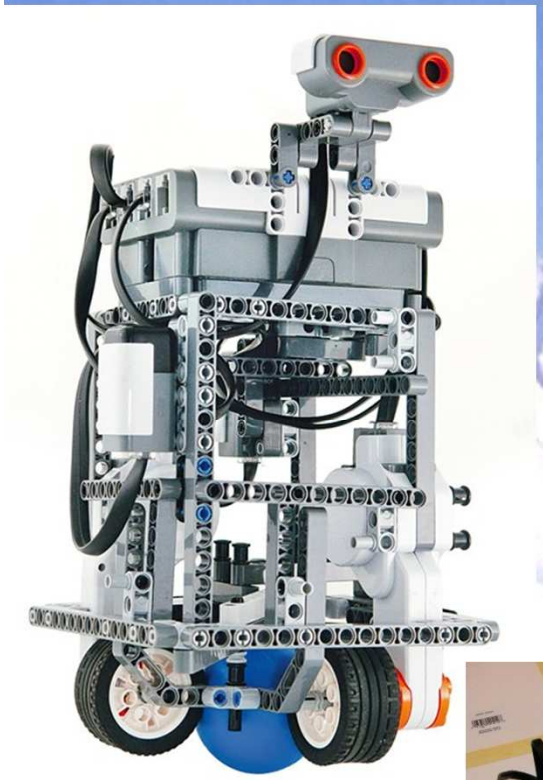
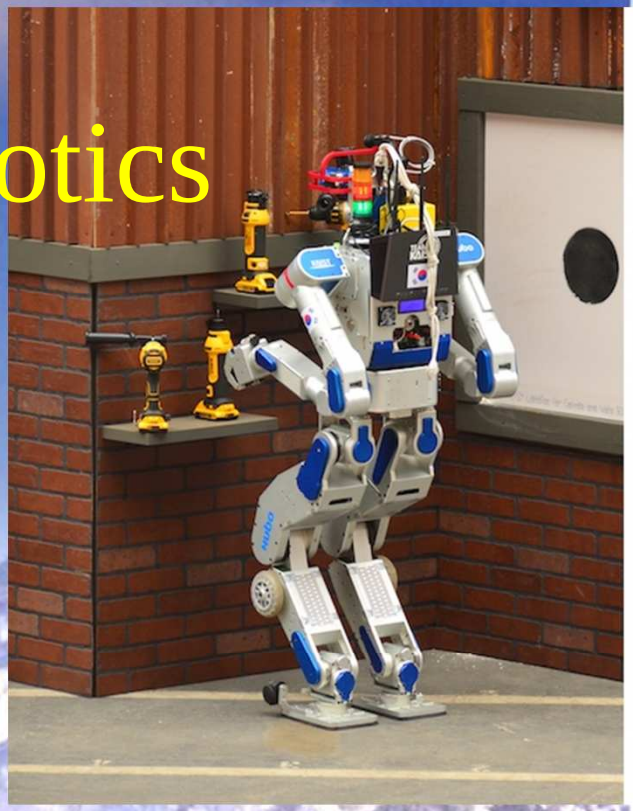
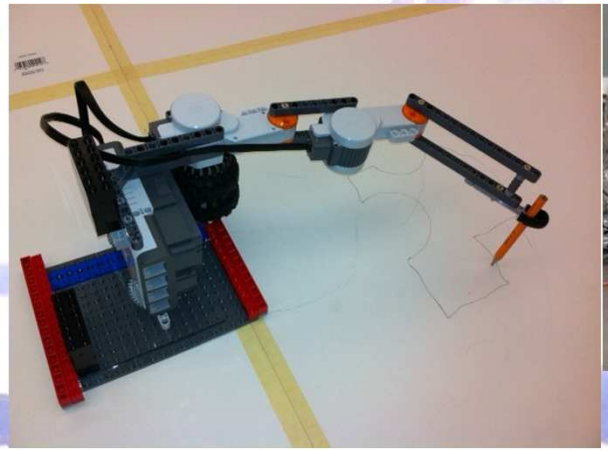
Experimental Robotics
CMPUT 412

Martin Jagersand

Camilo Perez







Course Questions

Why study robotics?

What, exactly, is robotics about?

What work is involved?

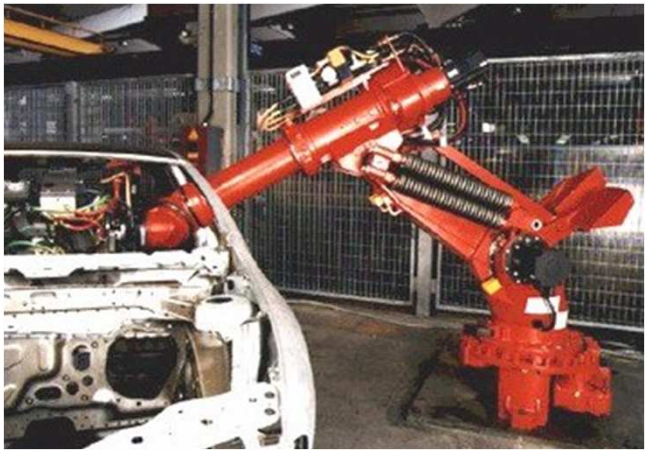
and other questions as well!

Why Robotics?

shift in robot numbers… !

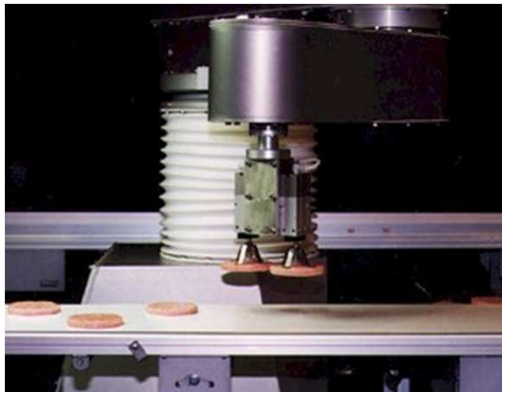
Practice

assembly



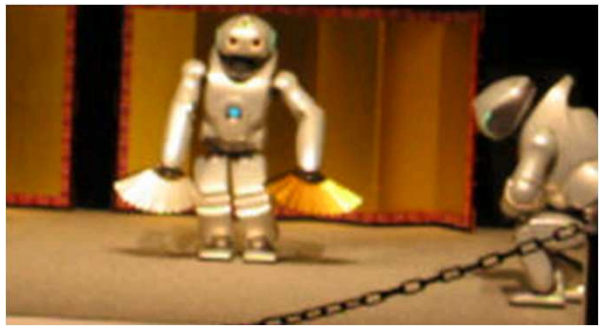
pumping gas

welding



packaging

eating automobiles



dancing

Promise

http://www.youtube.com/watch?v=wg8YYuLLoM0&feature=player_embedded#

Current Robot Arm Applications Manufacturing

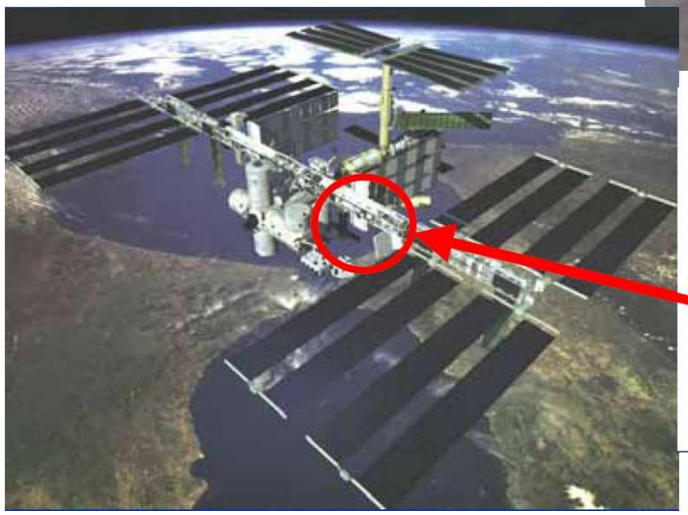
- Engineered environment
- Repeated motion

1 million arms in operation worldwide

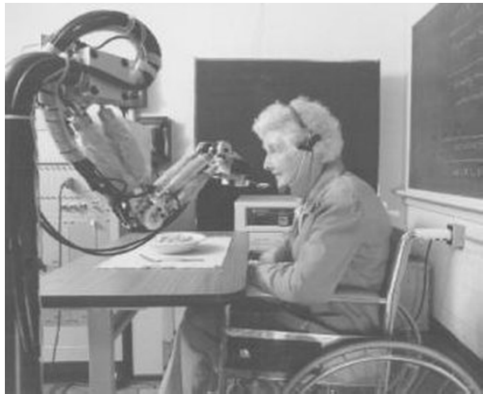
http://en.wikipedia.org/wiki/Industrial_robot

Emerging Robotics Applications

Space - in-orbit, repair and maintenance, planetary exploration anthropomorphic design facilitates collaboration with humans



Basic Science - computational models of cognitive systems, task learning, human interfaces



Health - clinical applications, "aging-in-place," physical and cognitive prosthetics in assisted-living facilities

Military or Hazardous - supply chain and logistics support, re-fueling, bomb disposal, toxic/radioactive cleanup

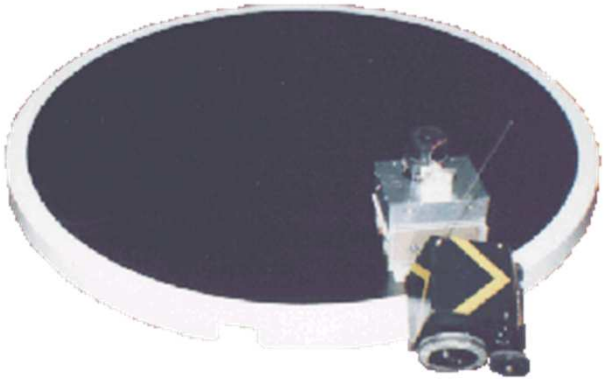
No or few robots currently operate reliably in these

kismet

Why Robotics?

Sony Aibo dogs – had to LEARN to run

Vibrant field



other competitions

Harold Cohen's Aaron

Why Robotics?

A window to the soul...

Rodney Brooks's Cog

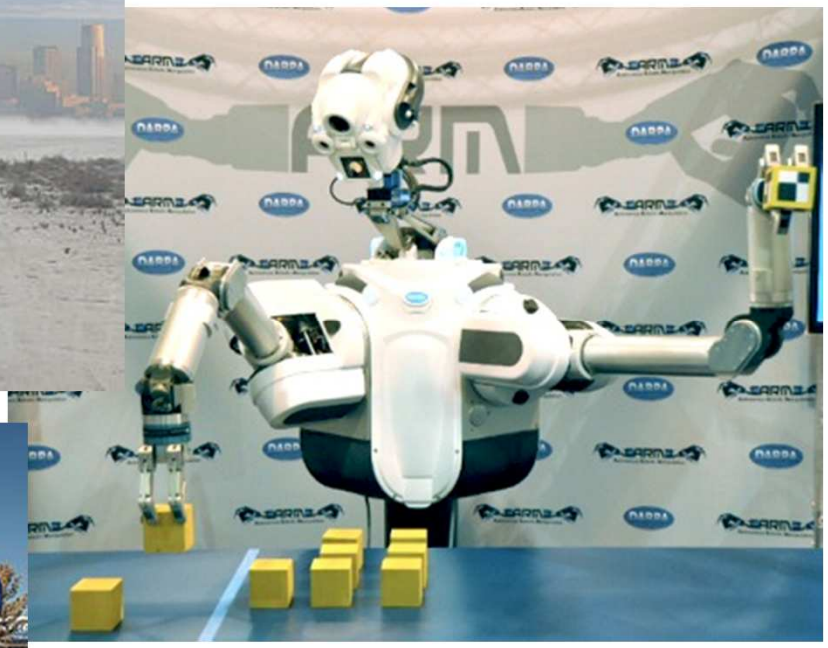
MIT's robotic fish with an unusual actuator!

