
  - Japanese robots tend to be female because they look less threatening

$450 Billion on Robotics by 2025: BCG

EXHIBIT 1 | Worldwide Spending on Robotics Is Expected to Reach $67 Billion by 2025



- Military market (2015): $7.5 billion
- UAVs, UGVs, UUVs, and task robots widely used for military applications
- Industrial market (2015): $11 billion
- ~1.2 million robots used in applications such as welding, assembly, and material handling
- In 2012, ~39% of industrial robots sold to auto factories
- Commercial market (2015): $5.9 billion
- Many new applications including medical and surgical robots, agricultural robots, and construction robots
- Personal market (2015): $2.5 billion
- Robots for entertainment, cleaning, education, security, and household applications

Sources: International Federation of Robotics, Japan Robot Association; Japan Ministry of Economy, Trade & Industry; euRobotics; company filings; BCG analysis.
Note: UAV = unmanned aerial vehicle; UGV = unmanned ground vehicle; UUV = unmanned underwater vehicle. Estimates do not include the cost of engineering, maintenance, training, or peripherals.

https://www.bcgperspectives.com/content/articles/business_unit_strategy_innovation_rise_of_robotics/

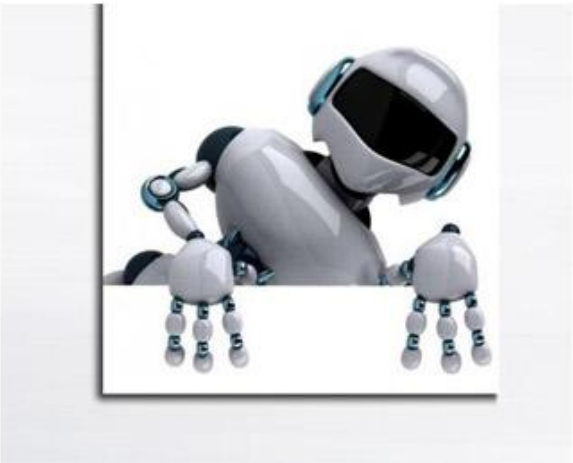
What is missing?

- Learning robots
  - Interacting with the environment
    - Approaching objects
    - Avoiding obstacles
    - Reaching for objects
    - Sorting objects (e.g., on conveyors)
  - Interacting with humans

Ten Trends of Robotics

SILICON VALLEY
RESEARCH INSTITUTE
ARTIFICIAL INTELLIGENCE

Ten Trends of Robotics
August 2018

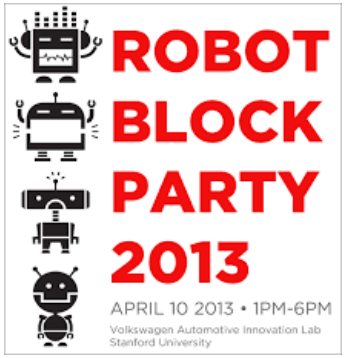


Robots of the 2020s

- Robots that can grasp any kind of object
- Robots that can learn multiple tasks
- Robots that can be trained by ordinary people

Ten Trends of Robotics

1. Robot-as-a-Service. Robots for hire the same way you hire a Uber/Didi car. Anybody can offer a robot for a task at an hourly price.
2. The recruiter of the future will need to know how to recruit robots, not just humans.
3. Ubiquitous sensors and transmitters to provide the robots with information about the environment



Ten Trends of Robotics

4. Dexterity
   - Abhinav Gupta (Carnegie Mellon Univ)
   - Ashutosh Saxena (Cornell Univ)
   - Sergey Levine (Google Brain)

Carnegie Mellon University
School of Computer Science

Cornell University
Computer Science

Research at Google
Google Brain

Robots

4. Dexterity/ Grasping technology

- Picking up things that the robot has never seen before
- And learning to pick up hard and soft objects in different ways
- Self-supervised learning of grasp poses
- Convolutional Neural Networks are de facto standards for computer vision

Robots

4. Dexterity/ Grasping technology

- Traditional approach: perception + planning
- Works well only in ideal conditions and for known objects
- Fails in cluttered environments and for objects never seen before
- "Data-driven" approach infers a grasp for an object without knowing its exact shape

Robots

4. Dexterity/ Grasping technology

- 2004: Andrew Miller's GraspIt simulator (Columbia Univ)
- 2006: Ashutosh Saxena's machine-learning approach (Stanford Univ)
- 2010: Microsoft's Kinect for depth sensing
- 2010: Kurt Konolige's "Projected Texture Stereo" (Willow Garage)

GraspIt!: A Versatile Simulator for Robotic Grasping

Andrew T. Miller

Columbia University, 2001

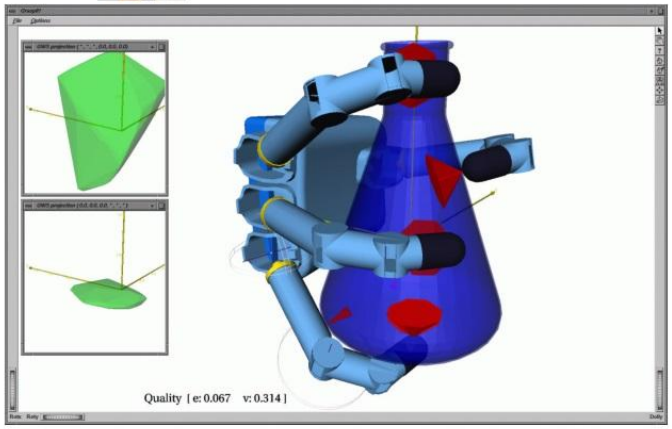


Figure 1.1: The DLR (German Aerospace Center) hand grasping an Erlenmeyer

Robotic Grasping of Novel Objects using Vision

Ashutosh Saxena, Justin Driemeyer, Andrew Y. Ng

Stanford University, Stanford, CA 94305

STAIR1

Robots

4. Dexterity/ Grasping technology

- 2013: David Fischinger (Vienna Univ)
- 2015: Andreas ten Pas (Northeastern)
- 2015: Daniel Kappler, Jeannette Bohg and Stefan Schaal (Max-Planck Institute)
- 2015: Lerrel Pinto & Abhinav Gupta (CMU)

Learning grasps for unknown objects in cluttered scenes

David Fischinger ; Markus Vincze ; Yun Jiang 2013

TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna University of Technology

Cornell University

Using Geometry to Detect Grasp Poses in 3D Point Clouds

Andreas ten Pas and Robert Platt
Northeastern University

Sep 2015

Supersizing Self-supervision: Learning to Grasp from 50K Tries and 700 Robot Hours

Lerrel Pinto and Abhinav Gupta
The Robotics Institute, Carnegie Mellon University

Max Planck Institute for Intelligent Systems
Autonomous Motion
Tübingen Campus

Leveraging big data for grasp planning

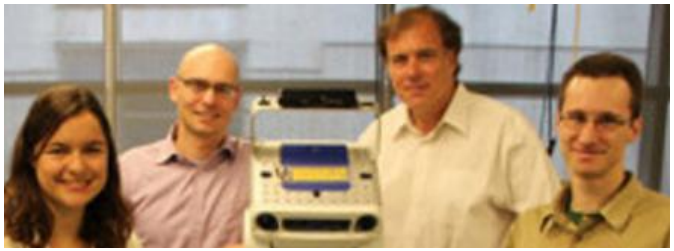
2015 IEEE International Conf

Daniel Kappler ; Jeannette Bohg ; Stefan Schaal

Robots

4. Dexterity/ Grasping technology

- 2015: Chelsea Finn (UC Berkeley)



The New York Times

New Approach Trains Robots to Match Human Dexterity and Speed

Guided by, from left, Chelsea Finn, Sergey Levine and Pieter Abbeel, Brett (the Berkeley Robot for the Elimination of Tedious Tasks) gets the peg into the hole. Peter Earl McCollough for The New York Times

Robots

4. Dexterity/ Grasping technology

- 2018: Keng Peng Tee (Singapore A*STAR) & Gowrishankar Ganesh (Japan AIST)
- 2018: Sergey Levine's QT-Opt (Google-UC Berkeley)

Robots

Grasping technology

- Ashutosh Saxena (Cornell, 2014)
- Abhinav Gupta (Carnegie Mellon, 2015)
- FANUC/Preferred Networks (2015)
- Google Brain (2016)

Cornell University

ASHUTOSH SAXENA

Carnegie Mellon University

The Robotics Institute

Robo Brain

Abhinav Gupta

FANUC

Preferred Networks

Google Brain

Ten Trends of Robotics

4. Dexterity
   - Robert Platt's student Marcus Gualtieri at Northeastern University (2018) used reinforcement learning

Pick and Place Without Geometric Object Models

Marcus Gualtieri, Andreas ten Pas, and Robert Platt

Northeastern University

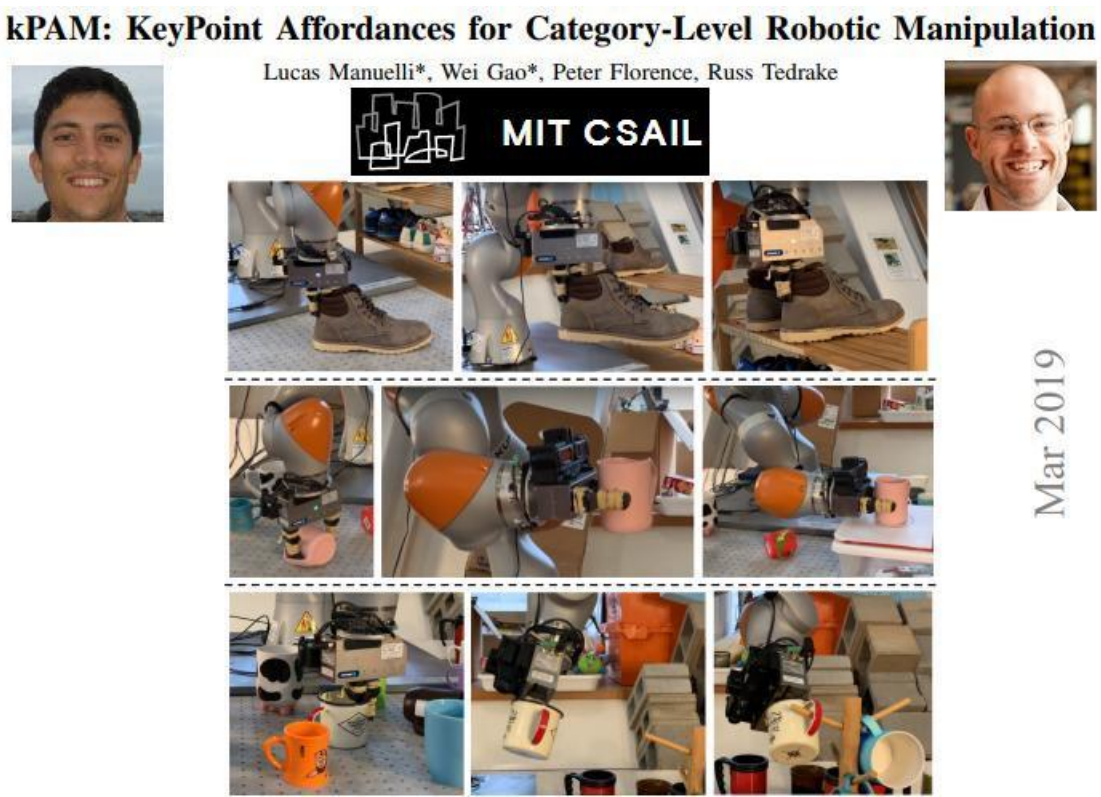
Learning 6-DoF Grasping and Pick-Place Using Attention Focus

