

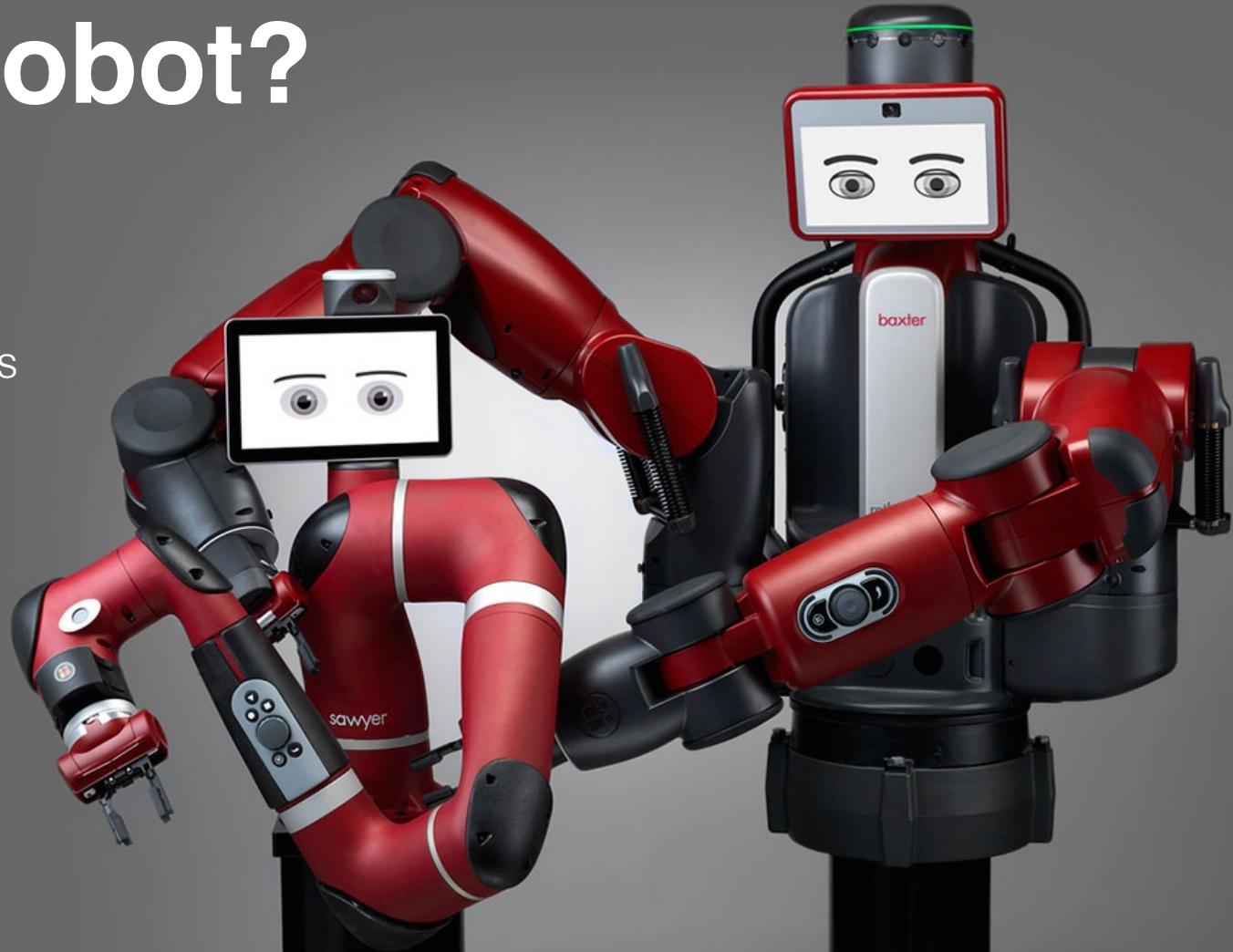
# What is a robot?

EECS 398  
Intro. to Autonomous Robotics

ME/EECS 567 ROB 510  
Robot Modeling and Control

Fall 2018

[autorob.org](http://autorob.org)



# What is a robot?

(don't be shy)



SINCE 1828

JOIN MWU | GAMES | BROWSE THESAURUS | WORD OF THE DAY | VIDEO | WORDS AT PLAY

robot

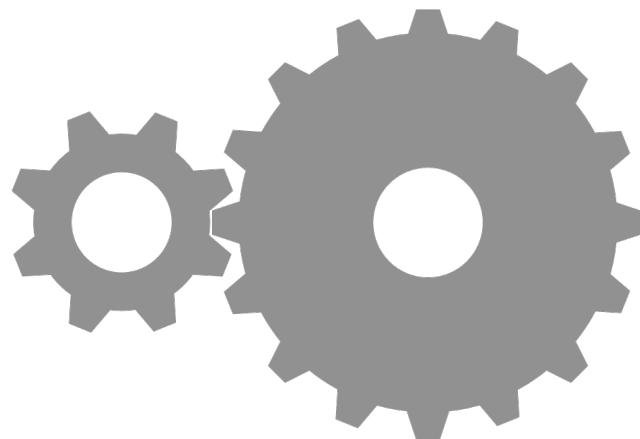
DICTIONARY

THESSAURUS

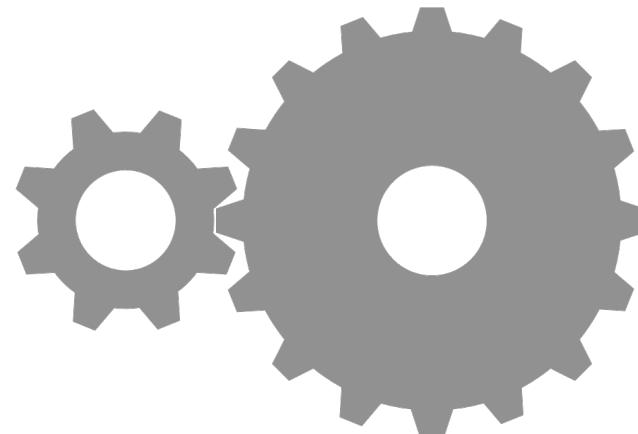
- 1 : a machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping and moving objects)
- When the next space lander headed for Mars, on board will be dozens of tiny mobile *robots* that will roll 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



Robotic machines are comprised of joints and links

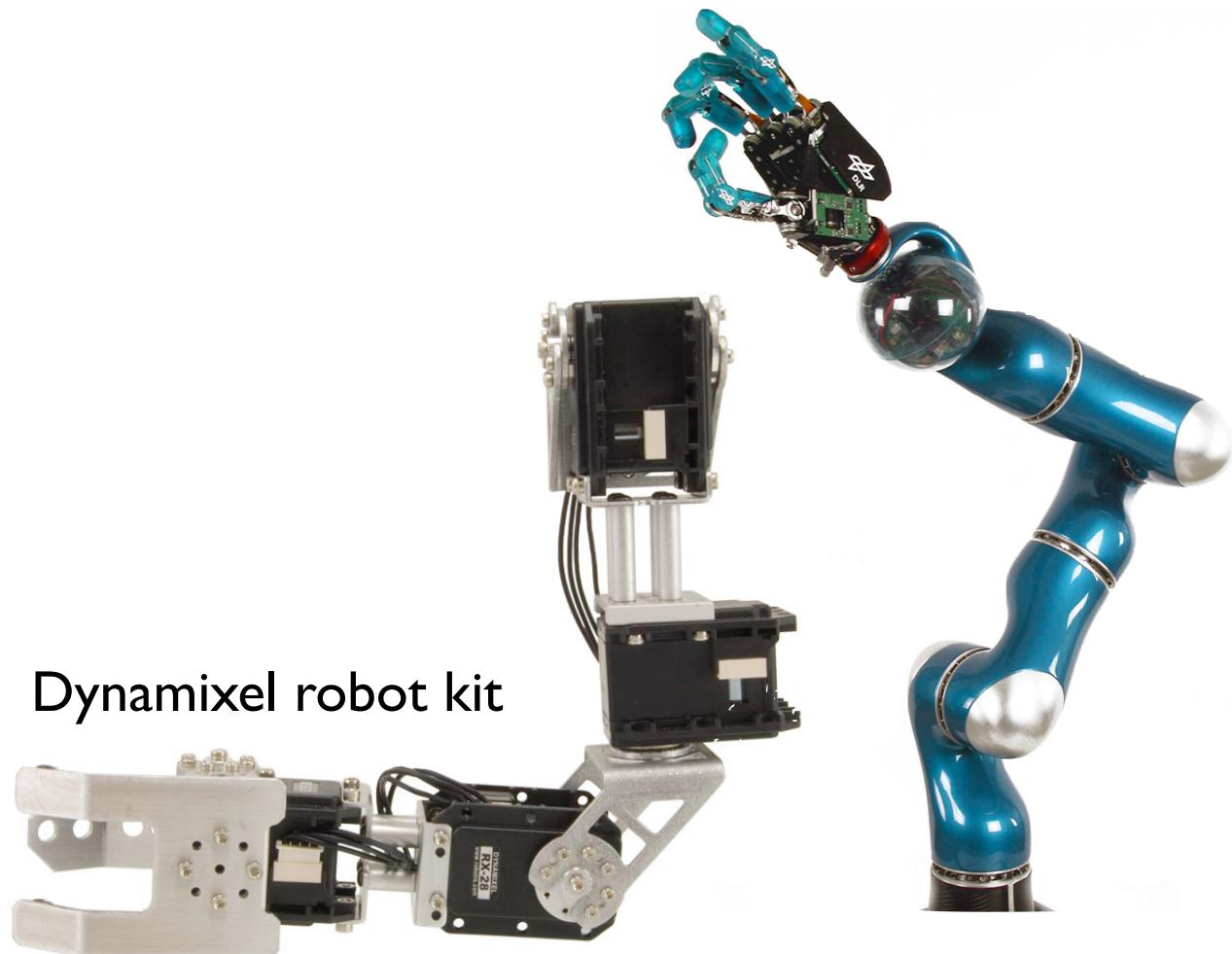
A link is a rigid part of the robot machine

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



Robotic machines are comprised of joints and links

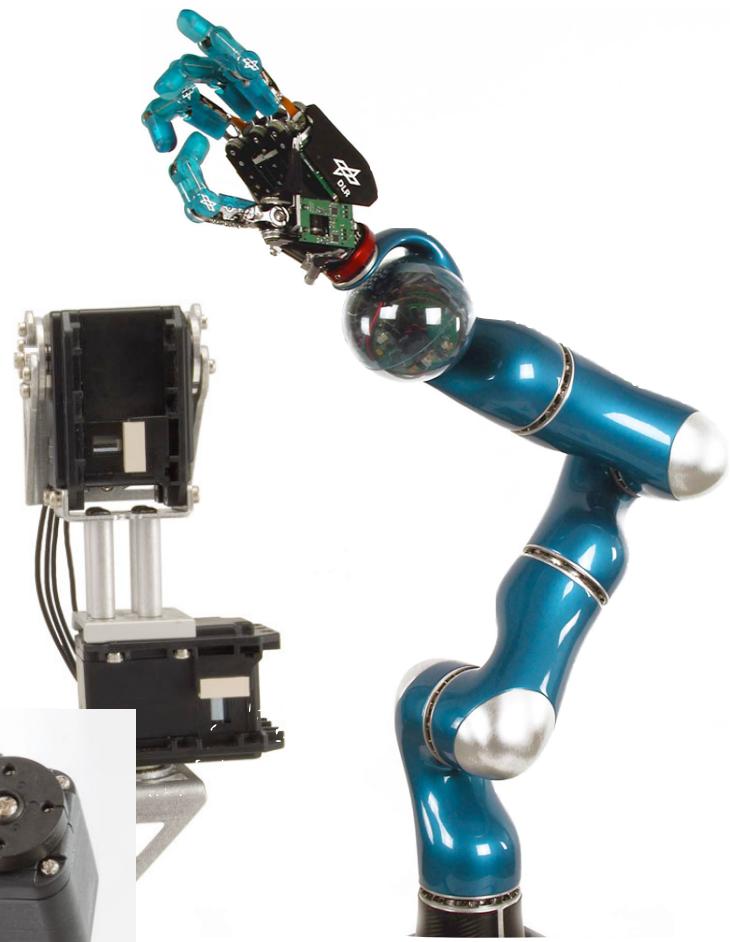
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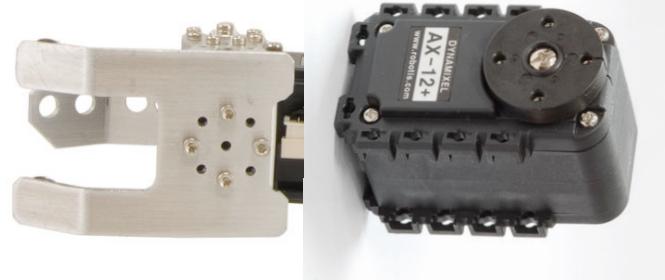
The pose of a joint can be controlled by motor and is called a degree-of-freedom

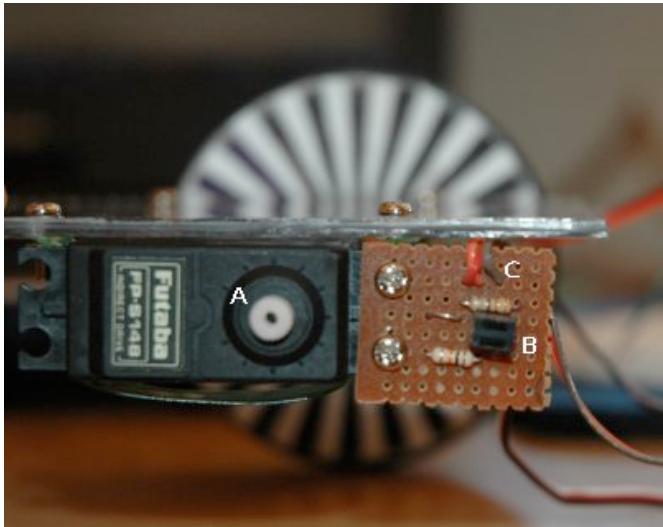
Connections of joints and links form a hierarchy of articulated motion

DLR Lightweight arm



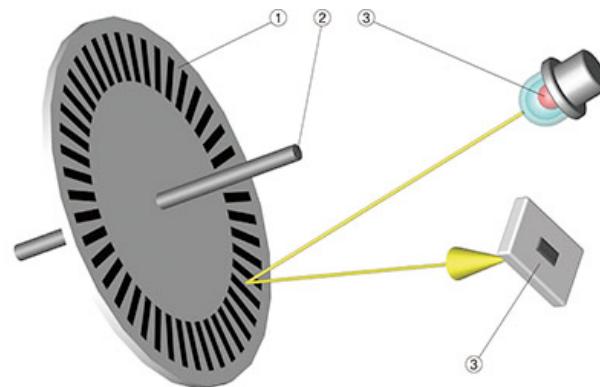
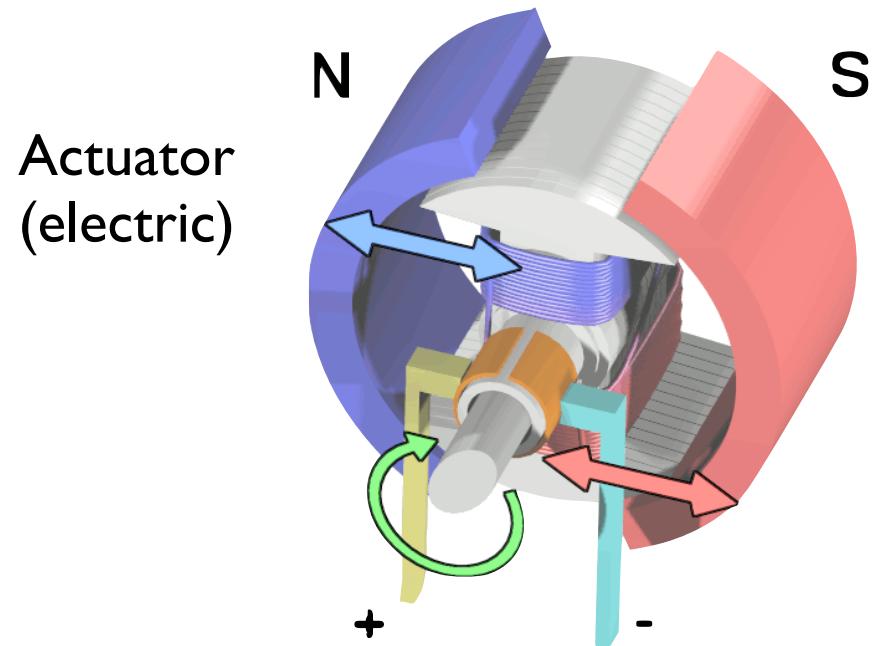
Dynamixel robot kit