Monkey/machine interface at the Univ. of Pittsburgh

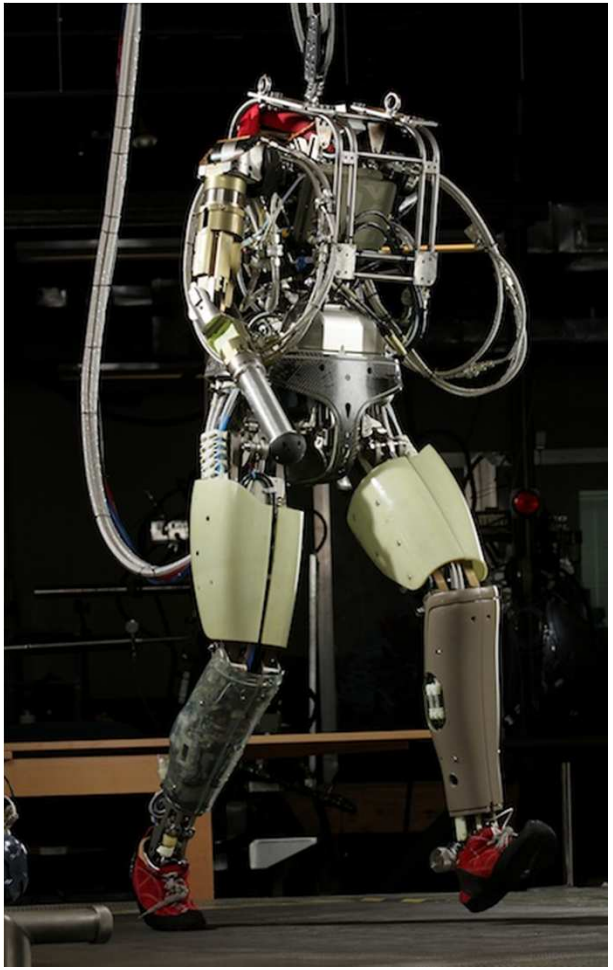
Advances in AI and in Robotics are one and the same.

Robotics challenges

Navigation ‘05

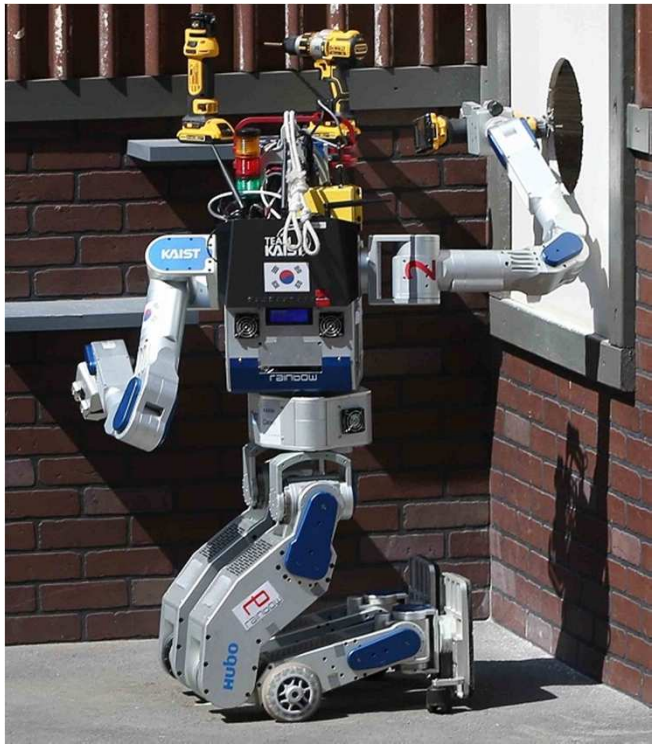


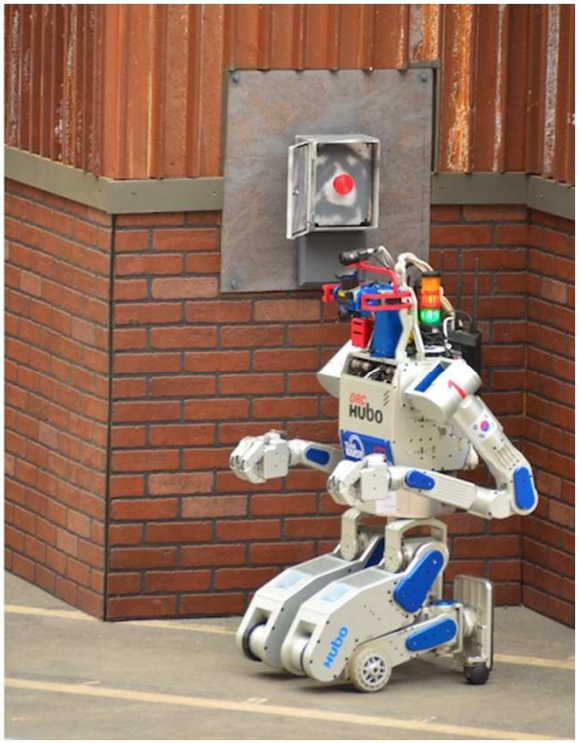
Manipulation ‘11-14



Humanoids ’12-15

DARPA Robotics Challenge





Course Questions

Why study robotics?

What, exactly, is robotics about?

Or at least what we learn here

What work is involved?

What is a robot?

Autonomous : Robot :: Unicycling : Awake : Student

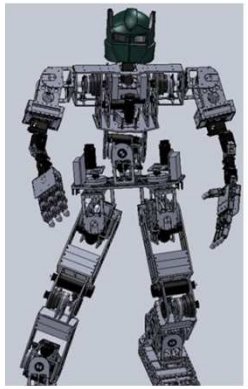
Autonomous

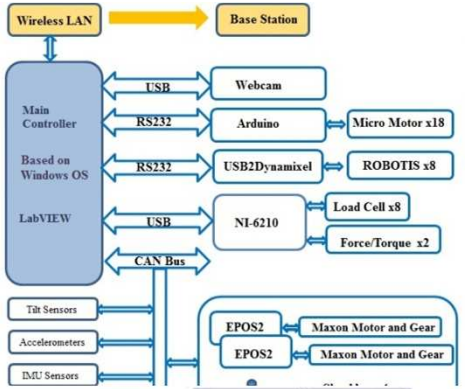
Choose one !

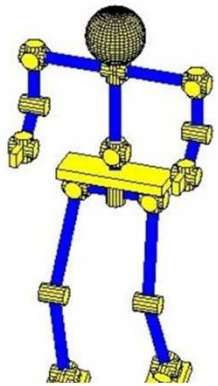
What is a robot?

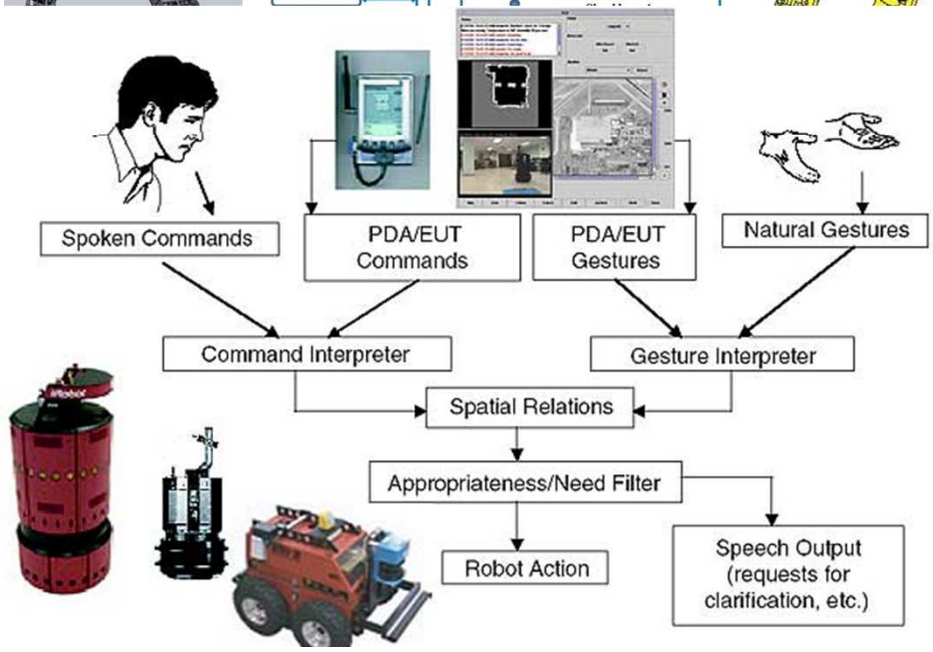
Physical instantiation (Hardware)

System and properties









What is a robot?

Robot :

A physical system that "*autonomously*" senses the environment and acts in it.

Autonomy might be a continuous, not a discrete attribute

Researchers disagree on what kind and how much autonomy is needed

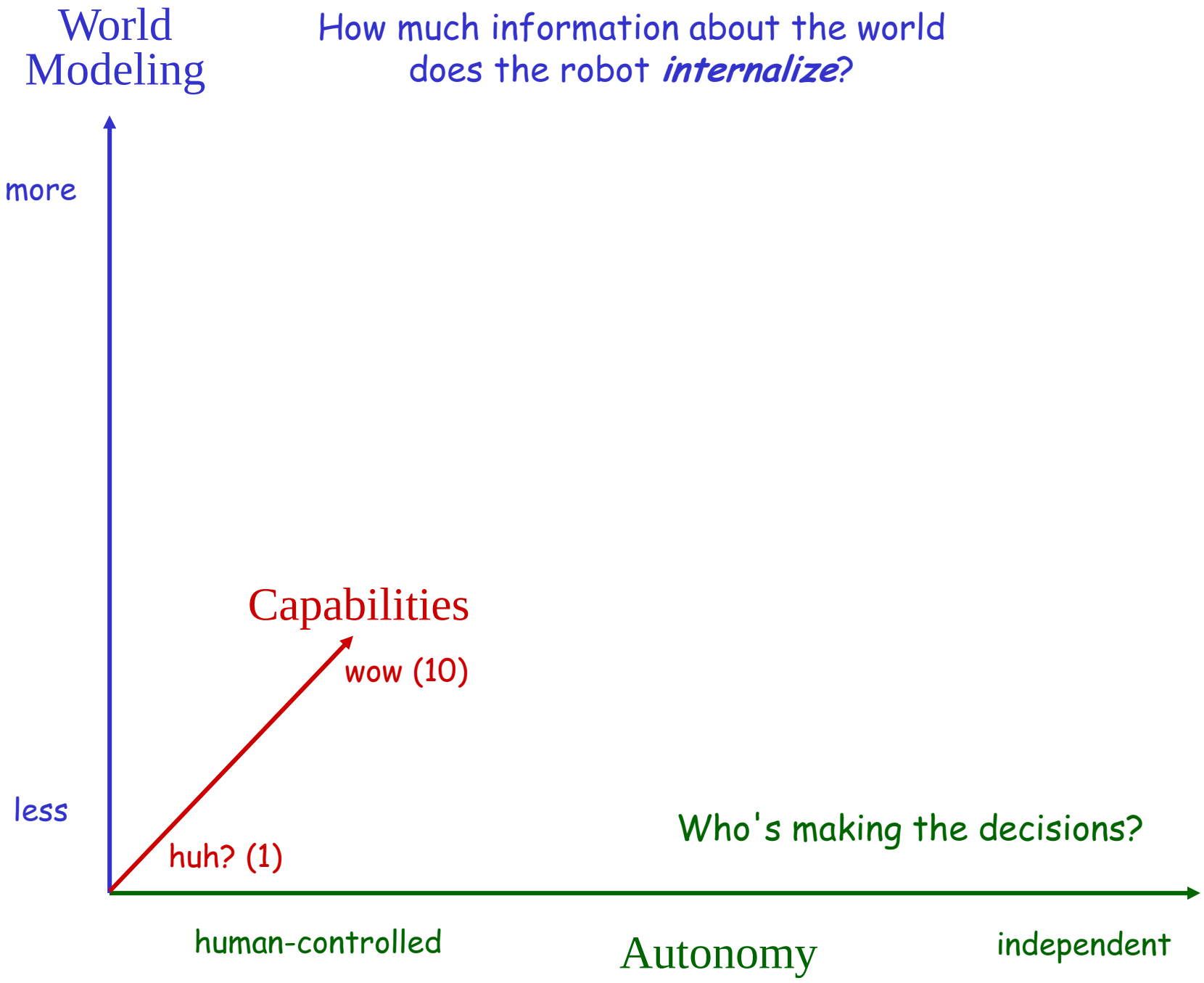
none → **full**

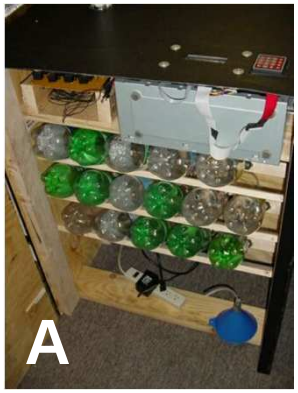
Robot Wars, Battlebots

FIRST Robotics

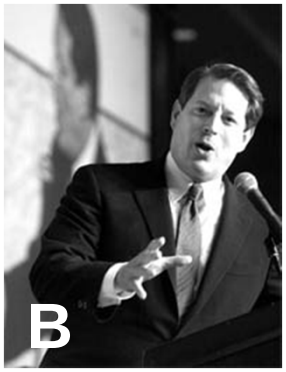
Robocup

There may be other axes along which to evaluate robots, too…


World Modeling
How much information about the world does the robot *internalize*?
more
less
Capabilities
wow (10)
huh? (1)
Who's making the decisions?
human-controlled
Autonomy
independent