Marcus Gualtieri
College of Computer and Information Science
Northeastern University, United States

Robert Platt
College of Computer and Information Science
Northeastern University, United States

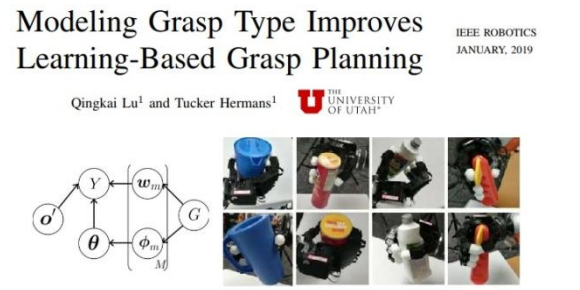
Ten Trends of Robotics

4. Dexterity
   - Lucas Manuelli and Wei Gao at MIT developed kPAM (2019) to model categories of objects



Ten Trends of Robotics

- Robots that can grasp any kind of object (multimodal precision grasping)
  - Qingkai Lu and Tucker Hermans (Univ of Utah, 2019)
  - Alberto Rodriguez (MIT, 2019)
  - Han-Pang Huang (National Taiwan University, 2019)
  - Oliver Kroemer (Carnegie Mellon, 2019)
  - Dieter Fox (Nvidia, 2019)
  - Keng Peng Tee (Singapore, 2019)


Modeling Grasp Type Improves Learning-Based Grasp Planning

IEEE ROBOTICS JANUARY, 2019

Qingkai Lu[1] and Tucker Hermans[1]

THE UNIVERSITY OF UTAH


MIT develops a way for robots to grasp and manipulate objects much faster

Massachusetts Institute of Technology

October 17, 2019

In-Hand Manipulation via Motion Cones

Nikhil Chavan-Dafle, Rachel Holladay, and Alberto Rodriguez
Massachusetts Institute of Technology

Alberto Rodriguez


sensors

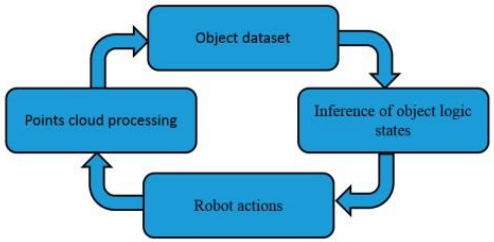
2 April 2019

MDPI

Robot Intelligent Grasp of Unknown Objects Based on Multi-Sensor Information

Shan-Qian Ji, Ming-Bao Huang and Han-Pang Huang *

Robotics Laboratory, Department of Mechanical Engineering, National Taiwan University,



Ten Trends of Robotics

- Robots that can grasp any kind of object (multimodal precision grasping)
  - Oliver Kroemer (CMU, 2019)
  - Dieter Fox (Nvidia, 2019)

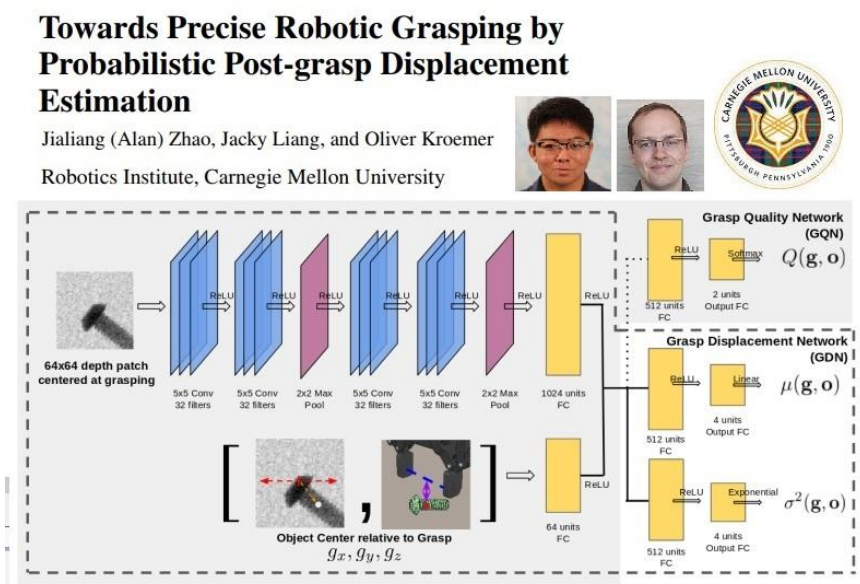
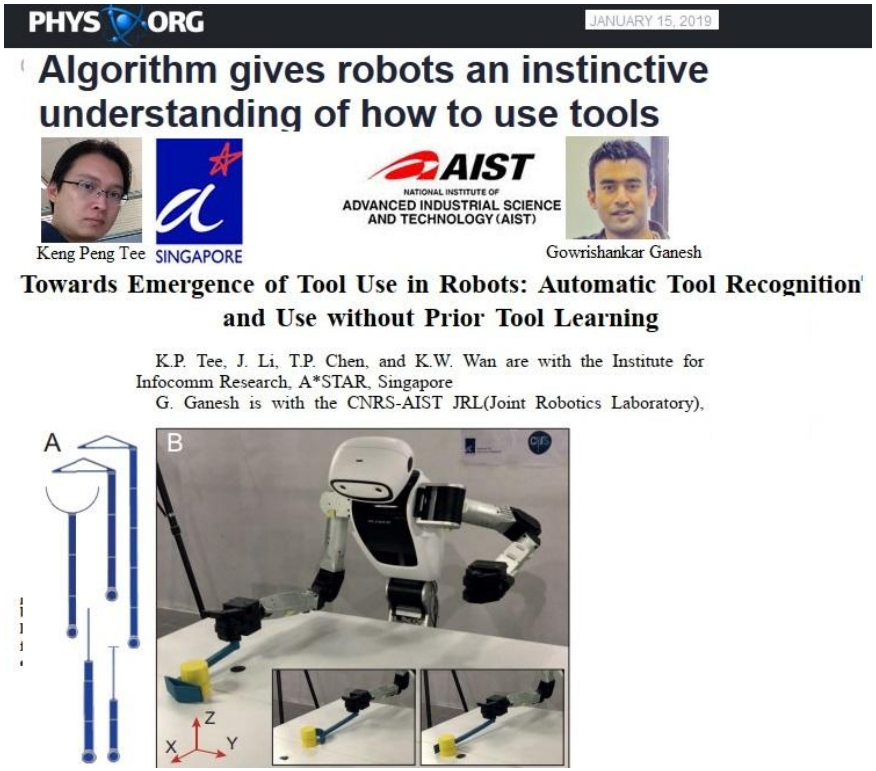


Fig. 3 Grasp Quality Network (GQN) and Grasp Displacement Network (GDN).

Ten Trends of Robotics

- Robots that can grasp any kind of object (multimodal precision grasping)
  - Keng Peng Tee (Singapore, 2019)



PHYS.ORG JANUARY 15, 2019

Algorithm gives robots an instinctive understanding of how to use tools

Keng Peng Tee SINGAPORE

AIST NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

Gowrishankar Ganesh

Towards Emergence of Tool Use in Robots: Automatic Tool Recognition and Use without Prior Tool Learning

K.P. Tee, J. Li, T.P. Chen, and K.W. Wan are with the Institute for Infocomm Research, A*STAR, Singapore

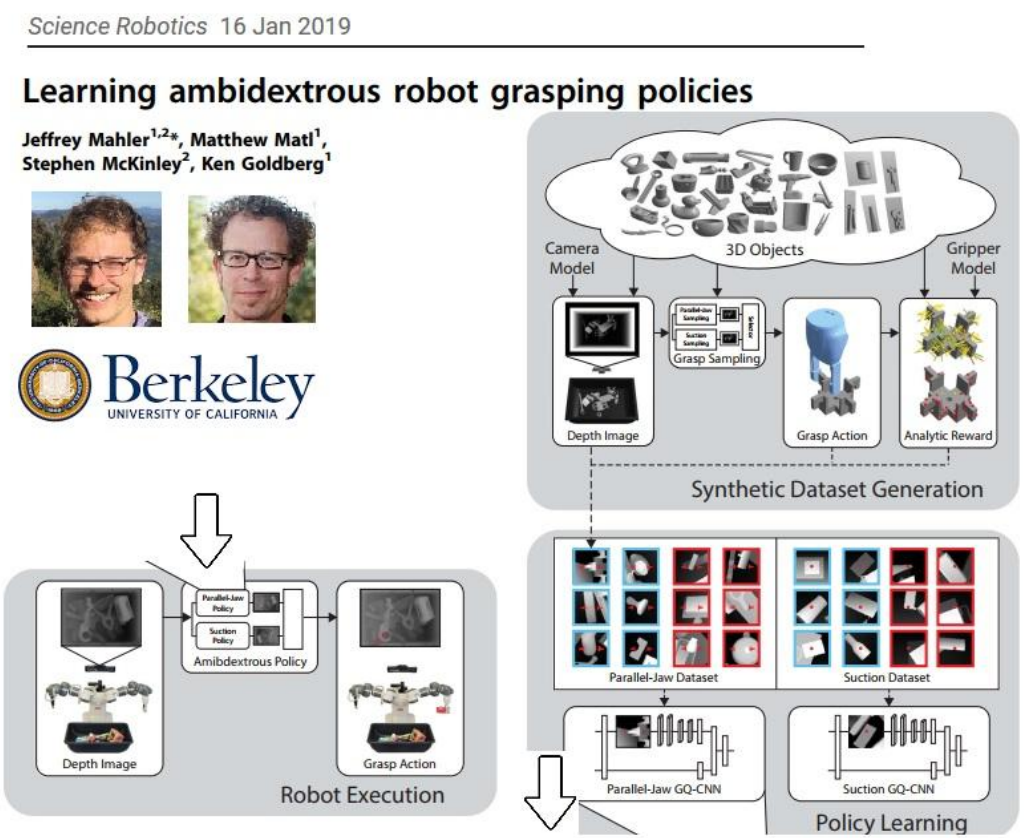
G. Ganesh is with the CNRS-AIST JRL(Joint Robotics Laboratory),

