

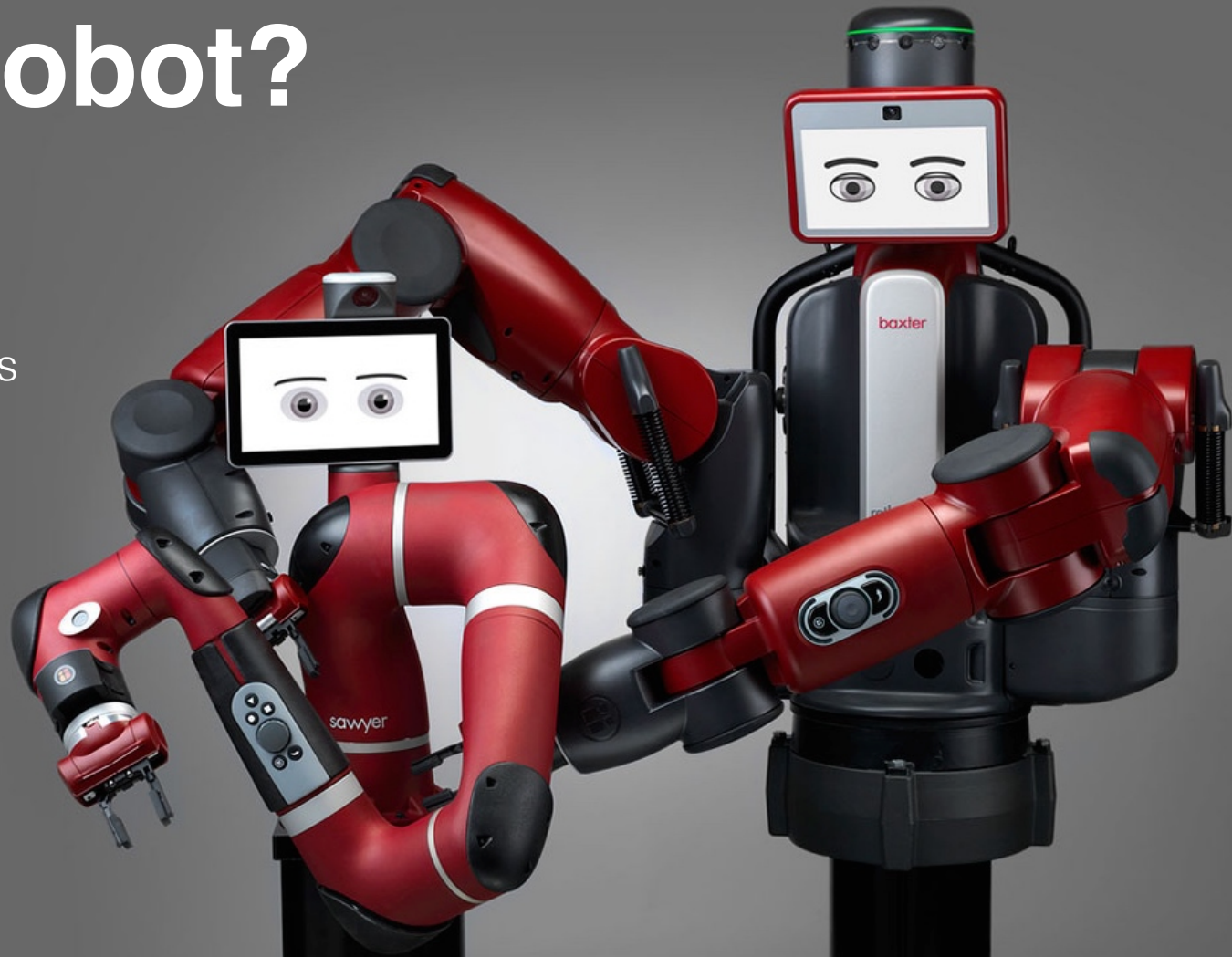
What is a robot?

EECS 367
Intro. to Autonomous Robotics

ROB 511
Robot Operating Systems

Fall 2020

autorob.org



What is a robot?

(don't be shy with your answer)



SINCE 1828

robot

DICTIONARY

THESAURUS

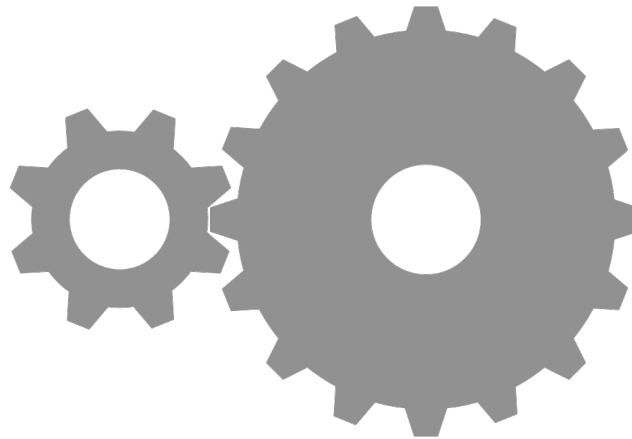
1 : a machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)

- When the next space lander heads for Mars, on board will be dozens of tiny mobile *robots* that will fan out across the Martian landscape, exploring every nook and cranny. —Michael Bowker

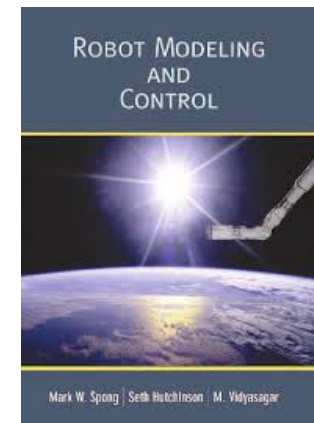
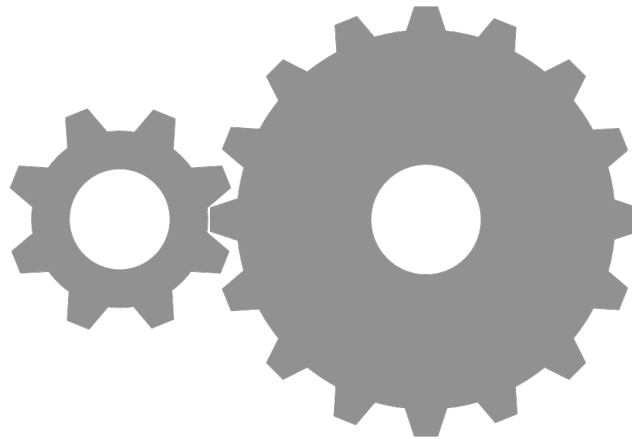
often : such a machine built to resemble a human being or animal in appearance and behavior

- While science fiction *robots* have been capable of independent thought, emotions, even a little cooking and sewing, scientists are finding that endowing a mechanical being with even the most basic human functions is a monumental

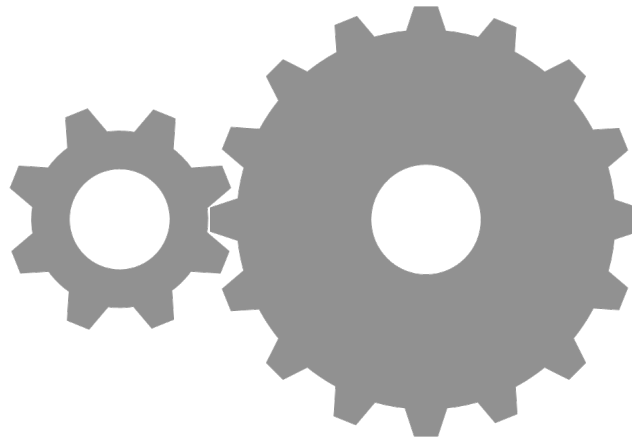
One possible thought...



robot (n):
a machine with actuated joints
whose motion can be programmed



robot (n):
a machine with actuated joints
whose motion can be programmed

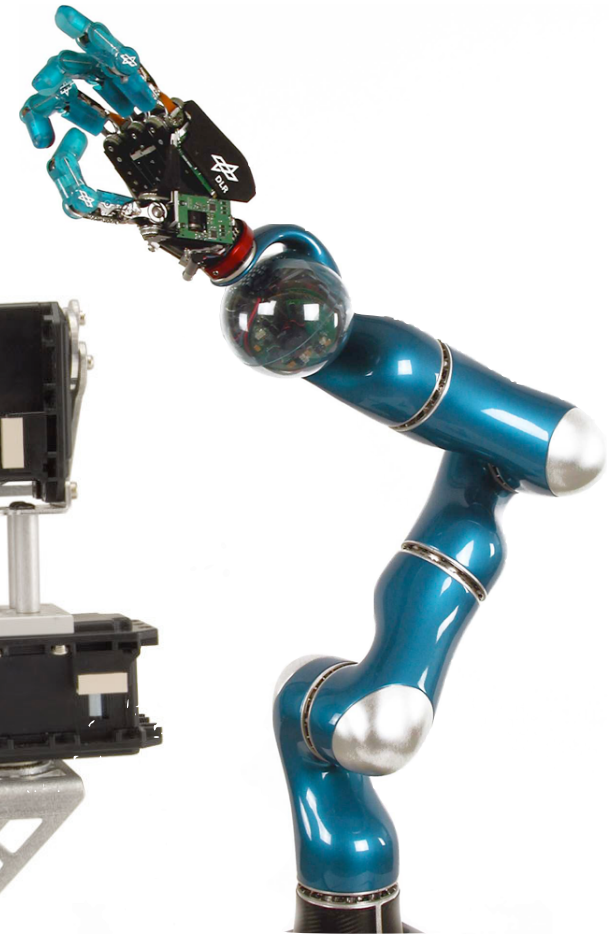


DLR Lightweight arm

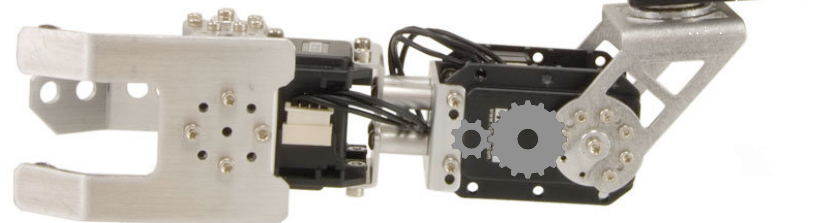


robot (n):
a machine with actuated joints
whose motion can be programmed

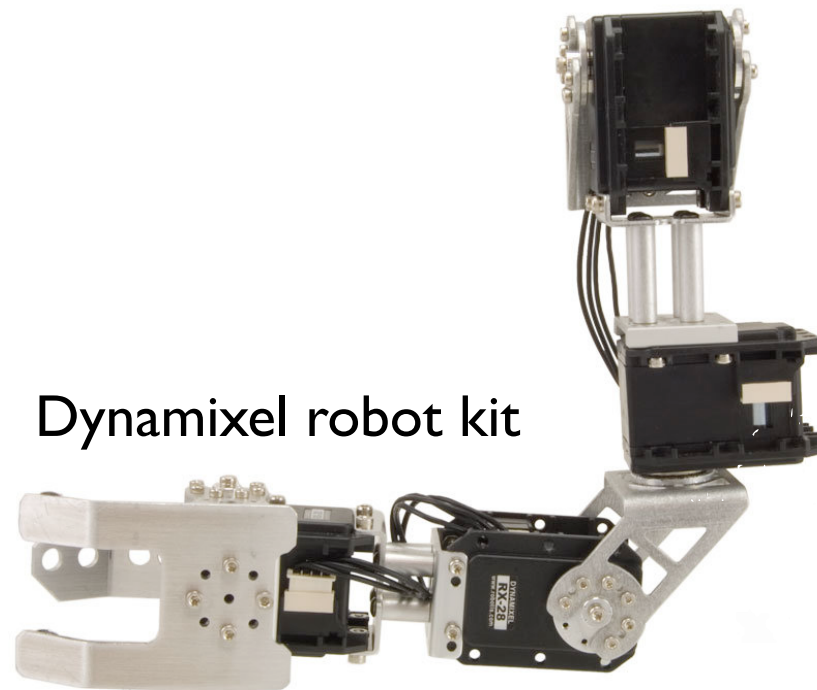
DLR Lightweight arm



Dynamixel robot kit

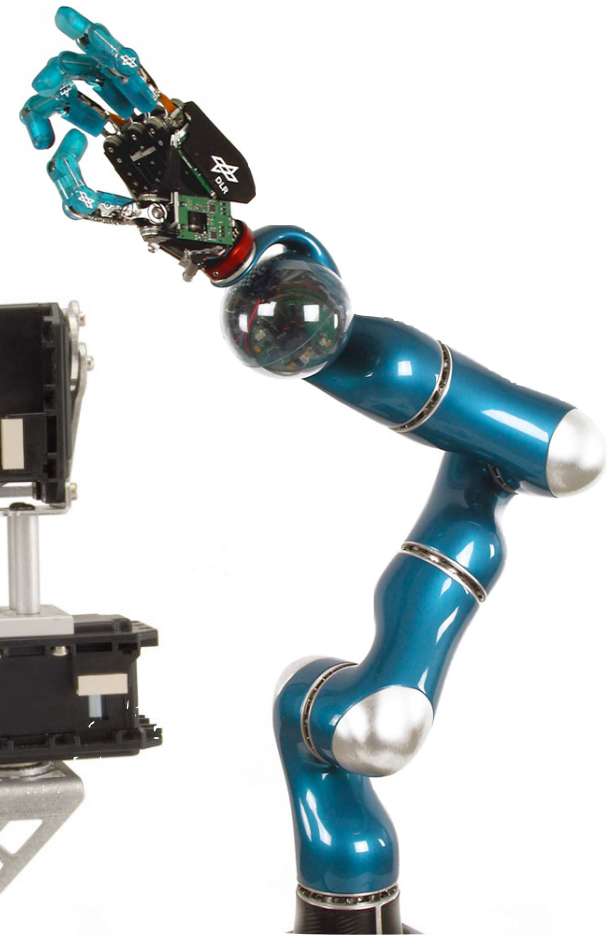


robot (n):
a machine with actuated joints
whose motion can be programmed



Dynamixel robot kit

DLR Lightweight arm



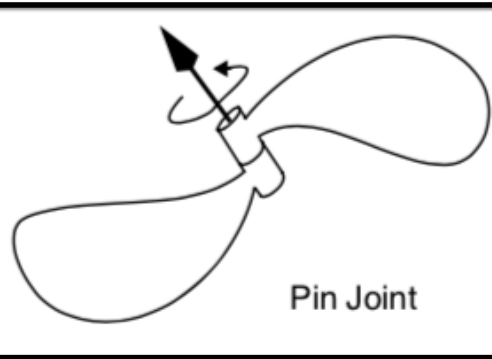
Robotic machines are comprised of joints and links

A link is a rigid part of the robot machine

A joint connects two links

The pose of a joint can be controlled by motor and is called a degree-of-freedom

Connections of joints and links form a hierarchy of articulated motion



DLR Lightweight arm



Dynamixel robot kit



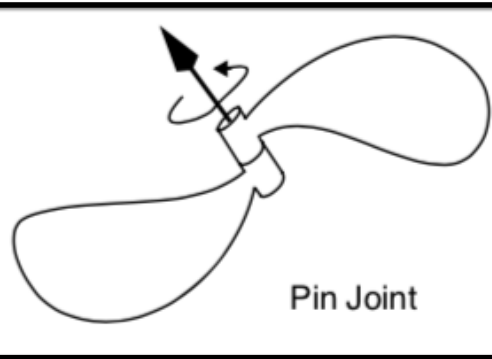
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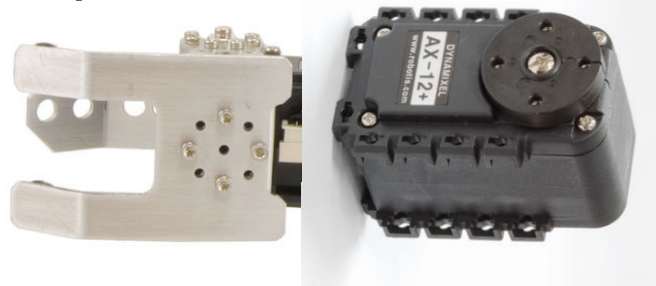
Connections of joints and links form a hierarchy of articulated motion

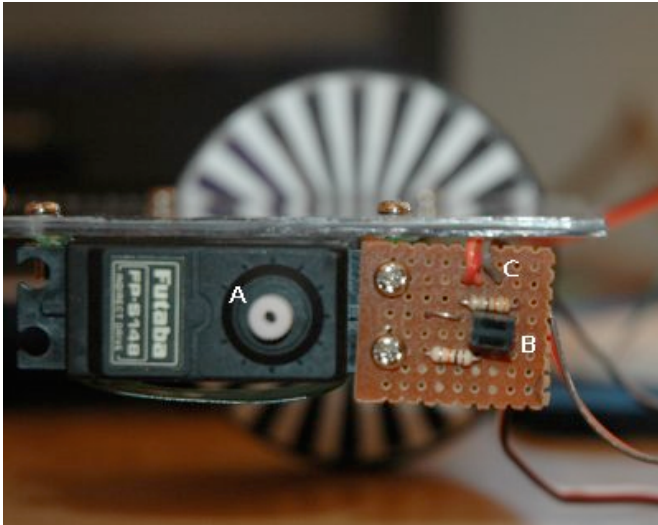


DLR Lightweight arm

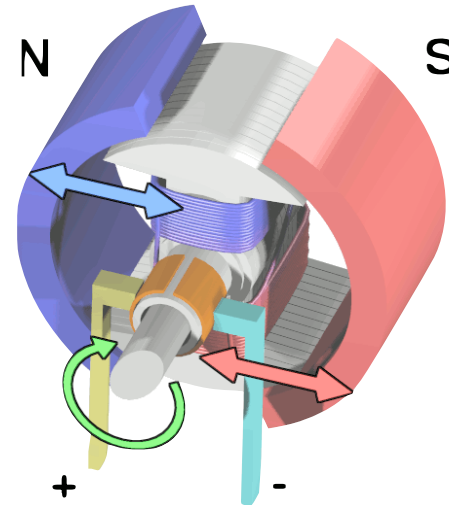


Dynamixel robot kit





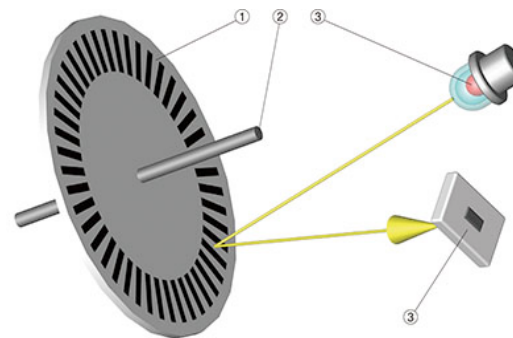
Motors have:



Electromagnetic motor

actuators to produce motion

proprioception to sense pose



Optical encoder

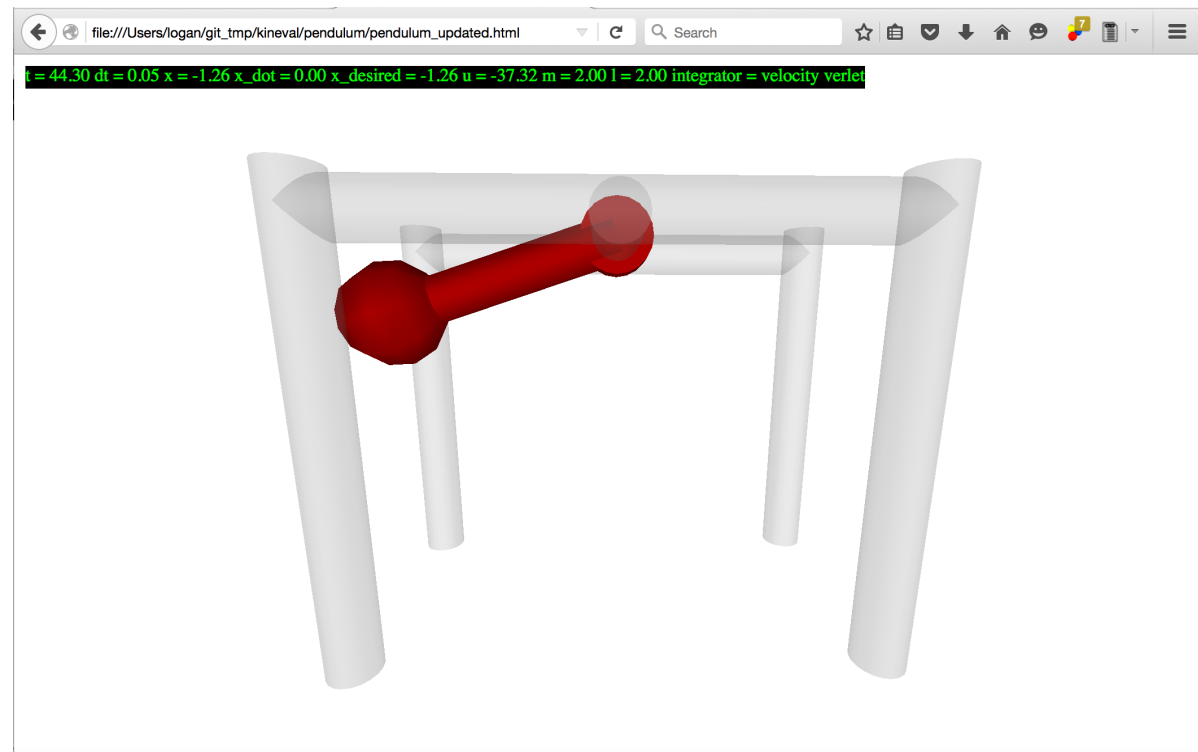
Project 2: Pendularm

- 1 degree-of-freedom robot arm
- Physically simulate through Lagrangian equations of motion
- Control arm pose with a PID controller



Project 2: Pendularm

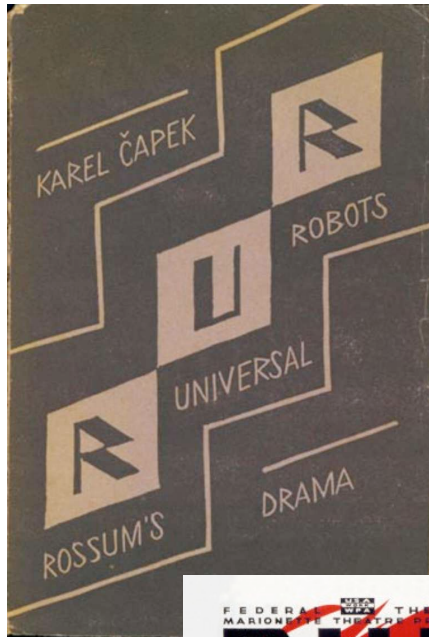
- 1 degree-of-freedom robot arm
- Physically simulate through Lagrangian equations of motion
- Control arm pose with a PID controller



“Robotics” is science fiction

Automation by “robots” is real

robot



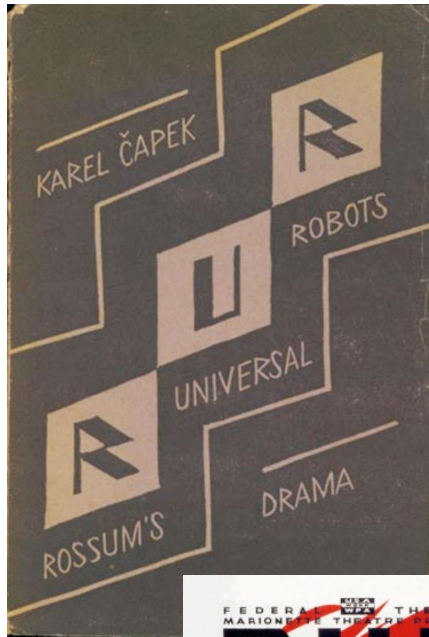
R.U.R.
(1920)



Karel Čapek
(1890-1938)



robot



R.U.R.
(1920)



robot

Karel Čapek
(1890-1938)



Josef Čapek
(1887-1945)

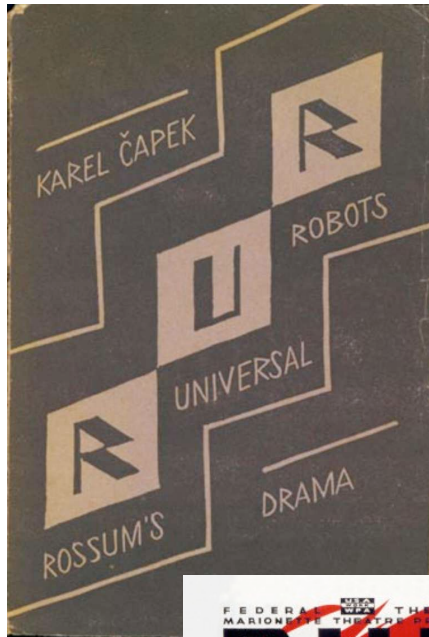


forced labor | serf | slave

robota

Josef Čapek
(1887-1945)





R.U.R.
(1920)



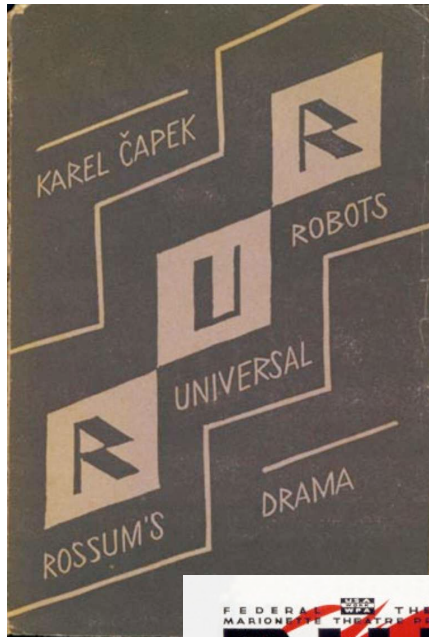
robot

Karel Čapek
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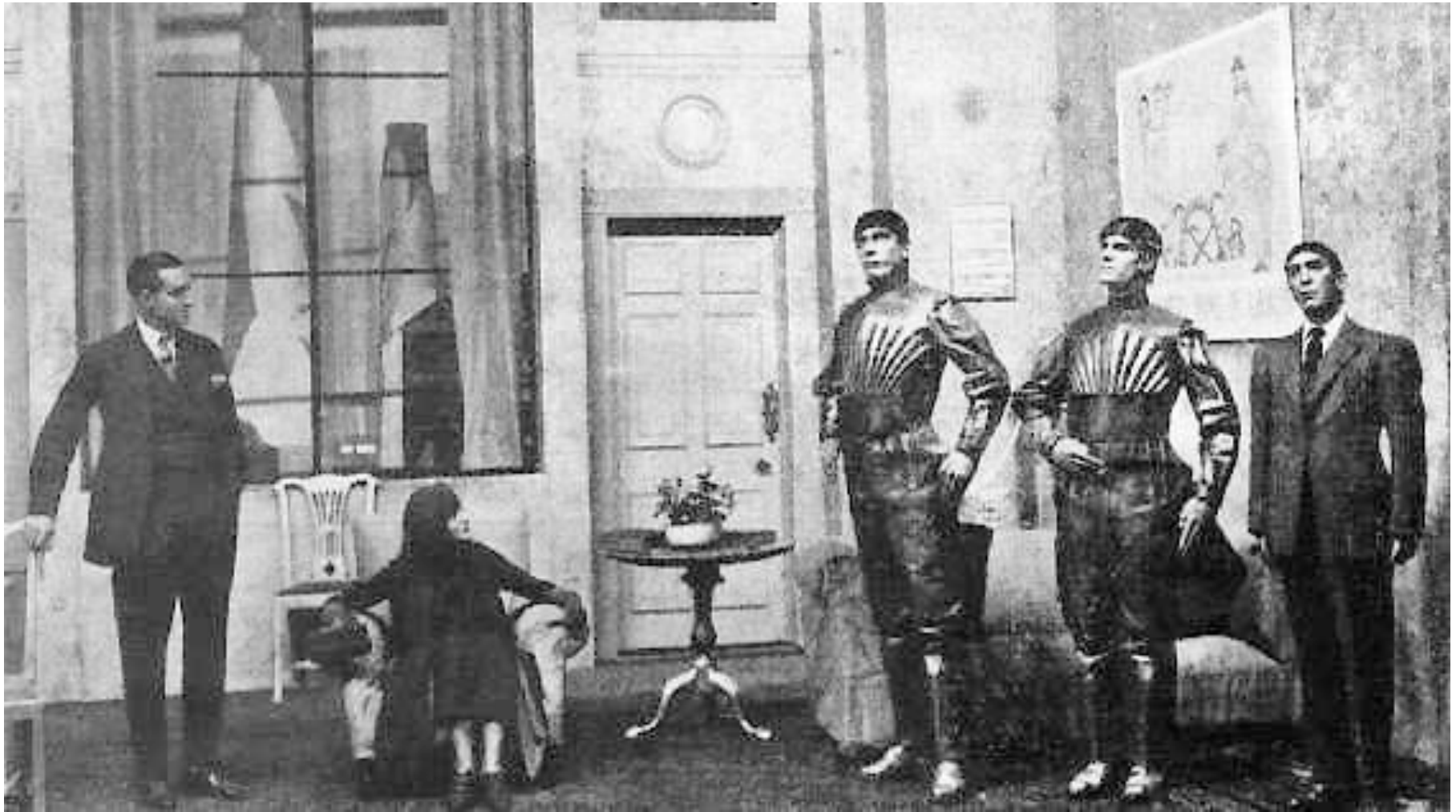
R.U.R.
(1920)



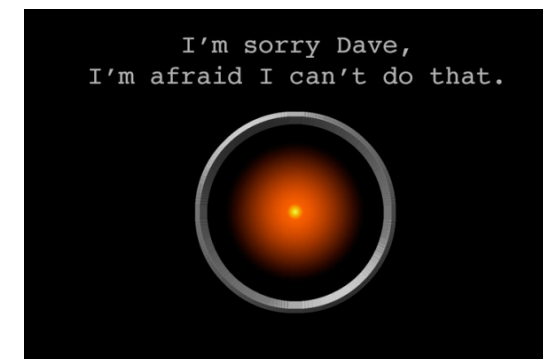
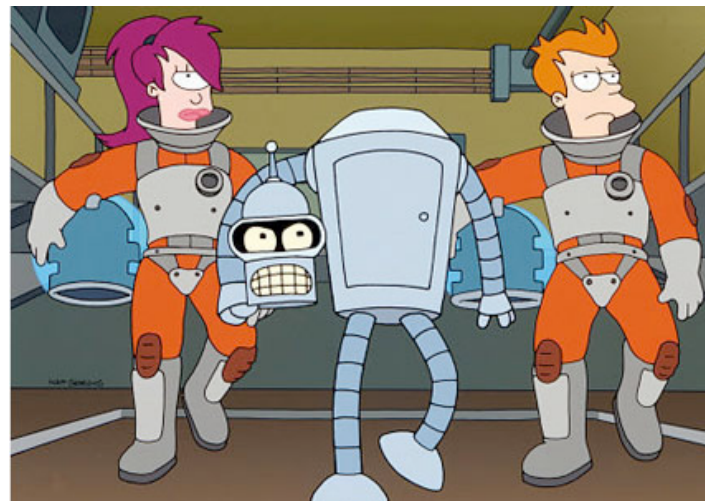
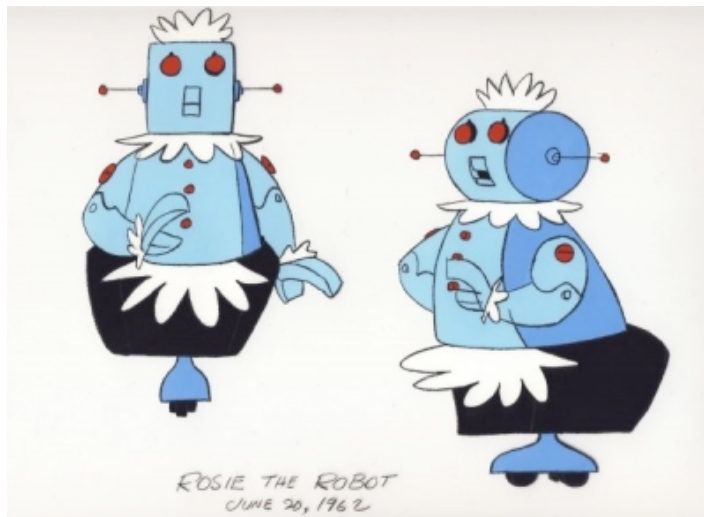
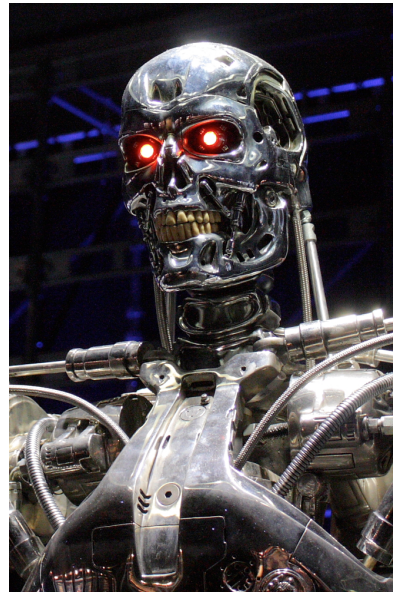
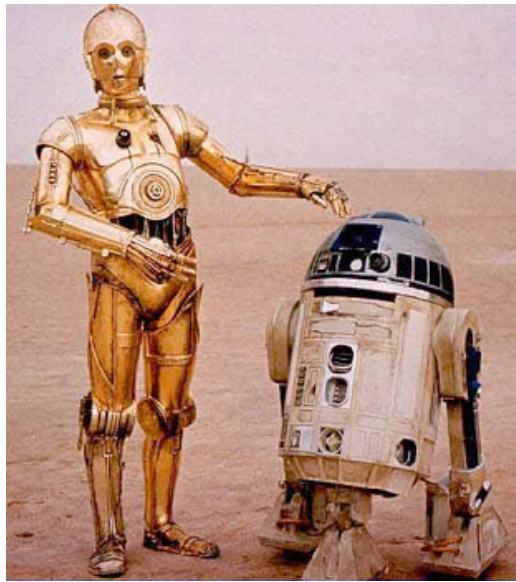
robot

Karel Čapek
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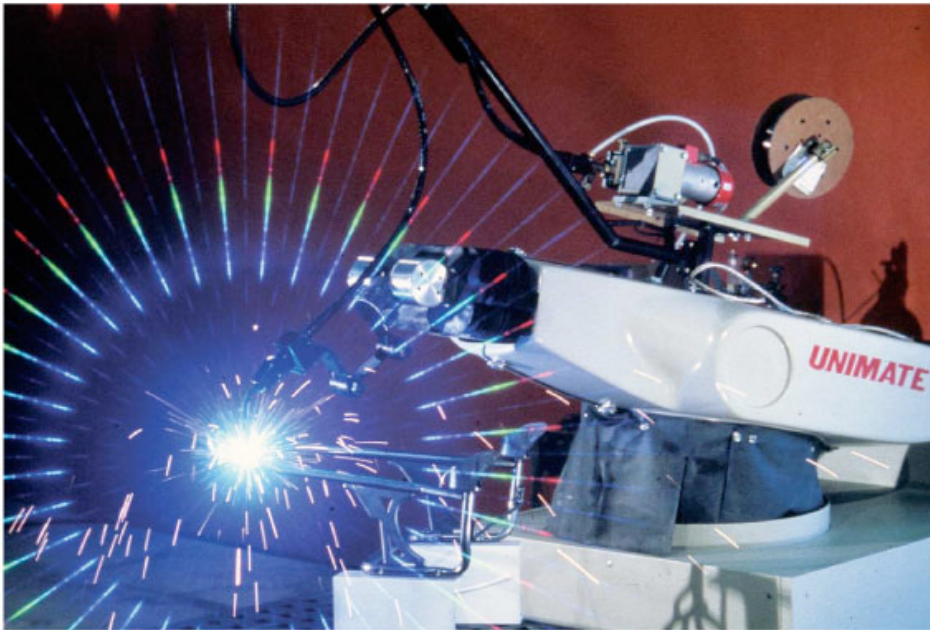


In reality, modern automation
began in the 1950s

by George E. Munson Condensed and edited by Leslie Ballard

The Rise and Fall OF UNIMATION INC.