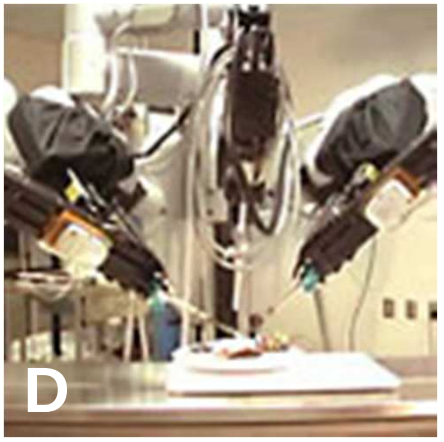
Bar Monkey



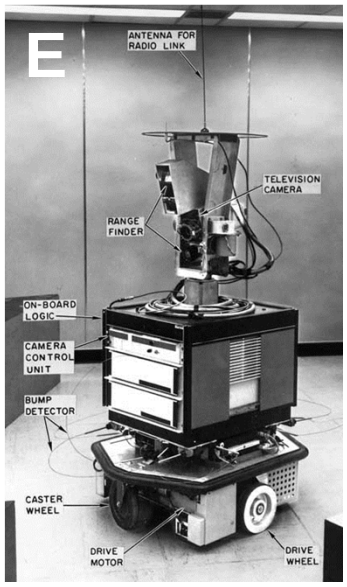
Al Gore
ex-VP, Nobelian

Genghis Robotic Insect

da Vinci
Robotic Surgeon



11 "robotic" systems

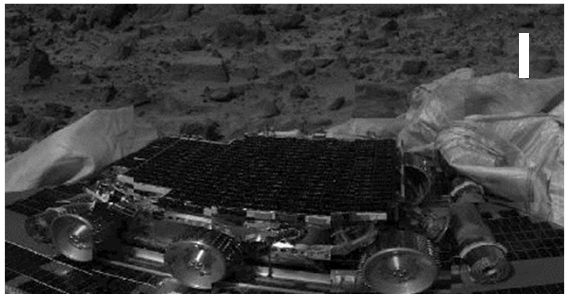


Shakey
object-"manipulator" (pusher) from SRI (1969)

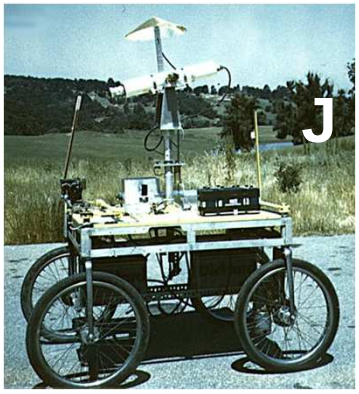
Roomba
Robotic vacuum cleaner

Sims
now with professor!

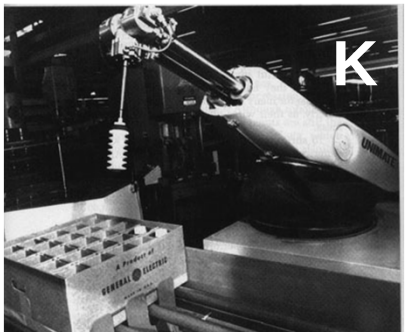
Stanford's Stanley/CMU's Boss
each a $2 million winner



Sojourner/Spirit/Opportunity
Mars Exploration Rovers: 1997, 2004-now

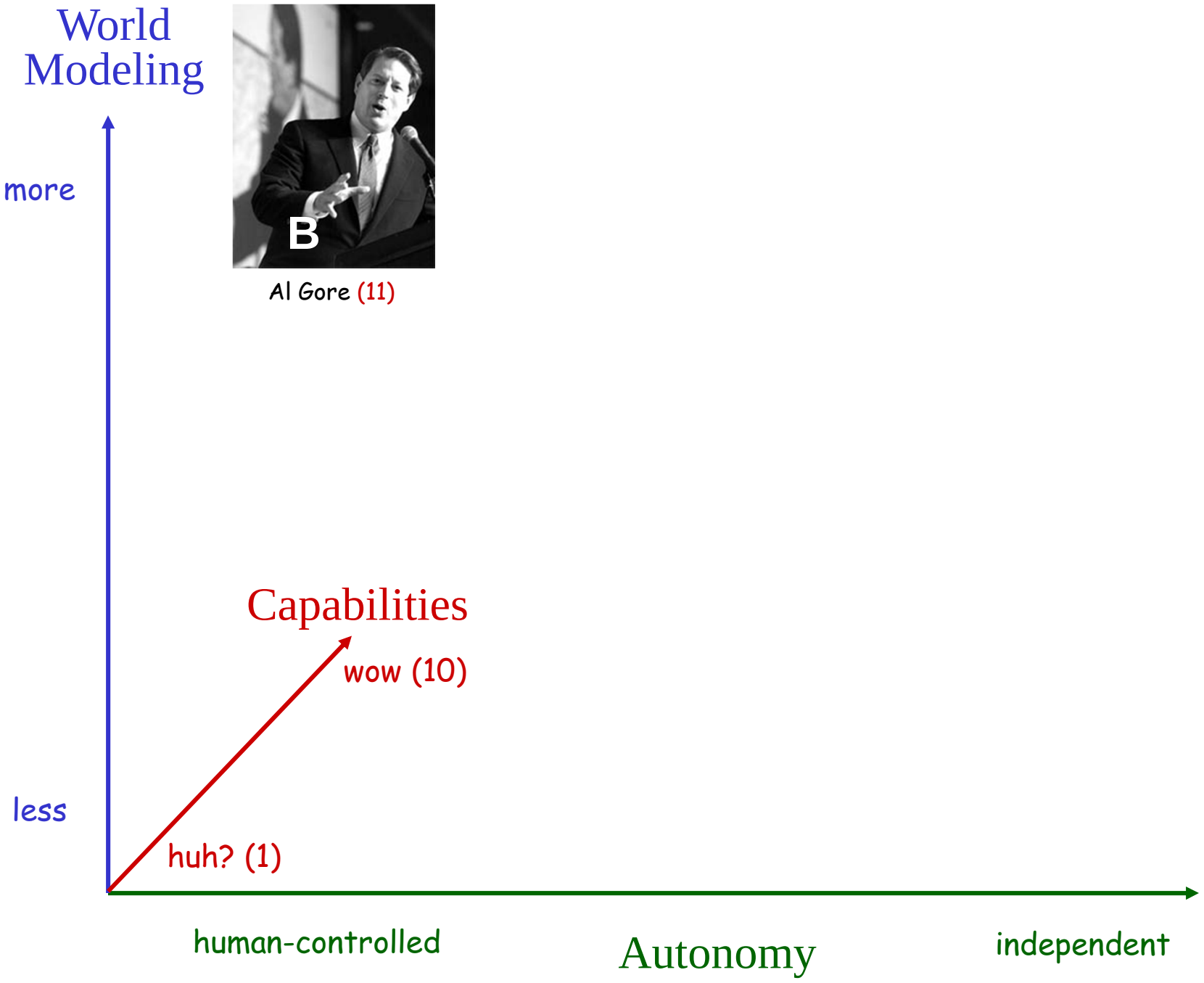


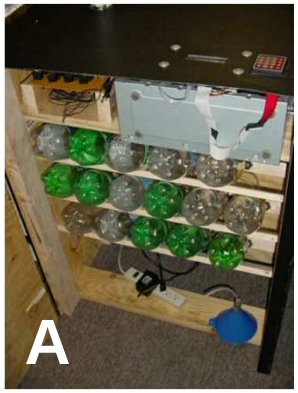
Stanford Cart
vision-based obstacle-avoider (1976)



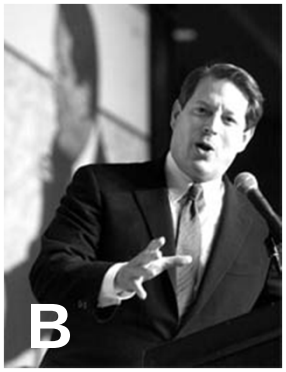
Unimate
first industrial robotic arm, '61
(now in the hall of fame)

Perhaps include a robot of your own choosing…


World Modeling
more
B
Al Gore (11)
Capabilities
wow (10)
less
huh? (1)
human-controlled
Autonomy
independent



Bar Monkey
robotic barkeep



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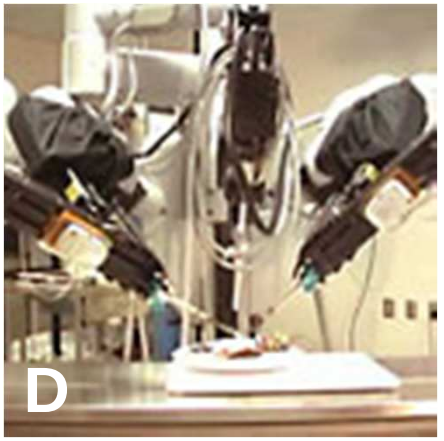

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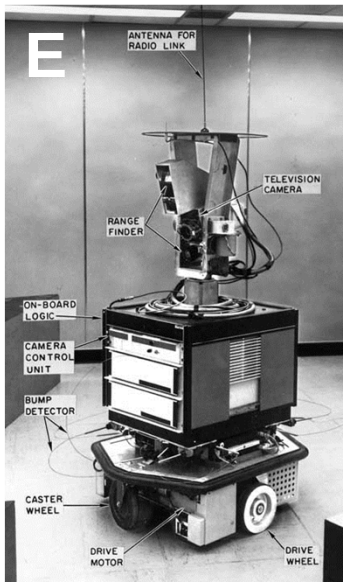

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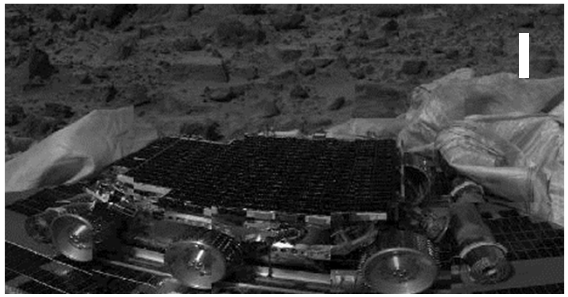

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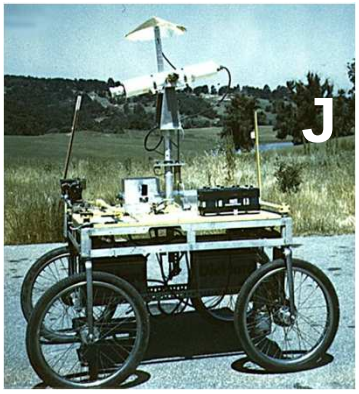

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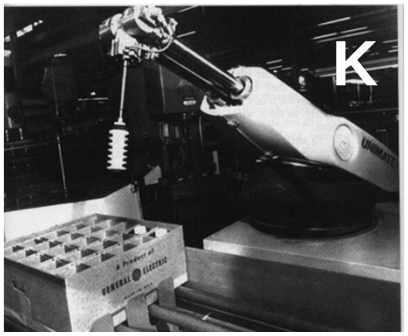