Ten Trends of Robotics

- Robots that can grasp any kind of object (multimodal precision grasping)
  - Mobile manipulation robots: Toyota Human Support Robot (2018), Fetch Robot (2016)

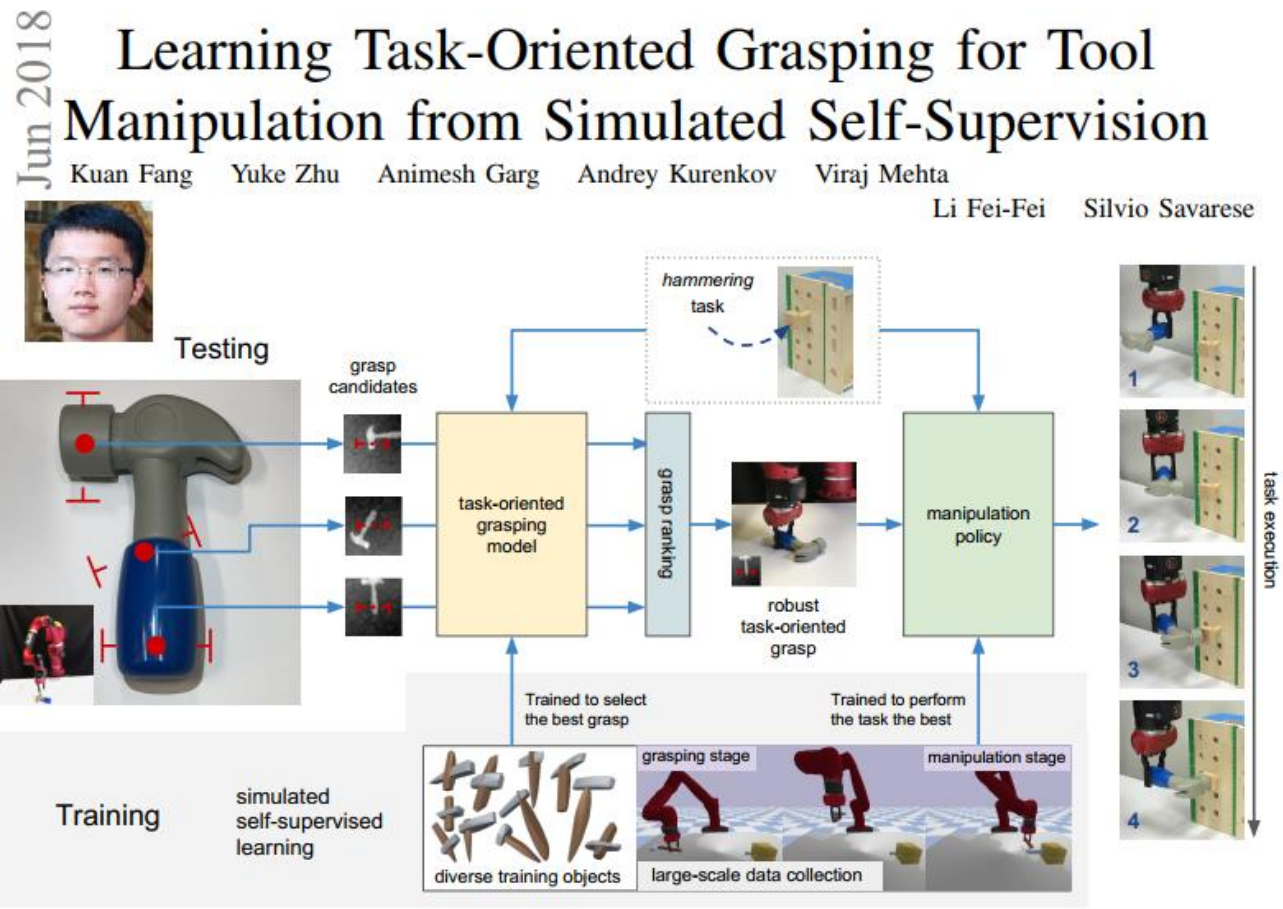
Ten Trends of Robotics

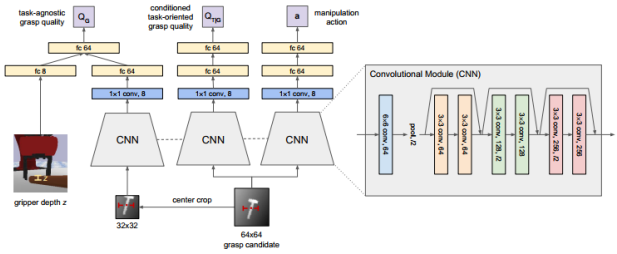
- Robots that can grasp any kind of object (multimodal precision grasping)
  - Ken Goldberg (UC Berkeley, 2019)



Ten Trends of Robotics

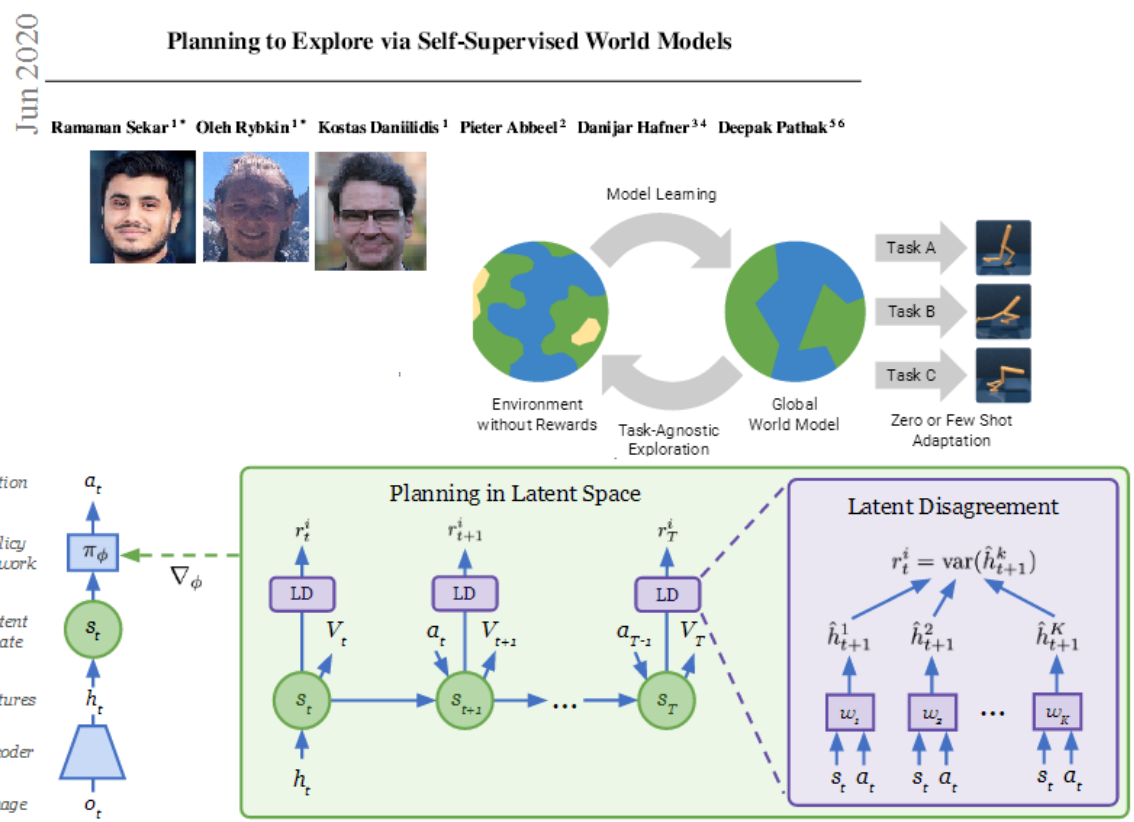
- Robots that can grasp any kind of object and use it
  - Humans can easily decide how to use an object
  - Kuan Fang (Stanford, 2018)





Ten Trends of Robotics

- Robots that can grasp any kind of object and use it
  - Kostas Daniilidis: plan2explore (Univ of Pennsylvania, 2020): self-supervised learning of the world model + reinforcement learning of specific tasks



Ten Trends of Robotics

- Robots that can grasp any kind of object and use it
  - Sudeep Dasari (UC Berkeley): RoboNET (2019), a library of videos about robot actions (learn from other robots)

BAIR

BERKELEY ARTIFICIAL INTELLIGENCE RESEARCH

RoboNet: A Dataset for Large-Scale Multi-Robot Learning

Sudeep Dasari[1,4], Frederik Ebert[1], Stephen Tian[1], Suraj Nair[2], Bernadette Bucher[3], Karl Schmeckpeper[3], Siddharth Singh[3], Sergey Levine[1], Chelsea Finn[2]

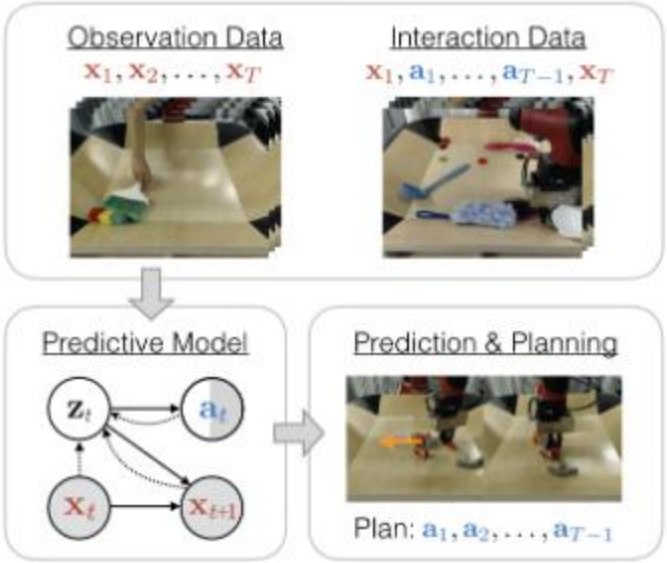
UC Berkeley[1], Stanford University[2], University of Pennsylvania[3], CMU[4]

Ten Trends of Robotics

- Robots that can grasp any kind of object and use it
  - Kostas Daniilidis (Upenn, 2019): learn from observing humans

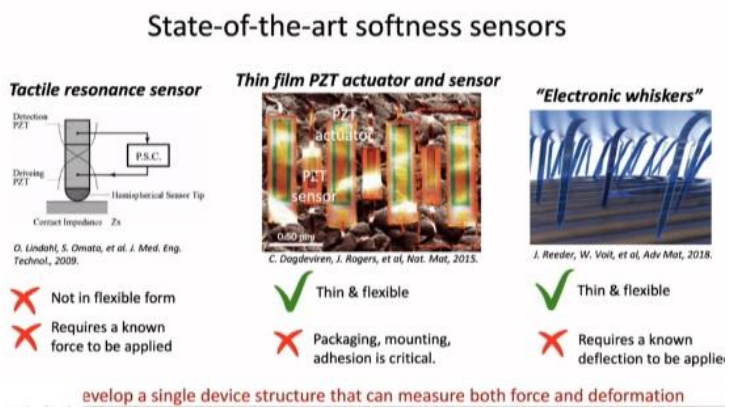
Learning Predictive Models From Observation and Interaction