A story of robotics innovation & triumph that changed the world



June 13, 1961

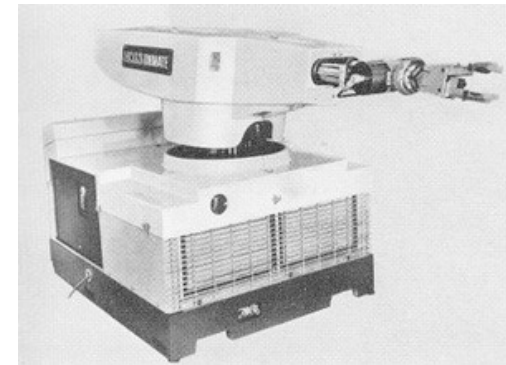
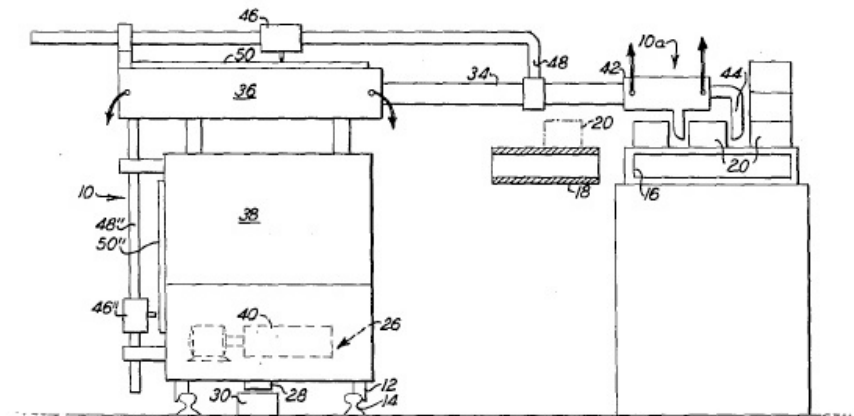
G. C. DEVOL, JR

2,988,237

PROGRAMMED ARTICLE TRANSFER

Filed Dec. 10, 1954

3 Sheets-Sheet 1



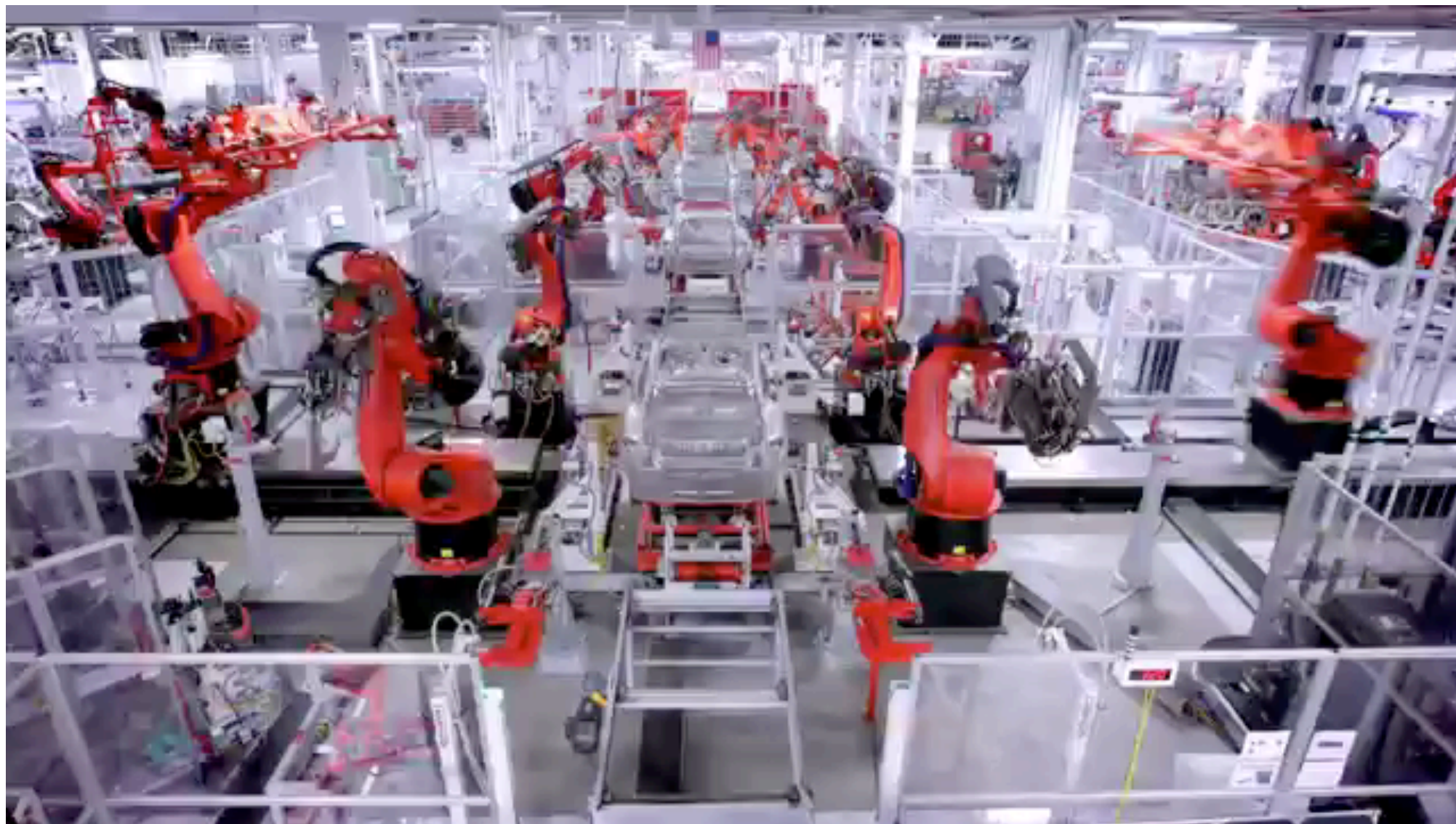
<http://www.botmag.com/the-rise-and-fall-of-unimation-inc-story-of-robotics-innovation-triumph-that-changed-the-world/> Michigan Robotics 367/511 - autorob.org



<http://wn.com/unimate>

Industrial One-Arm Bandit AKA Industrial One Armed Bandit (1968) - <https://youtu.be/VdolSBpyCaU>

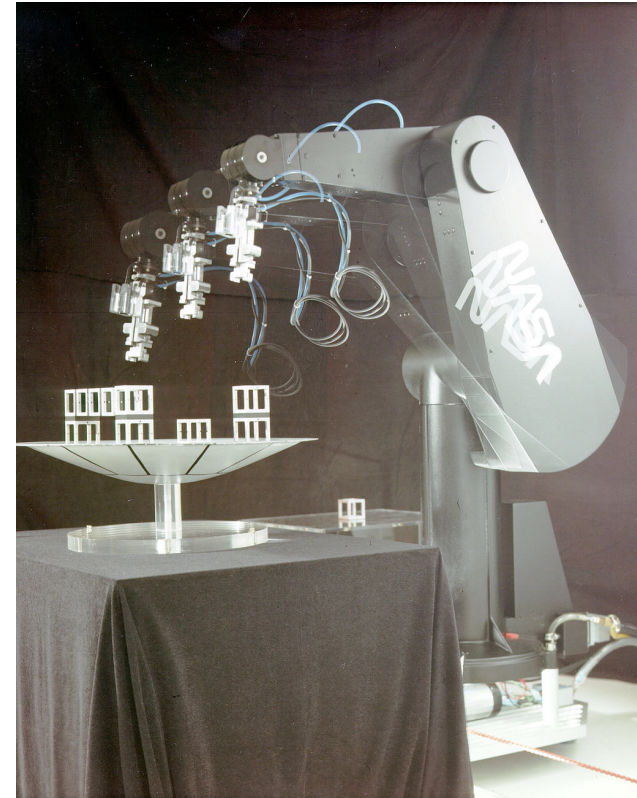
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WIRED at Tesla - https://www.youtube.com/watch?v=8_lfxPI5ObM

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Industrial robotics has focused mostly on pick-and-place tasks



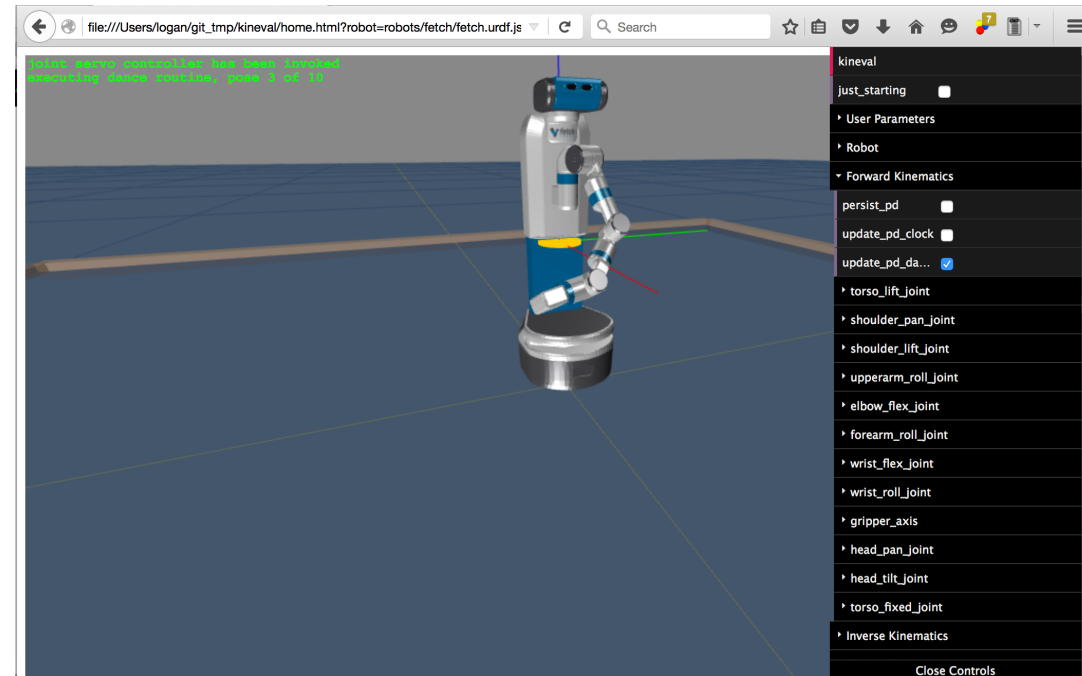
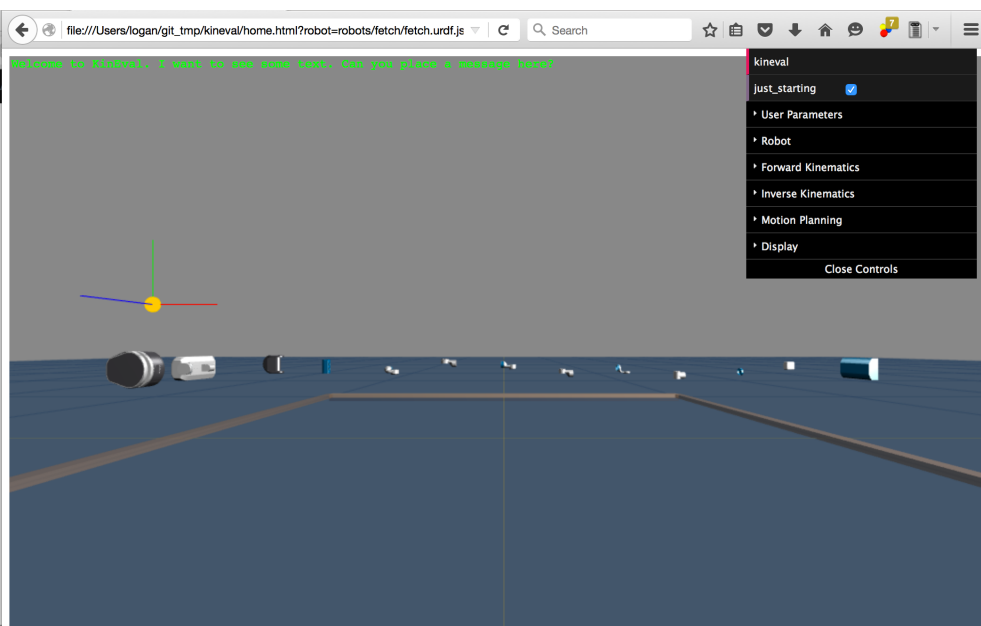
often the 3Ds — “Dirty, Dull, or Dangerous”

Unimate PUMA (*Programmable Universal Machine for Assembly*, or *Programmable Universal Manipulation Arm*)

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Projects 3-4: Forward Kinematics

Assemble individual robot links and joints into a posable robot that can dance



Does perfect sensing with perfect
motors make a perfect robot?

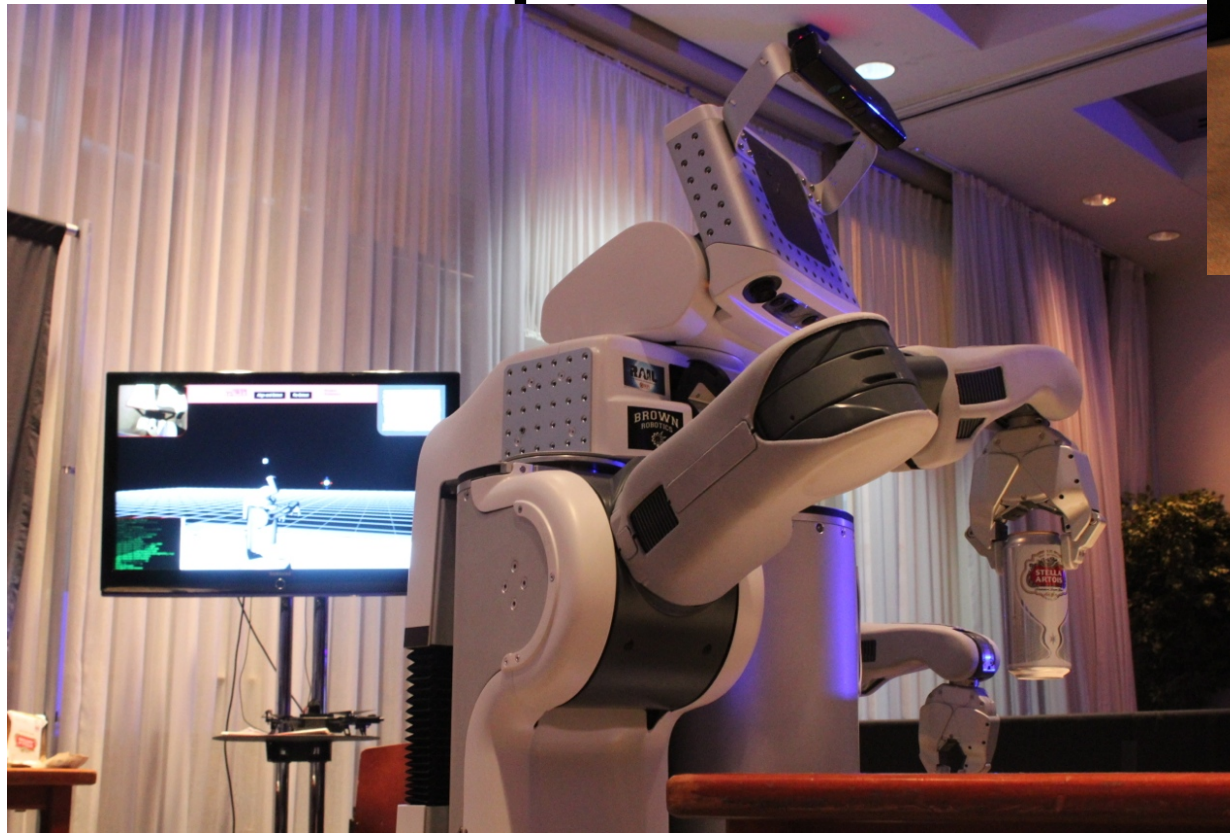
Does perfect sensing with perfect
motors make a perfect robot?

No

Does perfect sensing with perfect motors make a perfect robot?

A robot also needs computation to map sensing to action.