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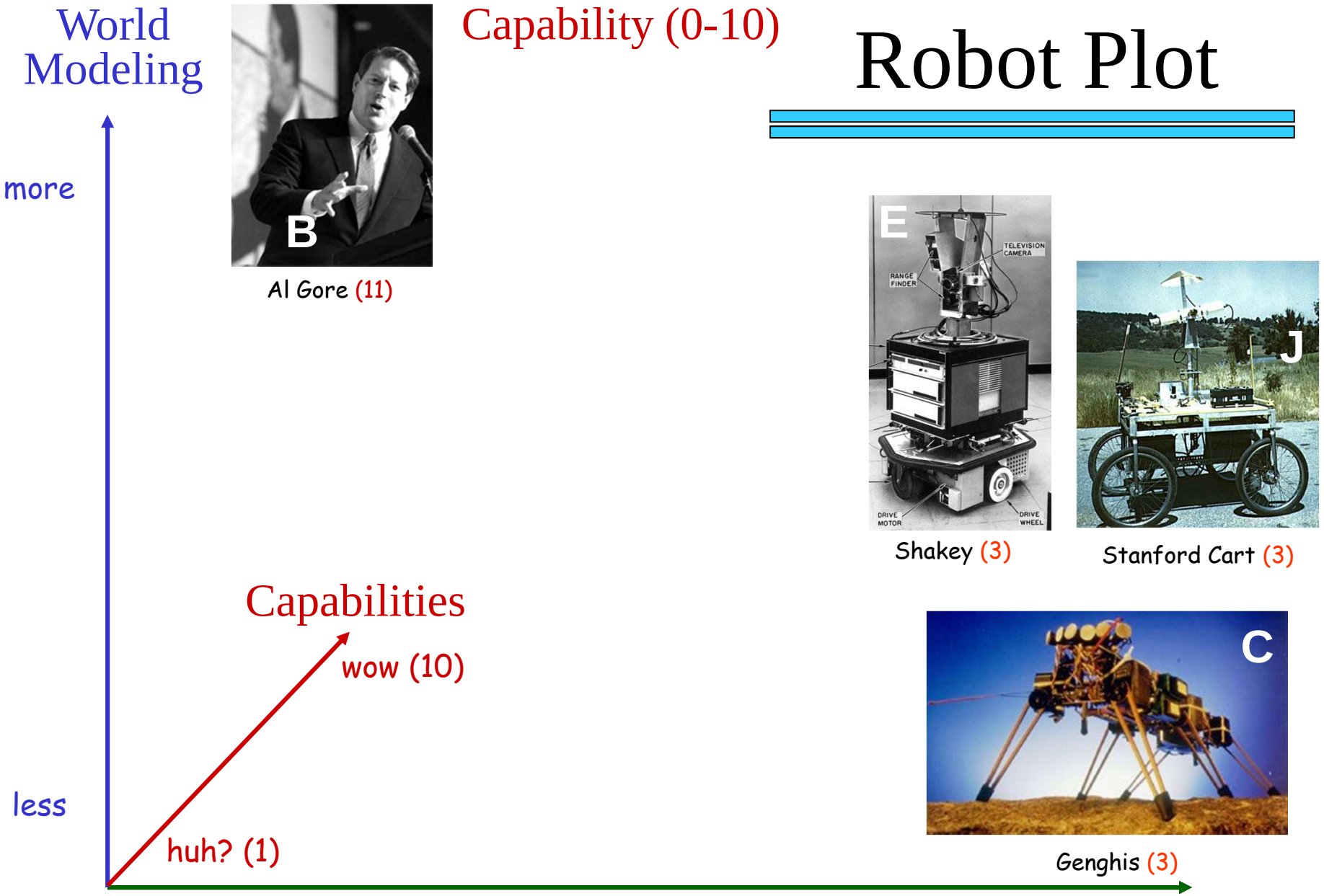
Robot Plot


World Modeling
more
less
Capability (0-10)
B
Al Gore (11)
E
TELEVISION CAMERA
RANGE FINDER
DRIVE MOTOR
DRIVE WHEEL
Shakey (3)
J
Stanford Cart (3)
Capabilities
wow (10)
huh? (1)
C
Genghis (3)
human-controlled
Autonomy
independent

Robot Plot

World Modeling

Capability (0-10)

more

less

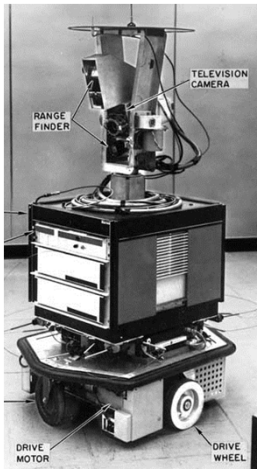
Al Gore (11)

Sims (5)

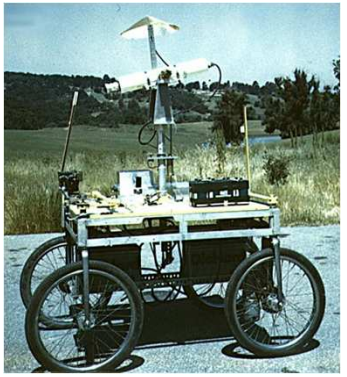
Bar Monkey (9)

MERs (8)

Stanley/Boss (9)

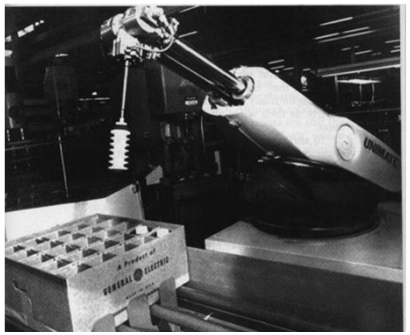


Shakey (3)



Stanford Cart (3)

da Vinci (2)



Unimate (4)

Roomba (7)

Genghis (3)

human-controlled

Autonomy

independent

Robot Plot

World Modeling

more

less

Capability (0-10)

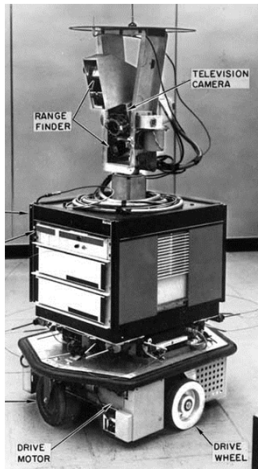
Al Gore (11)

Sims (5)

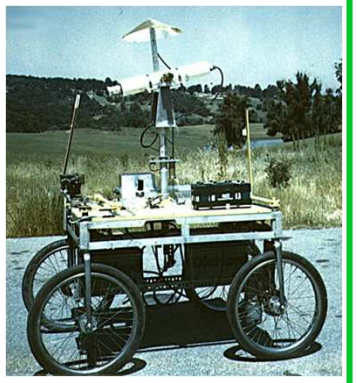
Bar Monkey (9)

MERs (8)

Stanley/Boss (9)

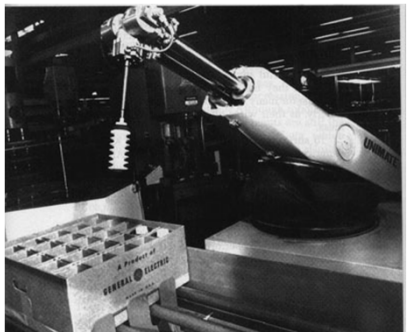


Shakey (3)



Stanford Cart (3)

da Vinci (2)



Unimate (4)

Roomba (7)

Genghis (3)

human-controlled

Autonomy

CS 154: **algorithms** for programming autonomous robots

Course Timeline

Low-level robotics

2wks
- architecture
- motors/actuators
- sensors

Vision

2wks regions and recognition
features and matching

Spatial Reasoning

5wks
- reasoning with uncertainty
- filtering and state estimation
- localization
- mapping
- localizing *and* mapping

Spatial Planning

5wks
- configuration space
- kinematics, dynamics
- path planning
- pursuer/evader algorithms

What am I? robots ~ bodies…

is seeing believing?

where am I?

how do I get there?

412 Course topics

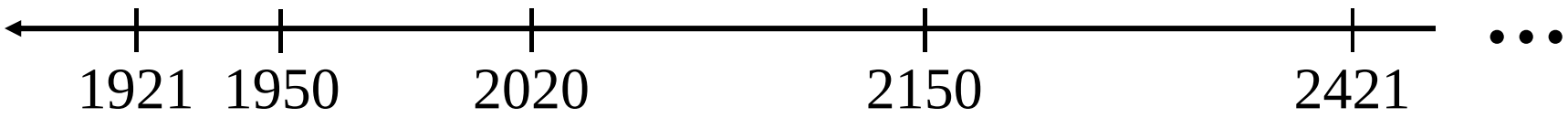
- **Introduction**
- **Robot hardware for mobile roobots, arms and UAV's**
- **Reactive robotics**
- **Modeling mobile robots, kinematics, navigation**
- **Robot sensors**
- **Robot arm types and kinematics**
- **Analytic and numerical arm inverse kinematics**
- **Machine vision and image processing**
- **Visual servo motion control**
- **Robot systems, mechatronics**

What am I? robots ~ bodies…

where am I?
how do I get there?

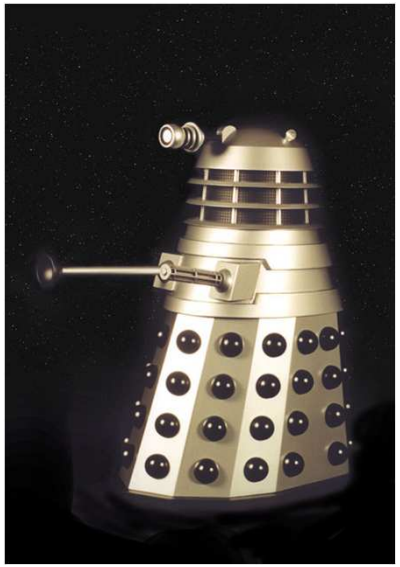
is seeing believing?

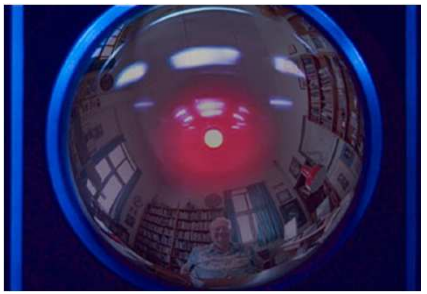
Robot timeline?

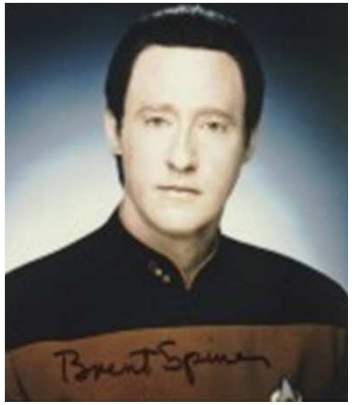


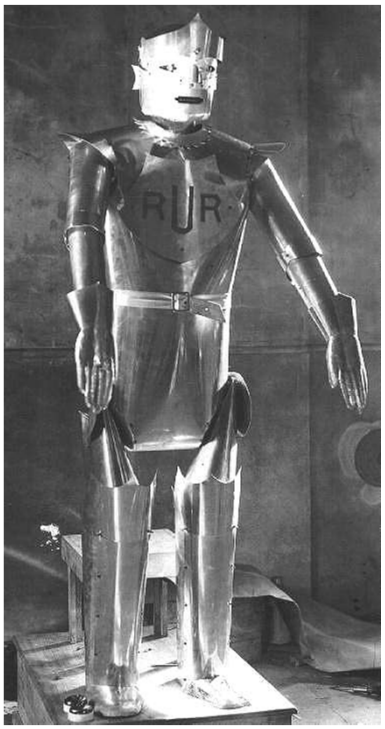
Fictional Robot timeline

Putting these robots in chronological order?







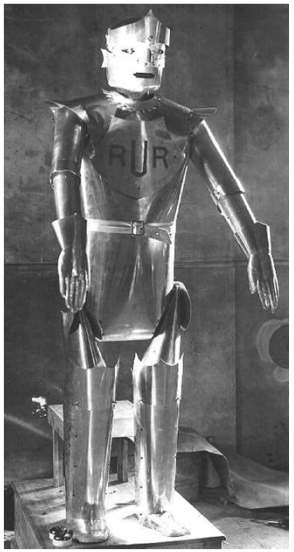


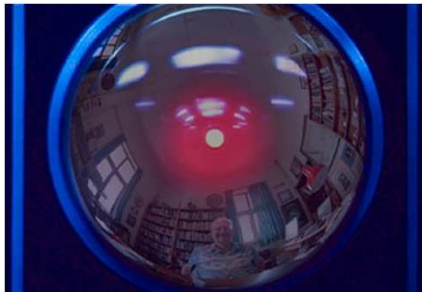
1921 2020 2150 2421 ...