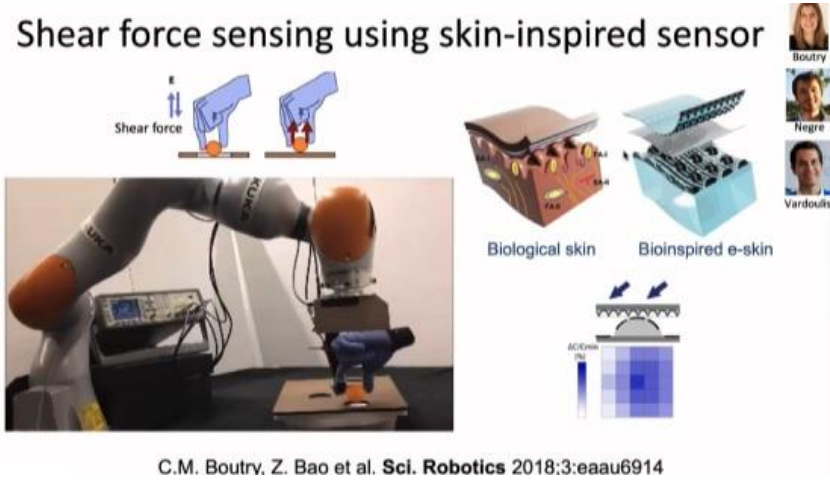
Karl Schmeckpeper[1], Annie Xie[2], Oleh Rybkin[1], Stephen Tian[3],
Kostas Daniilidis[1], Sergey Levine[3], Chelsea Finn[2]
[1]University of Pennsylvania, [2]Stanford University, [3]UC Berkeley



Ten Trends of Robotics

- Grasping: compliance (softness)
  - Zhenan Bao (Stanford)





Ten Trends of Robotics

- Grasping: compliance (softness)
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Stanford
ENGINEERING

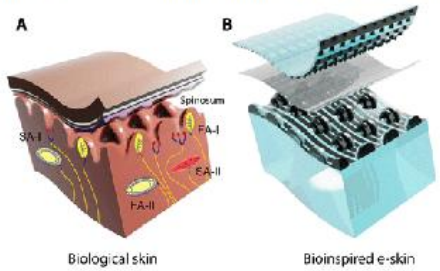
An electronic glove gives robots a sense of touch

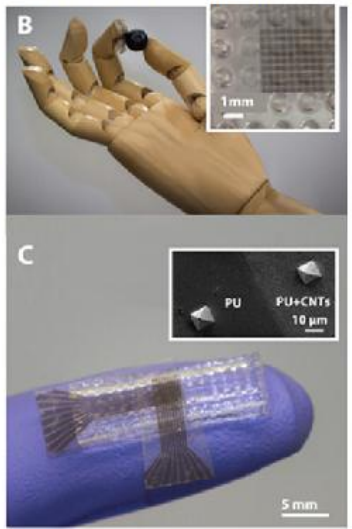
November 21, 2018 | By Tom Abate

A hierarchically patterned, bioinspired e-skin able to detect the direction of applied pressure for robotics

Clementine M. Boutry[1], Marc Negre[1], Mikael Jorda[2], Orestis Vardoulis[1], Alex Chortos[1], Oussama Khatib[2] and Zhenan Bao[1,*]

[1]Department of Chemical Engineering, Shriram Center Chemical Engineering, Stanford University





Ten Trends of Robotics

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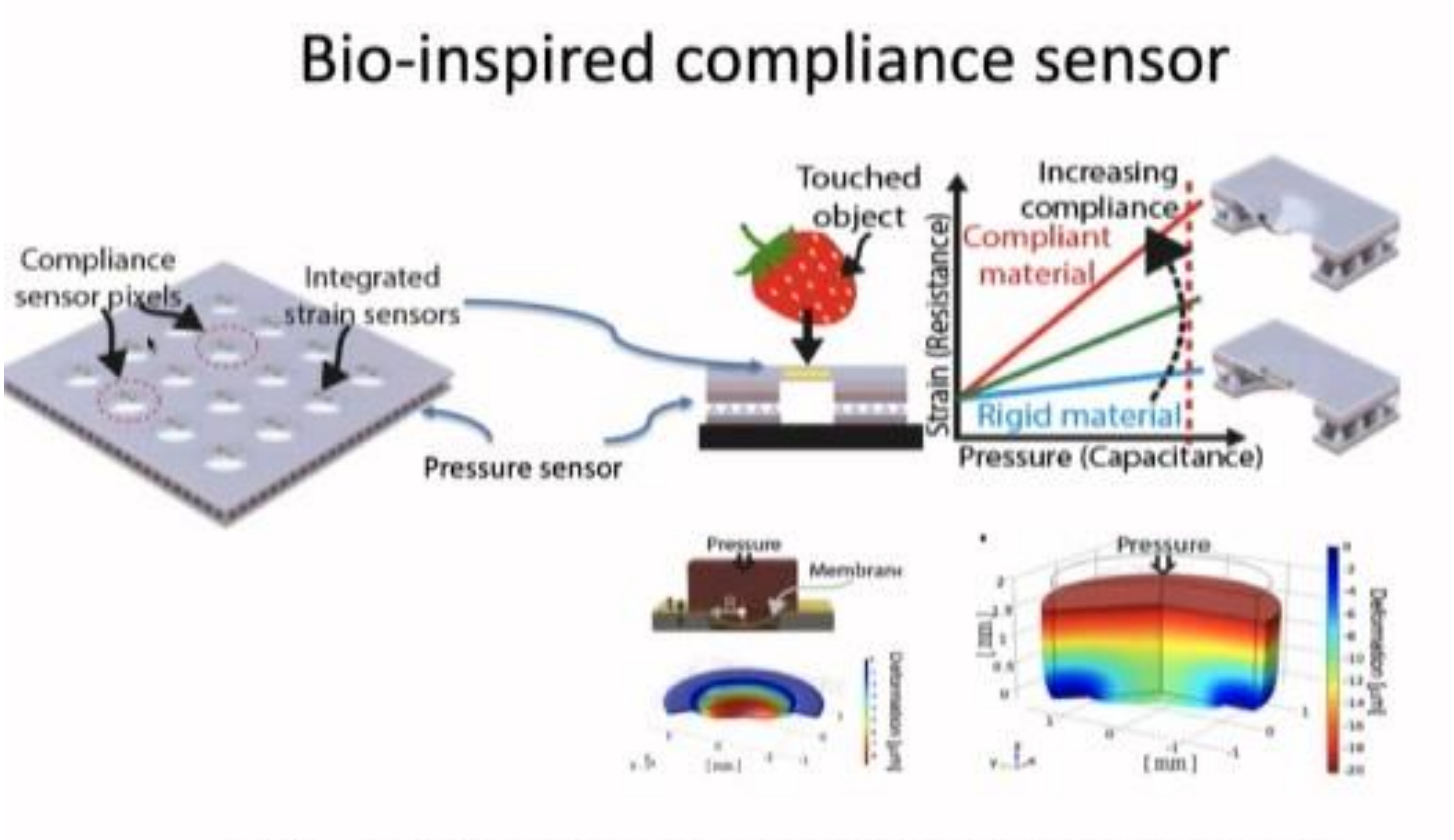
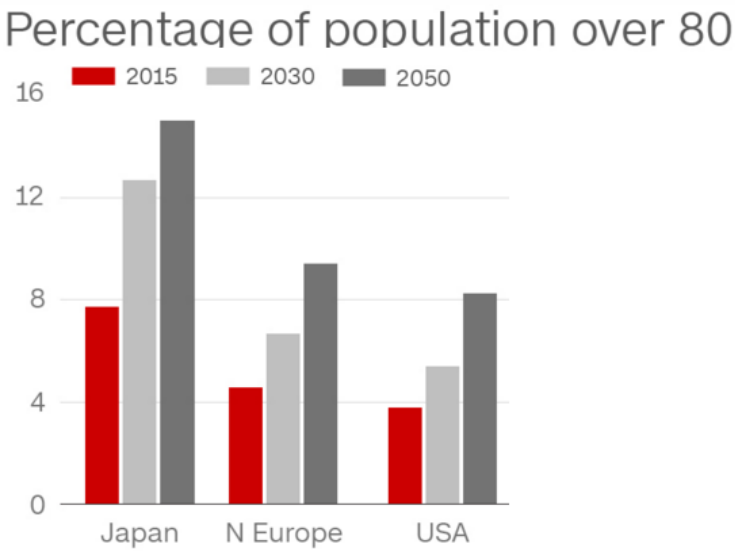
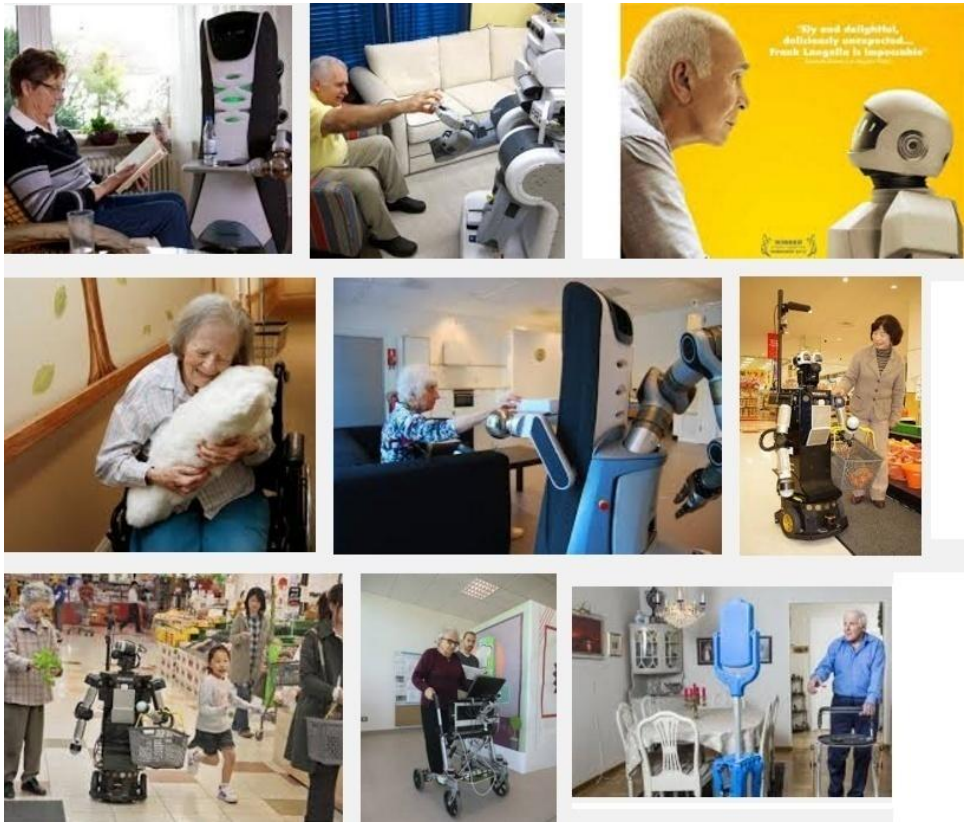