Dexterous Manipulation

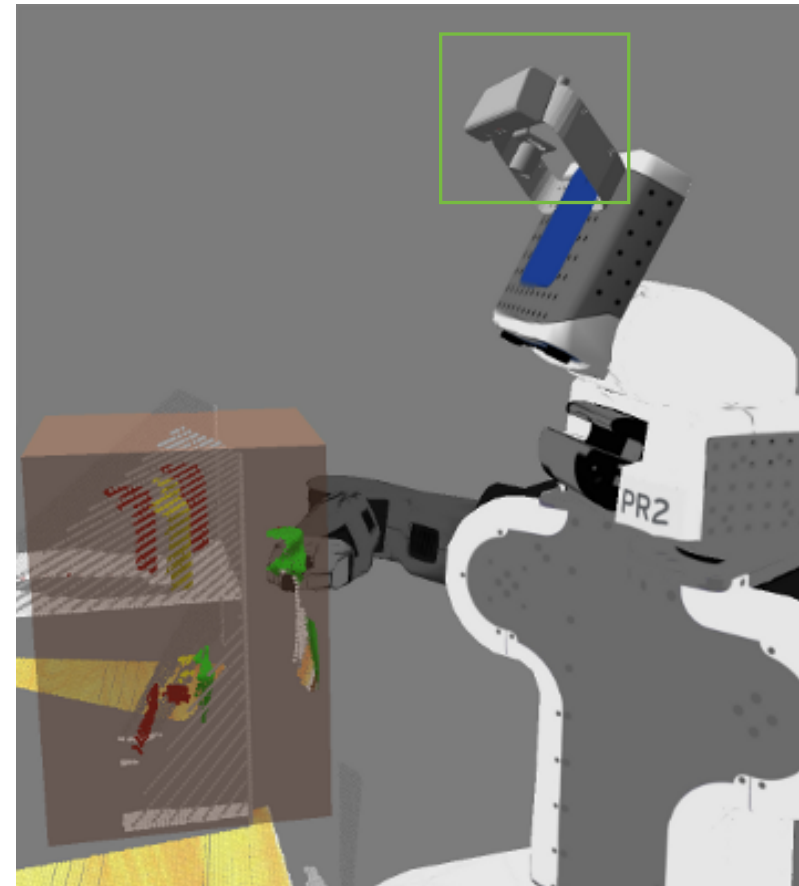
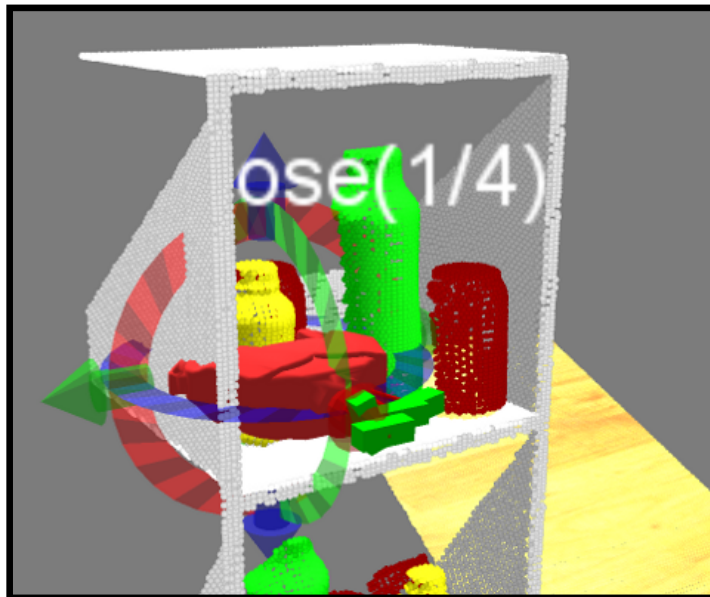




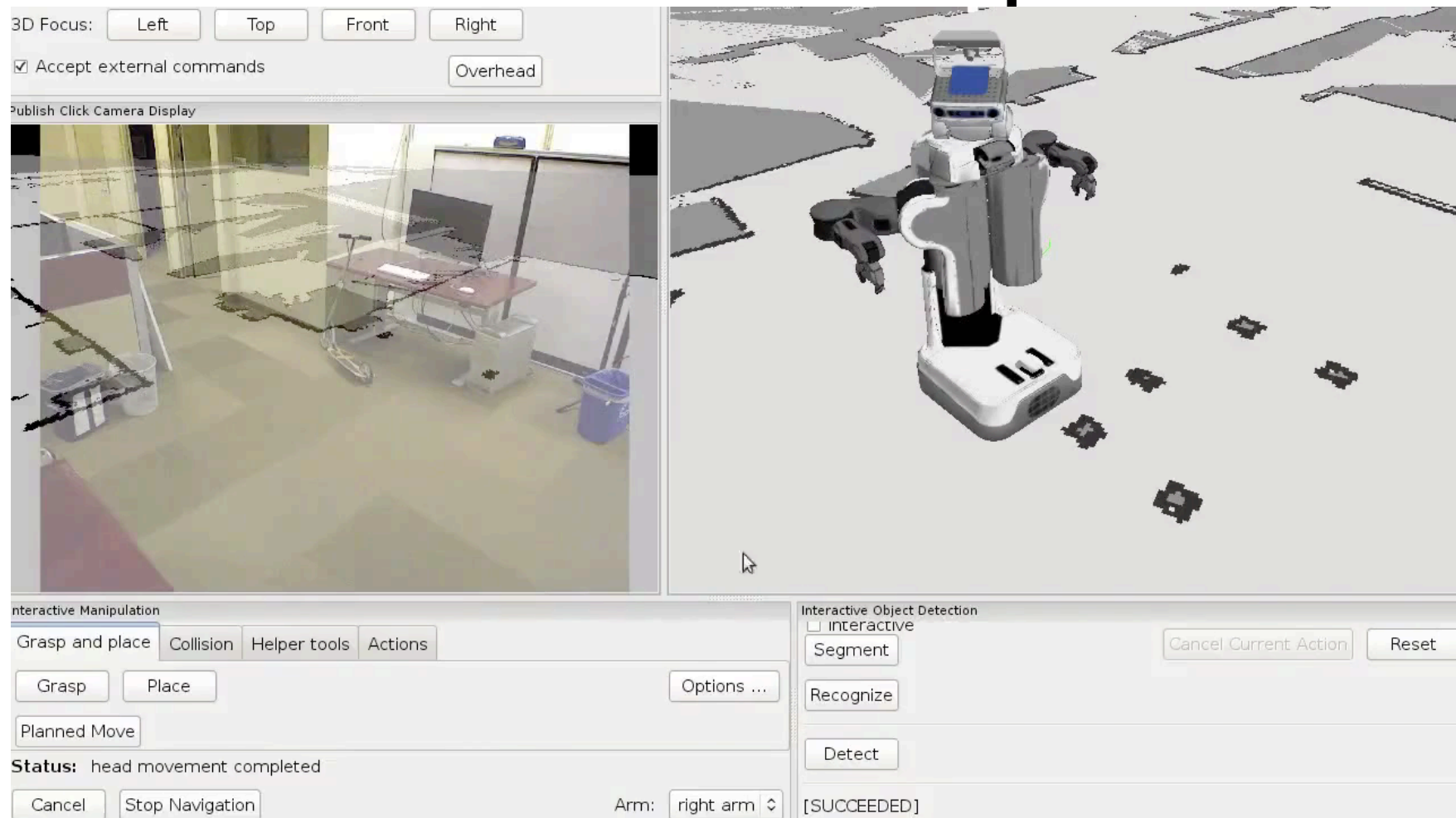
Robotic Roommates Shopping for and Preparing Bavarian Breakfast

TU-Munich - https://youtu.be/gbIDPqb_2iM

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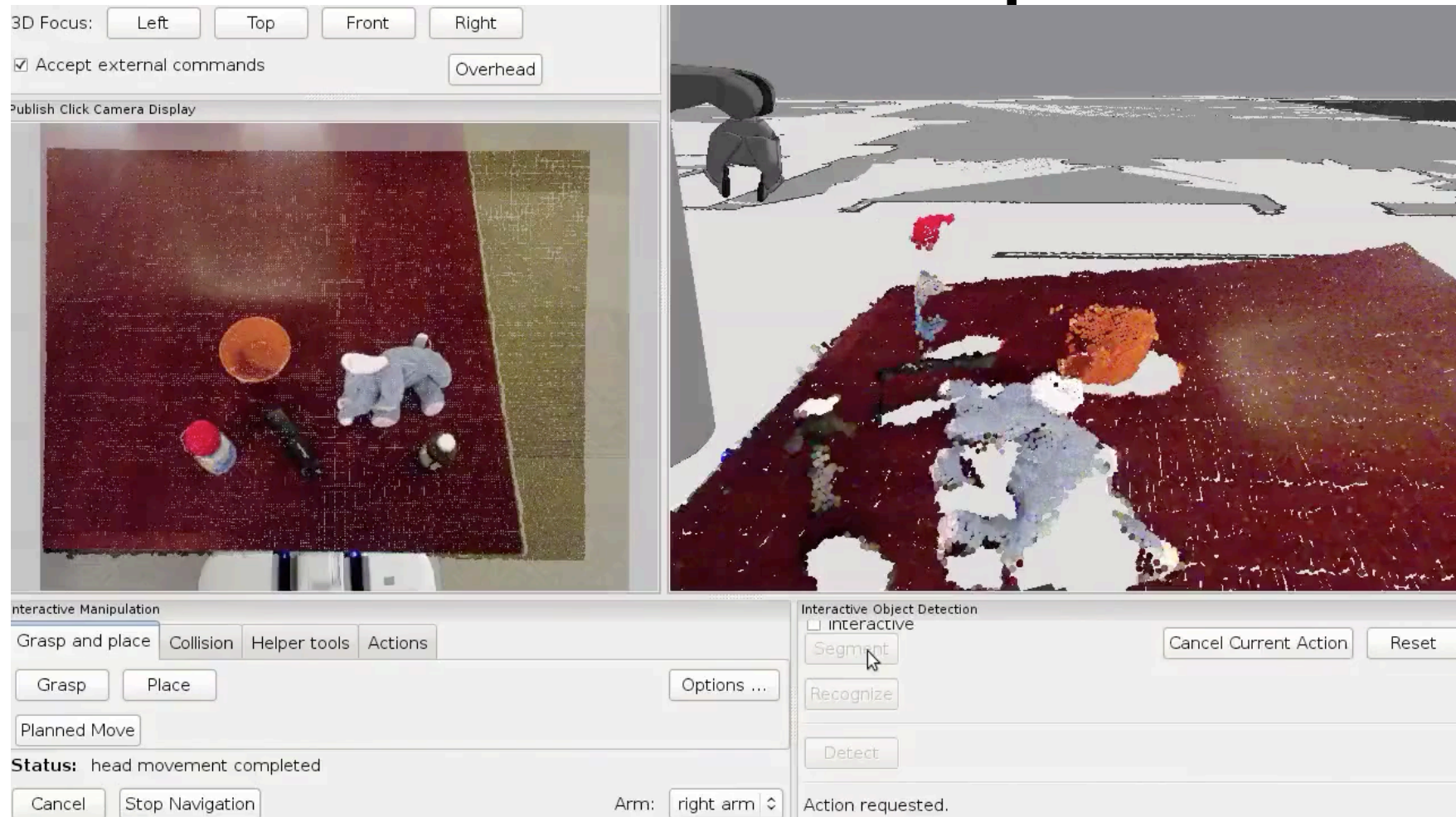
PR2 Interactive Manipulation



Willow Garage - https://wiki.ros.org/pr2_interactive_manipulation/groovy

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PR2 Interactive Manipulation



Willow Garage - https://wiki.ros.org/pr2_interactive_manipulation/groovy

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Sui, Zhou, Zeng, Jenkins 2017

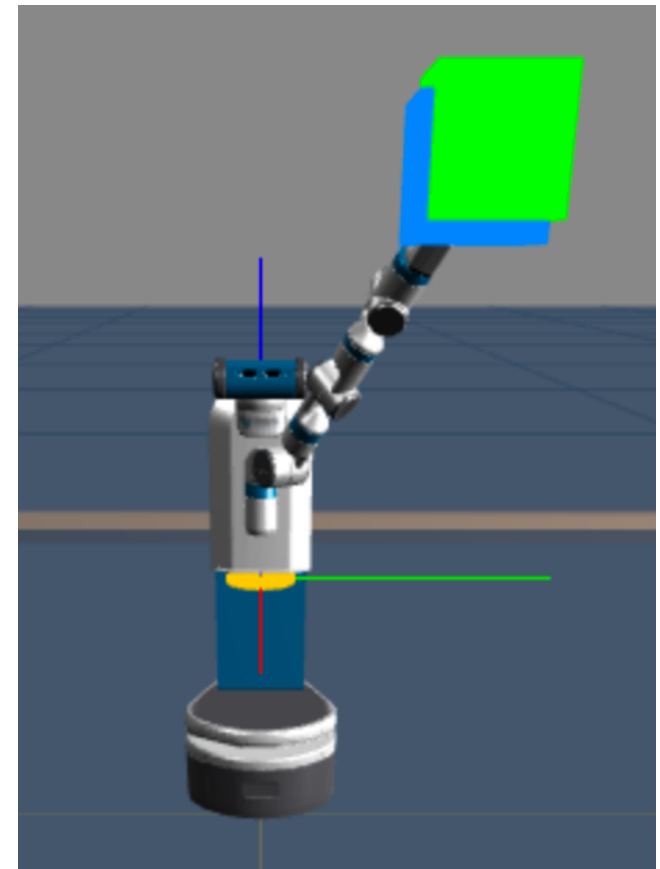


Project 5: Inverse Kinematics

Given target location for robot gripper,
compute joint angles to reach location

Compute Manipulator Jacobian

Perform gradient descent optimization



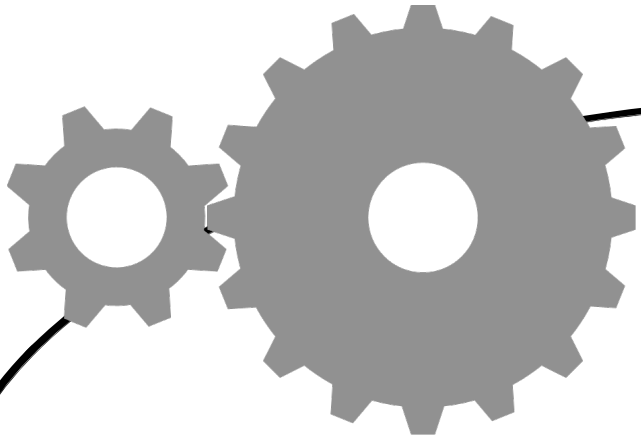
Another perspective on robot history



Unimate PUMA robot history - <http://vimeo.com/2276417>

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Robotics

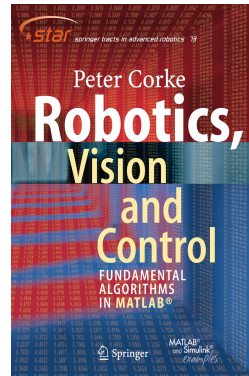


Mechanical Engineering
Electrical Engineering
“Mechatronics”



Computer Science
Artificial Intelligence
“Autonomy”

robot (n):
a goal oriented machine
that can sense, plan, and act



There are many definitions for “robot”.
AutoRob will use this one.

Mobility/Navigation

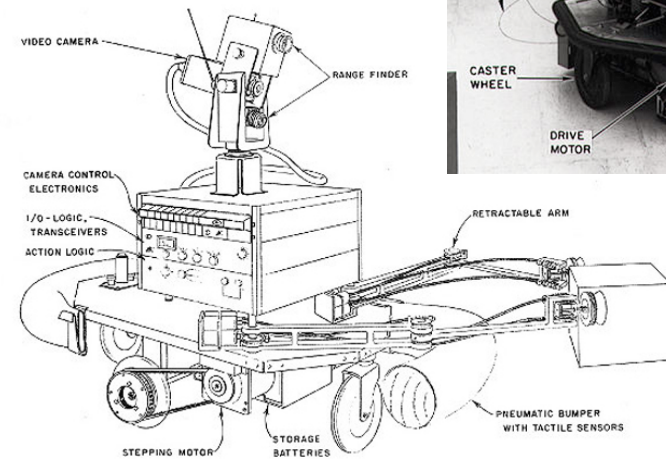
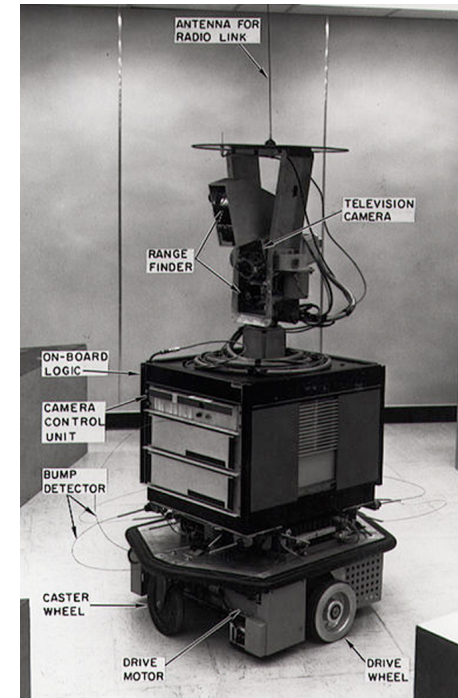


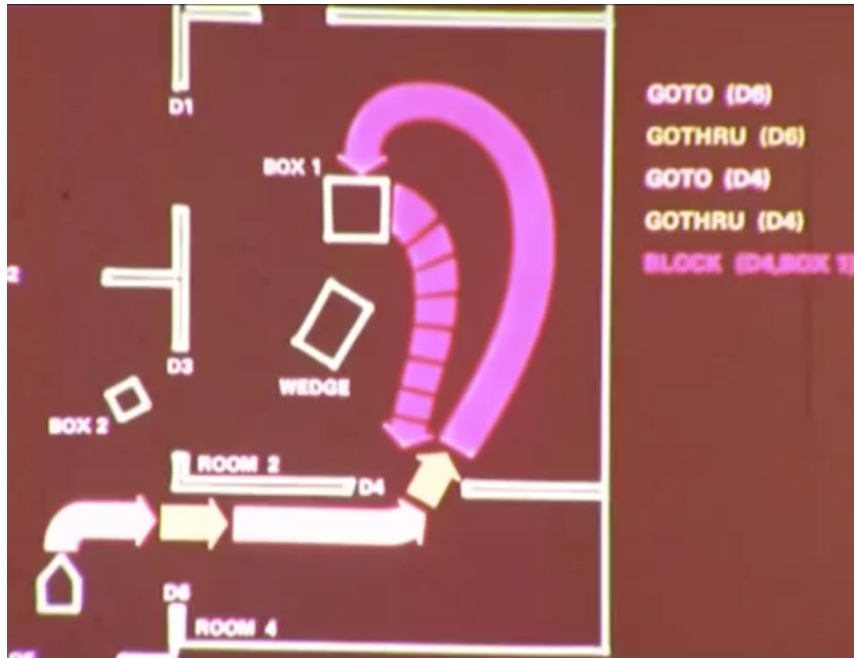
FIG. 2 AUTOMATON VEHICLE



Shakey SRI (1969) - <http://www.ai.sri.com/shakey/>

Michigan Robotics 367/511 - autorob.org

"SHAKY: Experimentation in Robot Learning and Planning" (1972) - <https://youtu.be/GmU7SimFkpU>