Motors have:

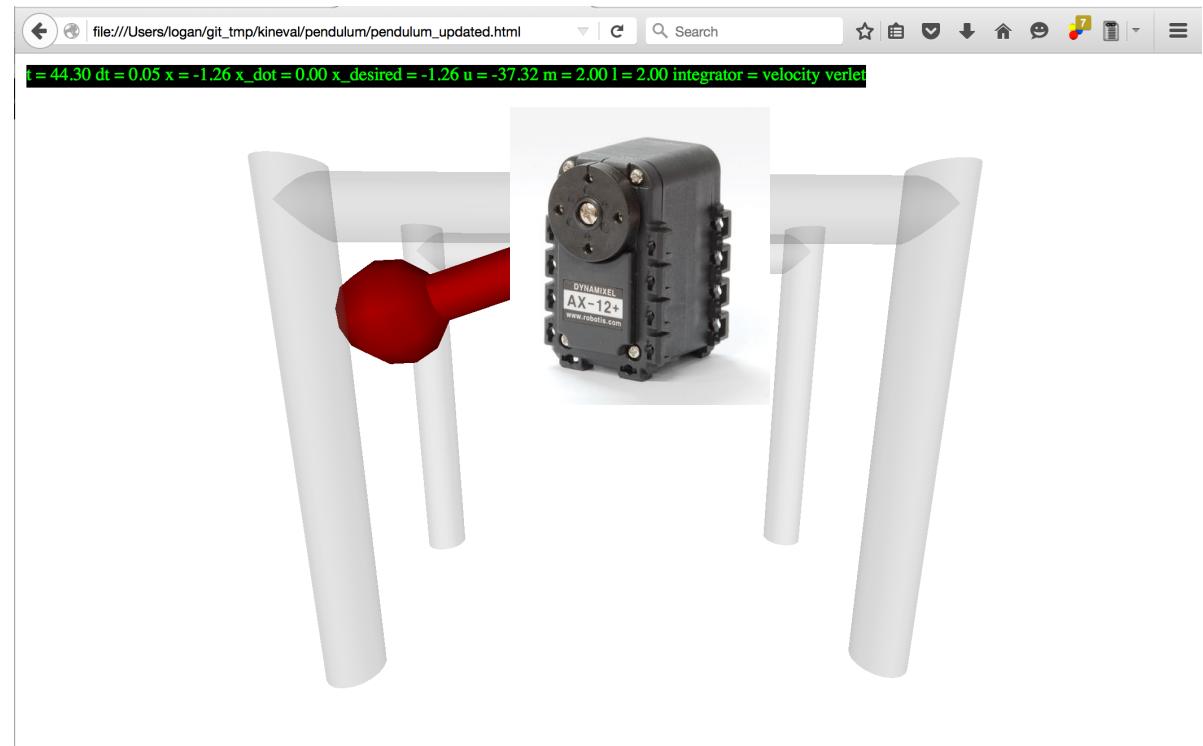
- actuators to produce motion
- proprioception to sense pose



Proprioception  
(optical encoder)

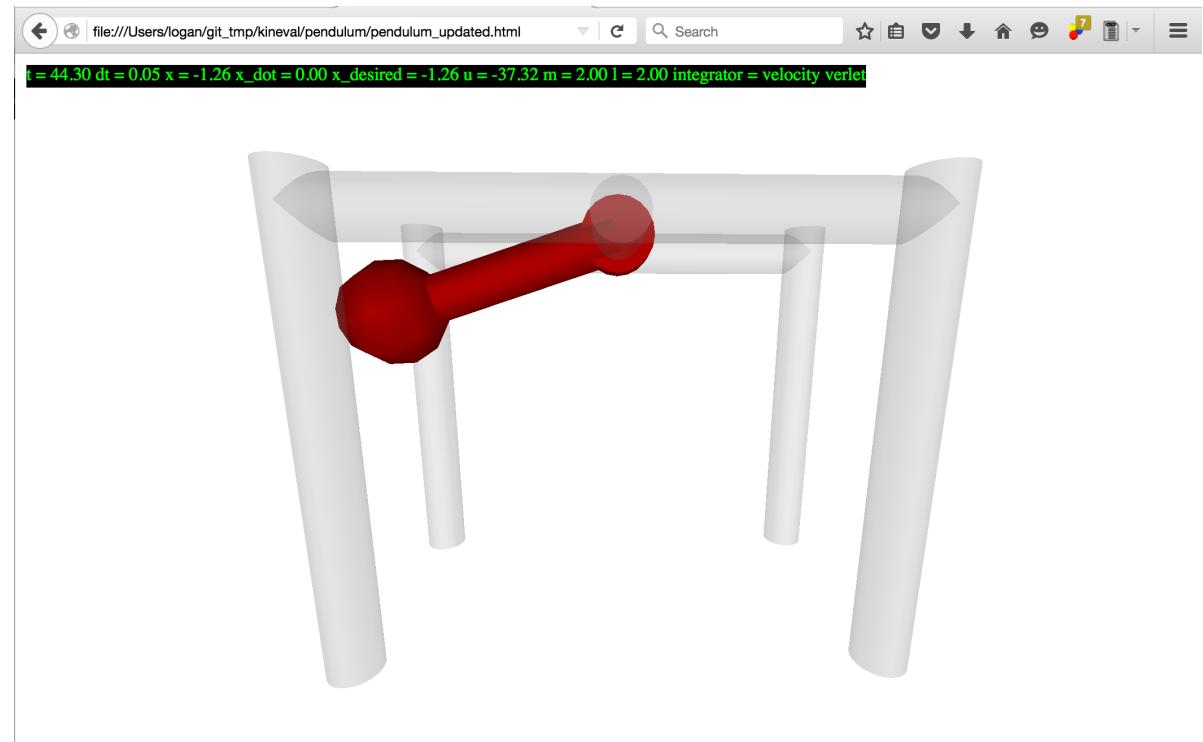
# Project 2: Pendularm

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



# Project 2: Pendularm

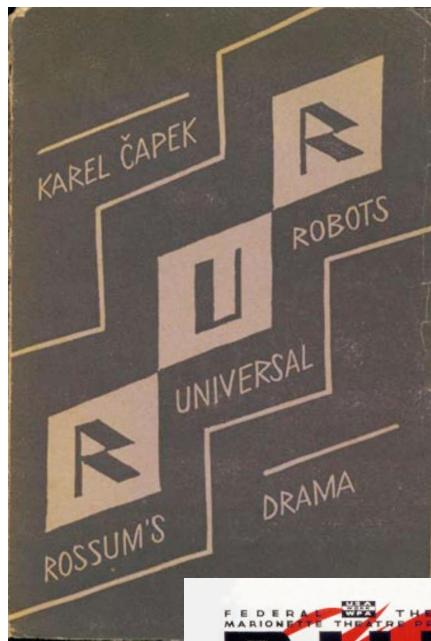
- 1 degree-of-freedom robot arm
- Physically simulate through Lagrangian equations of motion
- Control arm pose with a PID controller



“Robotics” is science fiction

Automation by “robots” is real

robot



R.U.R.  
(1920)

Karel Čapek  
(1890-1938)



# robot

Josef Čapek  
(1887-1945)

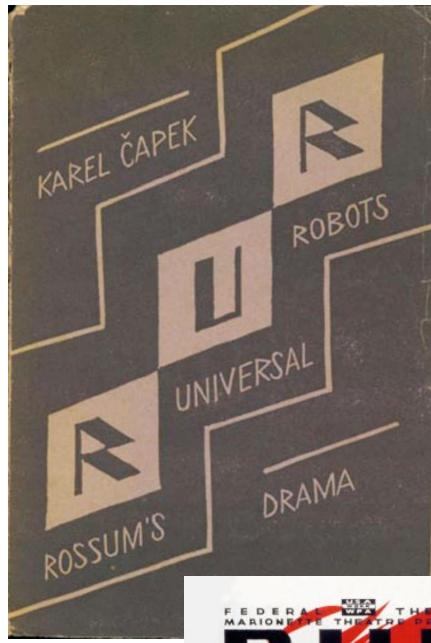


forced labor | serf | slave

# robota

Josef Čapek  
(1887-1945)





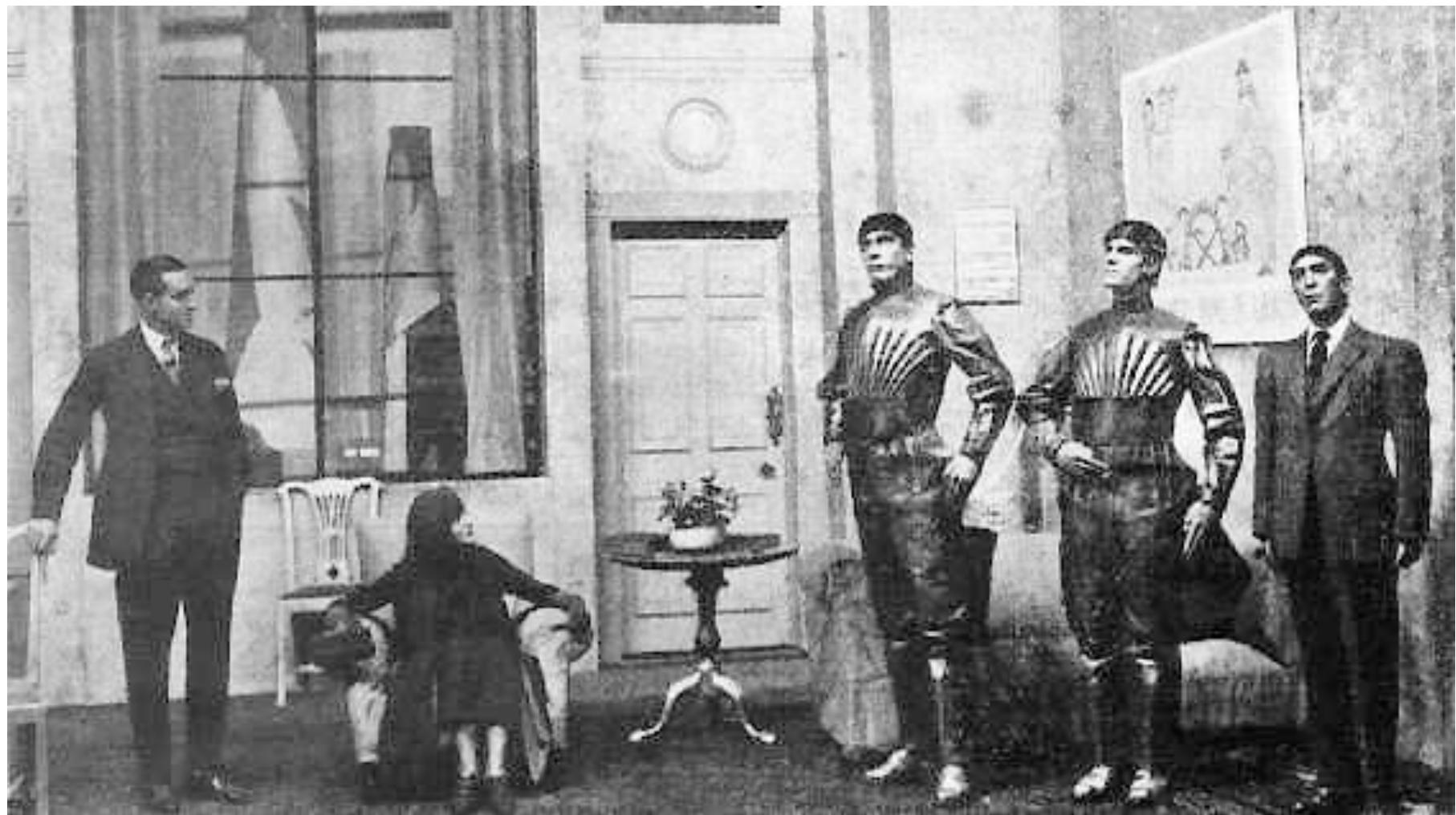
R.U.R.  
(1920)



Karel Čapek  
(1890-1938)

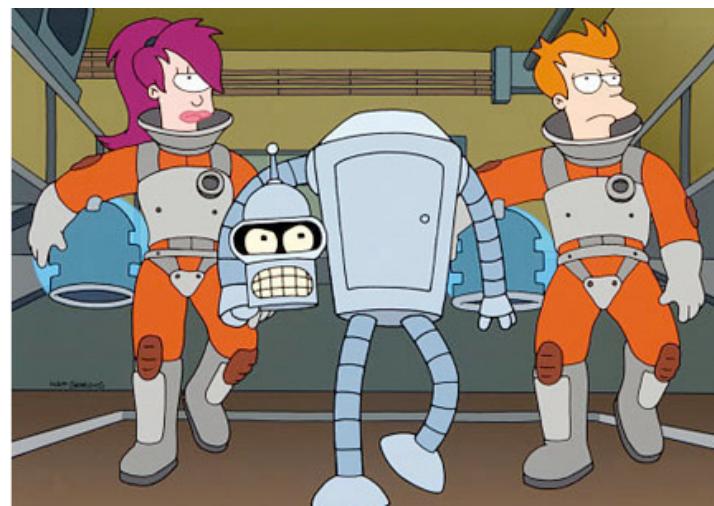
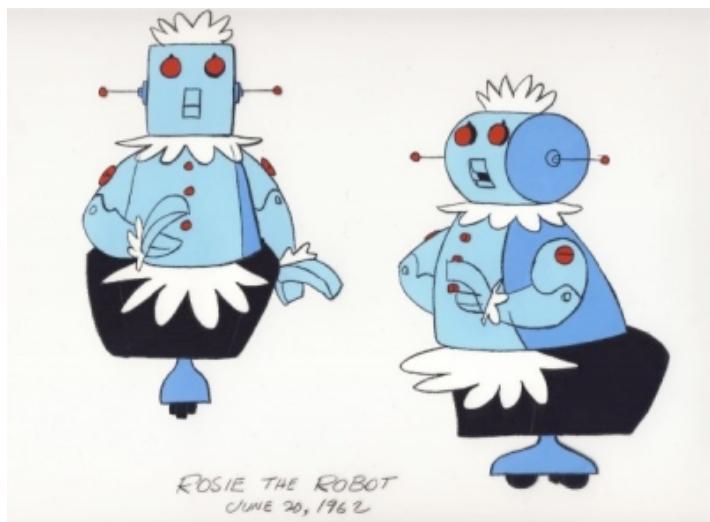
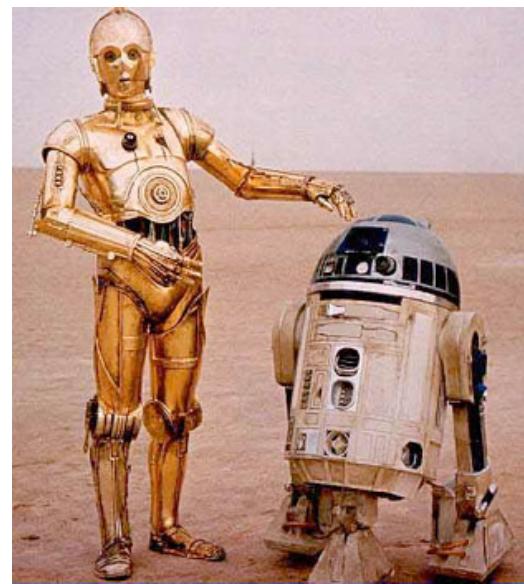