L. Beker, N. Matsuhisa, Z. Bao et al. **Proc. Natl. Acad. Sci. U.S.A.**, 117, 11314-11320, 2020.

Ten Trends of Robotics

5. Robots for an aging society (social companion robots)

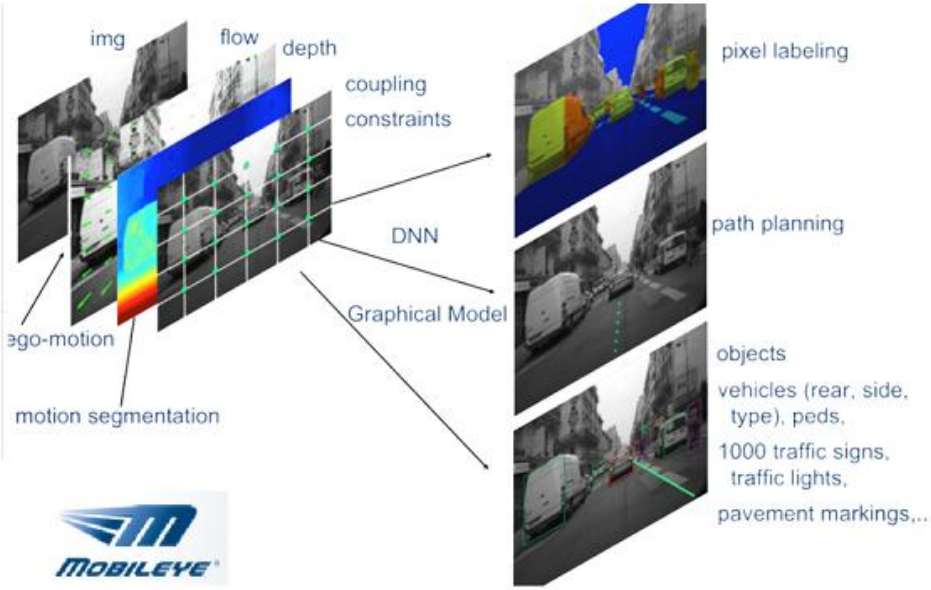




Ten Trends of Robotics

6. Kits for self-driving features
   - Comma.ai (San Francisco, 2015)
   - Tesla + MobilEye (2016)
   - Nvidia + Mercedes (announced in 2017)

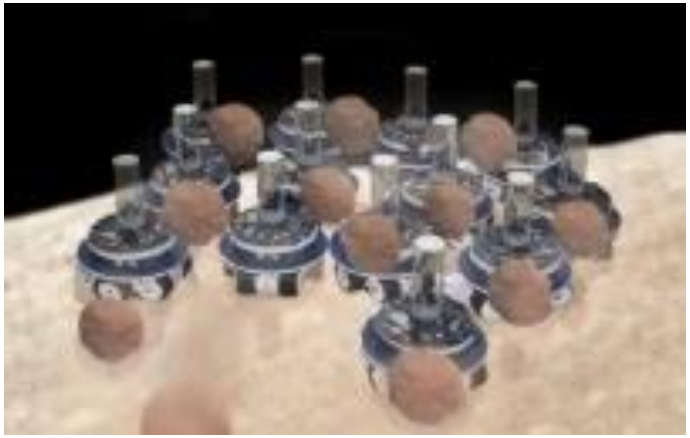
Tesla's Autopilot, powered by Mobileye, is the world's first DNN deployed on the road



Nvidia and Mercedes-Benz to bring an AI car to market within a year

Ten Trends of Robotics

7. “Collaborative intelligence”: robots that can self-organize to solve a problem
   - Harvard Univ
   - Eliseo Ferrante (Belgium)



Ten Trends of Robotics

8. Turning a smartphone into a robot

- Cellbots (2010) by a group of makers in Silicon Valley
- Your phone can be the robot: it has touch, hearing, speech, many more senses… but no legs
- Solution: an Android phone connected to an Arduino with wheels

Ten Trends of Robotics

8. Turning a smartphone into a robot

Robot Intelligence:

- Dexterity
- Mobility
- **Wireless networking**
- **Cloud Robotics**
- **Big Data and Machine Learning**
- **Object Recognition**
- **Speech-to-Speech**
- **Real-time Image-Based Language Translation**

Ten Trends of Robotics

9. Cloud Robotics

- A shared knowledge database that organizes information about the world in a universal format
- A library of programs that can we executed remotely (a “skills library”)
- Masayuki Ibana (Tokyo Univ): the “remote brain” (1993)
- James Kuffner (CMU): “cloud robotics” (2010)
- Ryan Hickman (Google): “cellbots” (2010)

cellbots

Ten Trends of Robotics

- Benefits of cloud robotics
  - The robot as a “thin” client
  - Longer battery life
  - No need for software updates
  - Adaptability to complex situations
  - Collective progress of cloud-enabled robots
  - Large-scale deployment of data-sharing robots

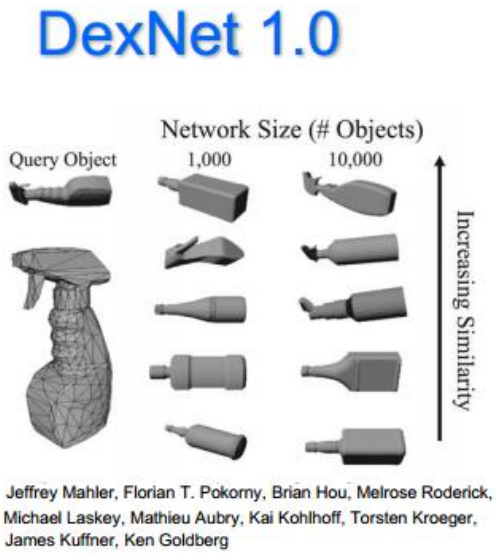
Ten Trends of Robotics

9. Clouds for robots
   - Knowledge sharing among machines – Wikipedia for robots
   - RoboEarth by EU (2010); Rapyuta by EU (2013)
   - Open Ease at University of Bremen (2015)

Ten Trends of Robotics

9. Cloud robotics

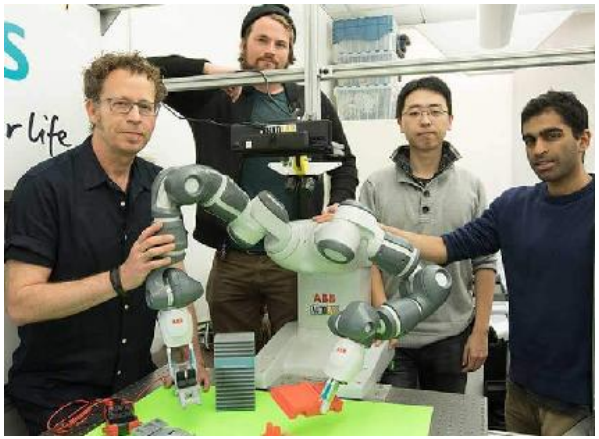
- Cloud Computing + Virtual Reality = High precision dexterity
  - DexNet 1.0 (2015): thousands of 3D models
  - Ken Goldberg (2017): robots practice using virtual objects in a simulated world

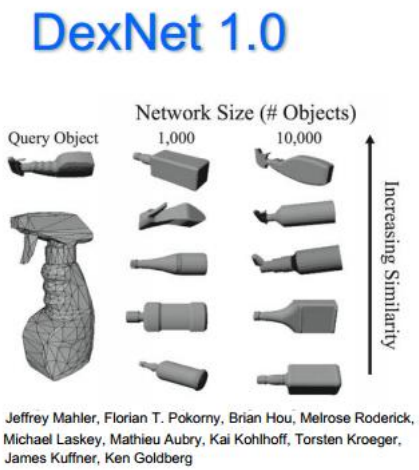


Ten Trends of Robotics

9. Cloud robotics

- Cloud Computing + Virtual Reality = Faster training of robots & Precision Grasping
  - DexNet 1.0 (2015): thousands of 3D models
  - Ken Goldberg (2017): robots practice using virtual objects in a simulated world