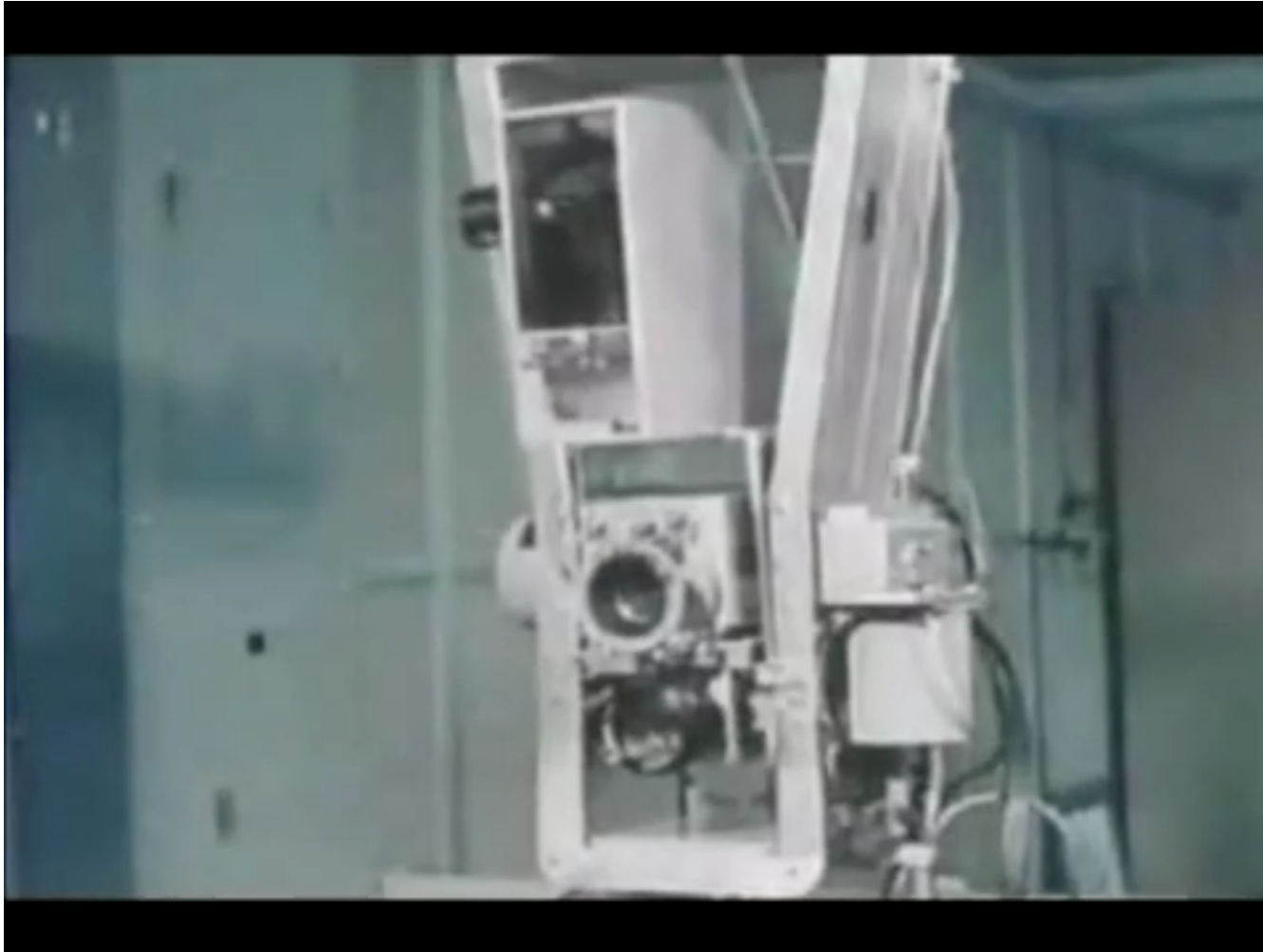
Autonomous robots traditionally use a sense-plan-act loop

Sense: perceive an accurate model of the world

Plan: decide a sequence of actions to reach goal

Act: execute actions to realize goal

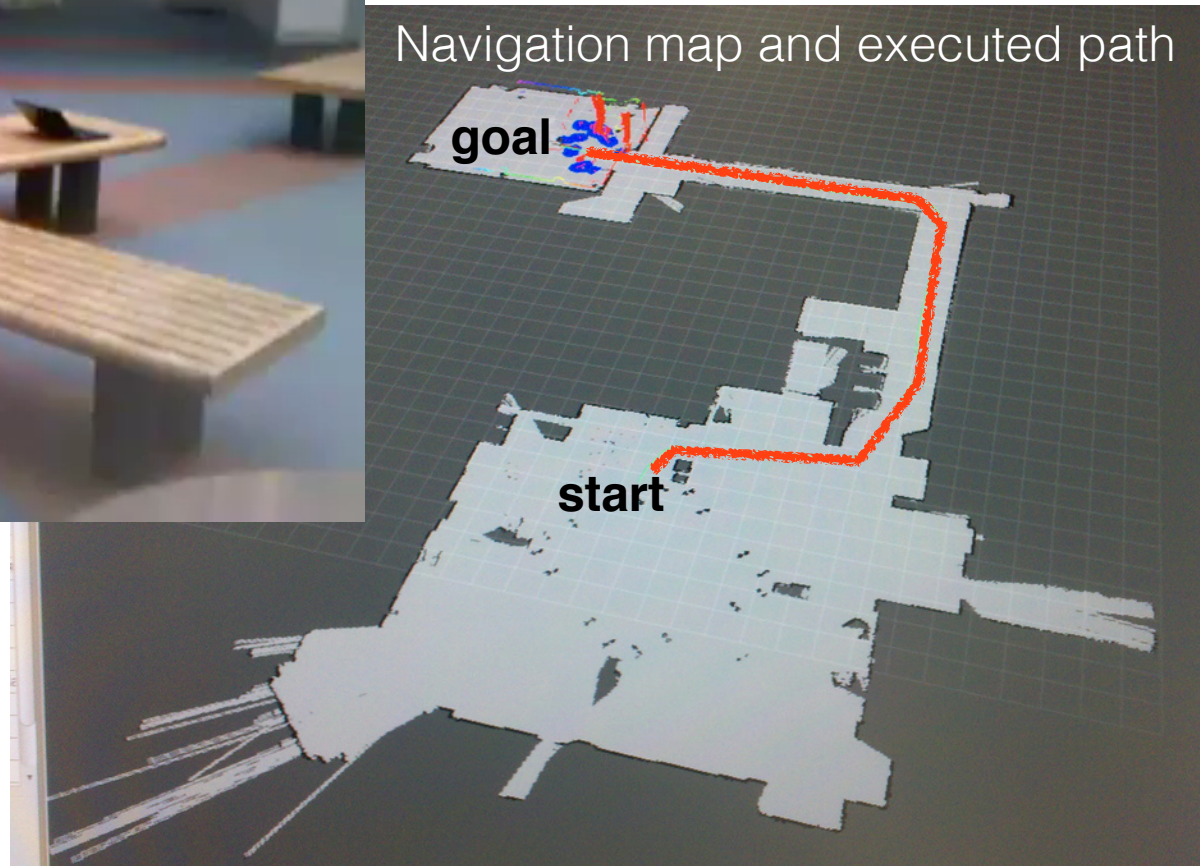
Early(est) computer vision



Modern robot navigation...



Navigation map and executed path



PR2 navigation at Brown University
June 2011

Jenkins Robotics Group - <https://youtu.be/Int62LmHXg0>

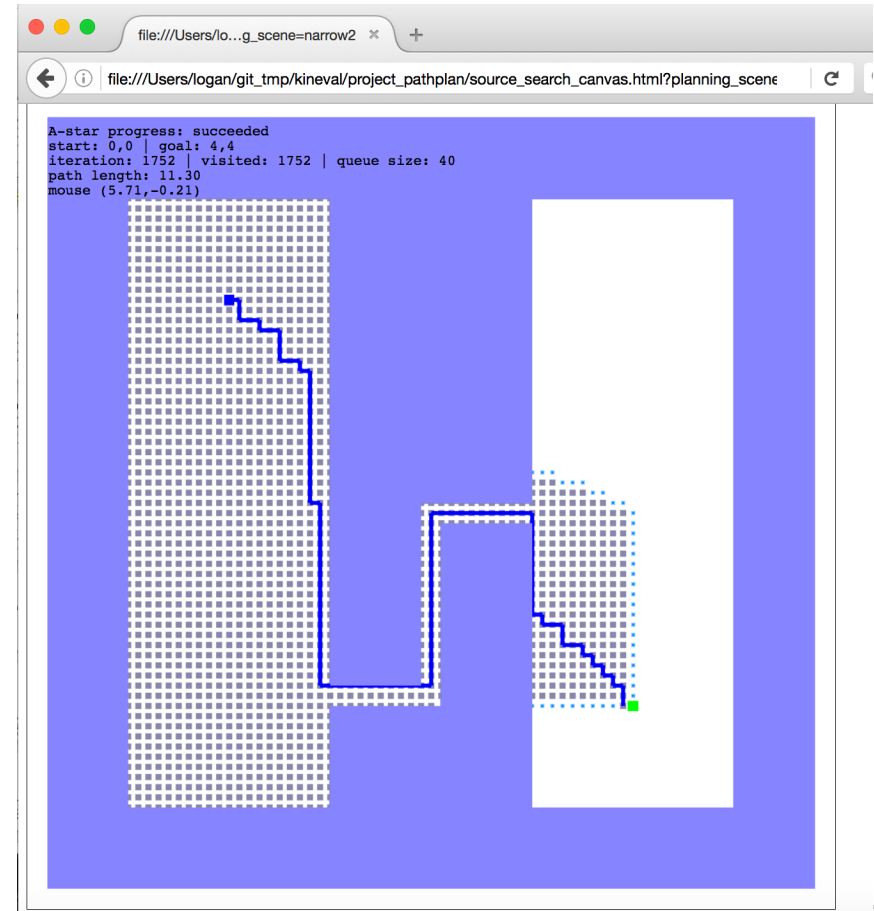
robot navigation
=
autonomous driving

(to a reasonable approximation)

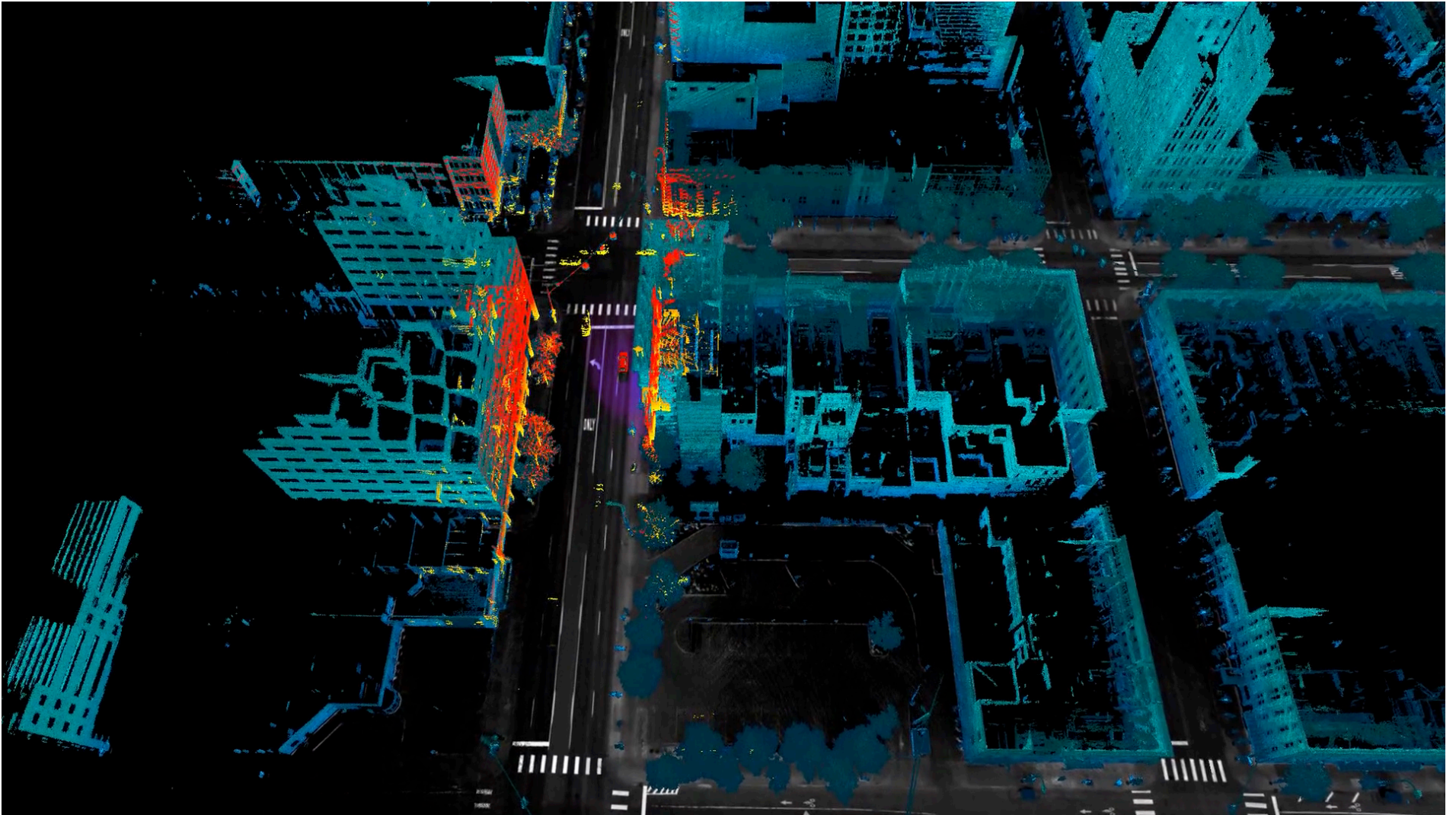
A side-profile photograph of a white Google self-driving car. The car features the Google logo on its side, with the 'o' replaced by a yellow self-driving car icon. Below the logo, the text 'self-driving car' is visible. The car is equipped with a roof-mounted sensor suite, including a prominent LIDAR unit. The background is a blurred green landscape.

Project 1: Path Planning

Compute collision-free motion path from current 2D location to goal location



How can we build that map?



Eustice, Olson, et al. - Next Generation Vehicle - <https://youtu.be/G6ARrD60IQk>

Do we need to build a map?

← → ↻  Secure | <https://www.technologyreview.com/s/400145/honey-theyve-shrunk-the-rover/>

Ghengis hexapod robot

MIT Technology Review

WELLS
FARGO

Wealth & Investment
Management

See how realigni
can help maxim



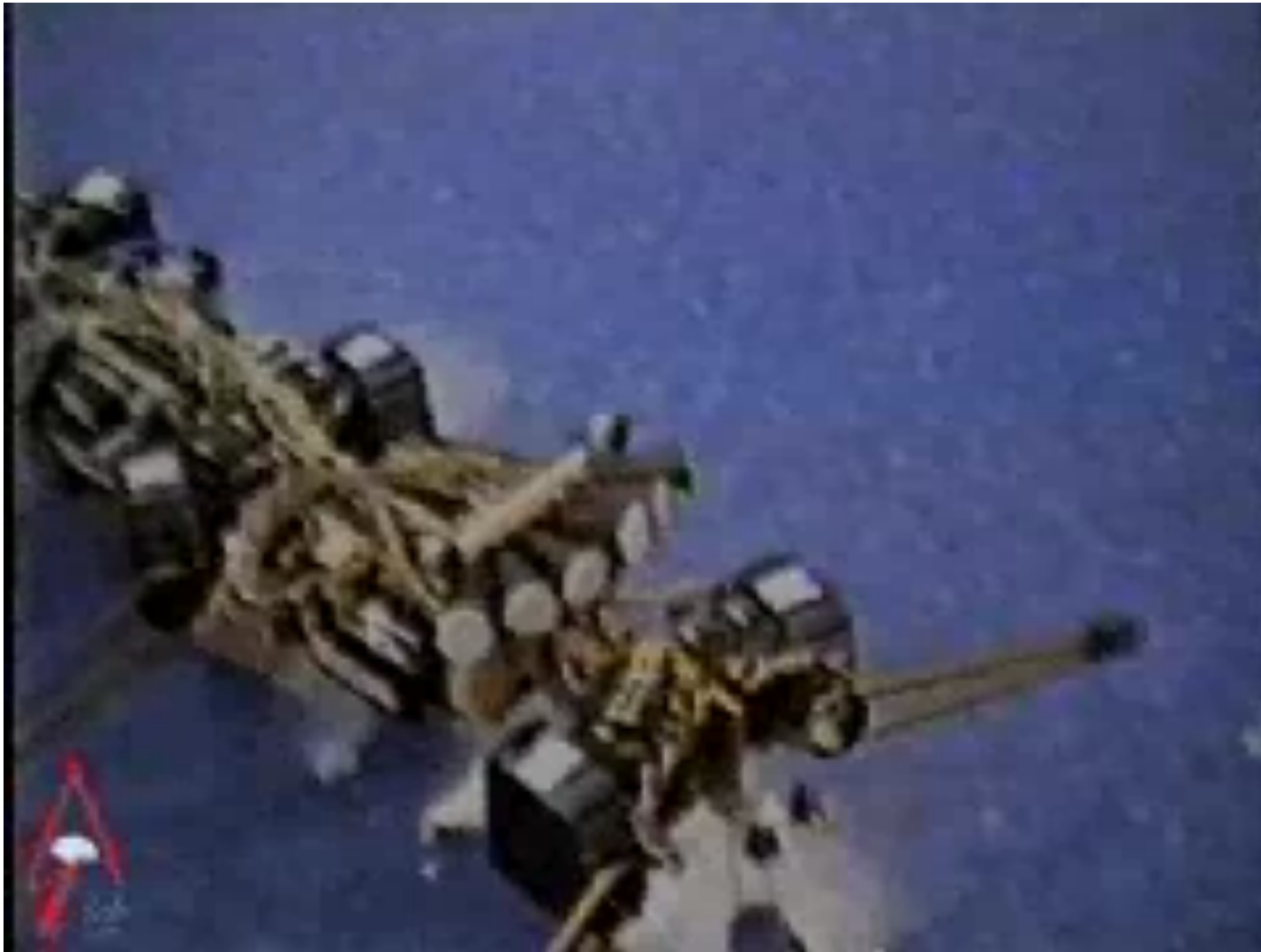
Intelligent Machines

Honey, They've Shrunk the Rover

The Sojourner vehicle that trekked across the Martian surface captured the world's fancy last summer, but we haven't seen anything yet. Next will come rovers that can roam miles across Mars and "aerobots" able to survey other planets.

by Eric Scigliano January 1, 1998

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Decision through
FSM-based reaction

MIT Ghenghis (1989)

<http://groups.csail.mit.edu/lbr/genghis/>

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Decision through
FSM-based reaction

MIT Ghengis (1989)

<http://groups.csail.mit.edu/lbr/genghis/>

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What is more difficult than Mars?