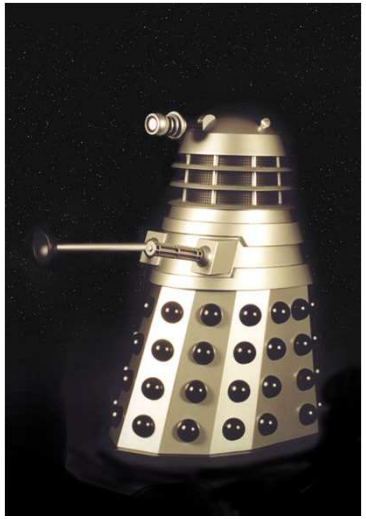
Fictional robot timeline

Karl Capek

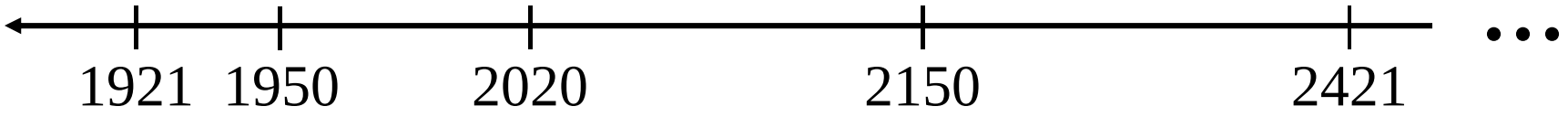
Rossum's Universal Robots







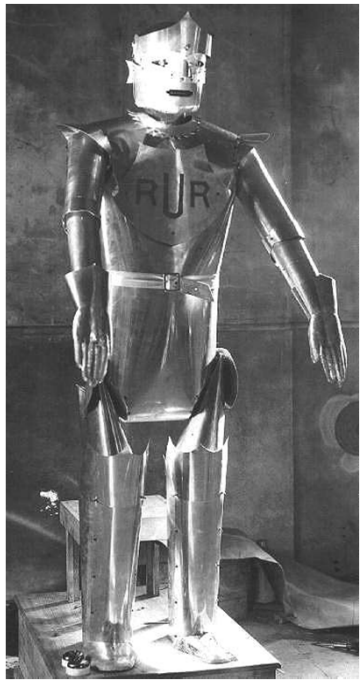
I, Robot **Asimov**



Robot timeline

Karl Capek

Rossum's Universal Robots



Isaac Asimov's Laws of Robotics

First Law:

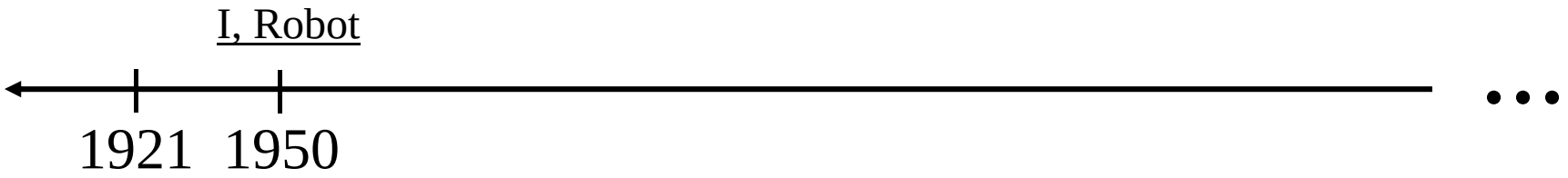
A robot may not injure a human being, or, through inaction, allow a human being to come to harm.

Second Law:

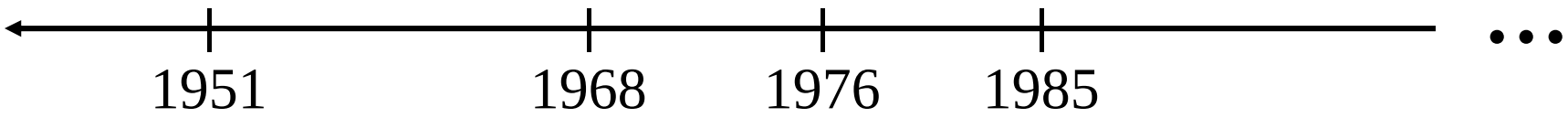
A robot must obey orders given it by human beings, except where such orders would conflict with the First Law.

Third Law:

A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

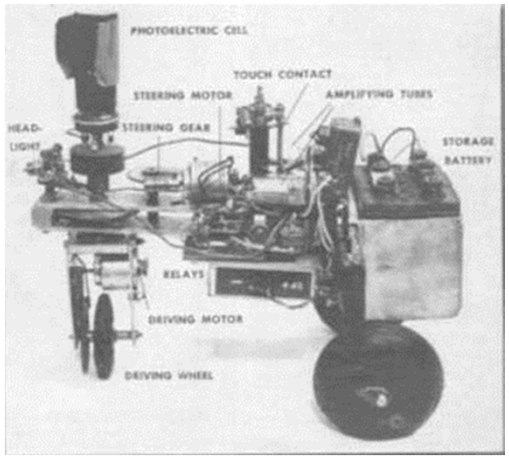


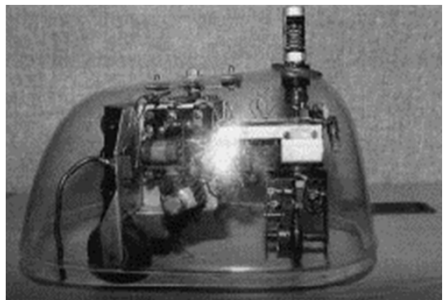
Real robot timeline

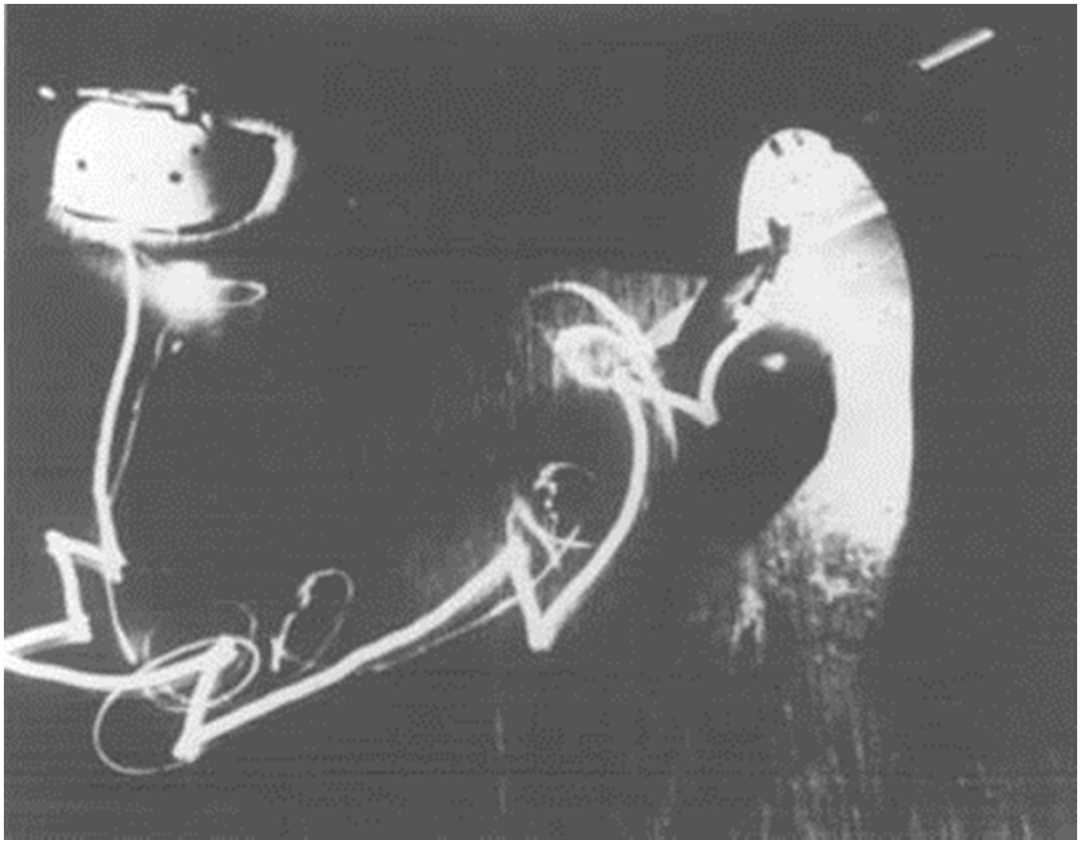


Real robot timeline

Tortoise “Elsie”