# robot





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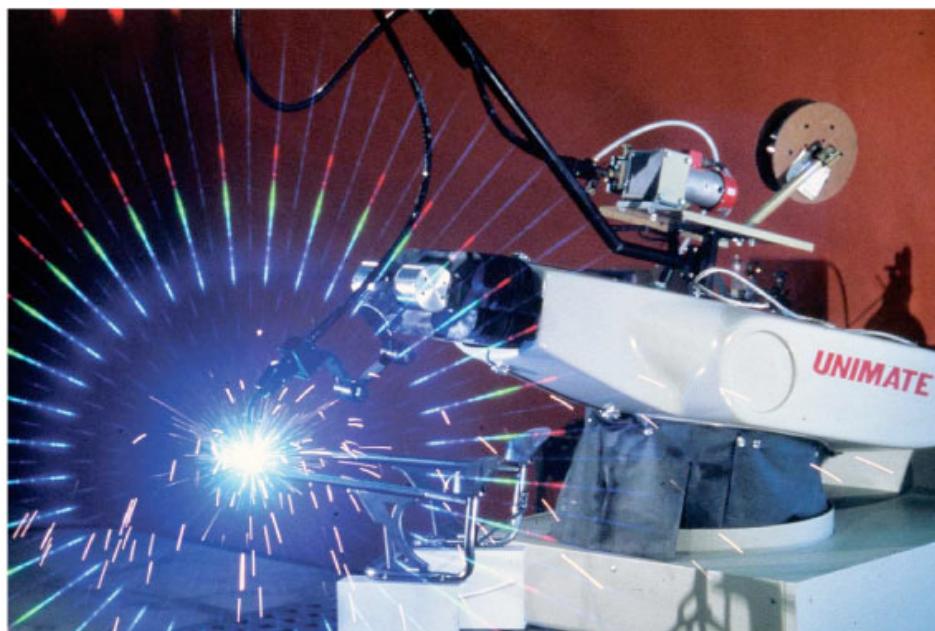


in reality, modern automation  
began in the 1950s

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

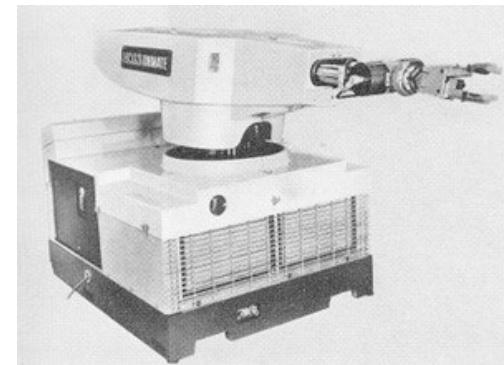
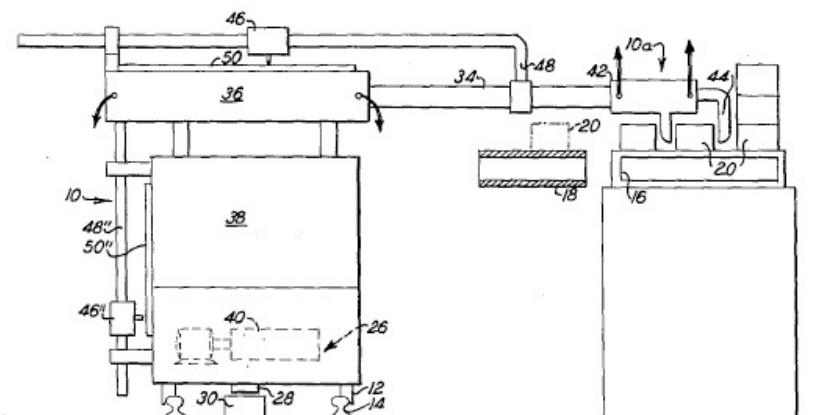
G. C. DEVOL, JR

2,988,237

Filed Dec. 10, 1954

PROGRAMMED ARTICLE TRANSFER

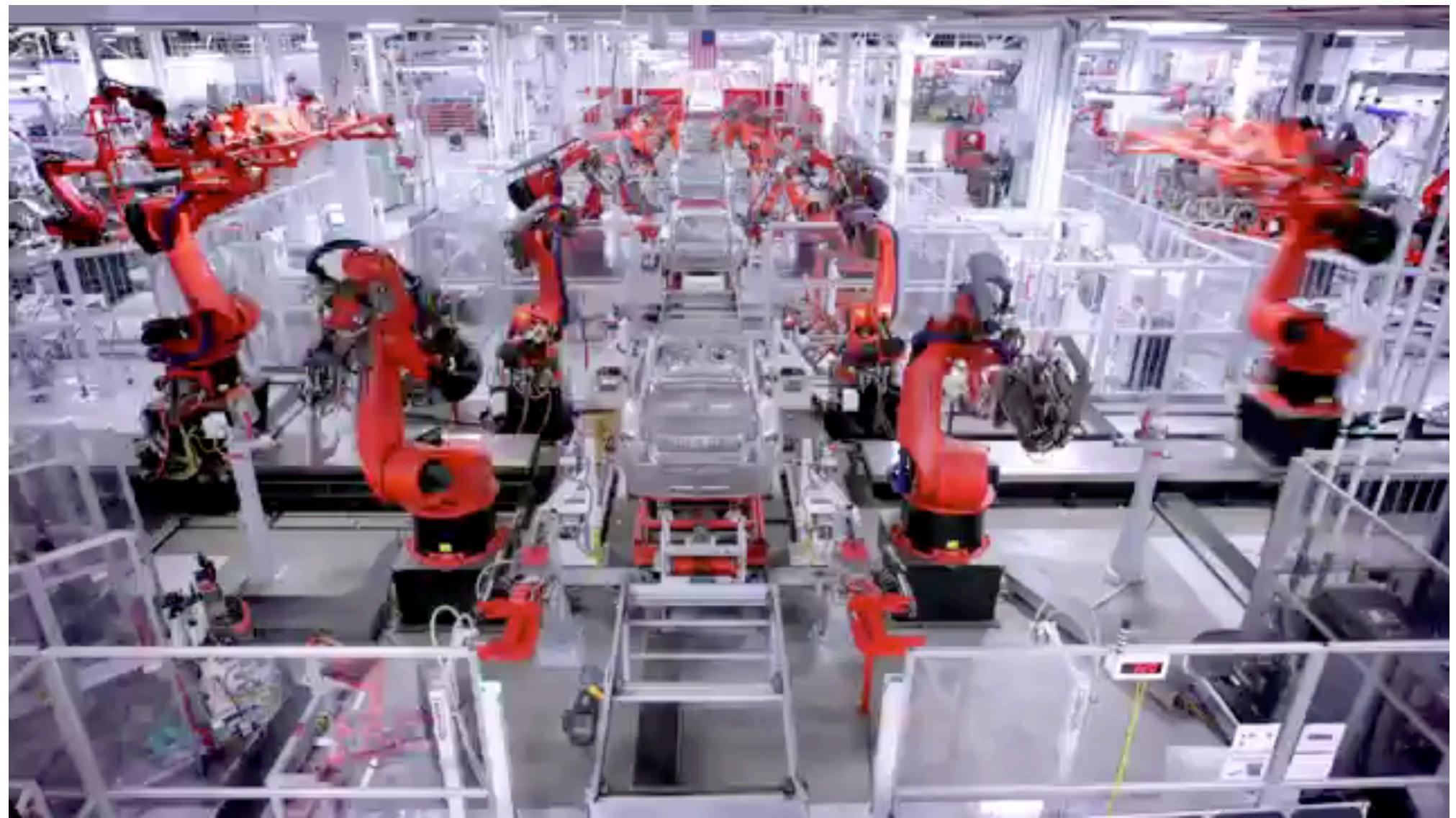
3 Sheets-Sheet 1





<http://wn.com/unimate>

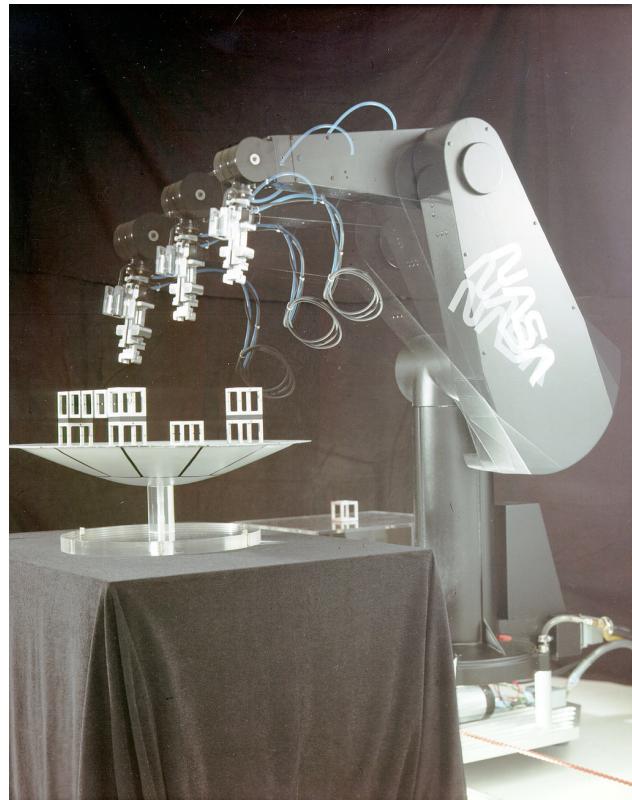
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WIRED at Tesla [https://www.youtube.com/watch?v=8\\_lfxPl5ObM](https://www.youtube.com/watch?v=8_lfxPl5ObM)

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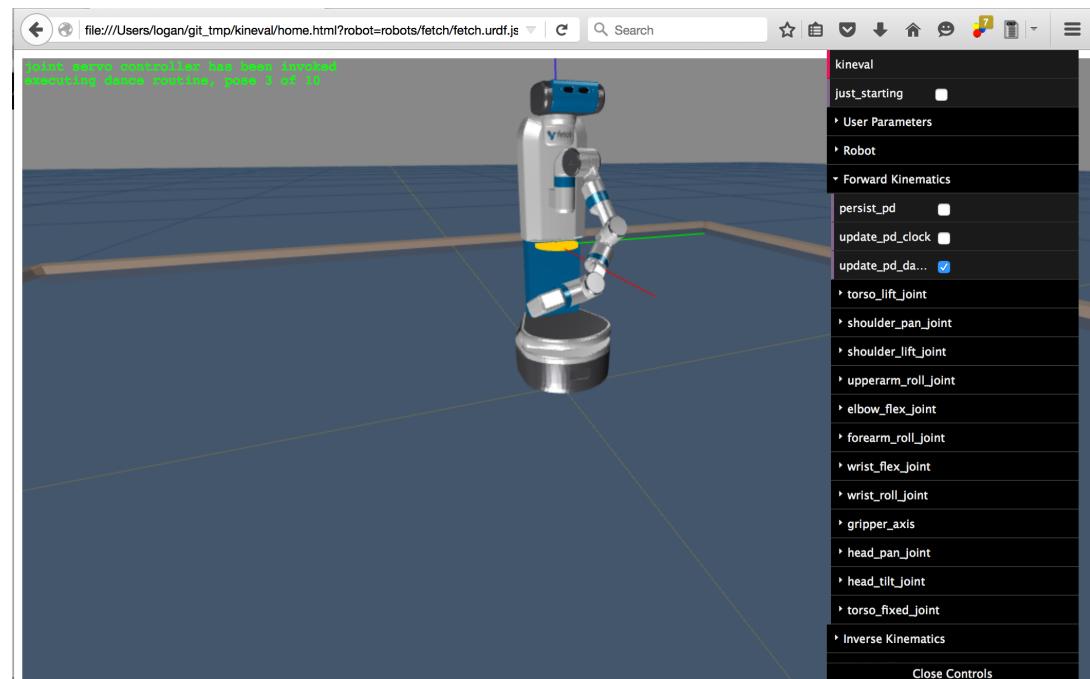
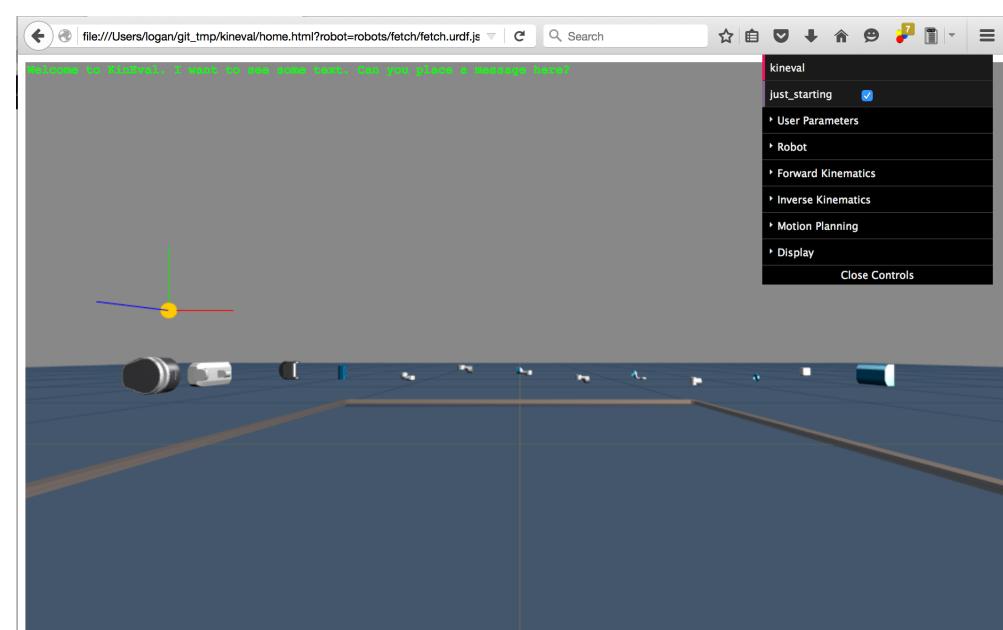
Industrial robotics has focused mostly on pick-and-place tasks



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

# Projects 3-4: Forward Kinematics

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

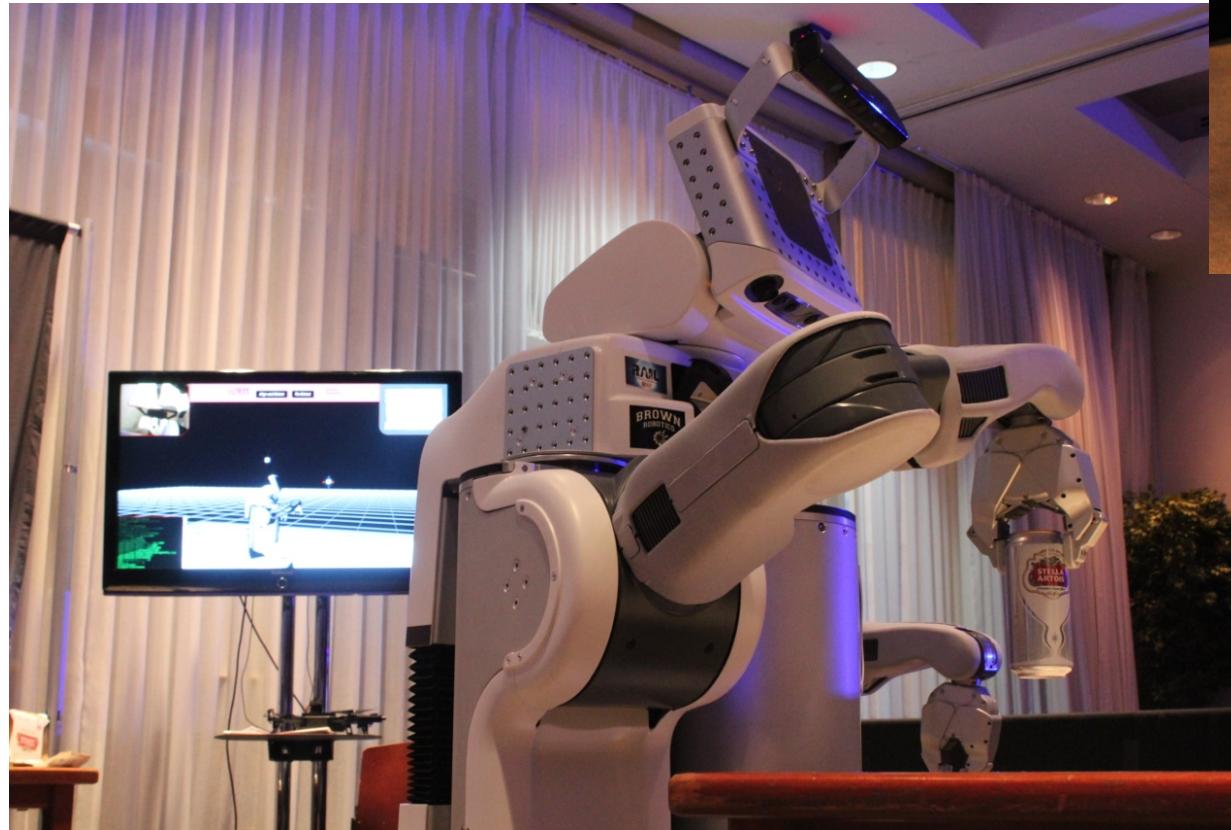


Does perfect sensing with perfect  
motors make a perfect robot?