Can today's robot vacuums handle the mess of two toddlers?

By **Ben Popper** on December 29, 2015 11:00 am



Some robots will need to be
more deliberate...



Amazon - <https://youtu.be/Ox05Bks2Q3s>

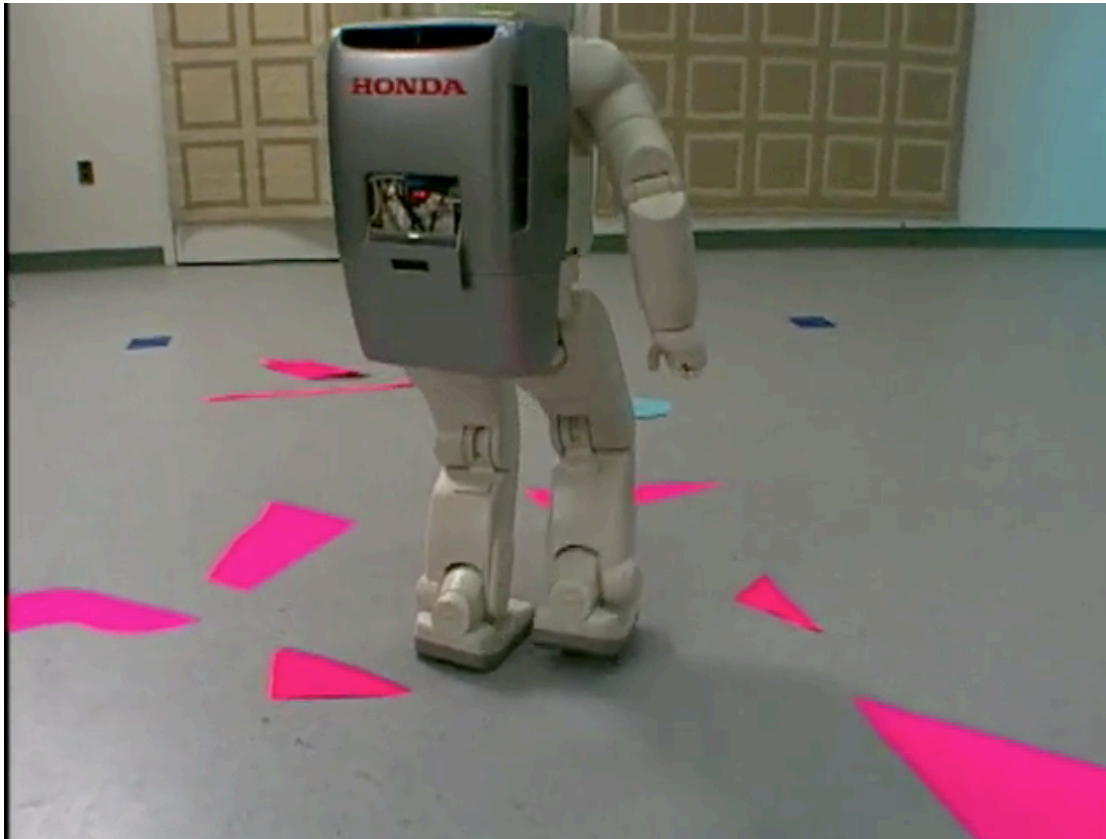
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https://youtu.be/0E4gt54_vHo

Michigan Robotics 367/511 - autorob.org

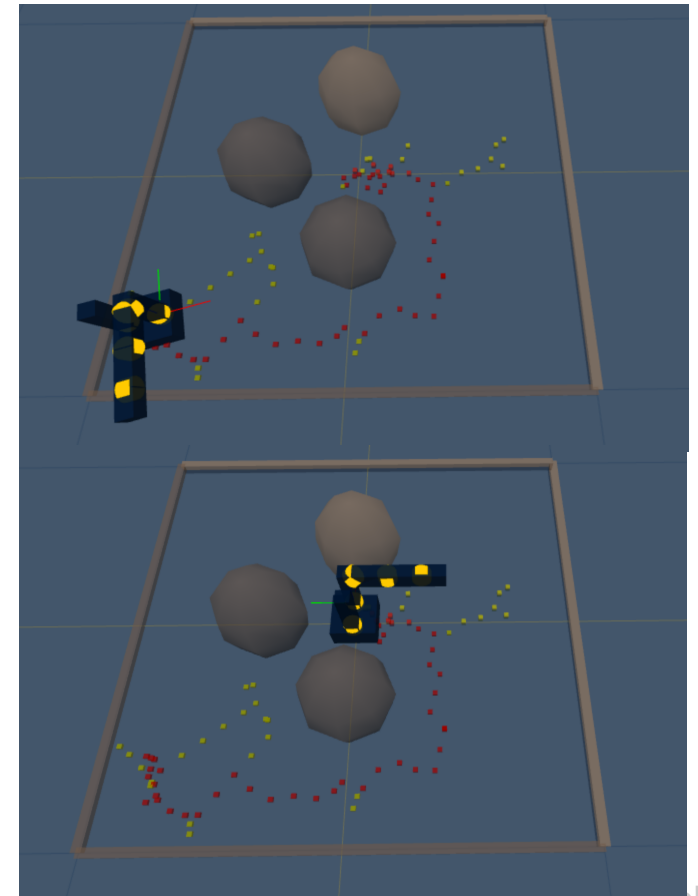
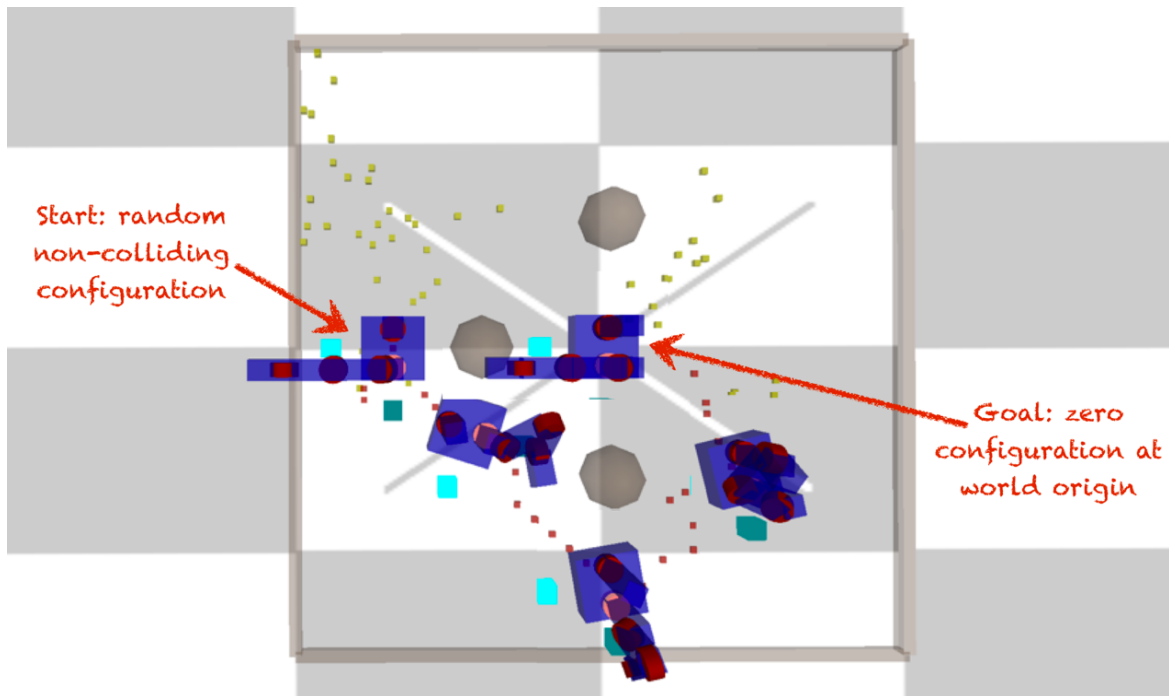
Rapidly-Exploring Random Trees



for high dimensional
search over robot
configurations

Project 6: RRT Planning

Compute collision-free motion path
from current pose to goal (start) pose



What about collisions?

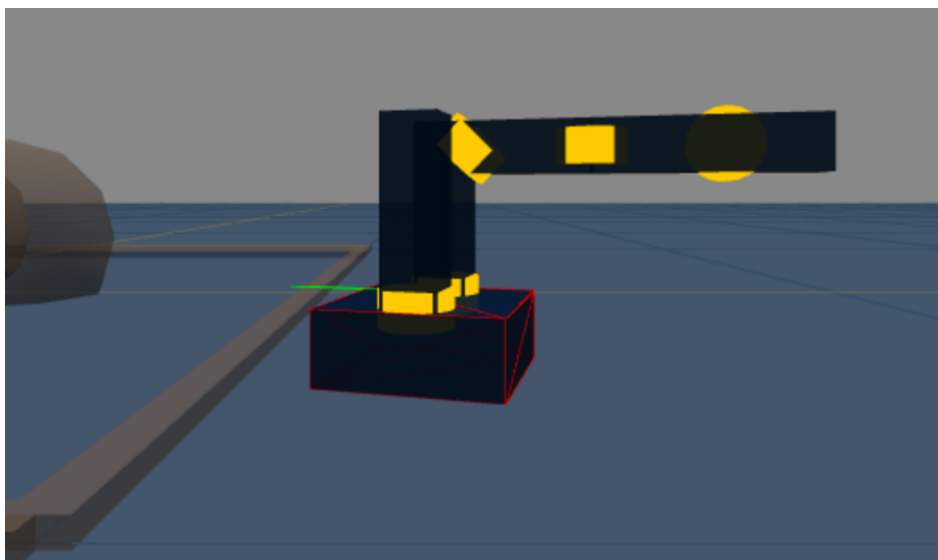
What about collisions?



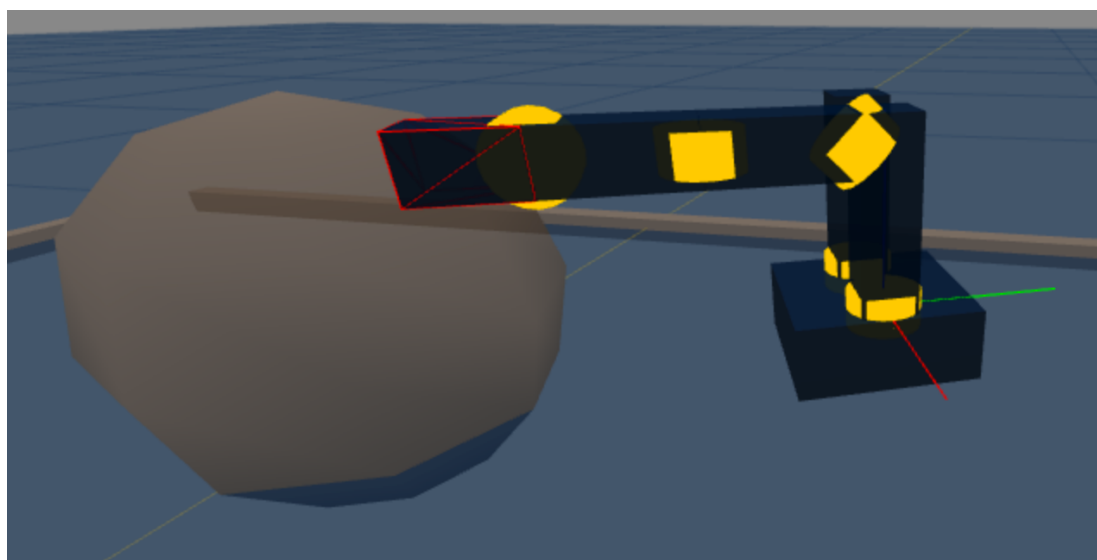
DLR - <https://youtu.be/dnUwqngH0bM>

Michigan Robotics 367/511 - autorob.org

Simple collision detection provided for course projects



“electric fence” on robot base



Axis-aligned bounding box
collision detection on each link

Completely autonomous robots
are a fantasy

Completely autonomous robots are a fantasy

Why?

Completely autonomous robots are a fantasy

Uncertainty Why? Accountability

Perception Liability

Reliability Ethics

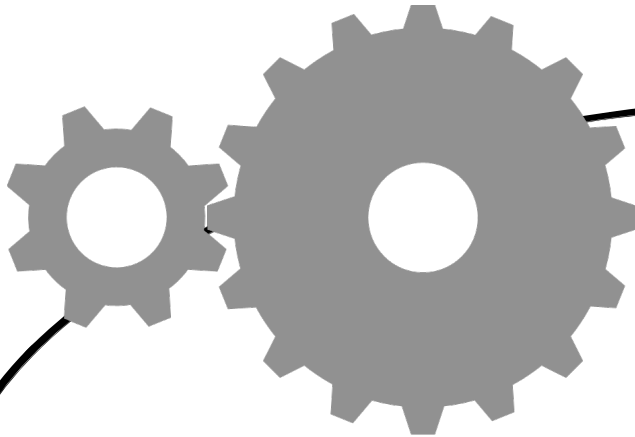
Adaptability Safety

Social norms

Always have a human in the loop



Robotics



Mechanical Engineering
Electrical Engineering
“Mechatronics”



Human Factors
Supervisory Control
“Usability”



Computer Science
Artificial Intelligence
“Autonomy”

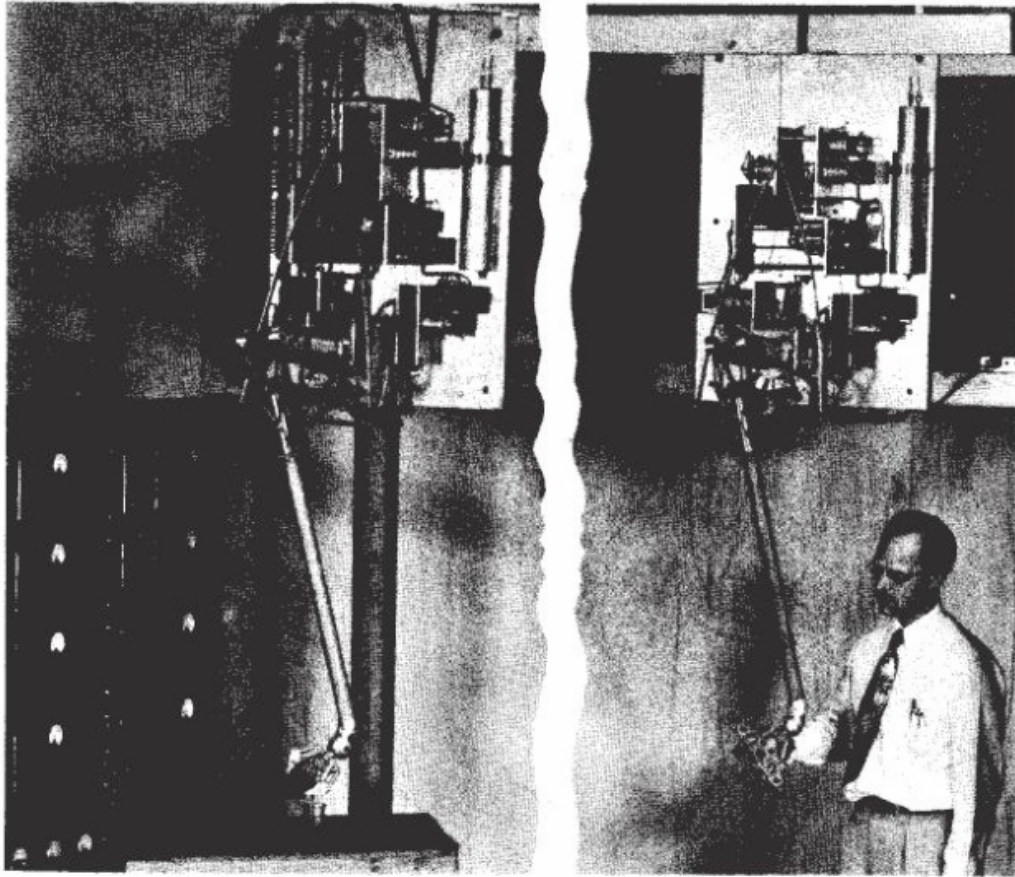


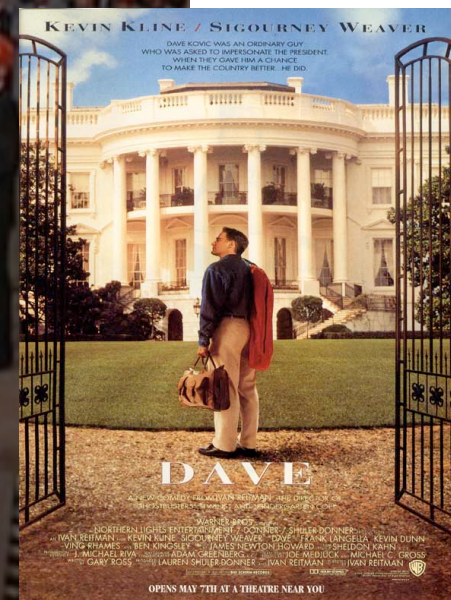
FIGURE 6.—The ANL Model E1 electric master slave. Used only for experimental purposes, this bilateral manipulator was developed in 1954. (Courtesy of Argonne National Laboratory.)

