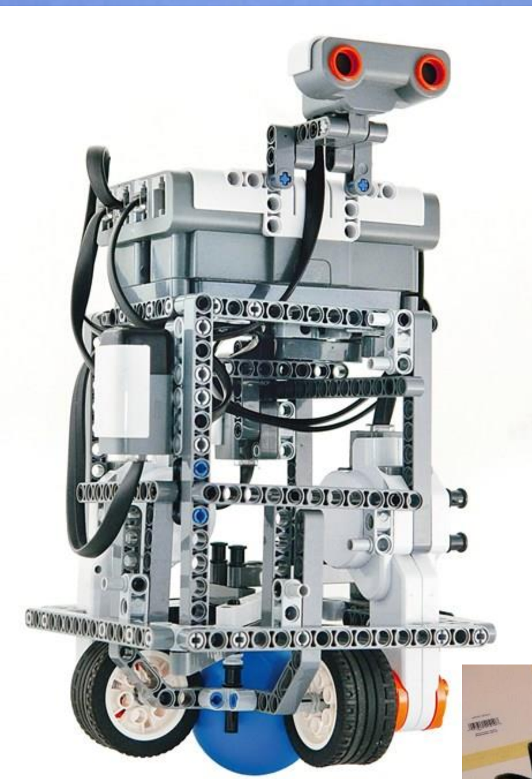
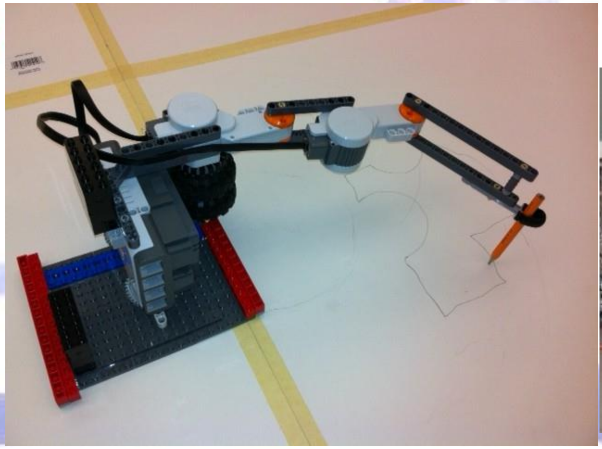
Intr. Robotics & Mechatronics
CMPUT 312



Martin Jagersand

Masood Dehghan



Course Questions

Why study robotics?

What, exactly, is robotics about?

What work is involved?

and other questions as well!

Why Robotics?

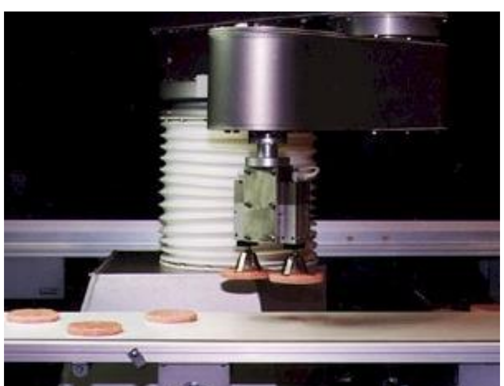
shift in robot numbers… !

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

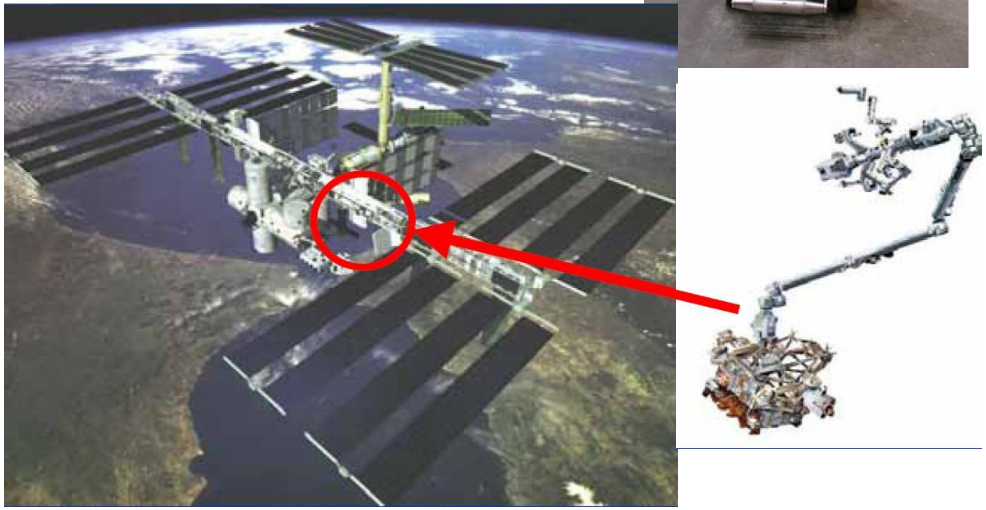
- Engineered environment
- Repeated motion