Does perfect sensing with perfect  
motors make a perfect robot?

No. A robot also needs computation  
to map sensing to action.

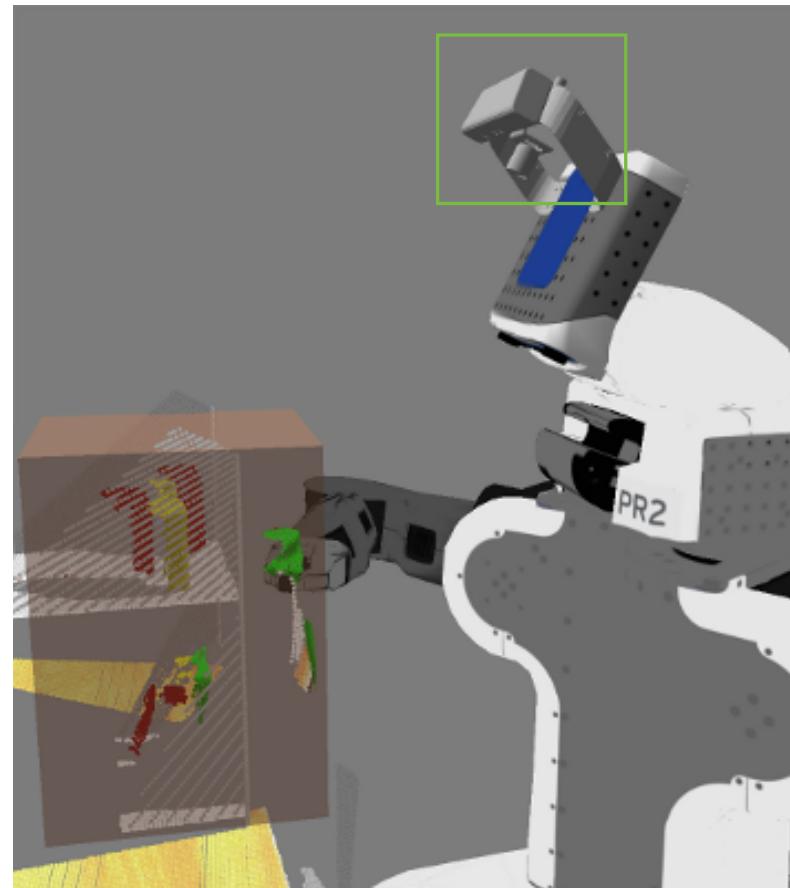
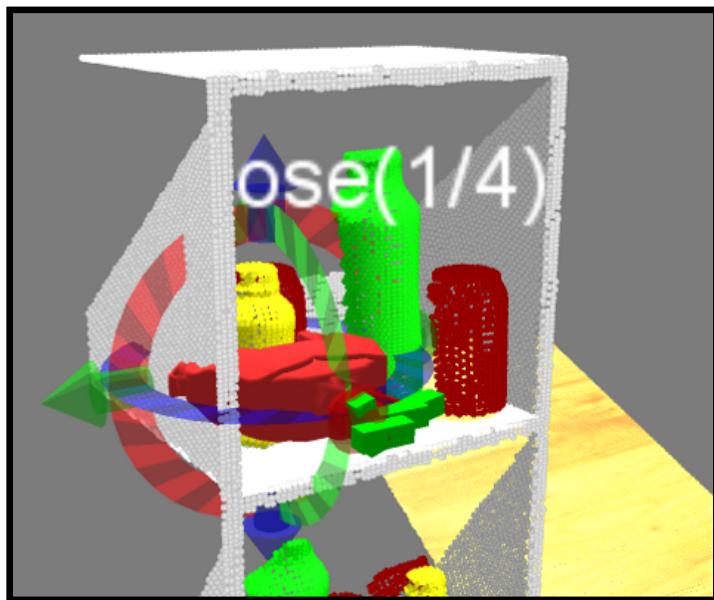
# Manipulation



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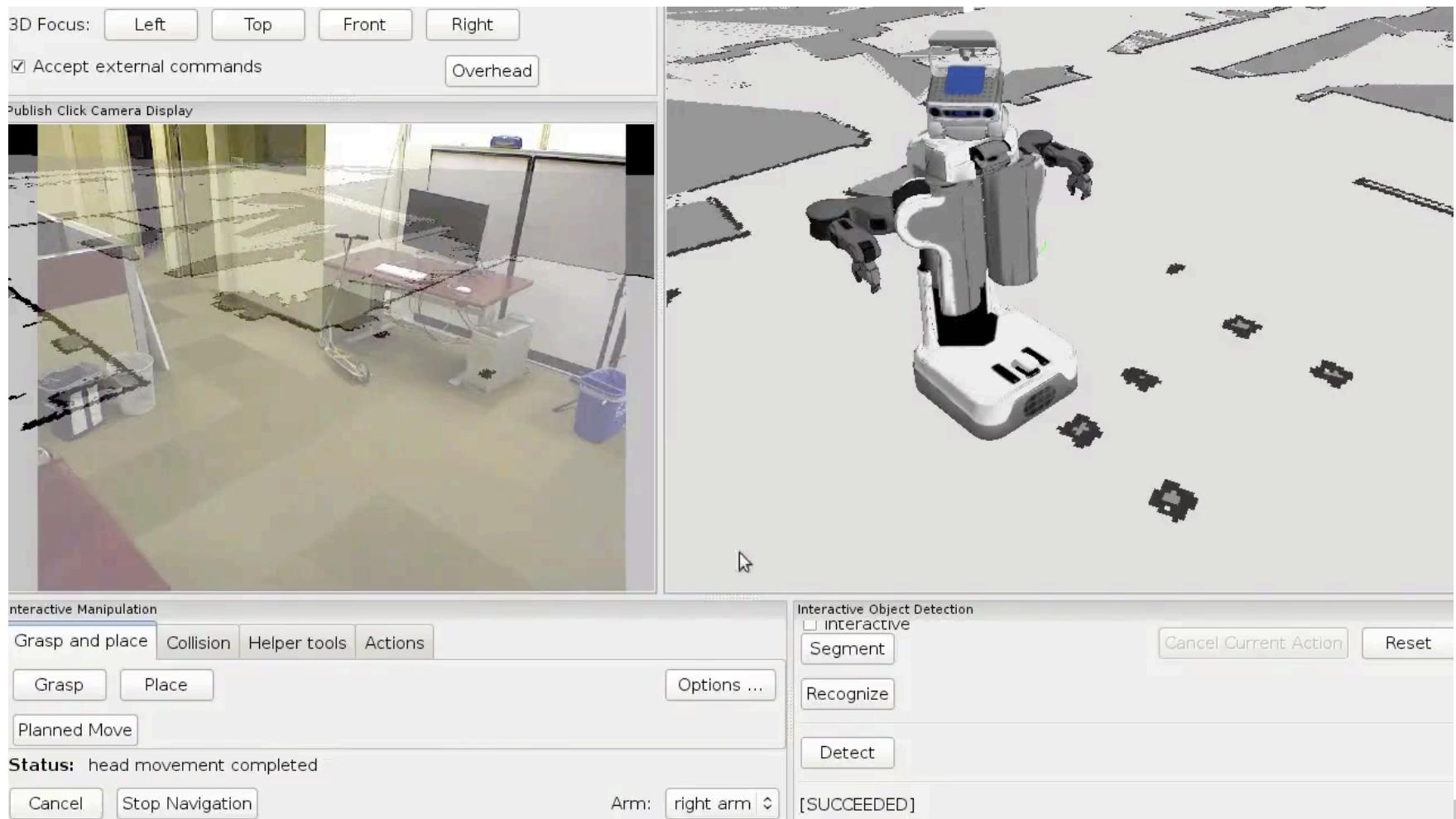


## Mobility and Manipulation



# Manipulation

Willow Garage



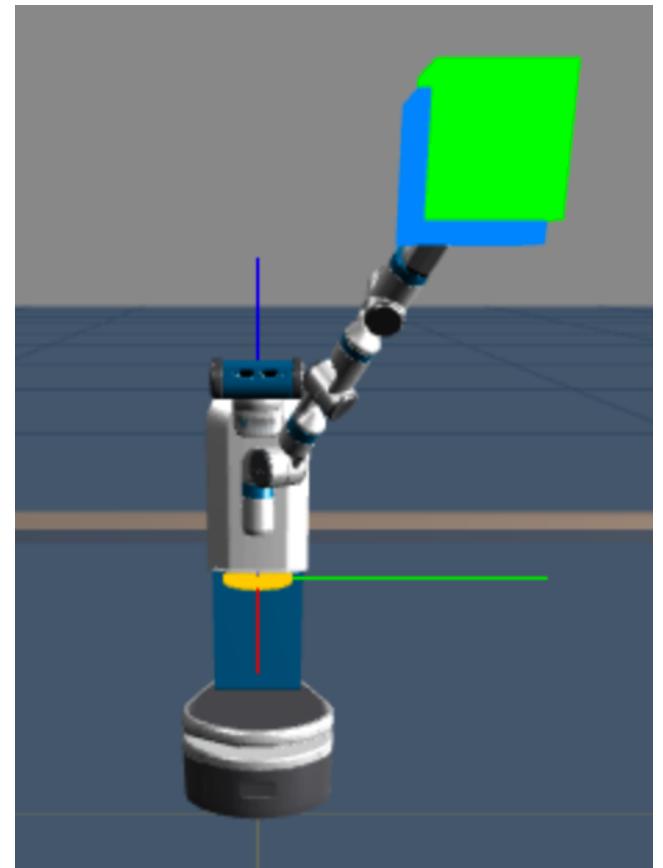
b.github.io

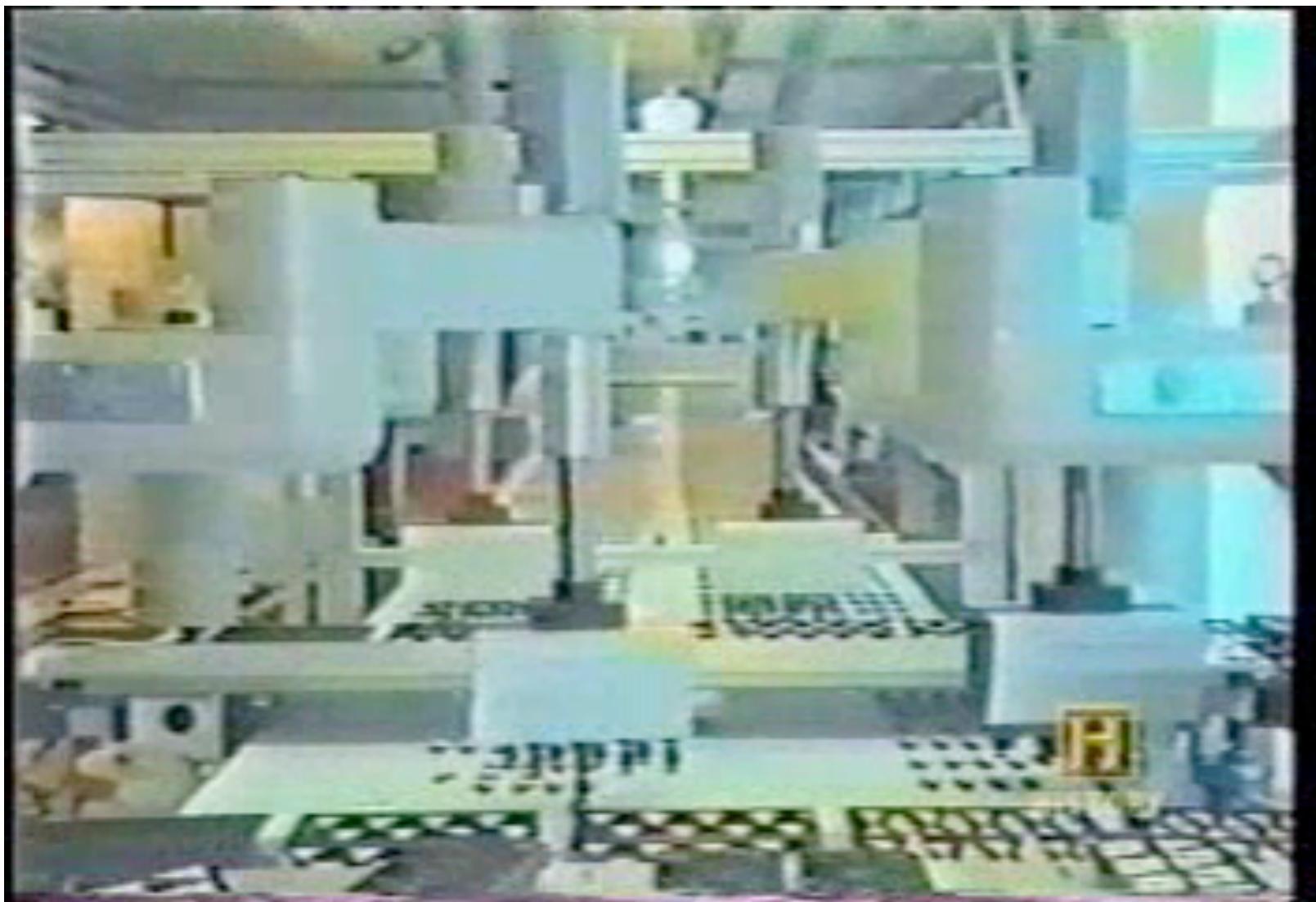
# Project 5: Inverse Kinematics

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

Compute Manipulator Jacobian

Perform gradient descent optimization

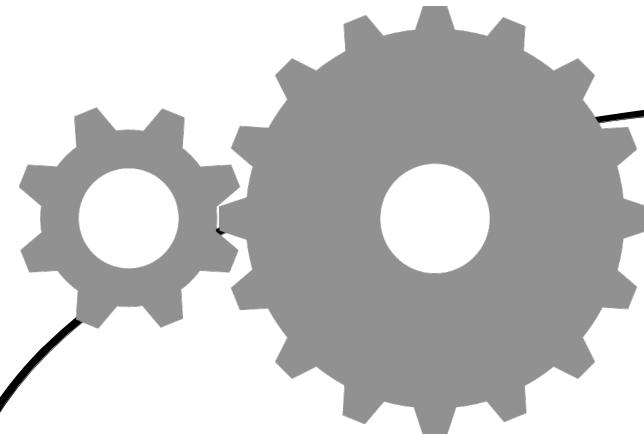




<http://vimeo.com/2276417>

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# Robotics

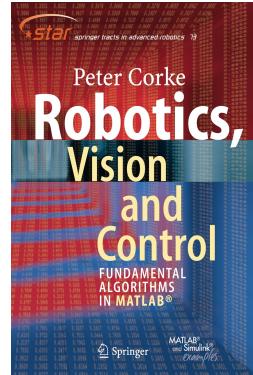


Mechanical Engineering  
Electrical Engineering  
“Mechatronics”