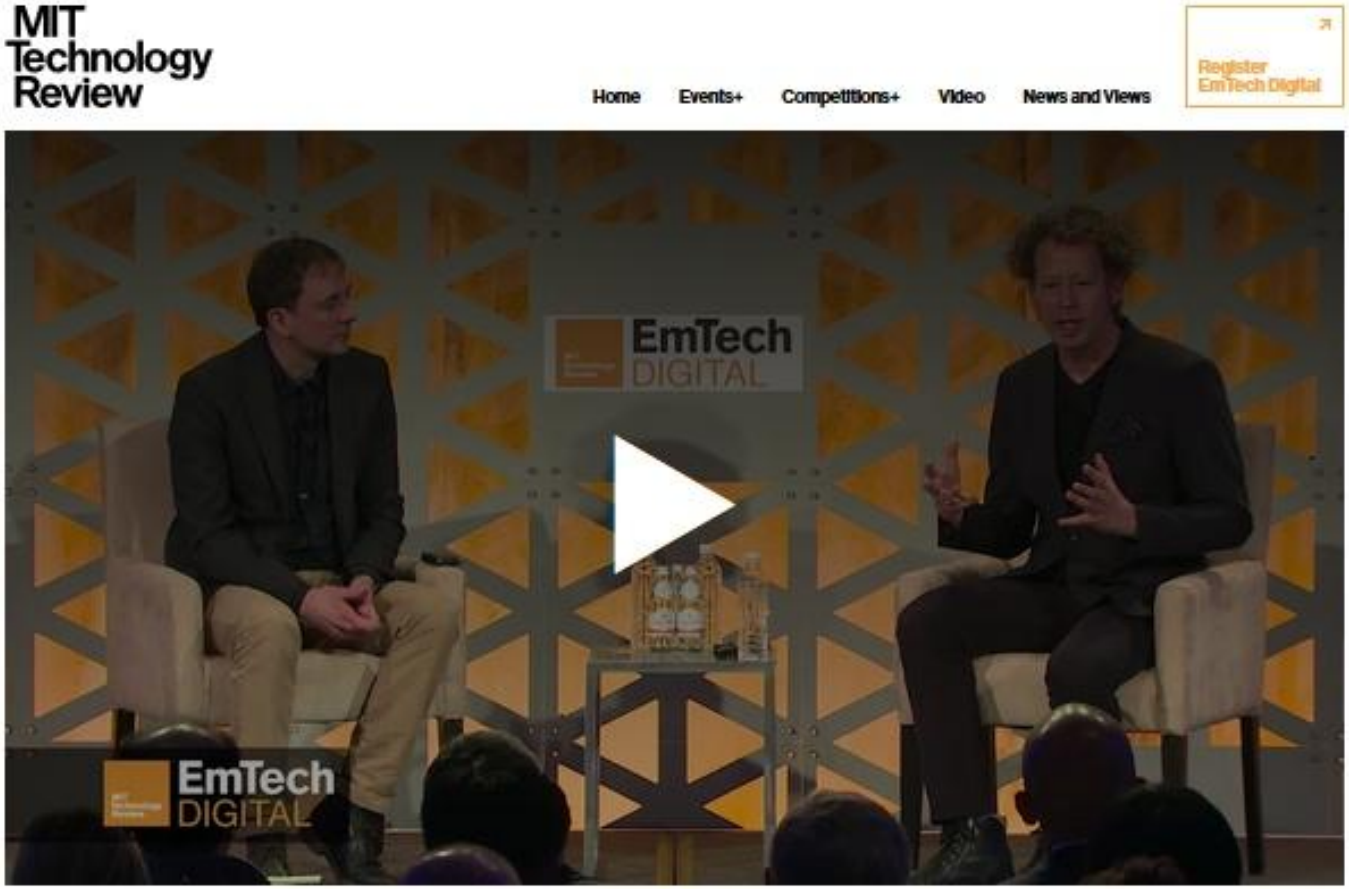


Ten Trends of Robotics

9. Cloud robotics

NEWS

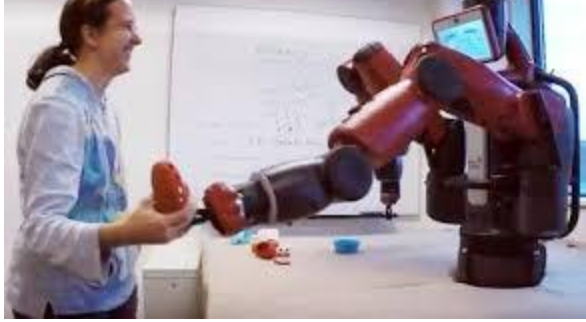
Ken Goldberg's AUTOLAB Takes Robot Grasping to a New Level



Ten Trends of Robotics

10. Learning robots

- Robots that can turn high-level descriptions into specific actions (eg RoboHow, 2012)
- Learning from human demonstrations and advice, not just by imitation (eg RoboBrain at Stanford, 2014)
- Robots that teach other robots? (Stephanie Tellex's "Million Object Challenge", 2016)



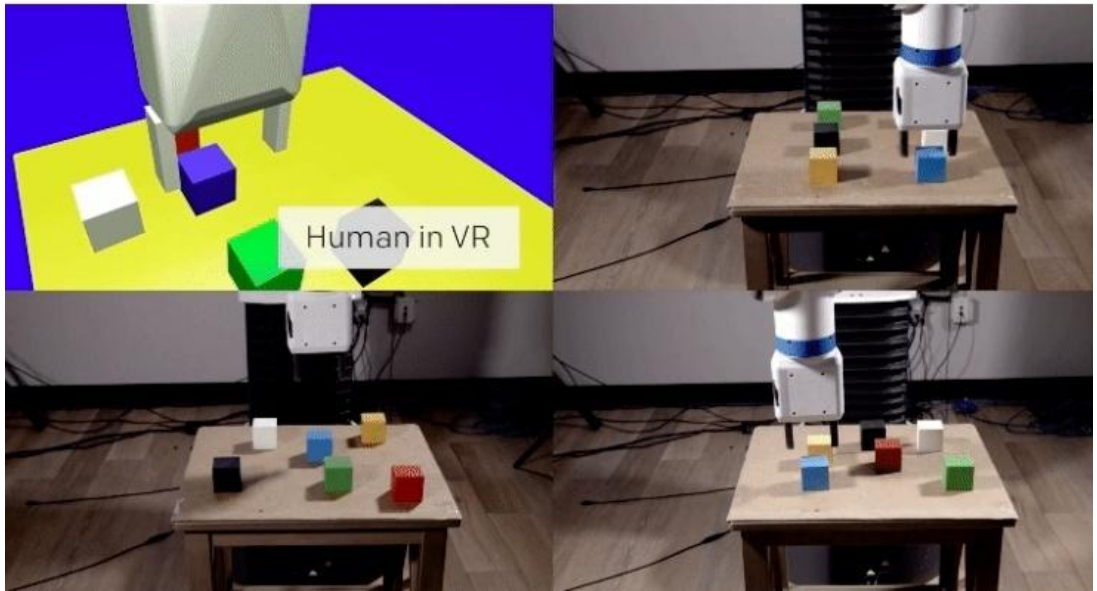
Ten Trends of Robotics

10. Learning robots

- Using VR to train robots
  - Ken Goldberg
  - Suzanne Gildert's Kindred.ai
  - OpenAi

KINDRED

OpenAI MAY 16, 2017



Ten Trends of Robotics

10. Human-like robots

- KindredAI (Canada, 2014)
- SanctuaryAI (Canada, 2018)

KINDRED

Sanctuary AI

Ten Trends of Robotics

IRIDIA

10. Self-organizing swarms of robots

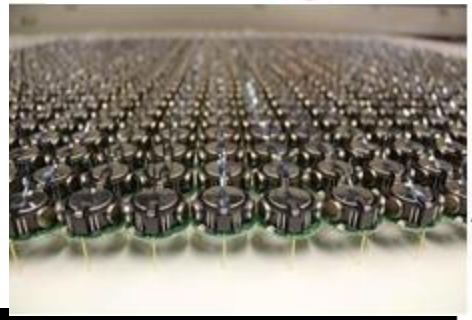
Marco Dorigo in Belgium

Simon Garnier's Alices (New Jersey Institute of Technology)

NJIT

Radhika Nagpal's "kilobot" swarms (Harvard University)

SwarmLab



Nikolaus Correll's tiny robots (University of Colorado)

Dana Randall and Daniel Goldman's "smarticles" (Georgia Tech)

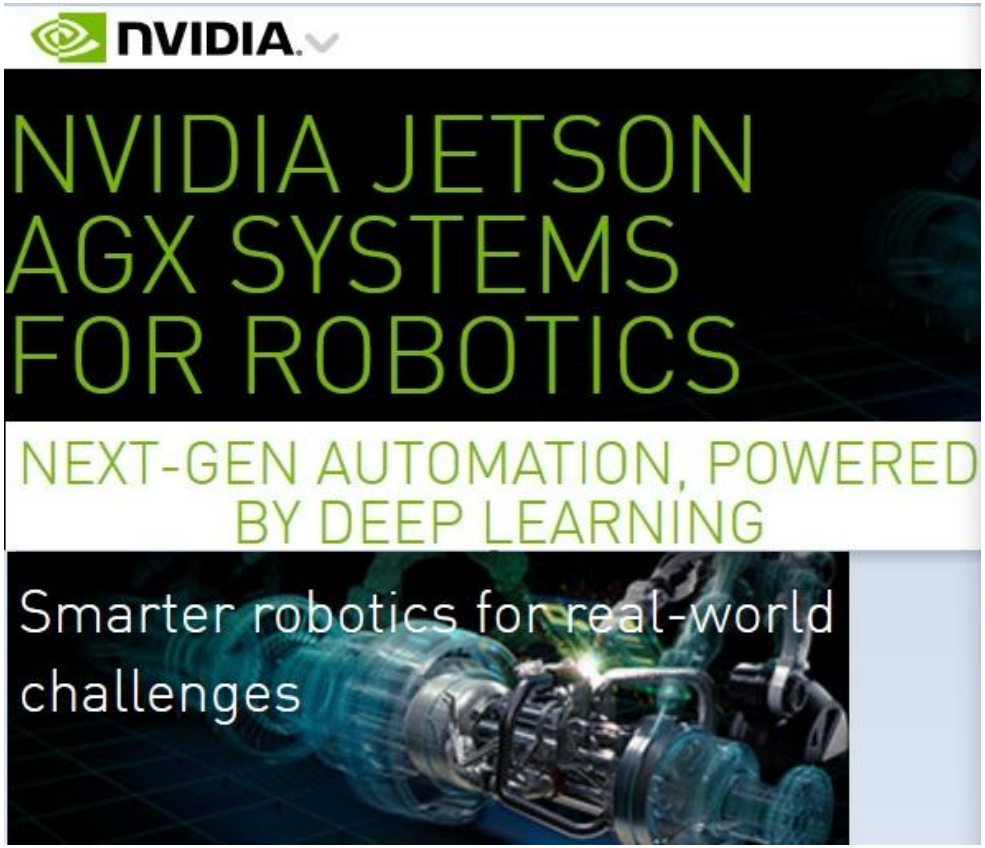
Georgia Tech

Ten Trends of Robotics

Berkeley Open Arms (Pieter Abbeel's team from UC Berkeley, 2019): a low-cost robot arm controlled using a virtual-reality headset ("Blue")

Ten Trends of Robotics

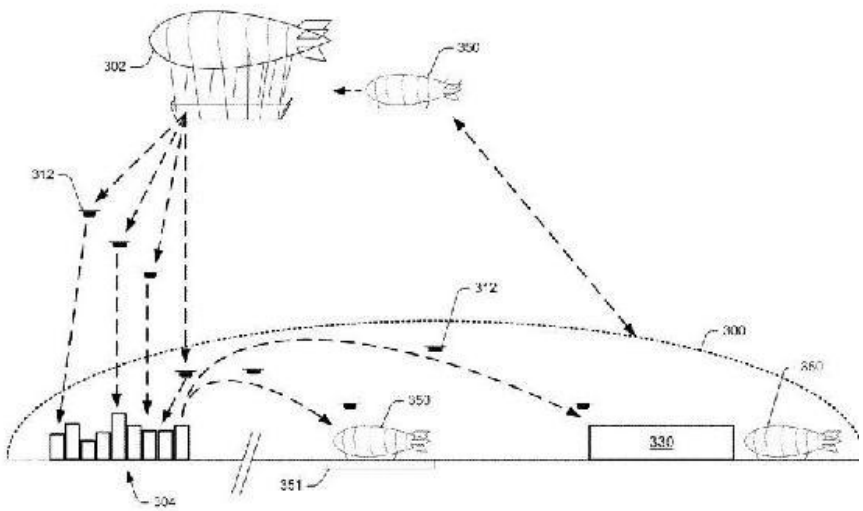
Nvidia ‘s lab dedicated to applications of deep learning to robots (2019)