1 million arms in operation worldwide

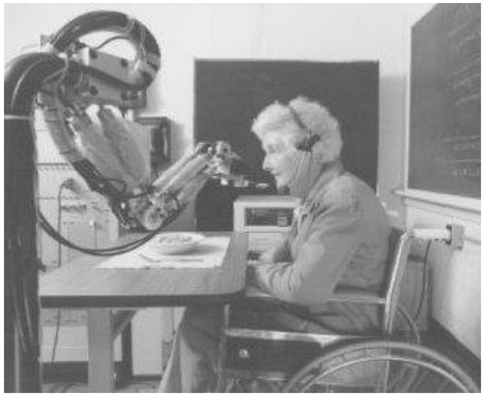
http://en.wikipedia.org/wiki/Industrial_robot

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



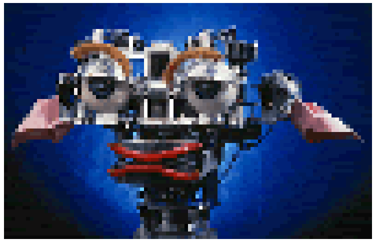
Health - clinical applications, "aging-in-place," physical and cognitive prosthetics in assisted-living facilities

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

No or few robots currently operate reliably in these areas!

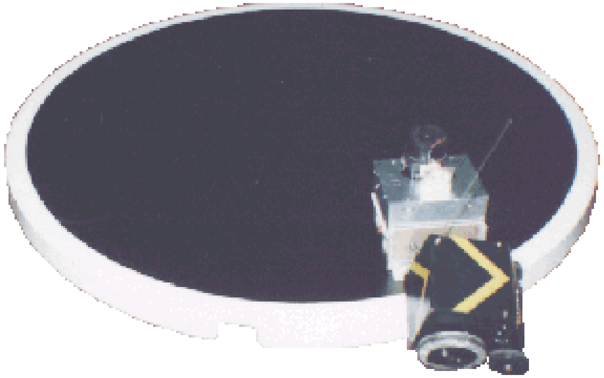
Why Robotics?

kismet



Sony Aibo dogs – had to LEARN to run

Vibrant field



other competitions

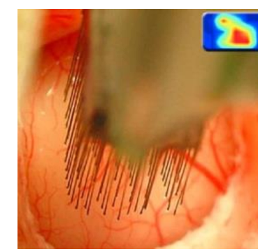
Harold Cohen's Aaron

Why Robotics?

A window to the soul...

Rodney Brooks's Cog

MIT's robotic fish with an unusual actuator!