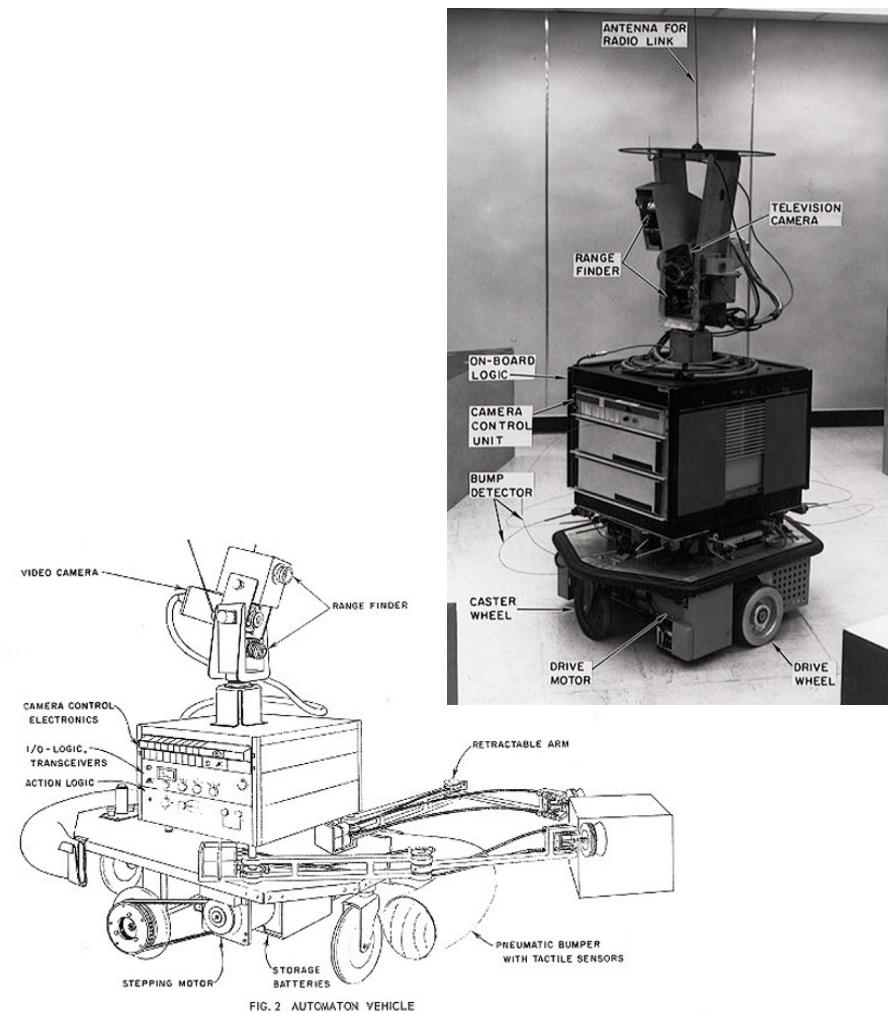
Computer Science  
Artificial Intelligence

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



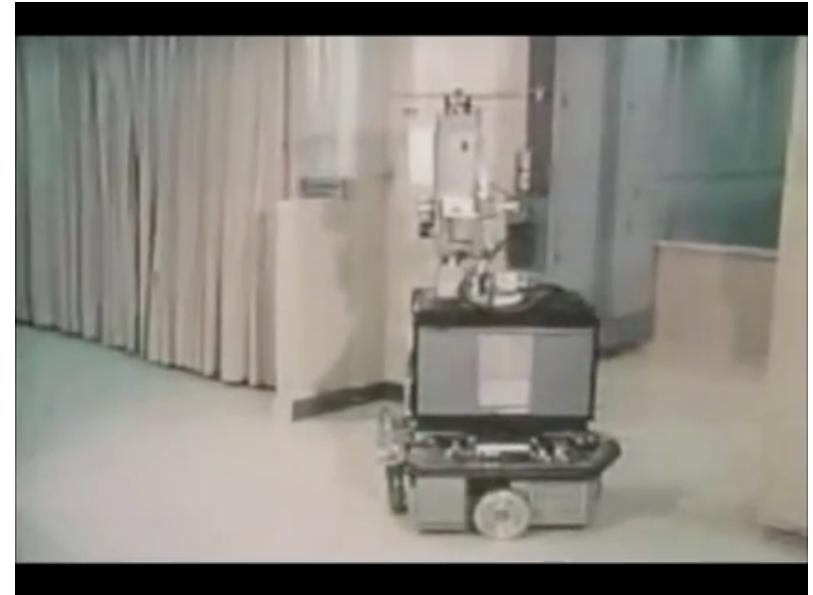
There are many definitions for “robot”.  
AutoRob will use this one.

# Mobility/Navigation



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

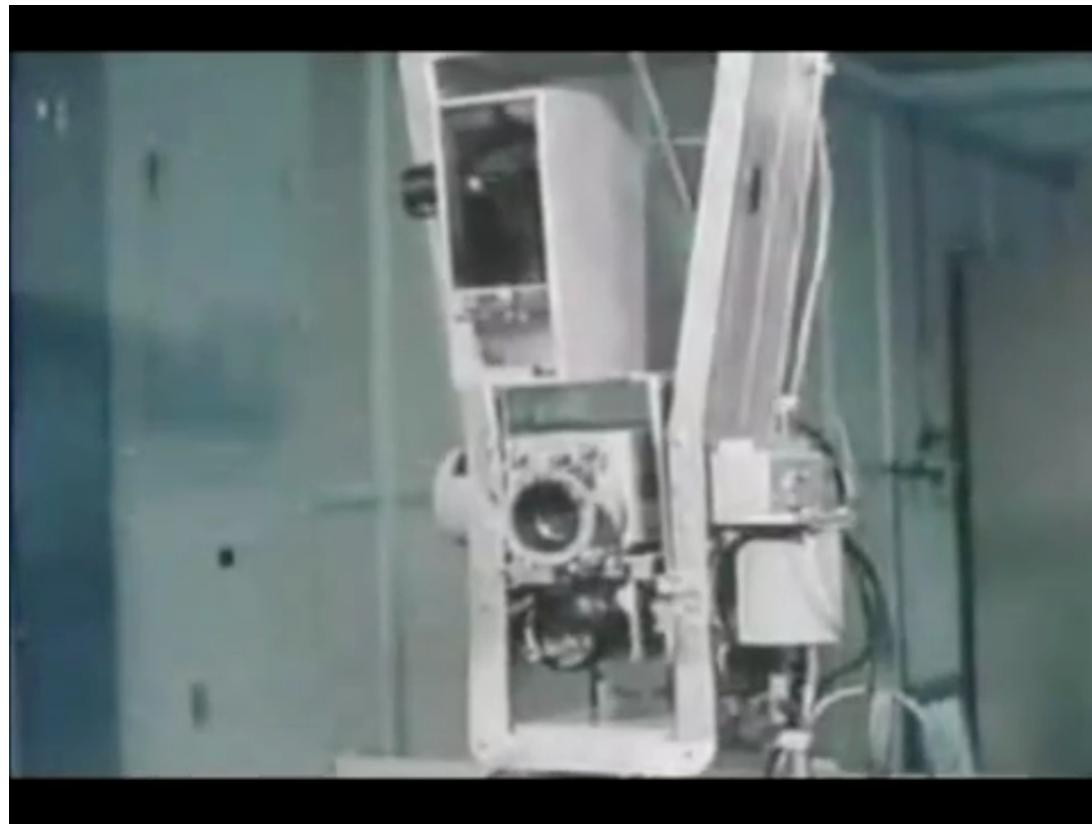
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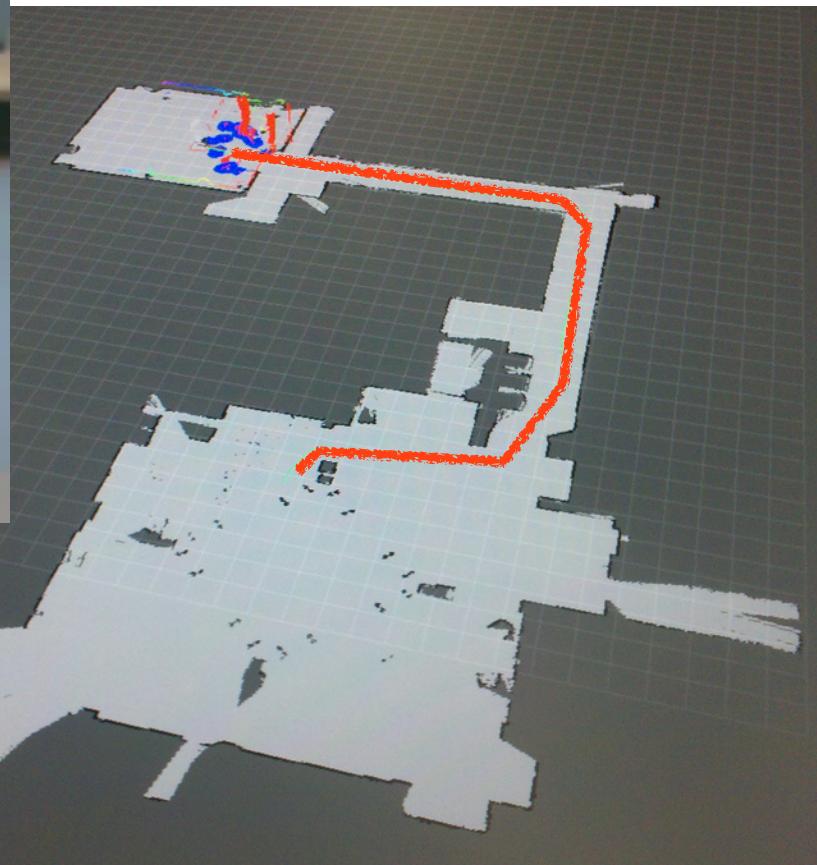
Autonomous robots traditionally use a  
sense-plan-act loop

Sense: perceive an accurate model of the world  
Plan: decide a sequence of actions to reach goal  
Act: execute actions to realize goal

# Early computer vision



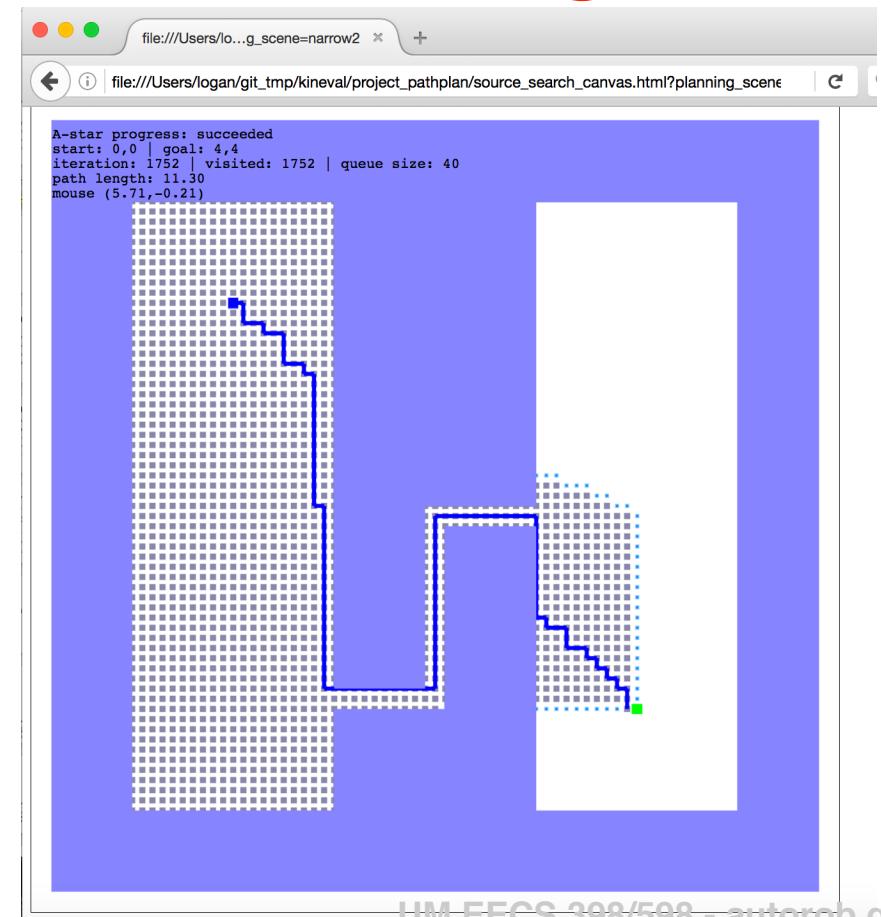
UM EECS 398/567 - autorob.github.io



PR2 navigation at Brown University  
June 2011

# Project 1: Path Planning

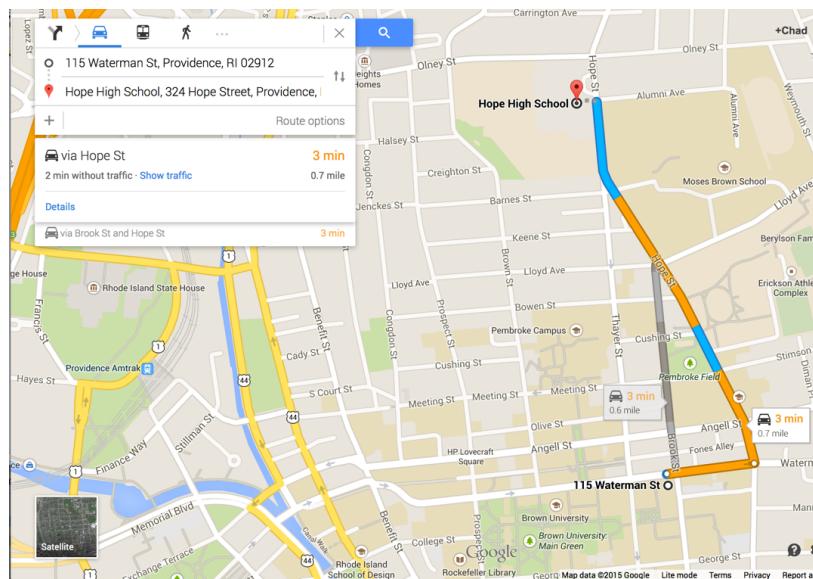
Compute collision-free motion path from current 2D location to goal location