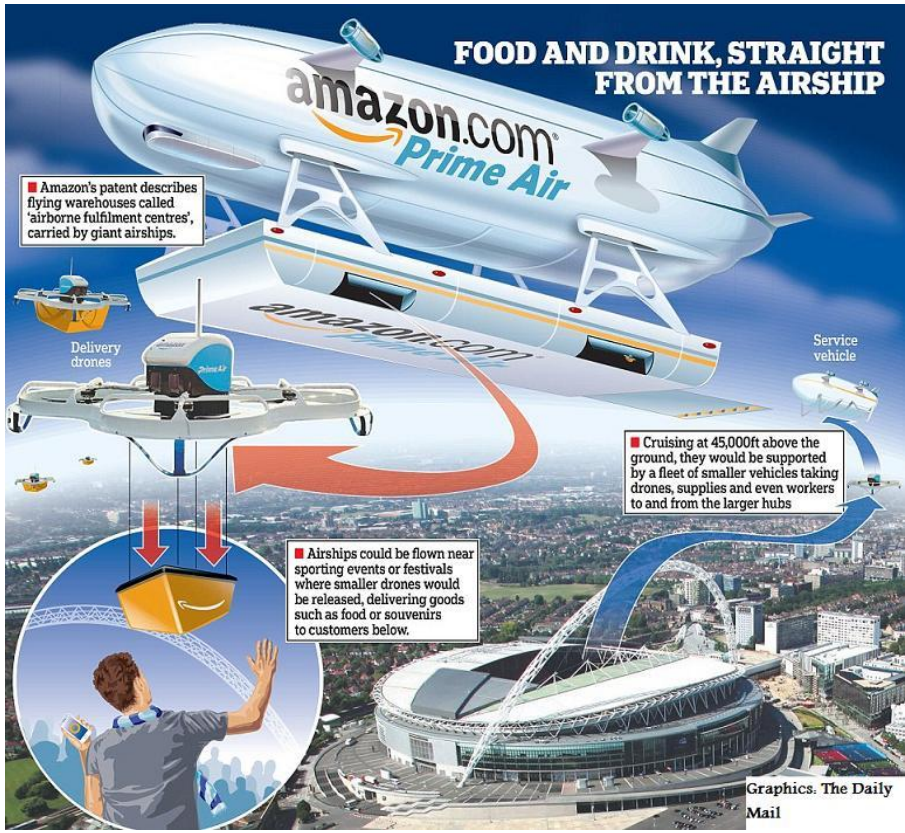


And don’t forget Drones

CNBC 29 Dec 2016

Amazon wins patent for a flying warehouse that will deploy drones to deliver parcels in minutes





Graphics. The Daily Mail

Robots & Covid17

Cruzr robots for temperature screening from China's Ubtech

UVD disinfectant robot from Denmark's Blue Ocean Robotics

Robots for mask detection in parks and for enforcing social distancing

Robots for remote patient interview

Robots & Covid17

Robots for mask detection in parks and for enforcing social distancing

Robots & Covid17

UVD disinfectant robot from Denmark's Blue Ocean Robotics

Robots & Covid17

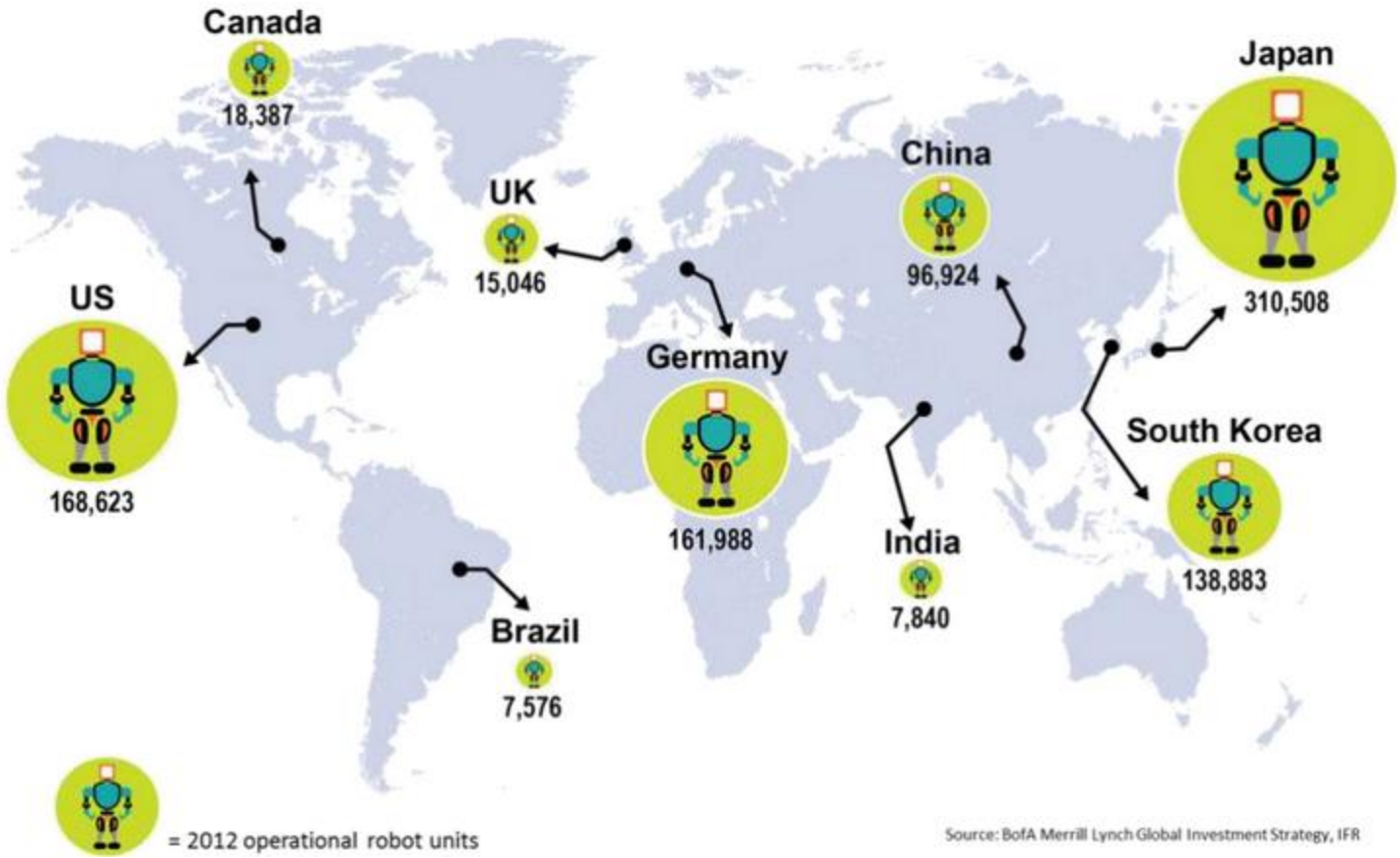
Cruzr robots for temperature screening from China's Ubtech

What else?


LOVE
&SEX
+
TRUTH
ROBOTS
LSR 2017
INTERNATIONAL CONGRESS
ON LOVE AND SEX WITH ROBOTS

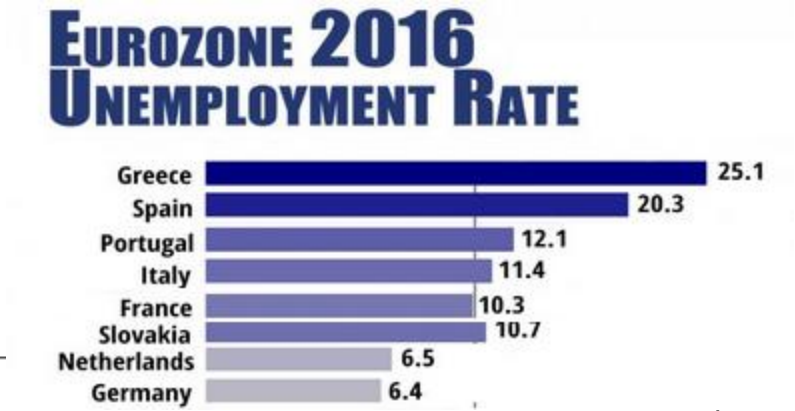
Do robots steal our jobs?

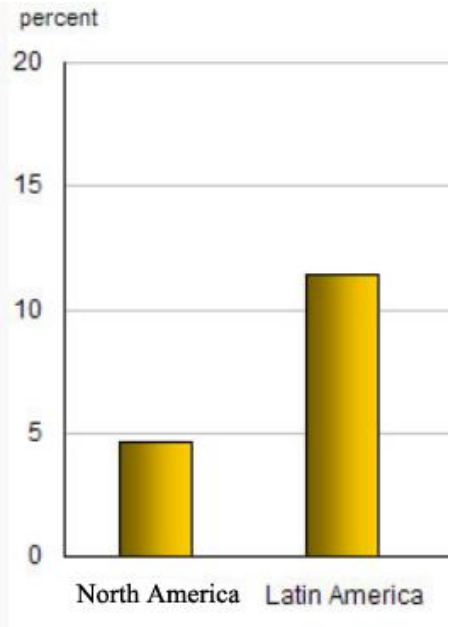
- The countries with the highest number of robots…

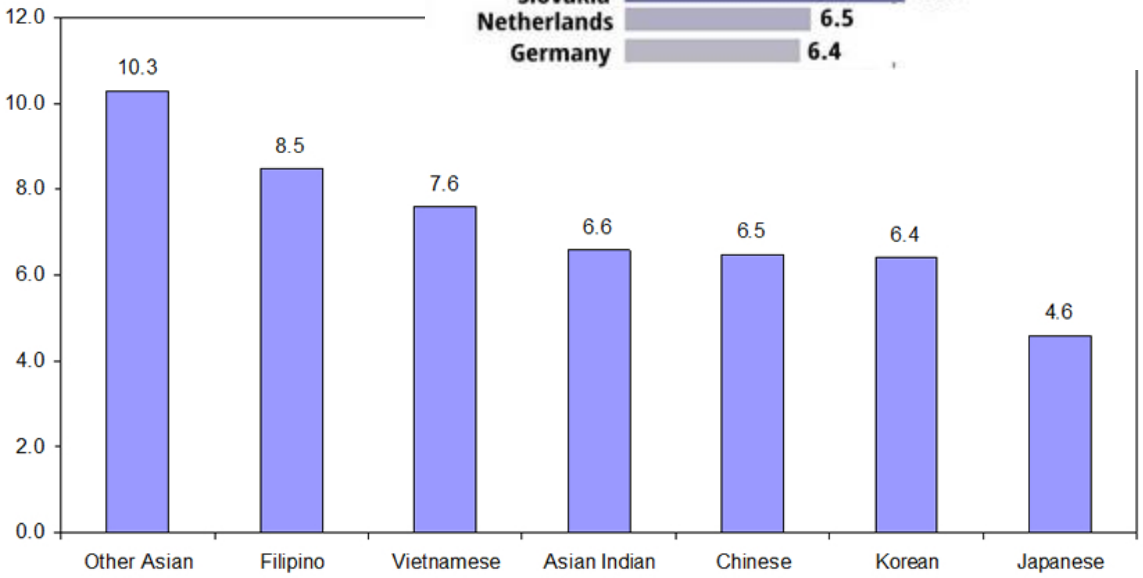


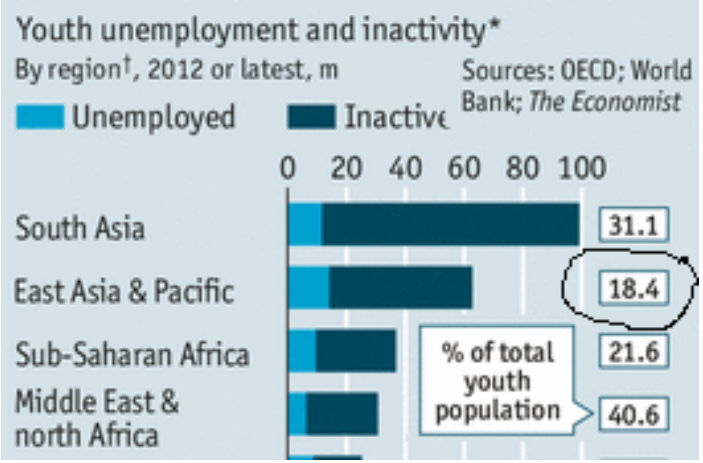
Do robots steal our jobs?