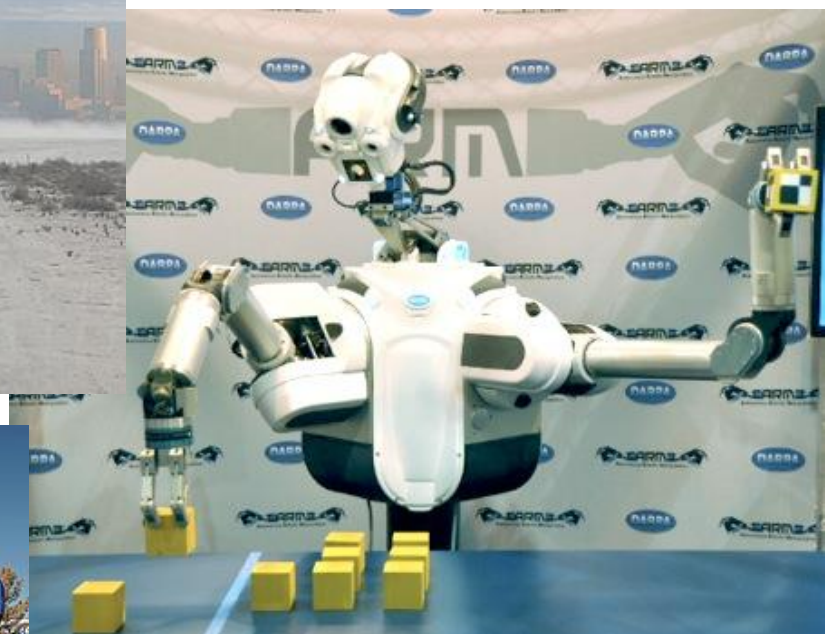


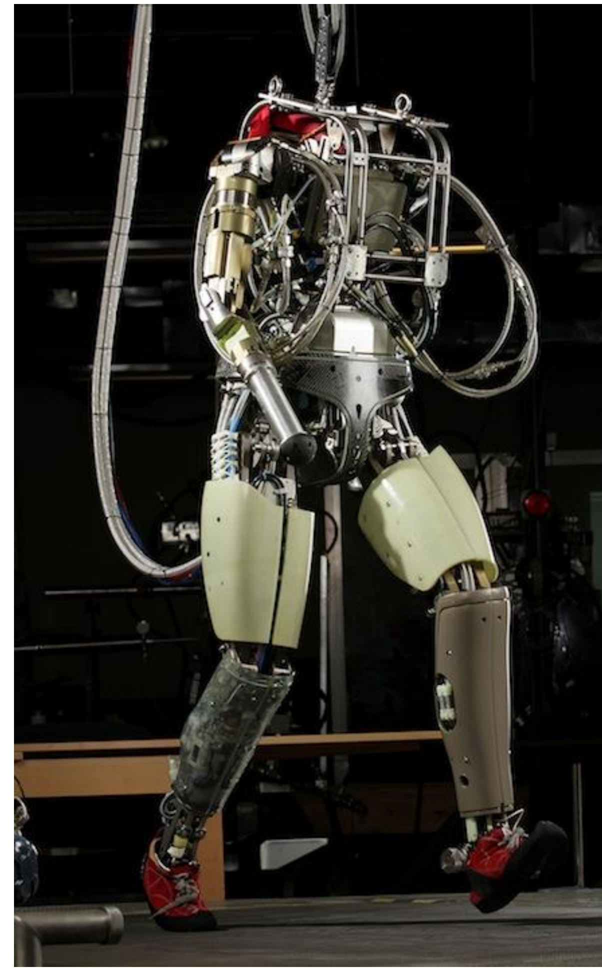
Monkey/machine interface at the Univ. of Pittsburgh

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

AI-complete…

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?

Unicycling

Autonomous : Robot :: Awake : Student

Autonomous

↑

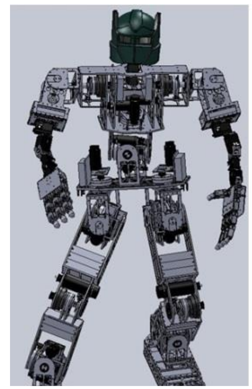
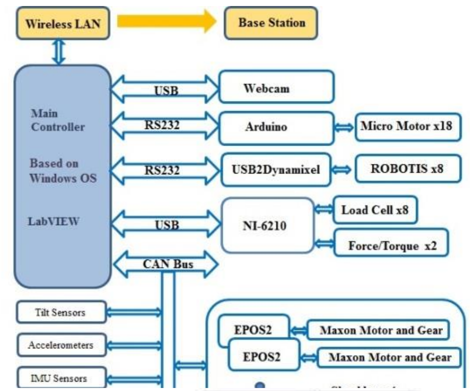
Choose one !