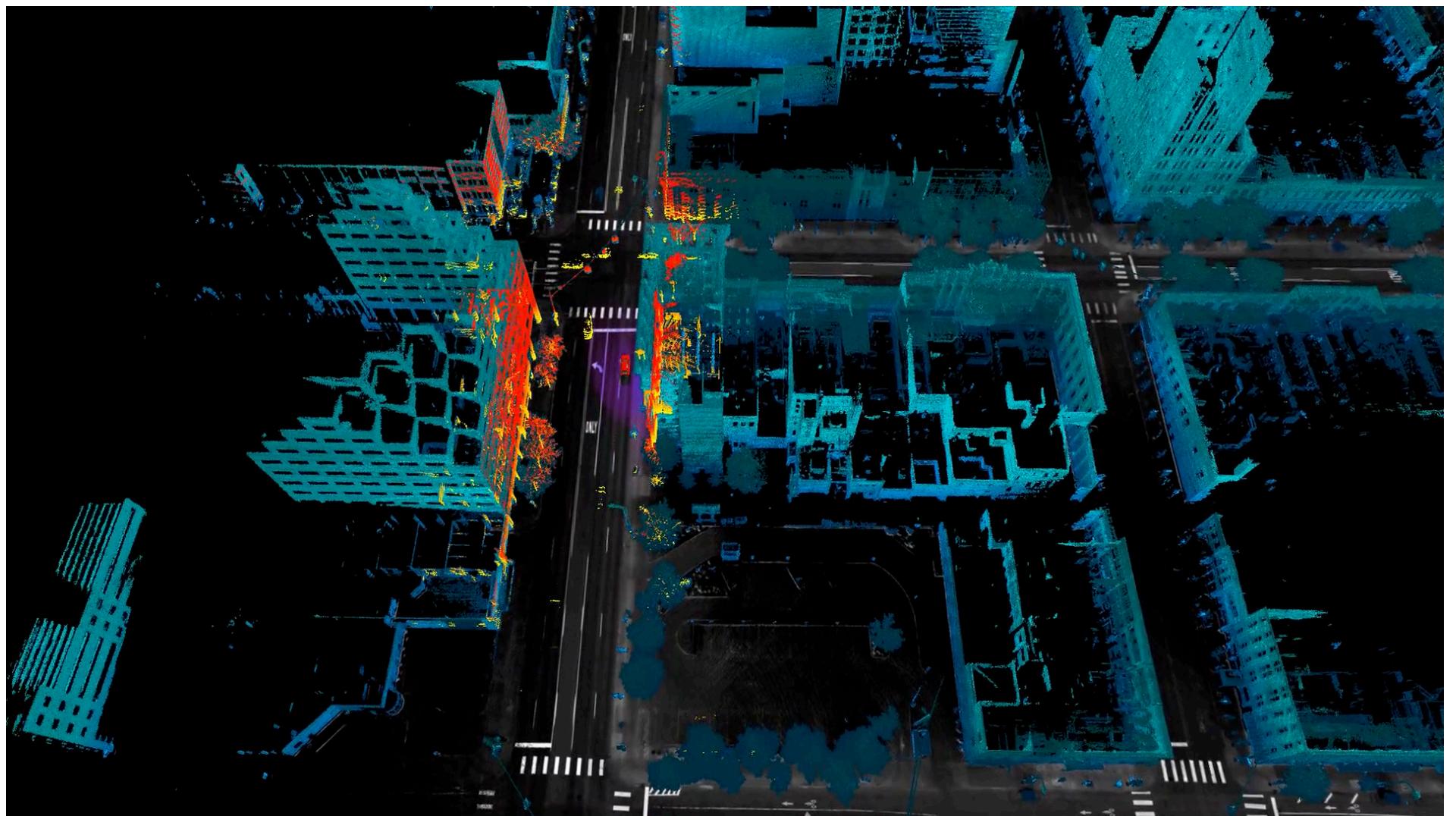
# UMich/Ford Next Generation Vehicle



Decision through  
search-based planning



Google Self-driving car  
SCECS 098767 autrob.github.io



Univ. Michigan APRIL - Next Generation Vehicle



Decision through  
FSM-based reaction

MIT Ghengis (1989)



Decision through  
FSM-based reaction

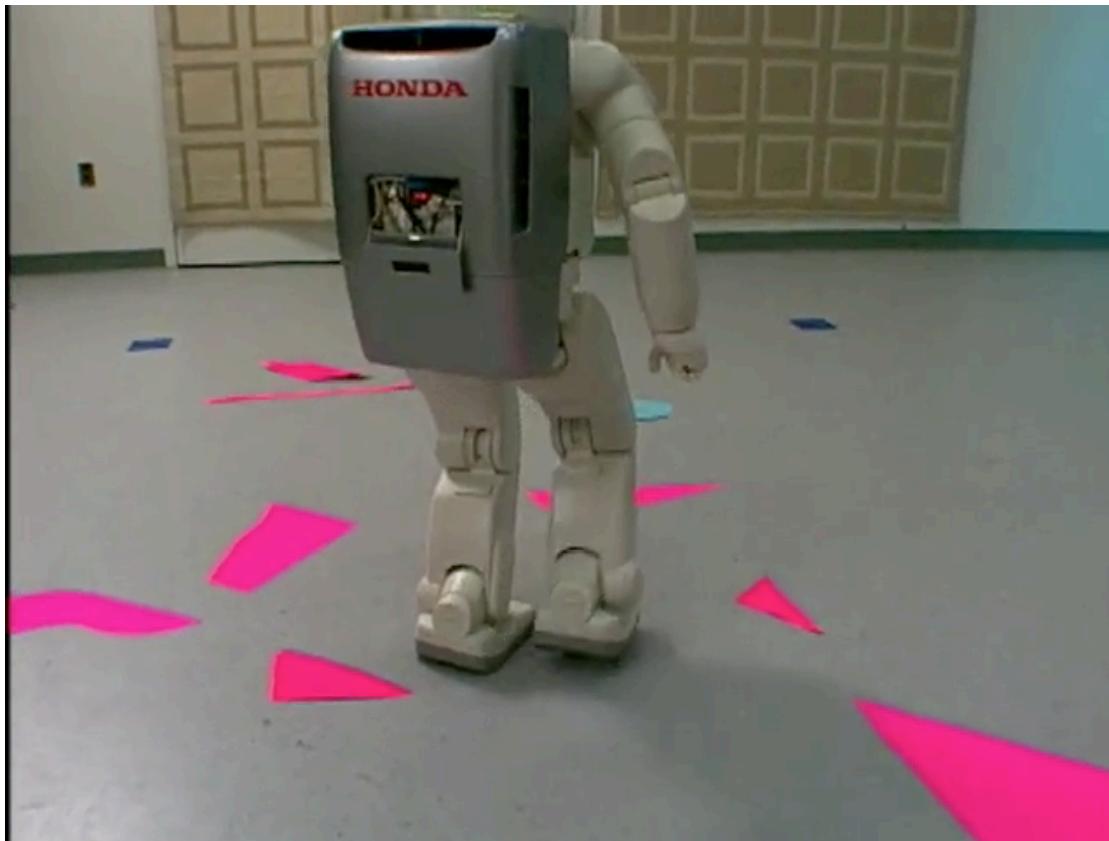
MIT Ghengis (1989)





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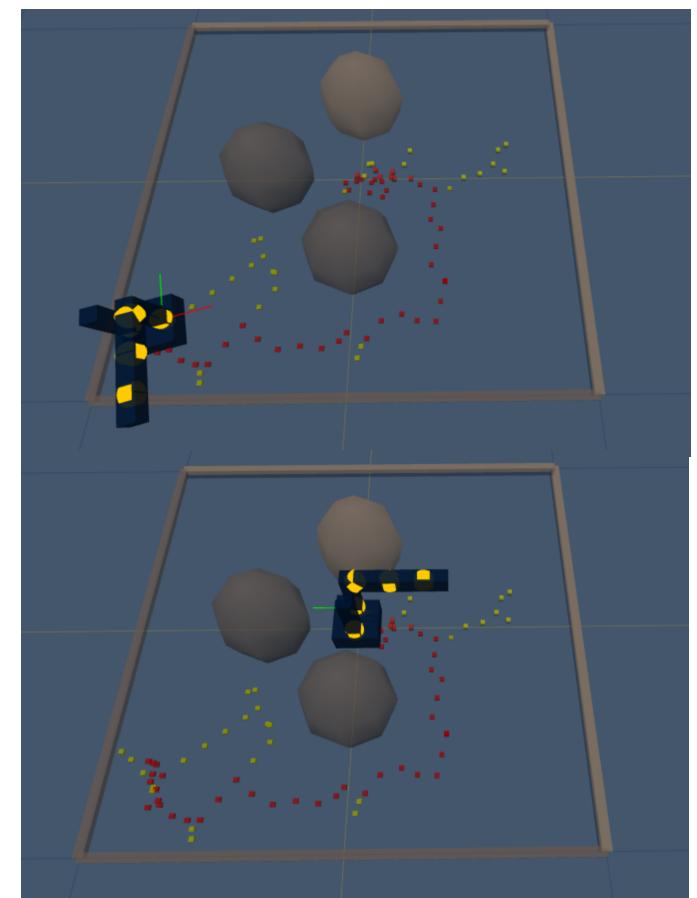
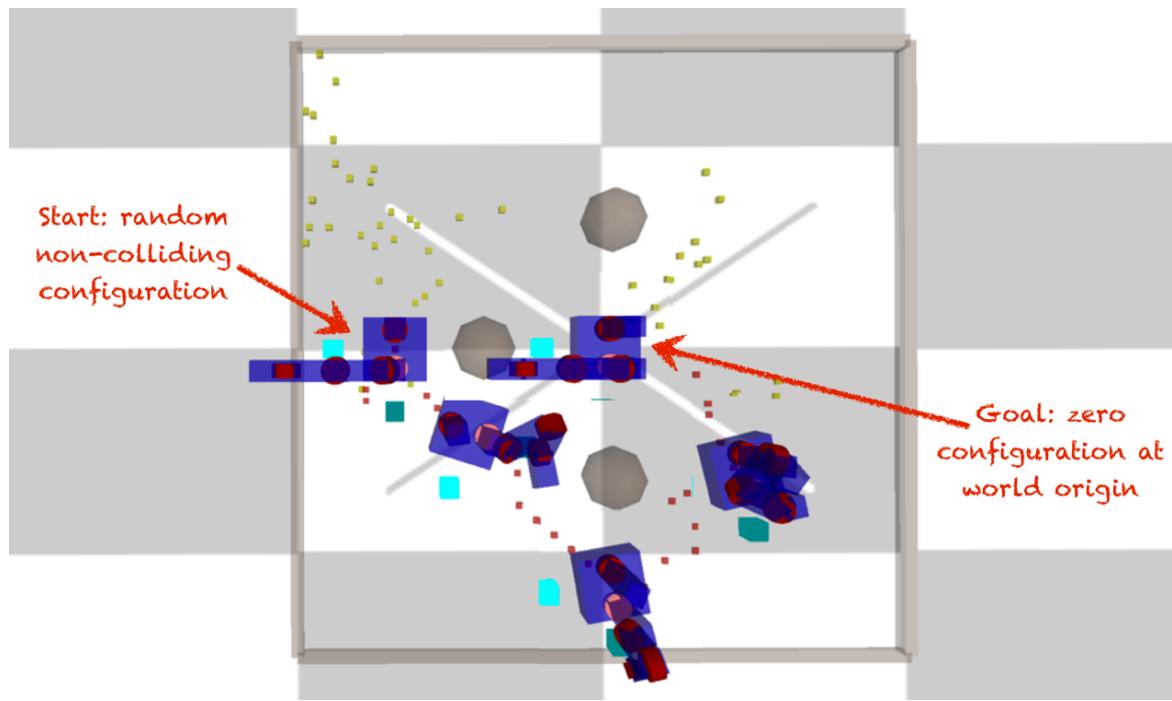
# Rapidly-Exploring Random Trees



for high dimensional  
search over robot  
configurations

# Project 6: RRT Planning

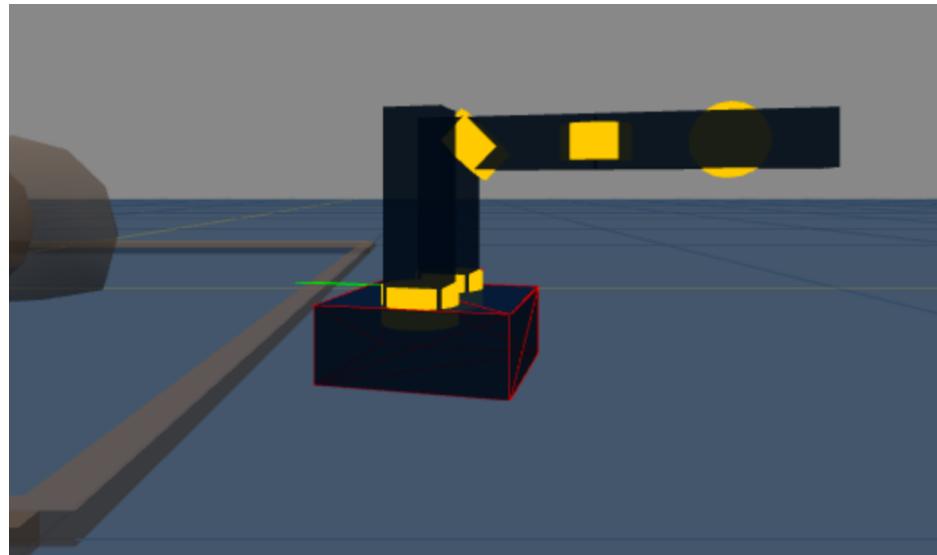
Compute collision-free motion path  
from current pose to goal (start) pose



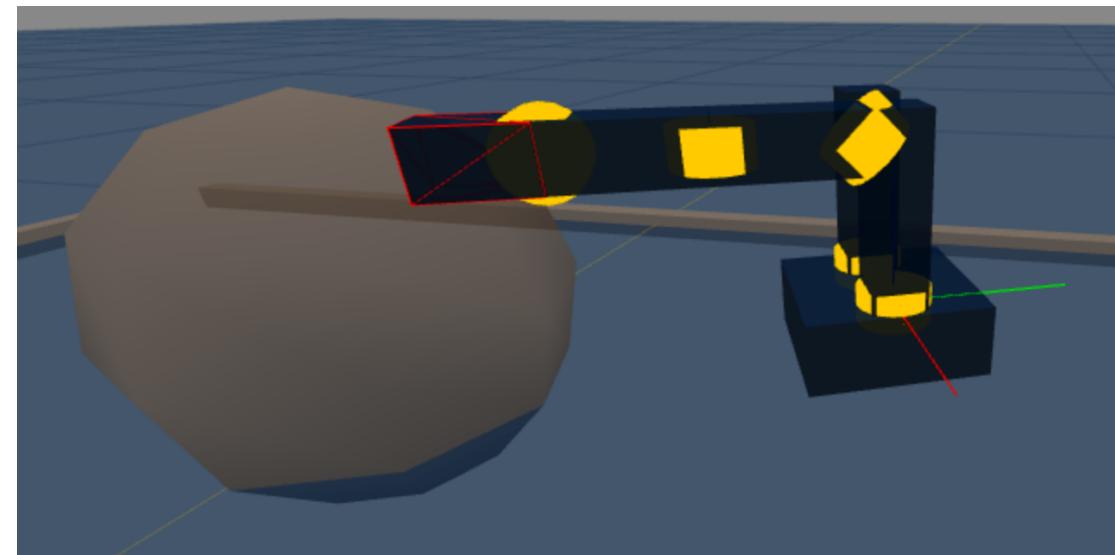
# What about collisions?



# Simple collision detection provided



“electric fence” on robot base



Axis-aligned bounding box  
collision detection on each link

Completely autonomous robots  
are a fantasy

Why?

# Completely autonomous robots are a fantasy

Why?