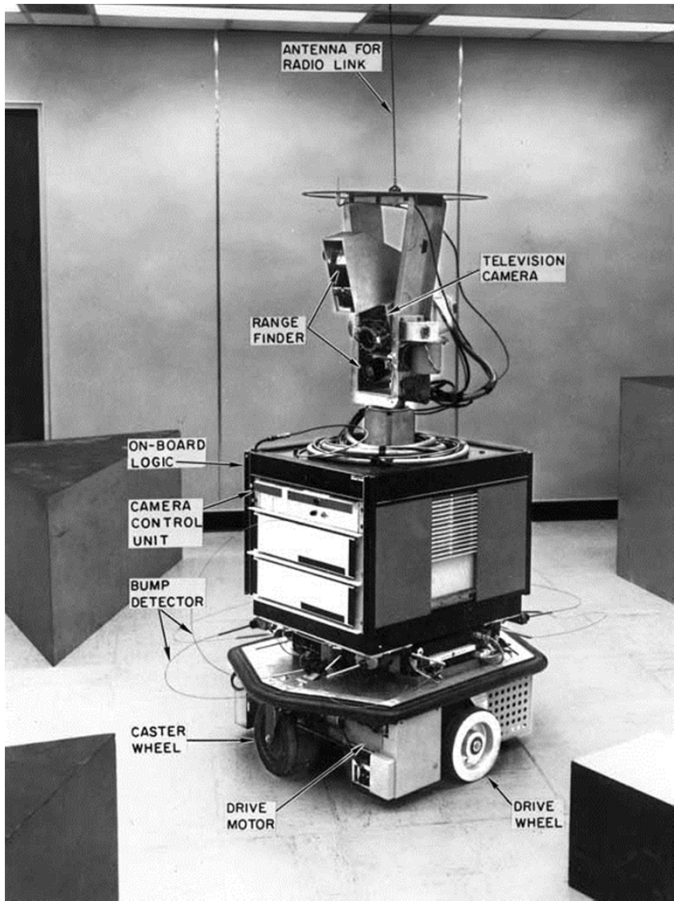




by Neurophysiologist Grey Walter

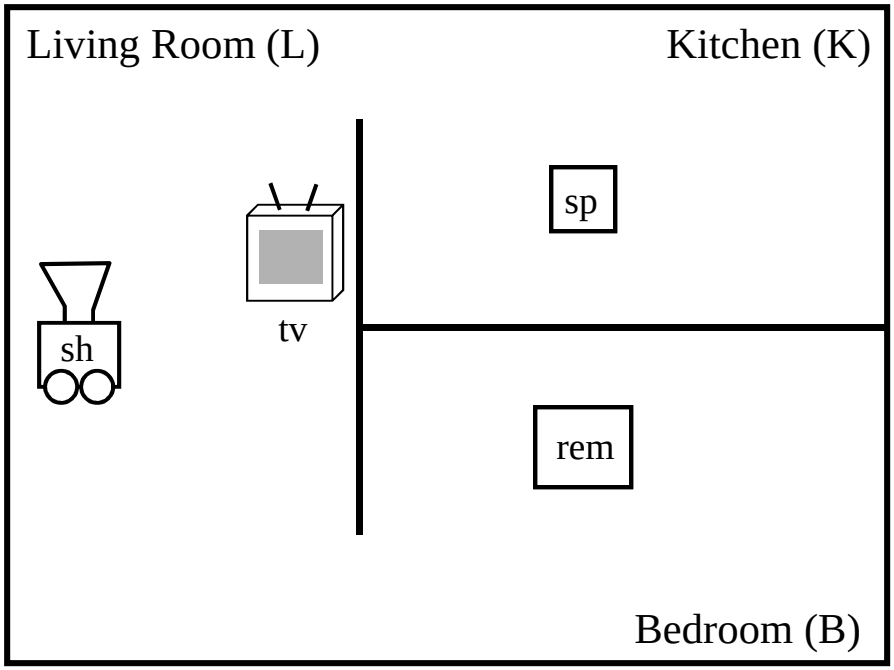
1951 • • •

Shakey



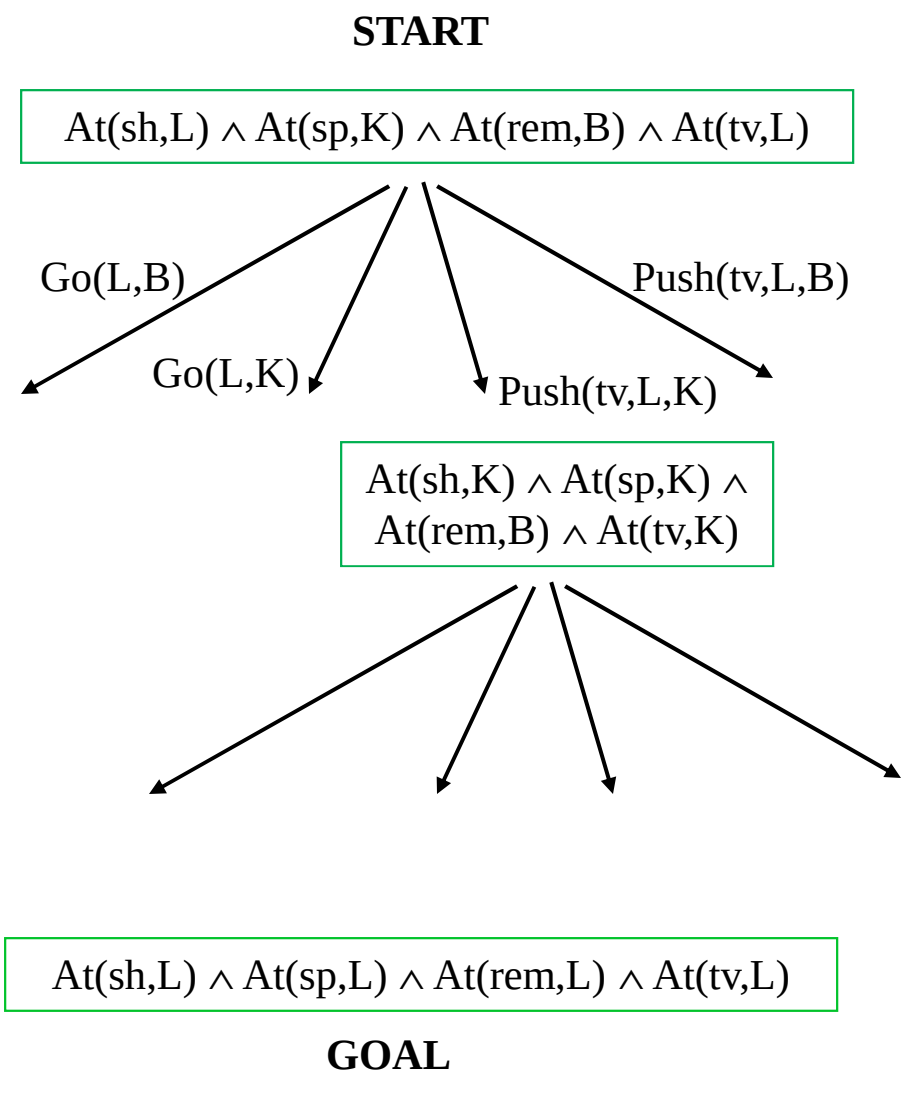
Nils Nilsson @ Stanford Research Inst.

first “general-purpose” mobile platform



1968

Robotics's ***Shakey*** start



ACTIONS

- **Go(from,to)**

Preconditions: At(sh,from)

Postconditions: At(sh,to)

- **Push(obj,fr,to)**

Preconditions: At(sh,fr) ∧ At(obj,fr)

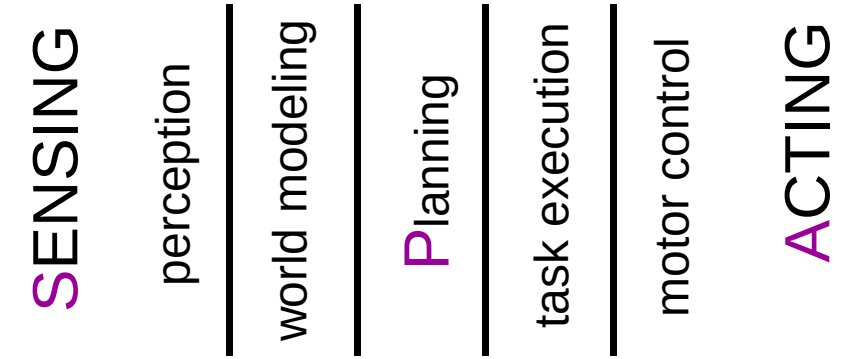
Postconditions: At(sh,to) ∧ At(obj,to)

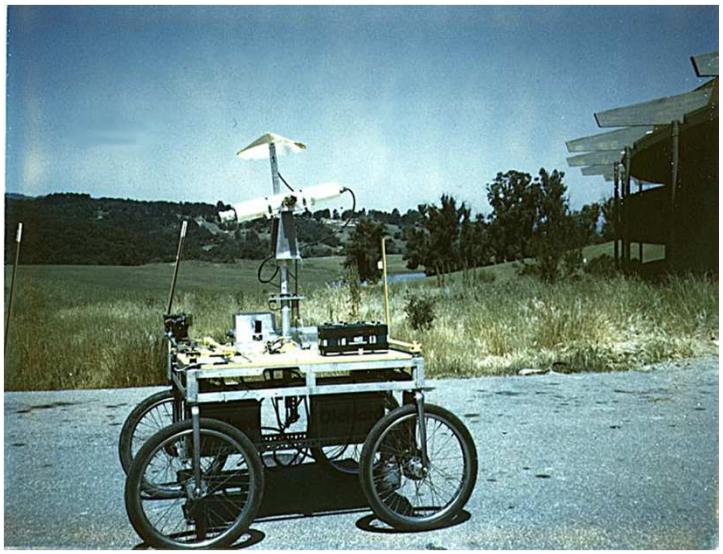
for details, see CS 151!

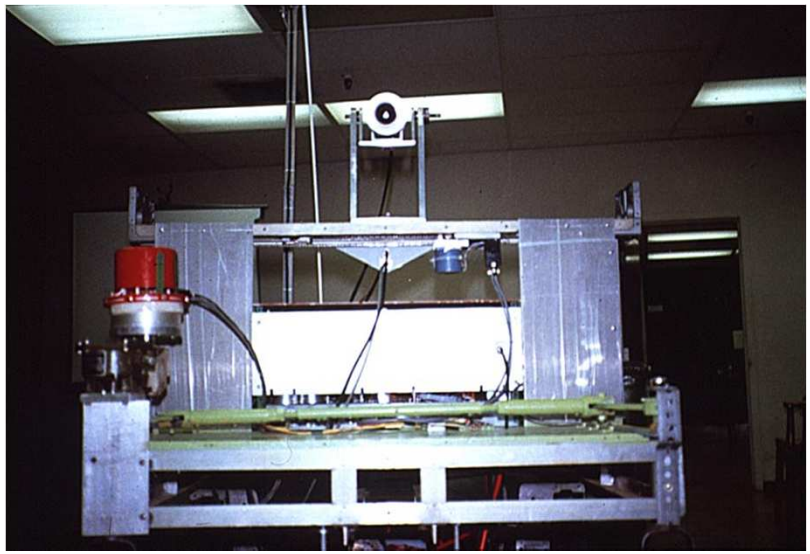
Stanford Cart: *SPA*

Hans Moravec @ SAIL

"functional" task decomposition
"horizontal" subtasks







1976

Cartland (outdoors)

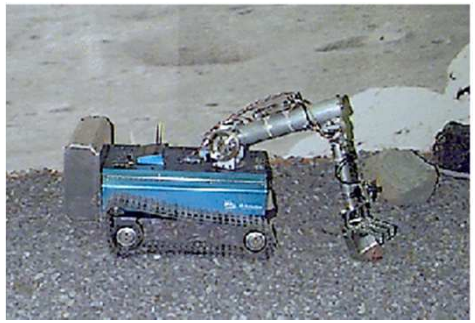
Cartland (indoors)

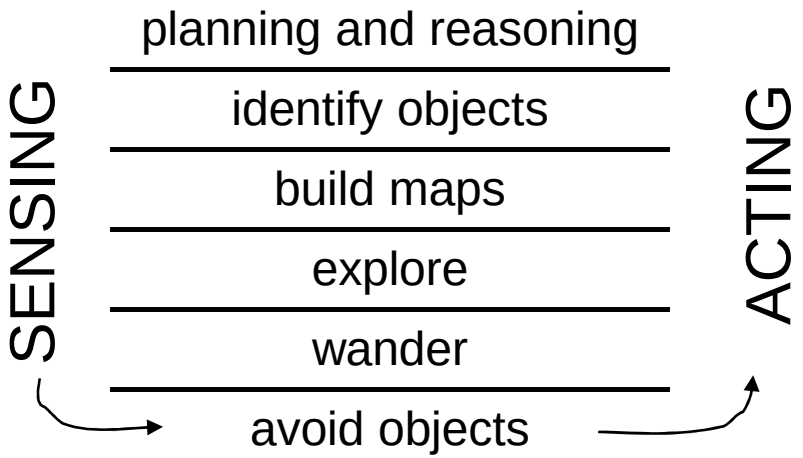
“Robot Insects”

Rodney Brooks @ MIT

“behavioral” task decomposition

“vertical” subtasks

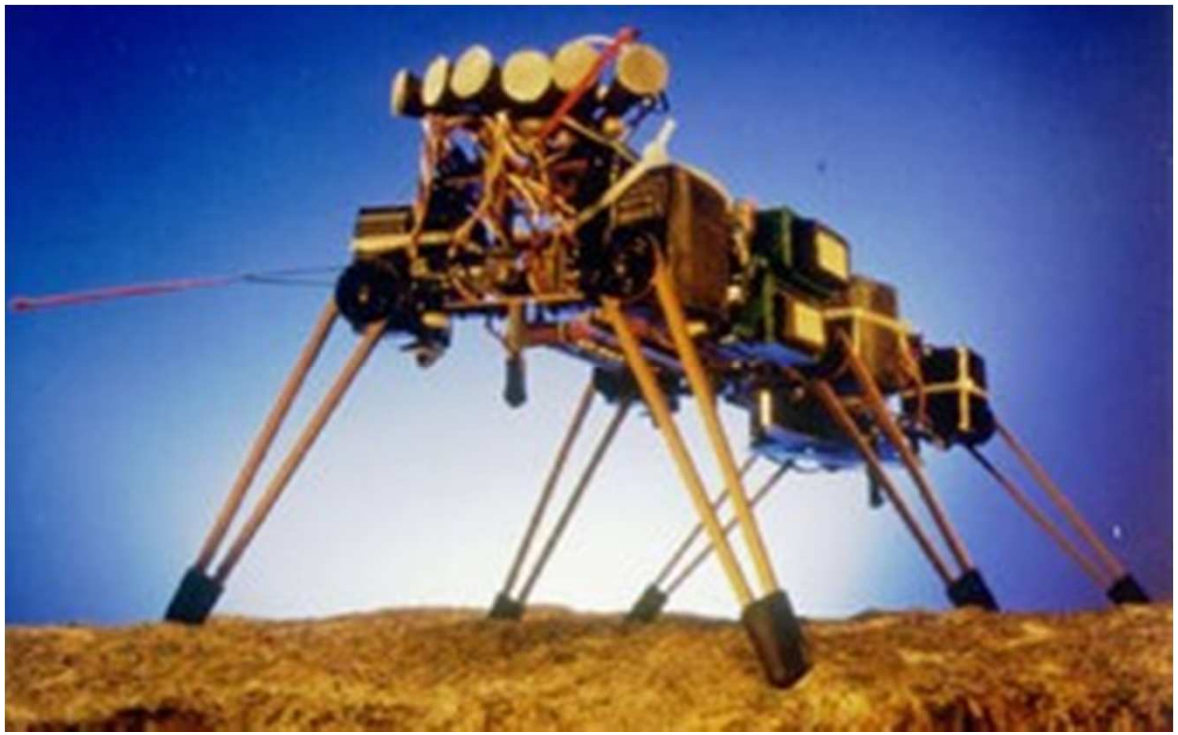




1985

Subsumption Architecture

Genghis in action!