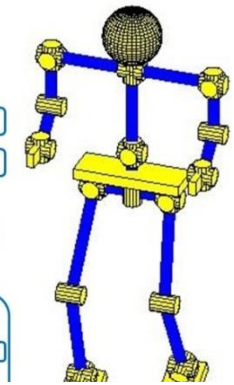
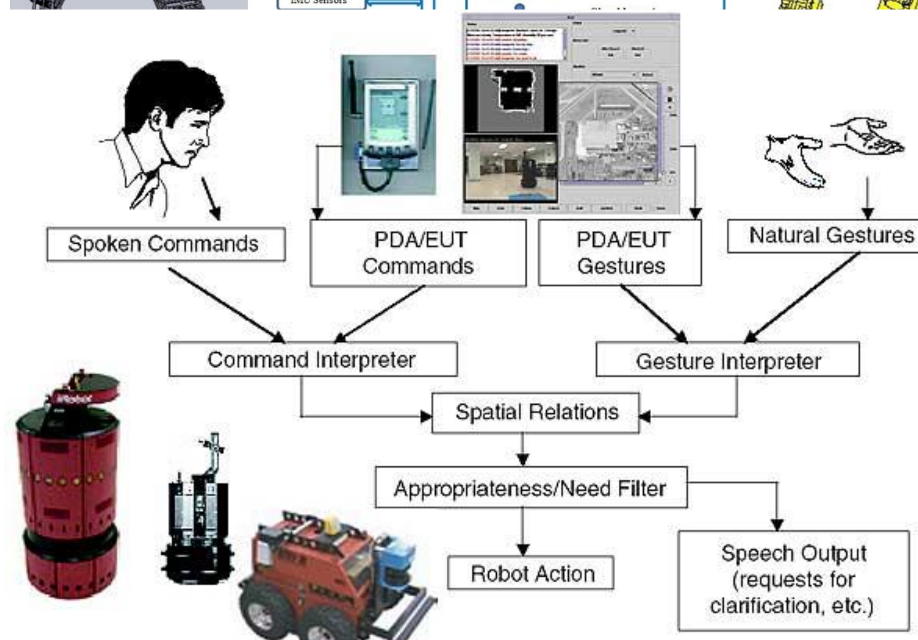
What is a robot?