R. Goertz - Argonne

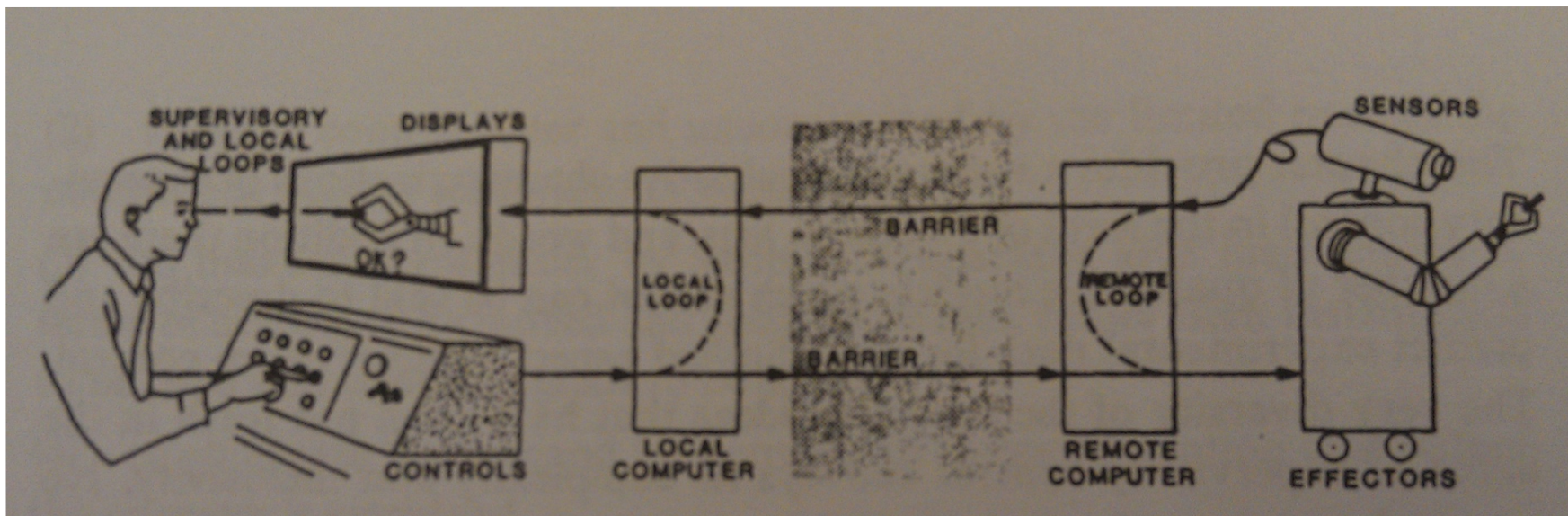


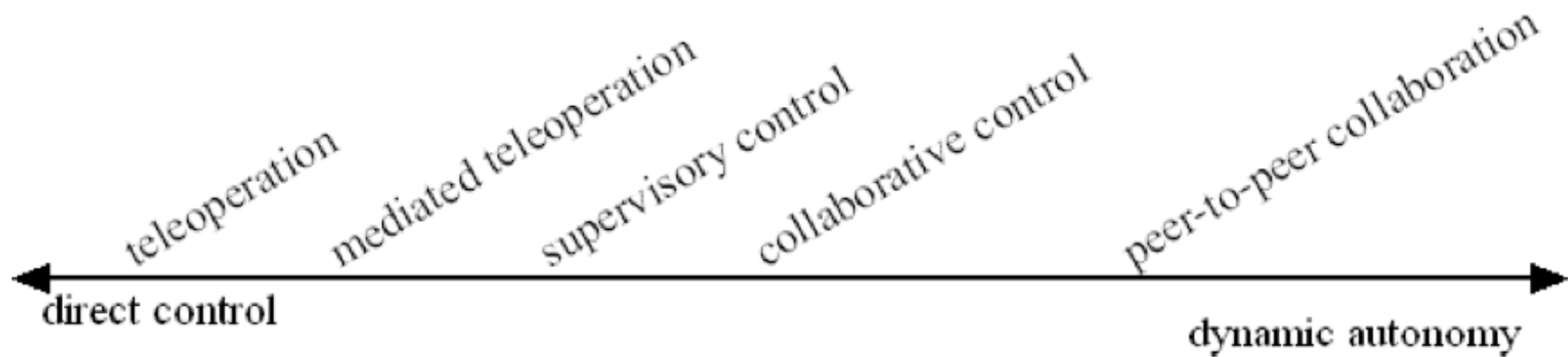
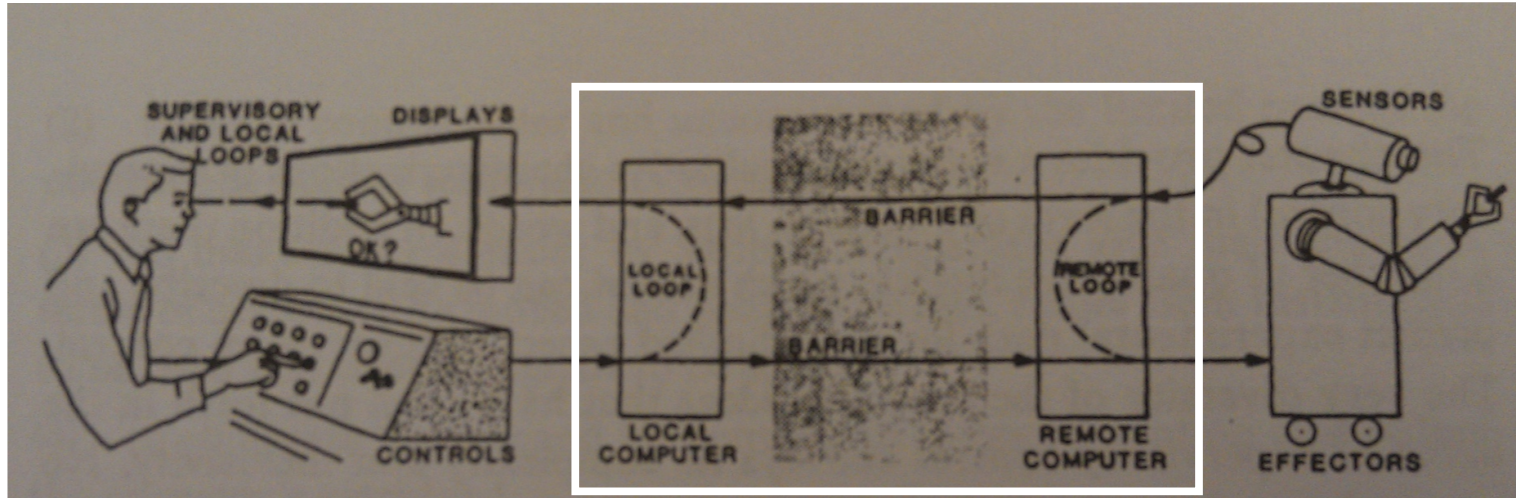
Teleoperation

Michigan Robotics 367/511 - autorob.org



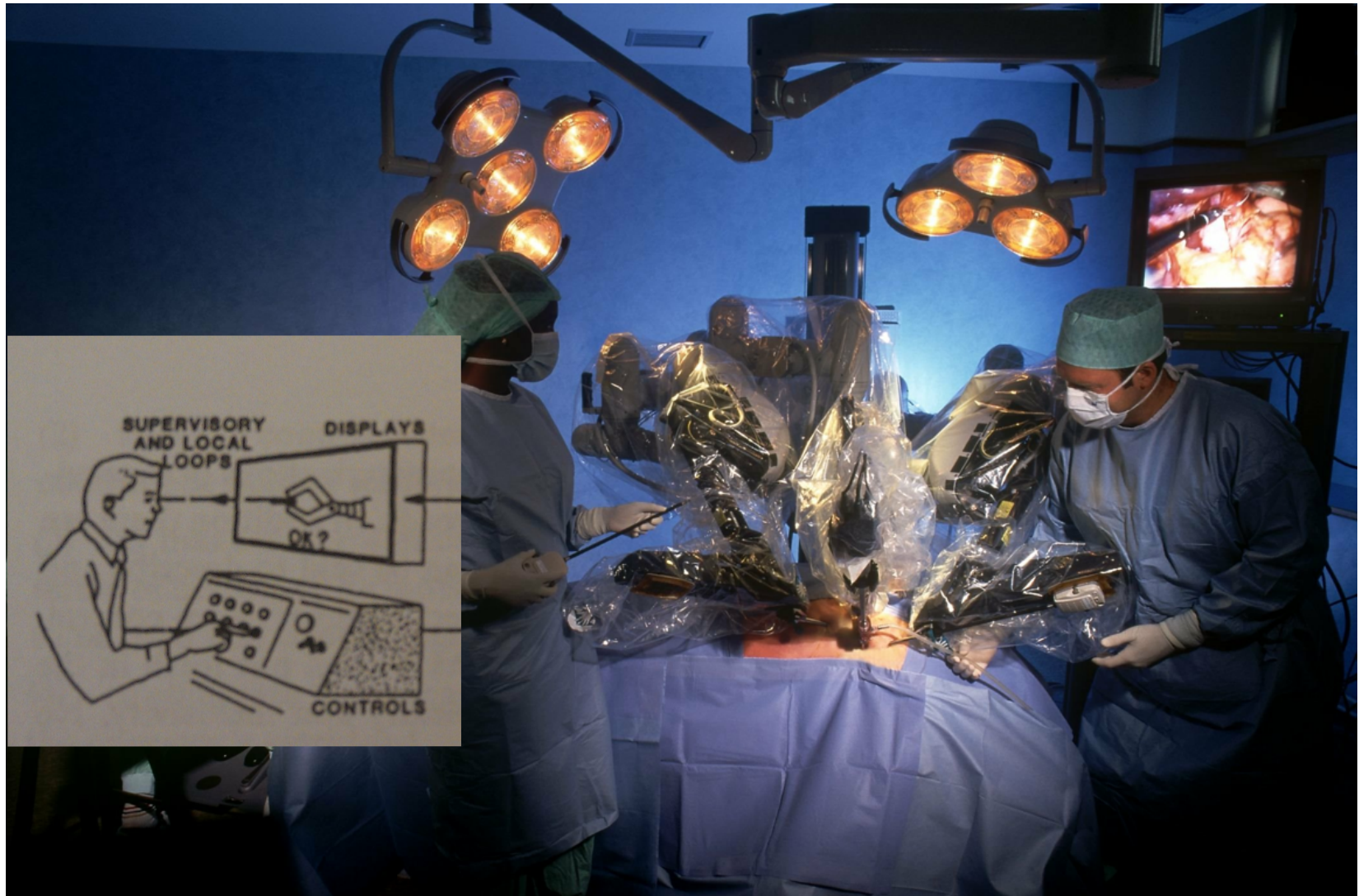
Supervisory Control





Sheridan [1992] "Telerobotics, Automation, and Human Supervisory Control"

Michigan Robotics 367/511 - autorob.org



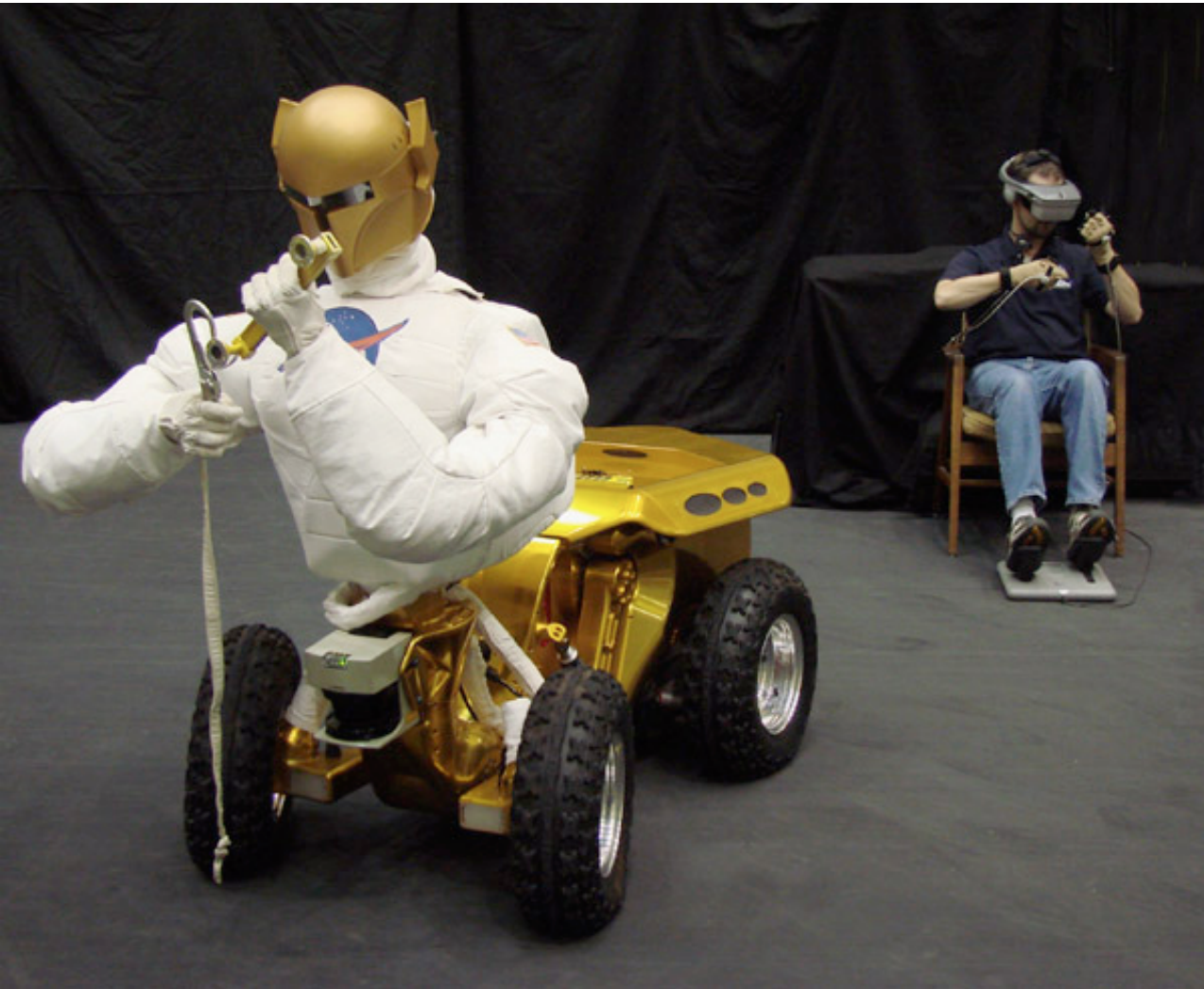
Intuitive Surgical



Intuitive Surgical



Sarcos



NASA Robonaut



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Making robotics accessible
for all people



Henry Evans and Chad Jenkins | TEDxMidAtlantic

Meet the robots for humanity

- Details**
About the talk
- Transcript**
28 languages
- Comments (227)**
Join the conversation

Paralyzed by a stroke, Henry Evans uses a telepresence robot to take the stage and show how new robotics, tweaked and personalized by a group called Robots for Humanity, help him live his life to the full. He shows off a nimble little quadrotor drone, created by a team led by

1,260,676 views

TEDxMidAtlantic | October

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Get Started

- A new perspective
- Ideas for self-improvement
- Insights about issues the
- Nature
- Smart entertainment
- Inspiration or motivation
- Design
- Collaboration
- Personal growth
- Science
- Innovation
- A sense of l
- ter
- Child development
- Activism
- Communication
- Technology