complex behavior = simple rules + complex environment

http://www.youtube.com/watch?v=BUxFfv9JimU

Subsumption

Genghis

1) *Standing* by tuning the parameters of two behaviors:
the leg “swing” and the leg “lift”

2) *Simple walking*: one leg at a time

3) *Force Balancing*: via incorporated force sensors on the legs

4) *Obstacle traversal*: the legs should lift much higher if need be

5) *Anticipation*: uses touch sensors (whiskers) to detect obstacles

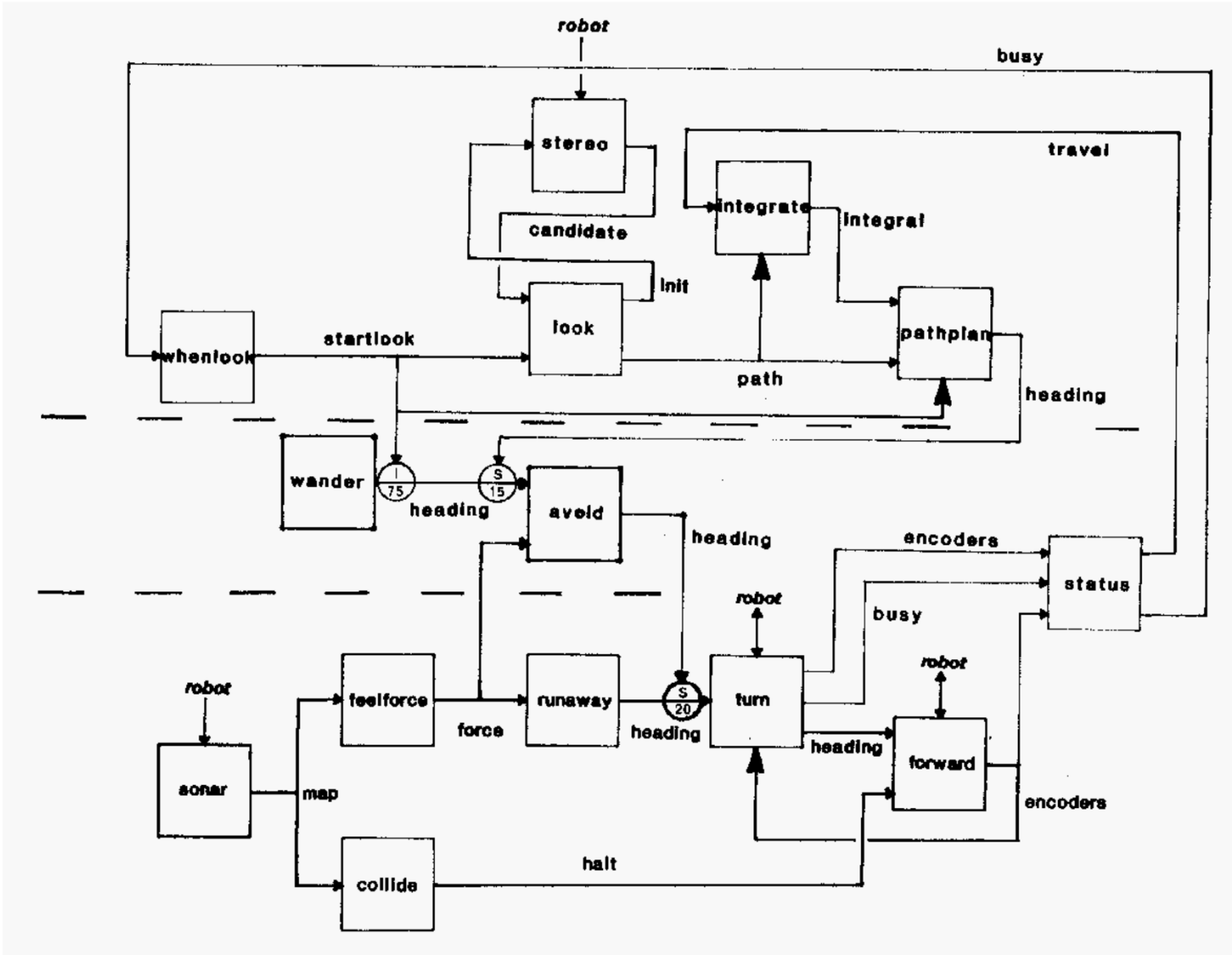
6) *Pitch stabilization*: uses an inclinometer to stabilize fore/aft pitch

7) *Prowling*: uses infrared sensors to start walking when a human approaches

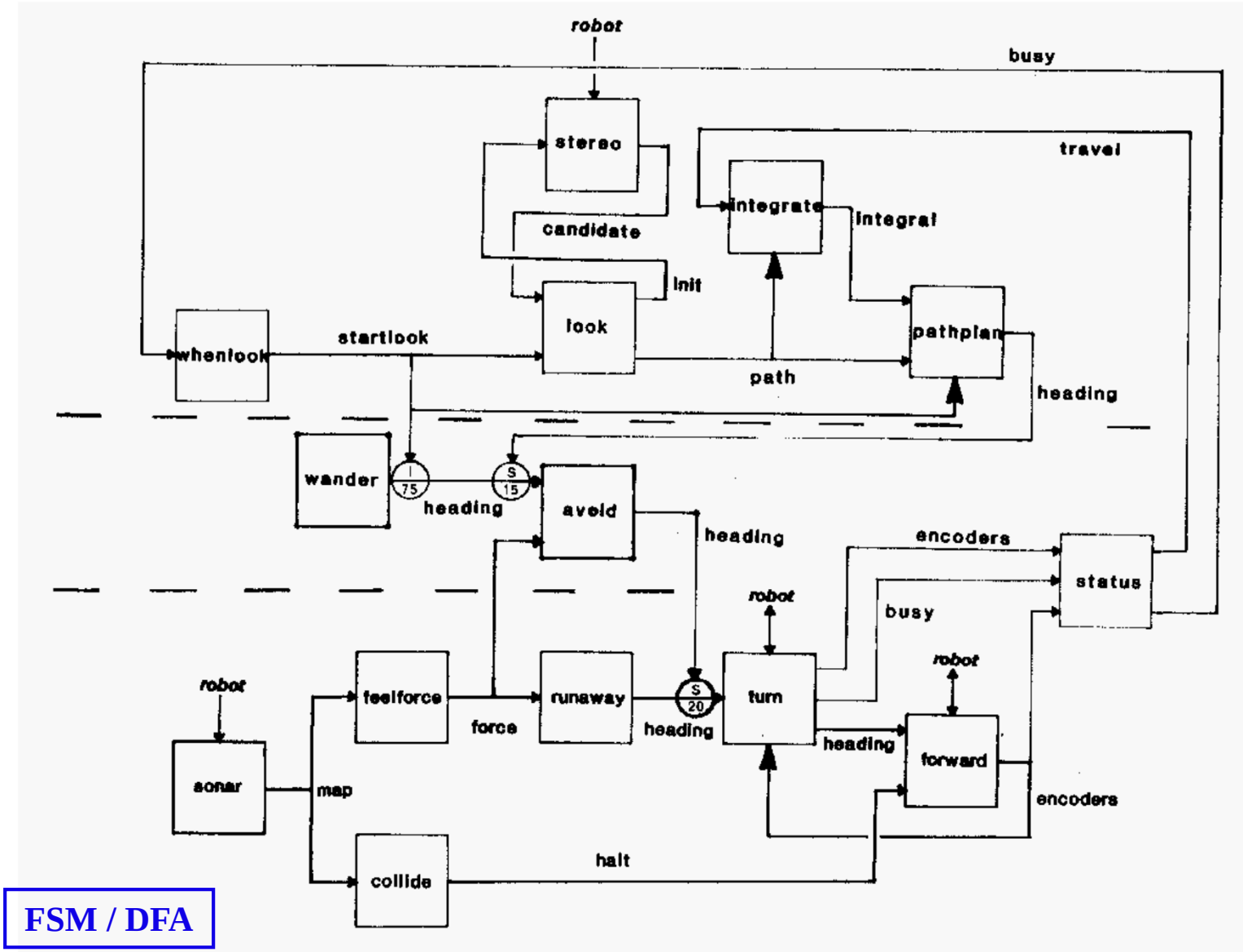
8) *Steering*: uses the difference in two IR sensors to follow

57 modules wired together !

Subsumption Architecture



Finite-state Architecture



Course Questions

Why study robotics?

What, exactly, is robotics about?

What work is involved?

Details

Reading

no required text

First week's paper:

Achieving Artificial Intelligence through Building Robots
Rodney Brooks

Calendar

class meetings:	Tue, Th **3:30-4:50**
Lab CSC 229:	W 2:00-4:30 pm
real office hours:	after class or W,F by appt

Web Page

http://ugweb.cs.ualberta.ca/~vis/courses/robotics/

Assignments ...

- Three lab assignments
- An individual reading and presentation
- A group project
- Two in class exams

Lab Projects - Options

Choose a platform

Default **Lego EV3** →

Other possibilities:

Robot arm

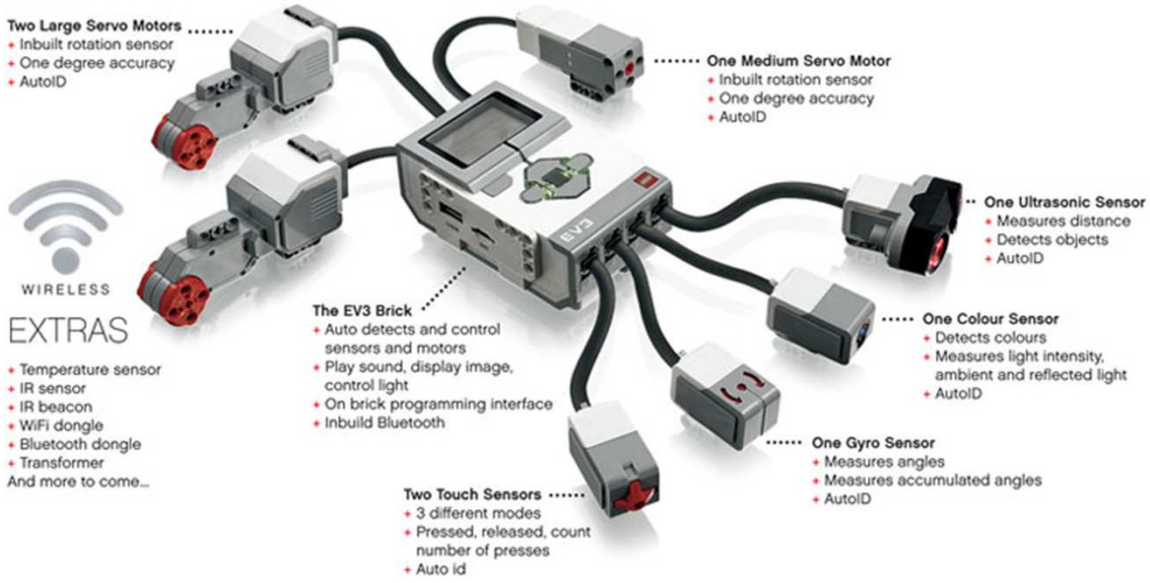
AIBO dog

Pioneer

UAV

Others… !