- … are also the countries with the lowest unemployment



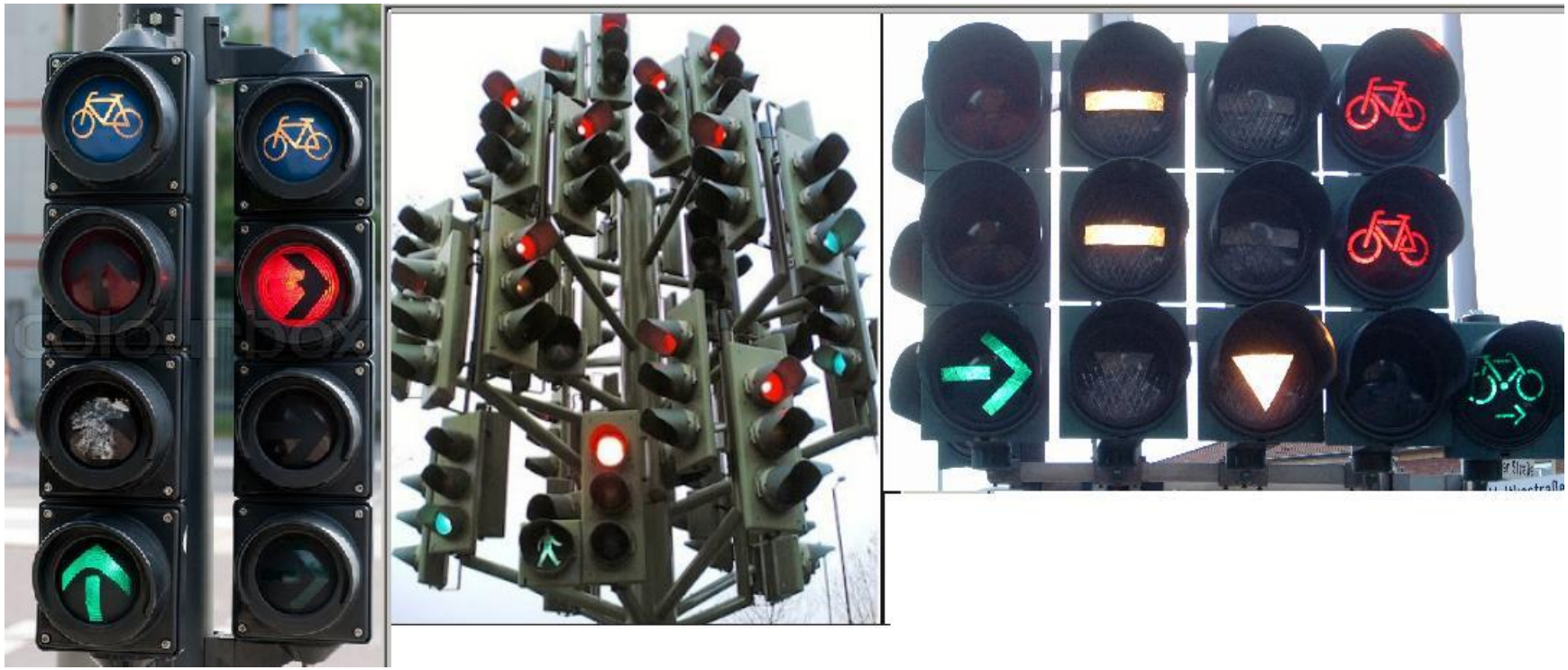






Do robots steal our jobs?

- They already stole millions of jobs: the traffic guards!



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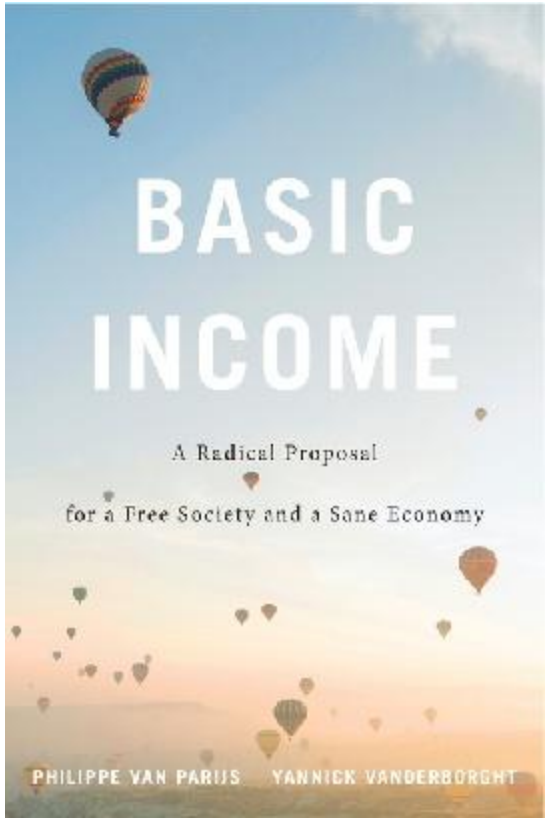
Do robots steal our jobs?

- Maybe it is time to rethink the economy: why not universal basic income?



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Do robots create jobs?

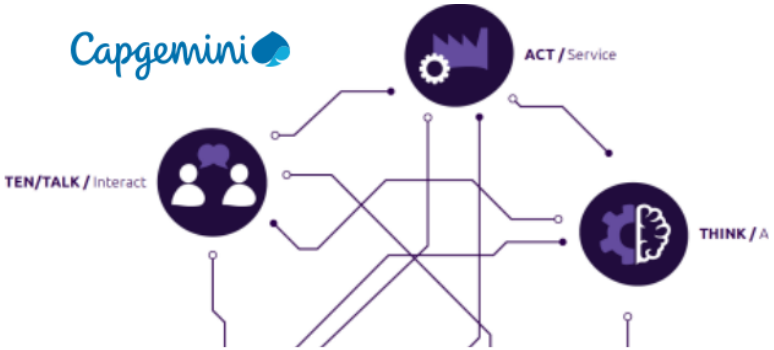
- Gartner: by 2020, AI will generate 2.3 million jobs, exceeding the 1.8 million that it will remove
- CapGemini: AI is creating new jobs in 4 out of 5 companies
- MIT: The jobs that AI will create

Gartner.

STAMFORD, Conn., December 13, 2017

Gartner Says By 2020, Artificial Intelligence Will Create More Jobs Than It Eliminates

AI Will Create 2.3 Million Jobs in 2020, While Eliminating 1.8 Million



The Five Senses of Artificial Intelligence

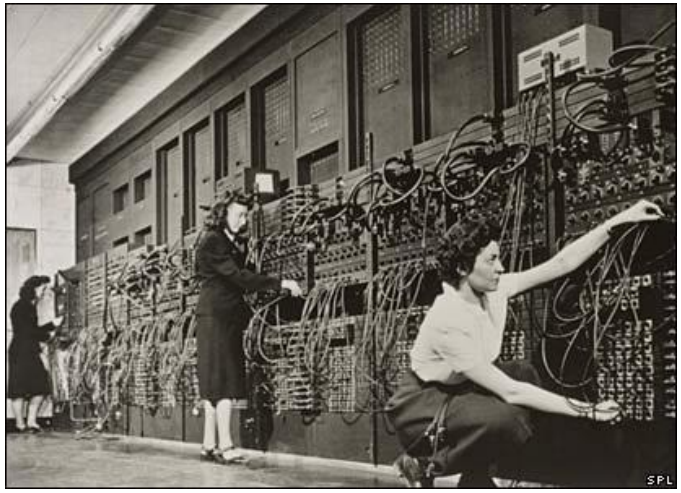
MITSloan Management Review

SUMMER 2017 ISSUE

The Jobs That Artificial Intelligence Will Create

Jobs

- The society of robots will create new jobs that today we can't even imagine.
- Who would have imagined that the same technology that gave us computer automation would create millions of jobs in mobile communications?



Jobs in the Age of Robots

- The Engineer of the Future:
  - The **language of AI** is computational mathematics

equations of backpropagation

$$\delta^L = \nabla_a C \odot \sigma'(z^L)$$

$$\delta^l = ((w^{l+1})^T \delta^{l+1}) \odot \sigma'(z^l)$$

$$\frac{\partial C}{\partial b^l_j} = \delta^l_j$$

$$\frac{\partial C}{\partial w^l_{jk}} = a^{l-1}_k \delta^l_j$$

$$\boldsymbol{P(x) = \frac{\exp(-E(x))}{Z}}$$

> E(x): Energy function

> Z: partition function where $\sum_x P(x) = 1$

Given functions $x(t)$ and $w(t)$, their convolution is a function $s(t)$

$$s(t) = \int x(a)w(t-a)da$$

Written as

$$s = (x * w) \quad \text{or} \quad s(t) = (x * w)(t)$$

$$P(\mathrm{v}, \mathrm{h}^1, \mathrm{h}^2, \mathrm{h}^3) = \underbrace{P(\mathrm{v}|\mathrm{h}^1)P(\mathrm{h}^1|\mathrm{h}^2)}_{\text{Sigmoid Belief Net}}\underbrace{P(\mathrm{h}^2, \mathrm{h}^3)}_{\text{RBM}}$$

$$P(\mathrm{v}|\mathrm{h}^1) = \prod_i P(v_i|\mathrm{h}^1)$$

$$P(\mathrm{h}^1|\mathrm{h}^2) = \prod_j P(h^1_j|\mathrm{h}^2)$$

$$P(\mathrm{h}^2, \mathrm{h}^3) = \frac{1}{Z(W^3)} \exp(\mathrm{h}^{2T} W^3 \mathrm{h}^3)$$

Next…

- See http://www.scaruffi.com/singular for the index of this Powerpoint presentation and links to the other parts