Watch next

The rise of personal robots
1.2M views

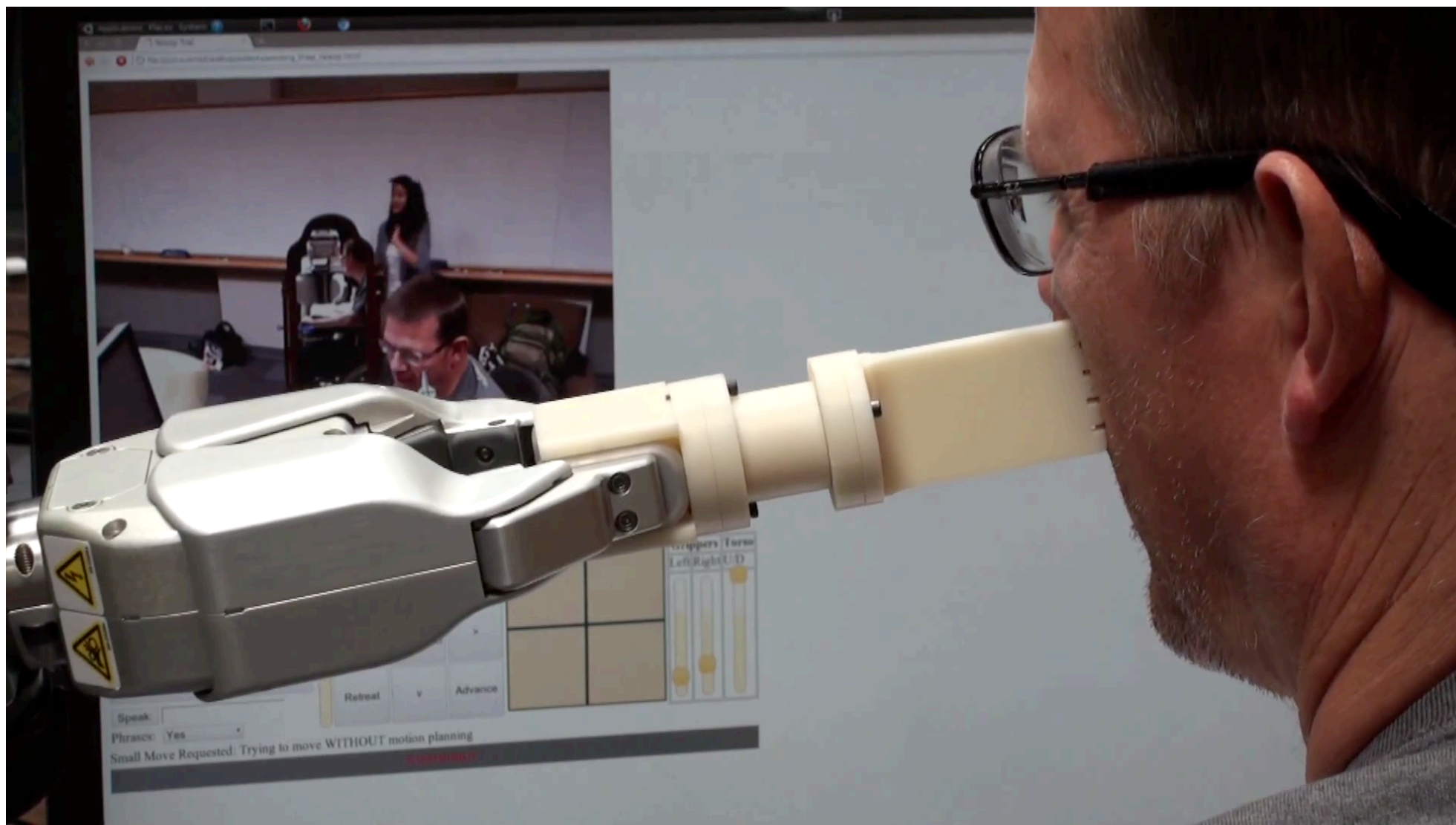


Deep sea diving ... in a wheelchair
2.3M views



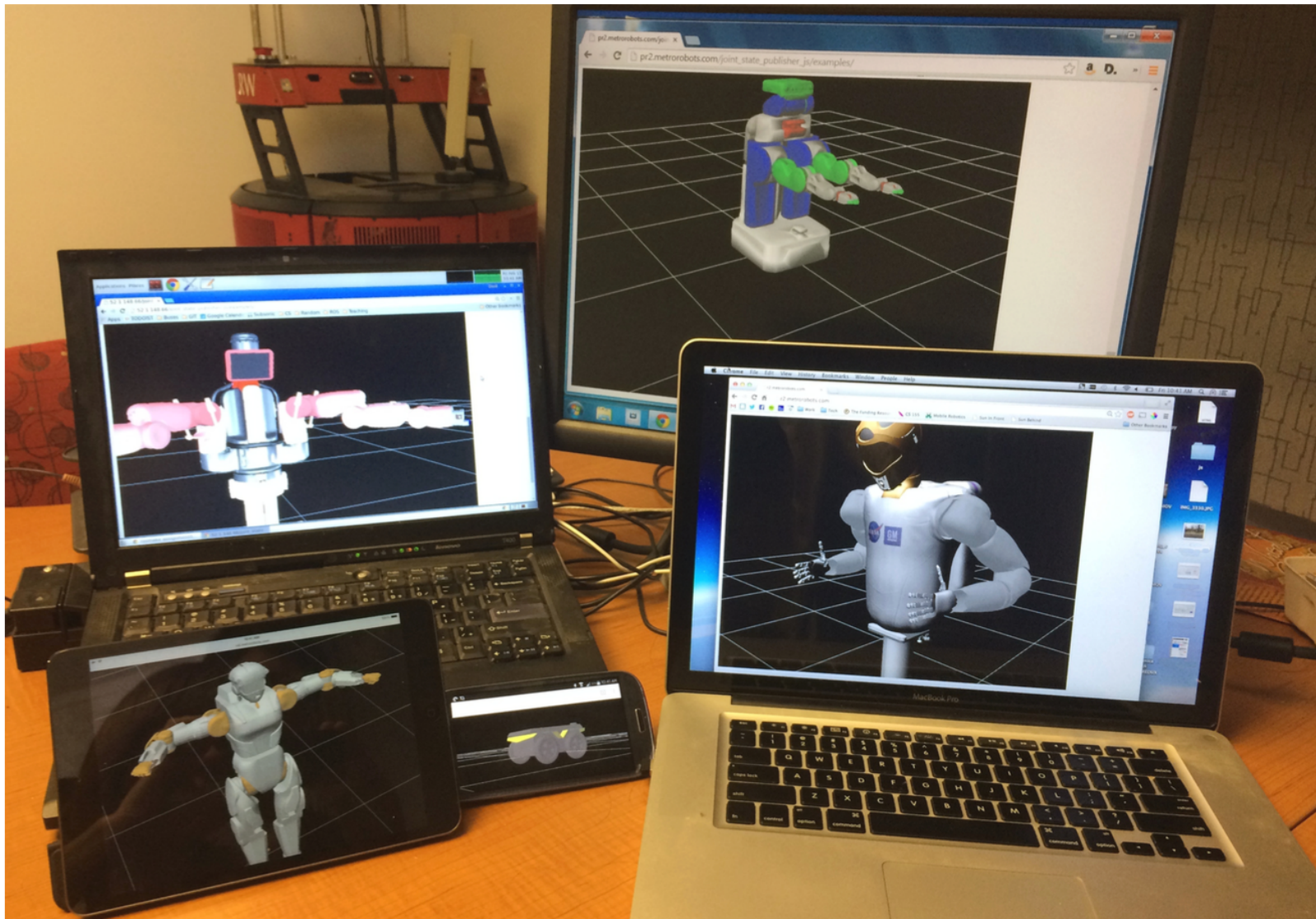
TED Talks are free thanks to our partners and advertisers

New! Activity Feed



Courtesy Robots for Humanity

Michigan Robotics 367/511 - autorob.org



Toris, Jenkins, et al. (2015)

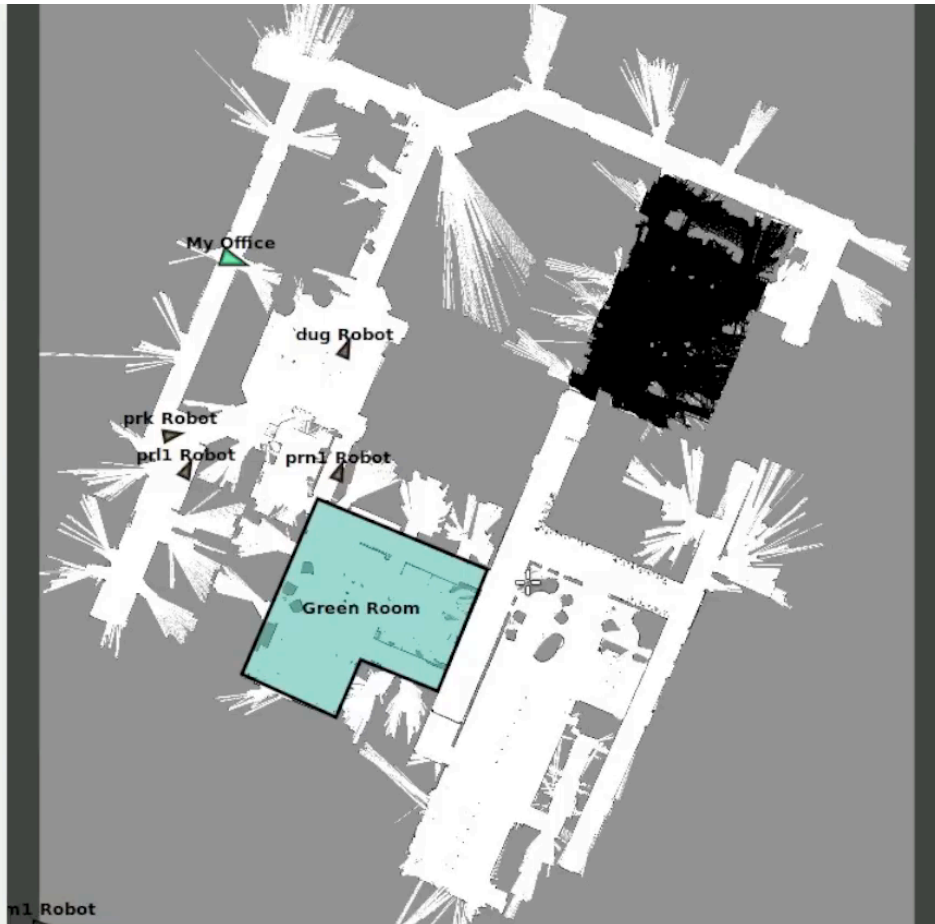
MAP BUILDER

SPEED: 90%





Courtesy Willow Garage



ADD WORLD LOCATION

ADD POINT OF INTEREST

ADD POLYGON

Number of Points: 0

Label:

ADD

CLEAR

My Office

GO HERE!

Courtesy Robot Web Tools / Willow Garage

Does a robot have free will?

How will people use your robot?

How well can people use your robot?

Will robots help or harm society?

Who is responsible if a robot causes harm?

Does a robot have free will?

Do you have free will?

Human-Robot Interaction

Human-Robot Interaction



Alan Schultz
(1959-2019)

Foundations and Trends® in
Human-Computer Interaction
Vol. 1, No. 3 (2007) 203-275
© 2007 M. A. Goodrich and A. C. Schultz
DOI: 10.1561/11000000005

now
the essence of knowledge

Human-Robot Interaction: A Survey

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² US Naval Research Laboratory, Washington, DC 20375, USA,
schultz@aic.nrl.navy.mil

Abstract

Human-Robot Interaction (HRI) has recently received considerable attention in the academic community, in labs, in technology companies, and through the media. Because of this attention, it is desirable to present a survey of HRI to serve as a tutorial to people outside the field and to promote discussion of a unified vision of HRI within the field. The goal of this review is to present a unified treatment of HRI-related problems, to identify key themes, and discuss challenge problems that are likely to shape the field in the near future. Although the review follows a survey structure, the goal of presenting a coher-

Human-Robot Interaction

HRI is a descendent of human factors and supervisory control

Modern HRI is largely regarded as the application of psychological user studies with design, computational, and mechanical considerations

HRI also includes **social robotics** and ethical issues around robotics

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Social Robotics

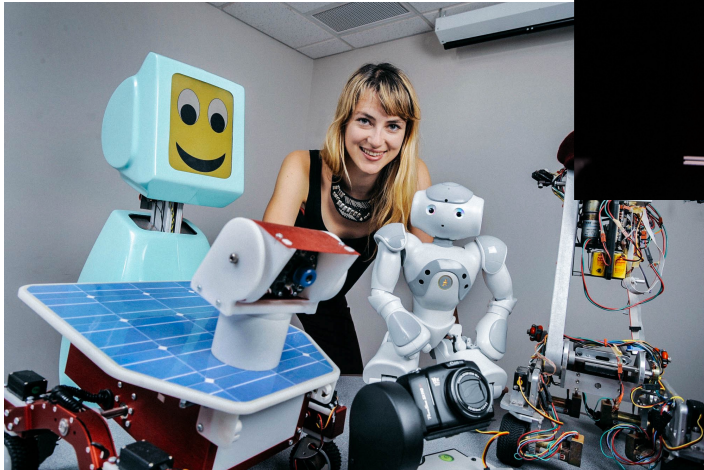


Autism treatment



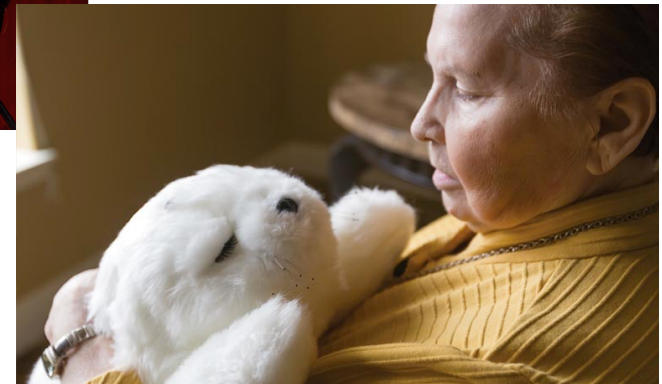
Education

Entertainment



Rehabilitation

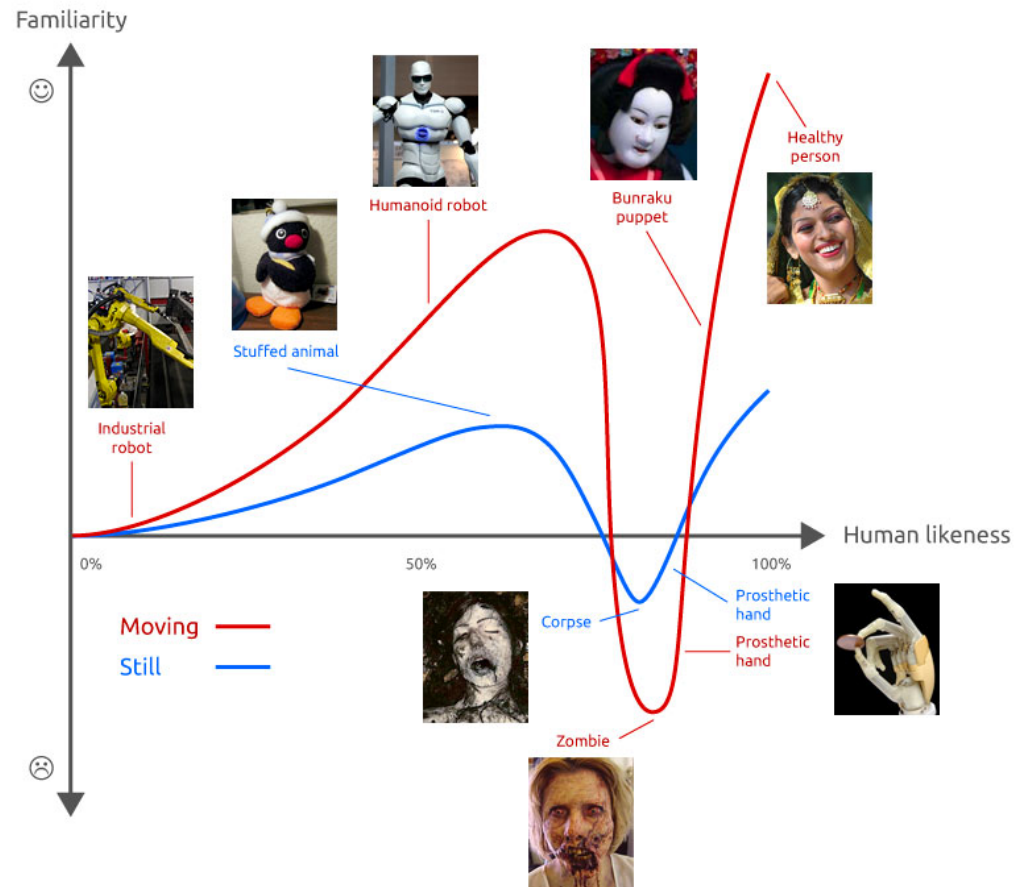
Elder care





<https://youtu.be/WijMCSfX0RA>

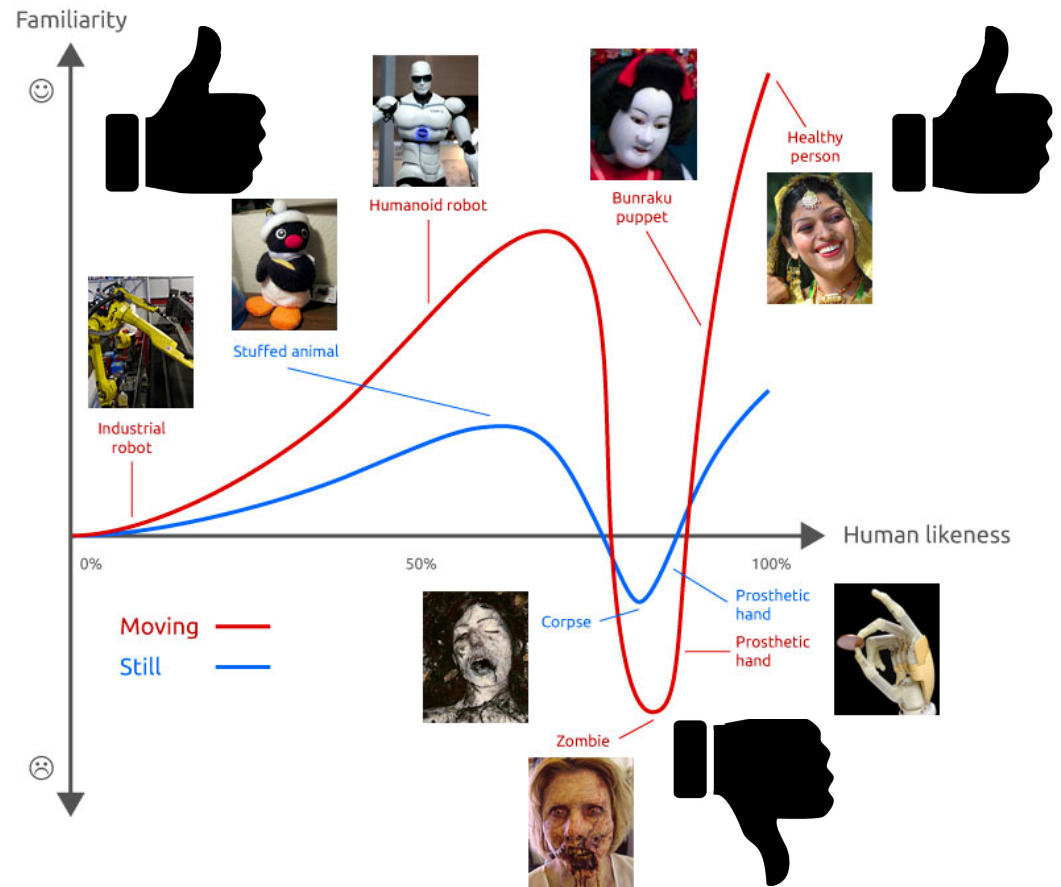
The Uncanny Valley





<https://youtu.be/WijMCSfX0RA>

The Uncanny Valley



robot (n):
a machine that resembles a living creature in
being capable of moving independently and
performing complex actions



Merriam-Webster

SINCE 1828

robot

DICTIONARY

THESAURUS

Maybe this is robotics after all...

1 : a machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)

- When the next space launch heads for Mars, on board will be dozens of tiny mobile *robots* that will fan out across the Martian landscape, exploring every nook and cranny. —Michael Bow

often : such a machine built to resemble a human being or animal in appearance and behavior

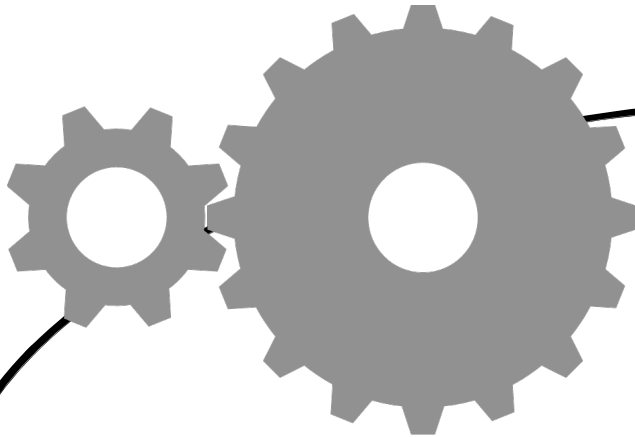
- While science fiction *robots* are capable of independent thought, emotions, even a little cooking and sewing, scientists are finding that endowing a mechanical being with even the most basic human functions is a monumental



CITE

7

Robotics



Mechanical Engineering
Electrical Engineering
“Mechatronics”



Human Factors
Supervisory Control
“Usability”



Computer Science
Artificial Intelligence
“Autonomy”

Good luck and make progress.