The EV3 Lego Robot Kit



Choose a task

spatial reasoning

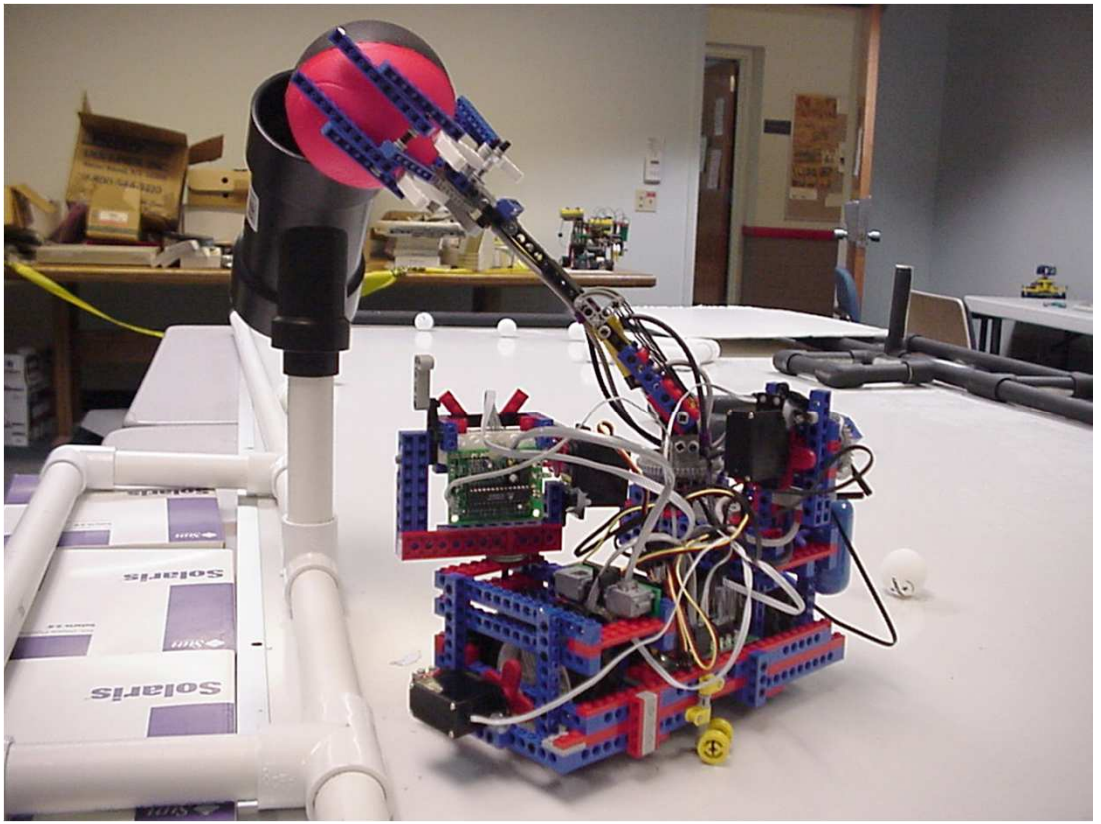
- tag / hide & seek
- Beyond Botball
-

itself publishable…

- fire extinguisher
- Vision guided motion
- Tele-operation

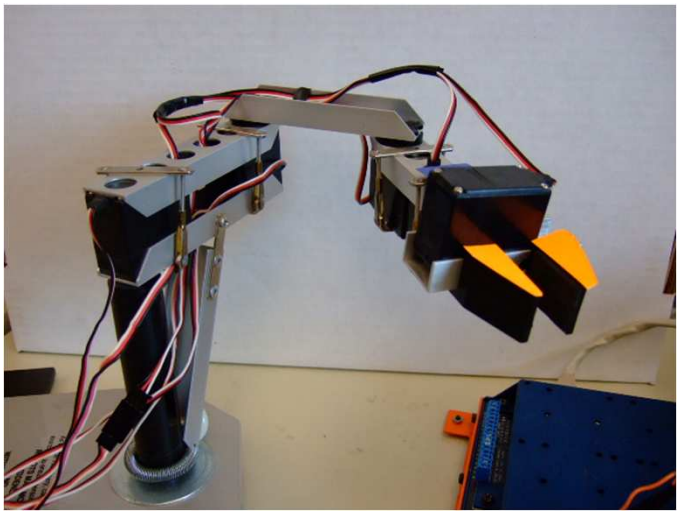
Robot and Project Options

http://jpbrown.i8.com/cubesolver.html

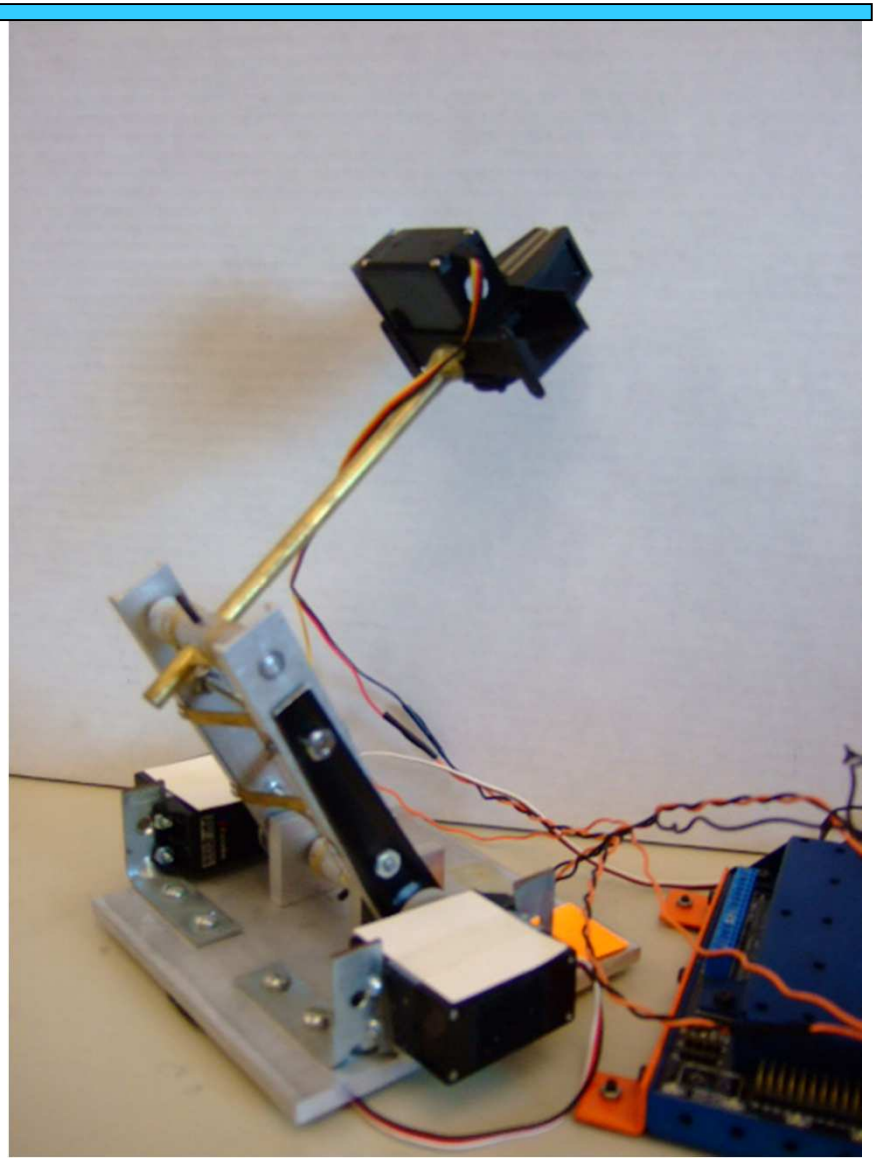


Lego Mapping?

Robot and Project Options



- Home built arm



Robot and Project Options

Sony's AIBO Robot Dog

1 AIBO

Robotics, unleashed

Soccer, machine learning, human-robot interaction

'06: aligning and scoring a goal

'07-'08: line-following and landmarks

lots of software on which to build

CMU's Tekkotsu

Unmanned Autonomous Ground Vehicle

Figure 2: Campus Path Example

Figure 3: Campus Path with Orange Cones

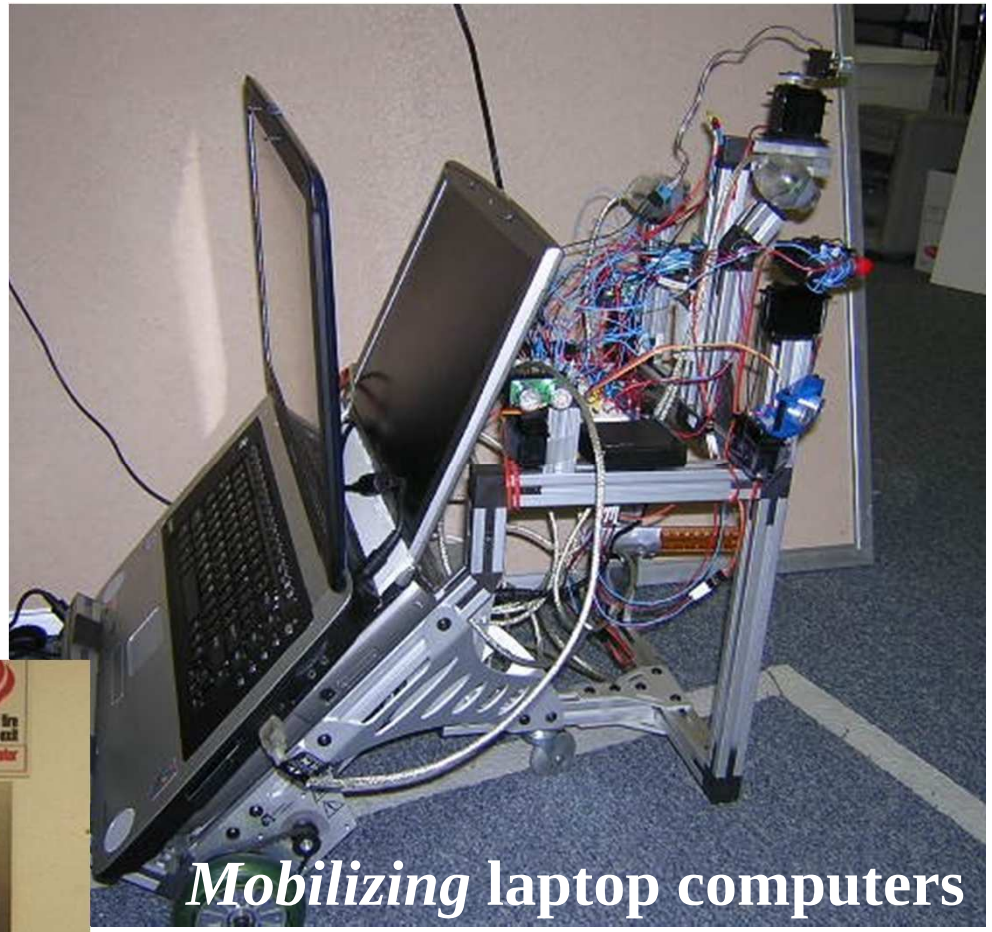
Heading Outdoors…

With Engineeering!

- International Ground Vehicle Competition

- Mini Grand Challenge

Robot and Project Options



Mobilizing **laptop computers**

someday…

'05: AAAI Scavenger Hunt

framework for almost any design

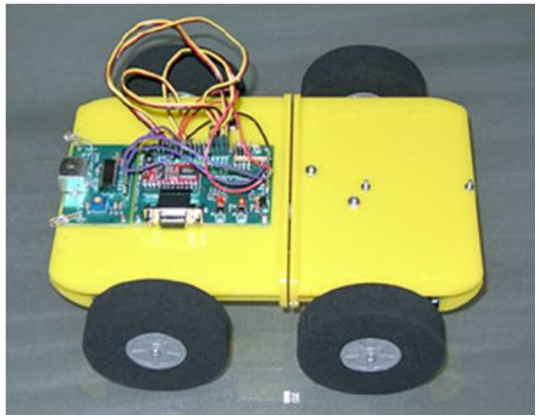
Other Options…

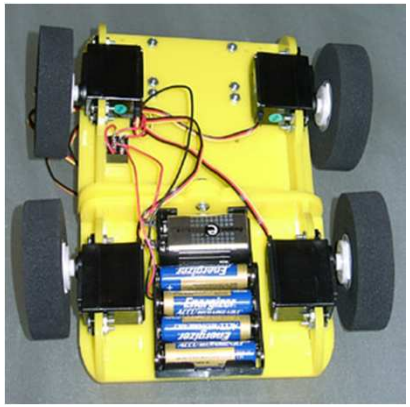
'04: NES Duck Hunt

Wii, anyone?

A robot system that *partners* in a game…

robotics.cs.brown.edu/projects/embodied_gaming/





A Turing *machine…*

Design and build a platform from scratch: wheeled or walking *(not aerial or underwater, however…)*