Safety

Uncertainty

Reliability

Adaptability

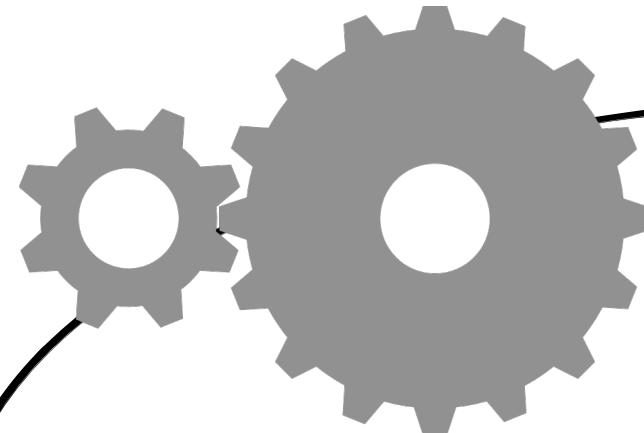
Perception

Not human

# Always have a human in the loop



# Robotics



Mechanical Engineering  
Electrical Engineering  
“Mechatronics”



Computer Science  
Artificial Intelligence

Human Factors  
Supervisory Control

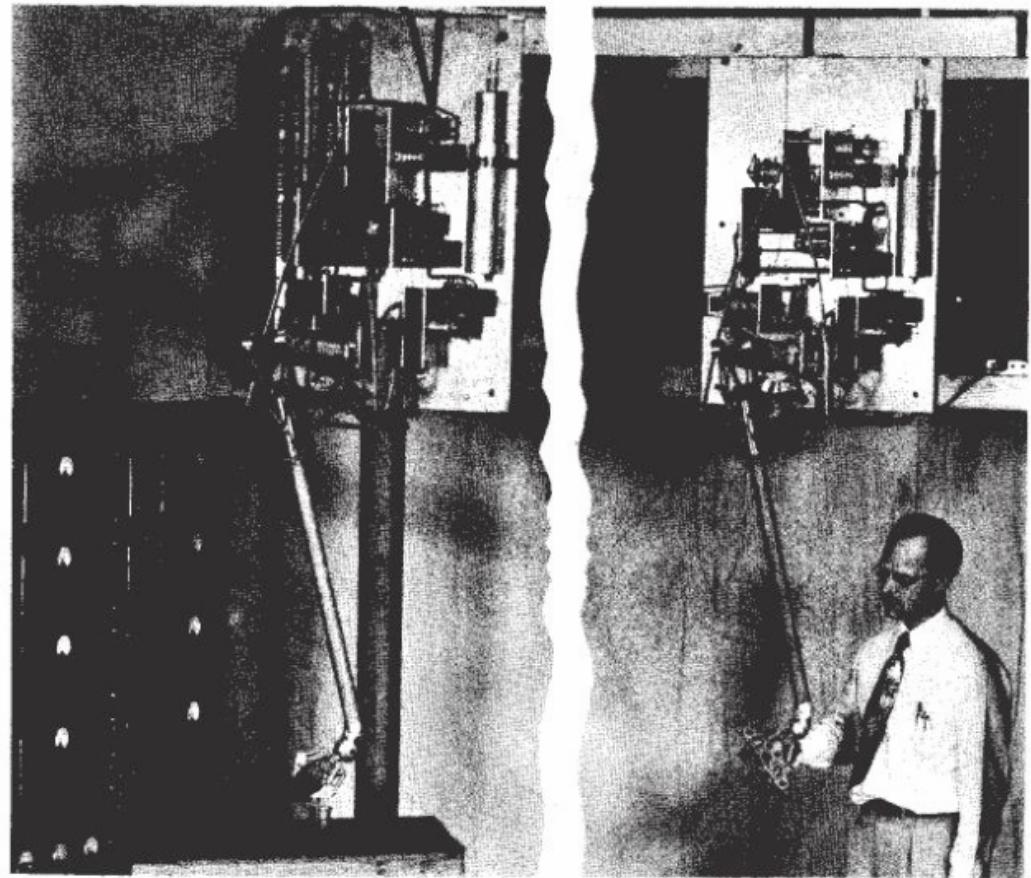


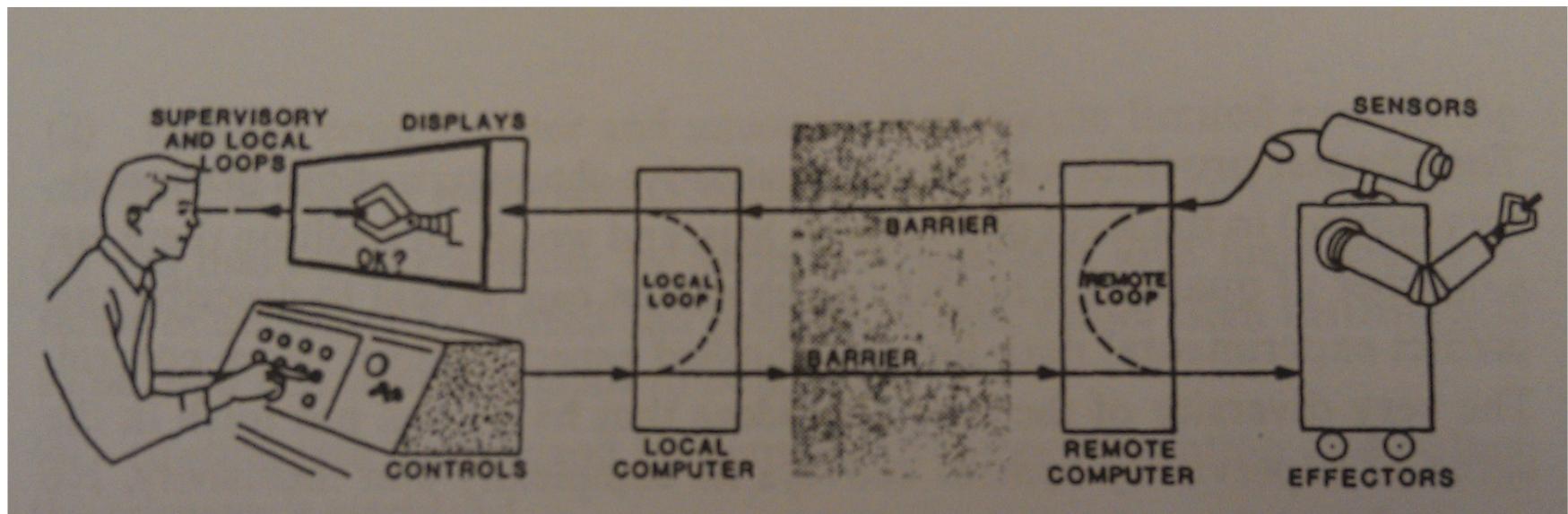
FIGURE 6.—The ANL Model E1 electric master slave. Used only for experimental purposes, this bilateral manipulator was developed in 1954. (Courtesy of Argonne National Laboratory.)

R. Goertz - Argonne

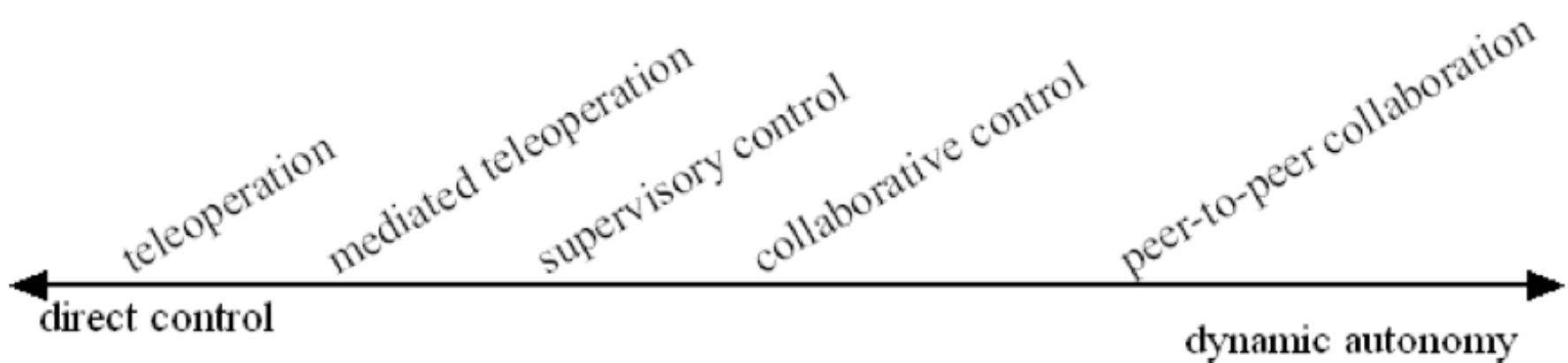
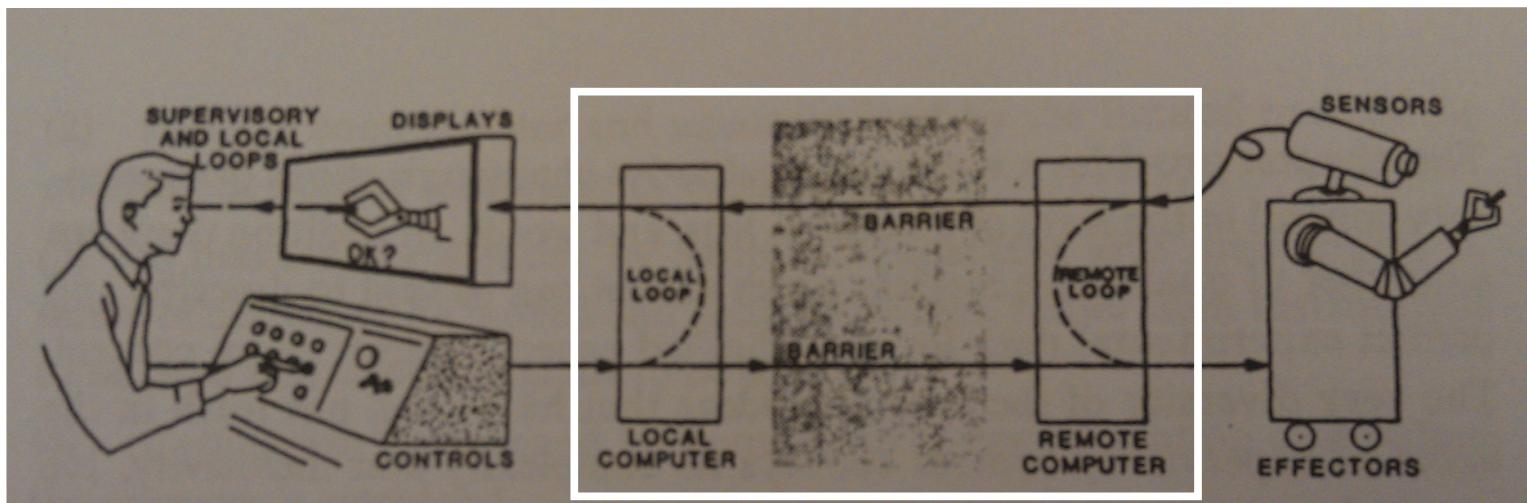


## Teleoperation

# Supervisory Control

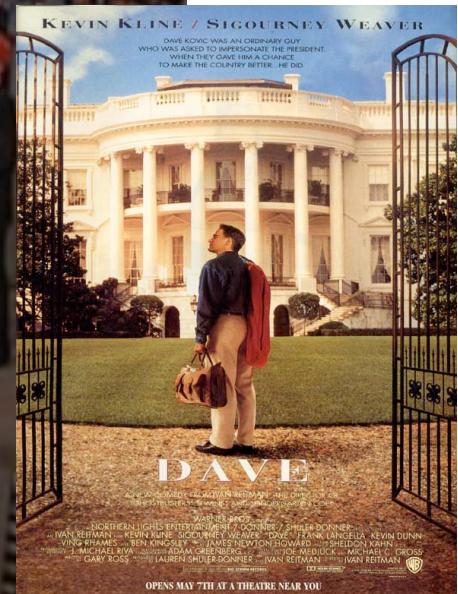


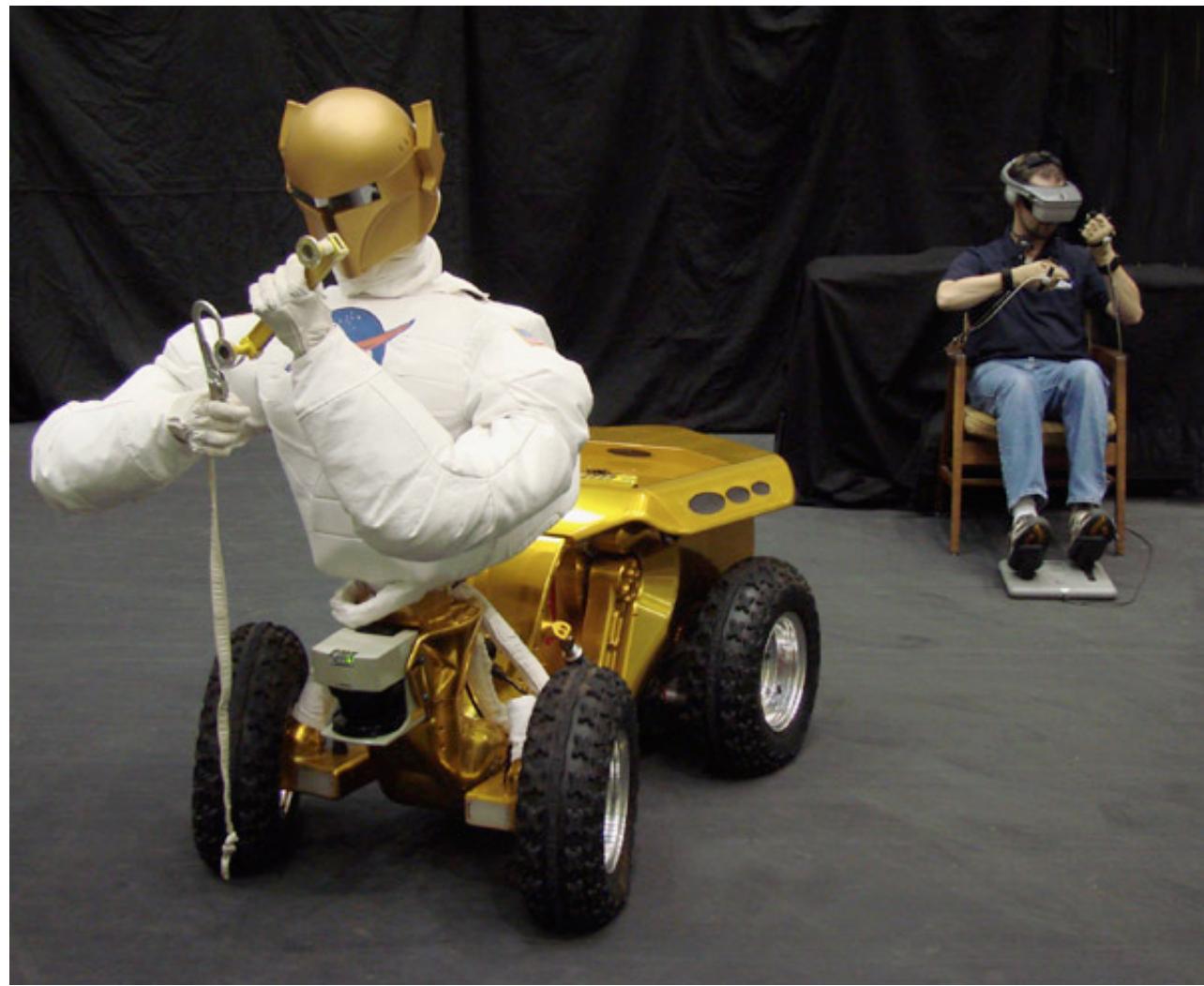
Sheridan [1992] "Telerobotics, Automation, and Human Supervisory Control"





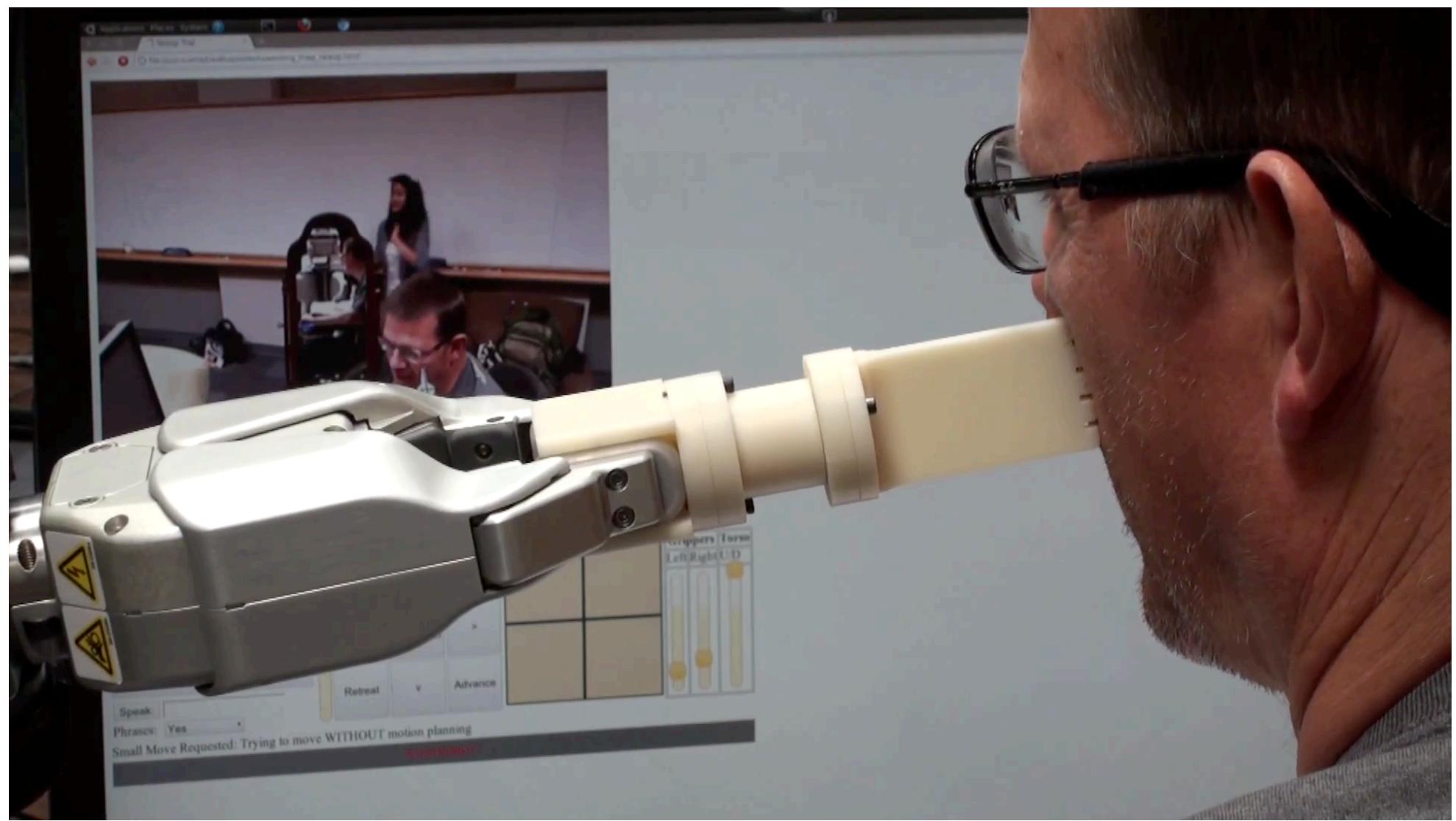




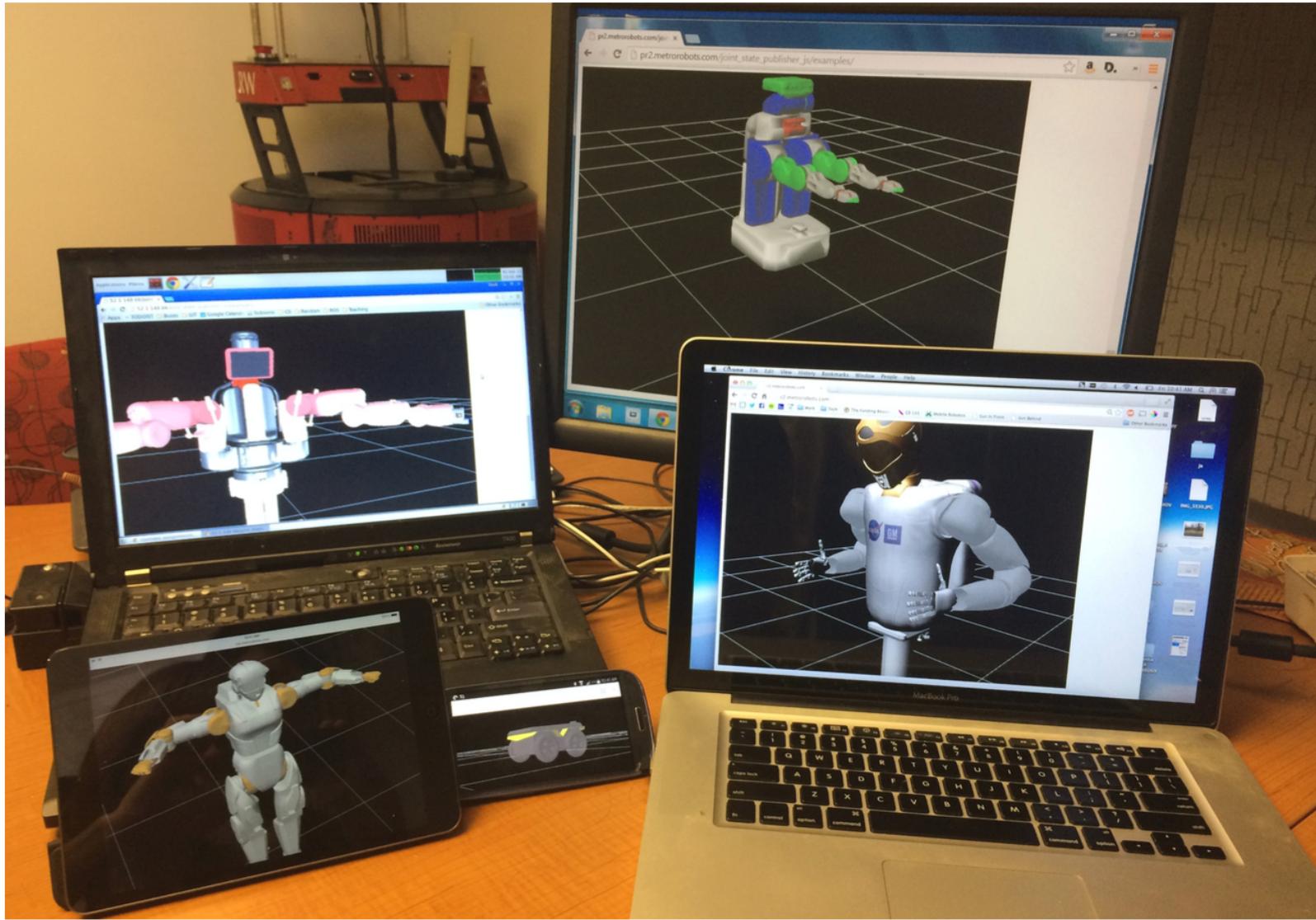


NASA Robonaut





Courtesy Robots for Humanity



Toris, Jenkins, et al. (2015)

[www.rob.ust.hk](http://www.rob.ust.hk) [www.jorob.github.io](http://www.jorob.github.io)

# MAP BUILDER

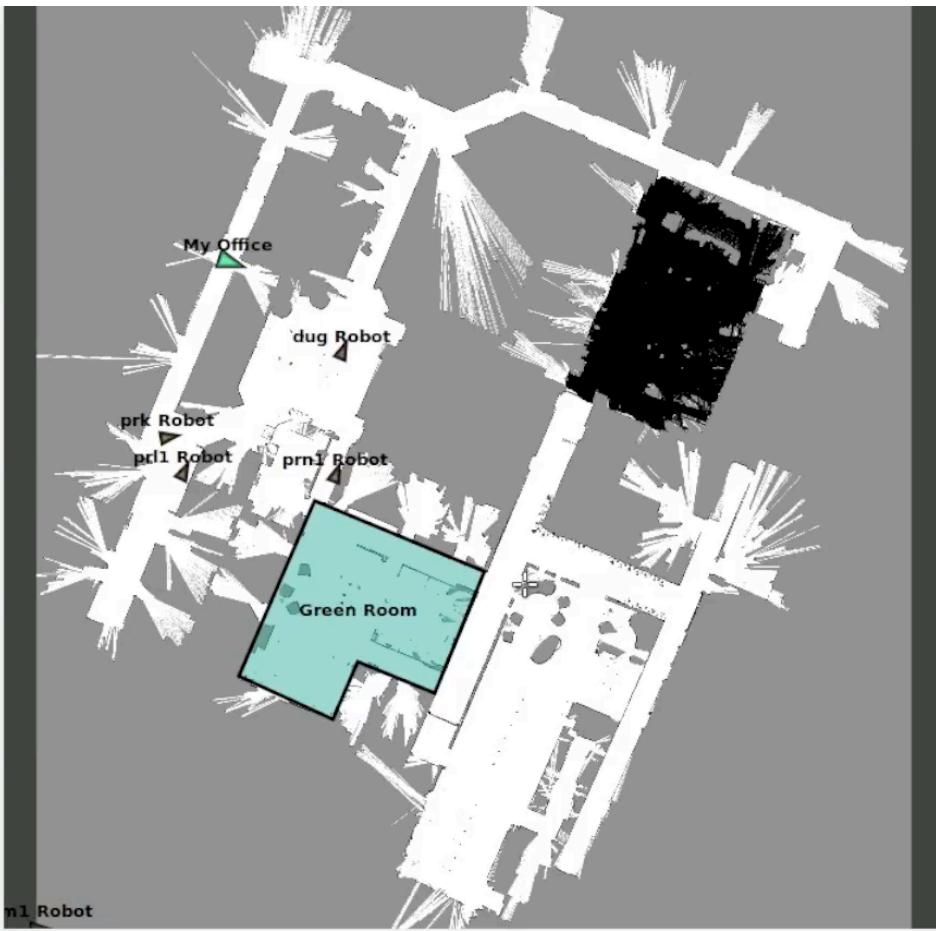
SPEED: 90%



Courtesy Russell Toris (WPI)



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

How will people use your robot?

Will robots help or harm society?

Who is responsible if a robot  
brings harm to a person?

Does a robot have free will?

Do you have free will?

# 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

Foundations and Trends® in  
Human–Computer Interaction  
Vol. 1, No. 3 (2007) 203–275  
© 2007 M. A. Goodrich and A. C. Schultz  
DOI: 10.1561/1100000005



## Human–Robot Interaction: A Survey

Michael A. Goodrich<sup>1</sup> and Alan C. Schultz<sup>2</sup>

<sup>1</sup> Brigham Young University, Provo, UT 84602, USA, mike@cs.byu.edu

<sup>2</sup> 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 coherent



Autism treatment

# Social Robotics

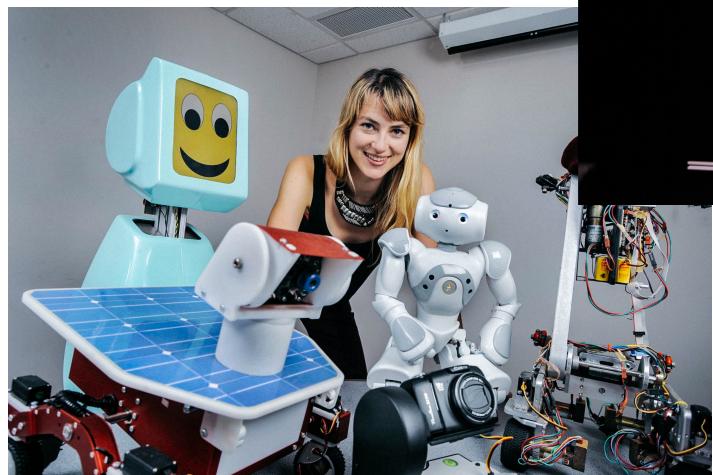


Education

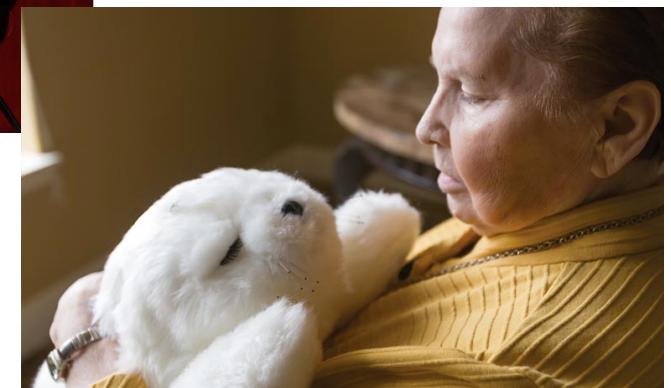


Rehabilitation

Entertainment



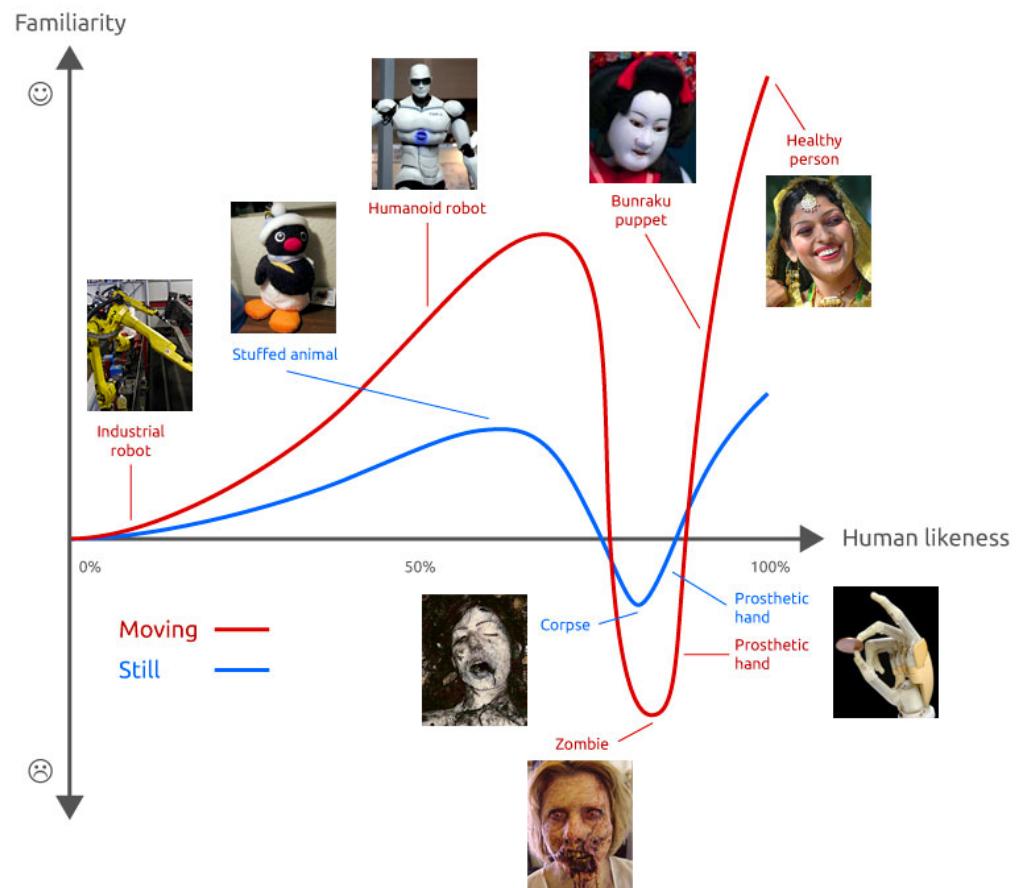
Elder care





<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



← → C ⓘ <https://www.merriam-webster.com/dictionary/robot>



SINCE 1828

JOIN MWU | GAMES | BROWSE THESAURUS | WORD OF THE DAY | VIDEO | WORDS AT PLATE

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 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

f

t

people

heart

CITE

T

Good luck and make progress.