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

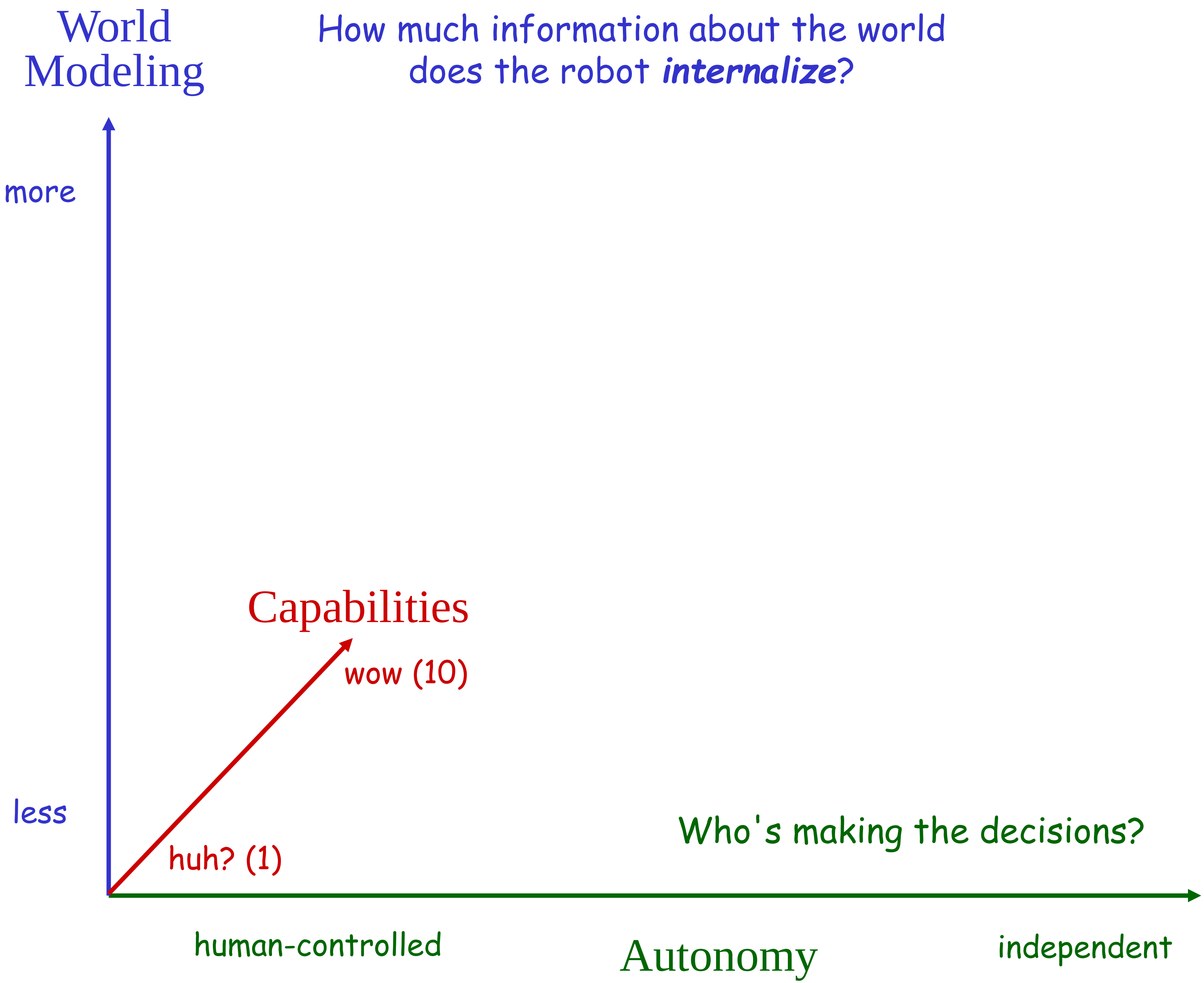
none → **full**

Robot Wars, Battlebots

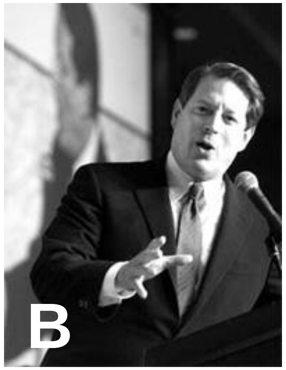
FIRST Robotics

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



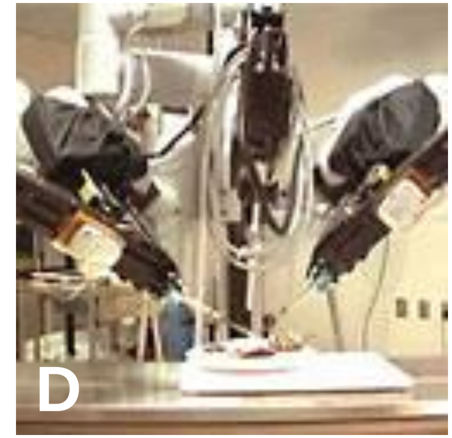
US VP Al Gore

ex-VP, Nobelian

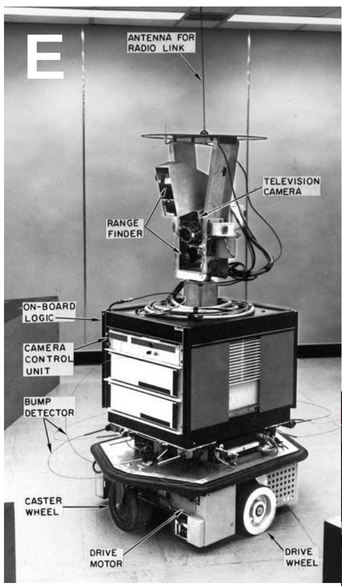
Genghis Robotic Insect

da Vinci

Robotic Surgeon



11 “robotic” systems



Shakey

object-”manipulator” (pusher) from SRI (1969)

Roomba

Robotic vacuum cleaner

Sims

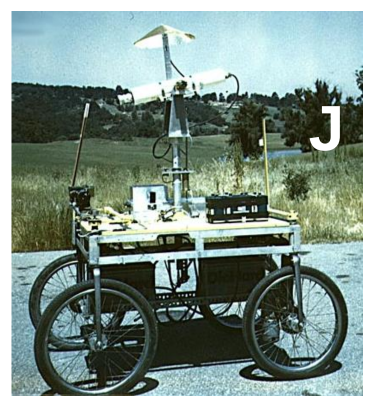
now with professor!

Stanford's Stanley/CMU's Boss

each a $2 million winner

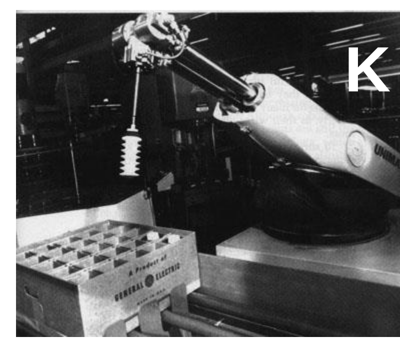
Spirit/Opportunity

n Rovers: 1997, 2004-now



Stanford Cart

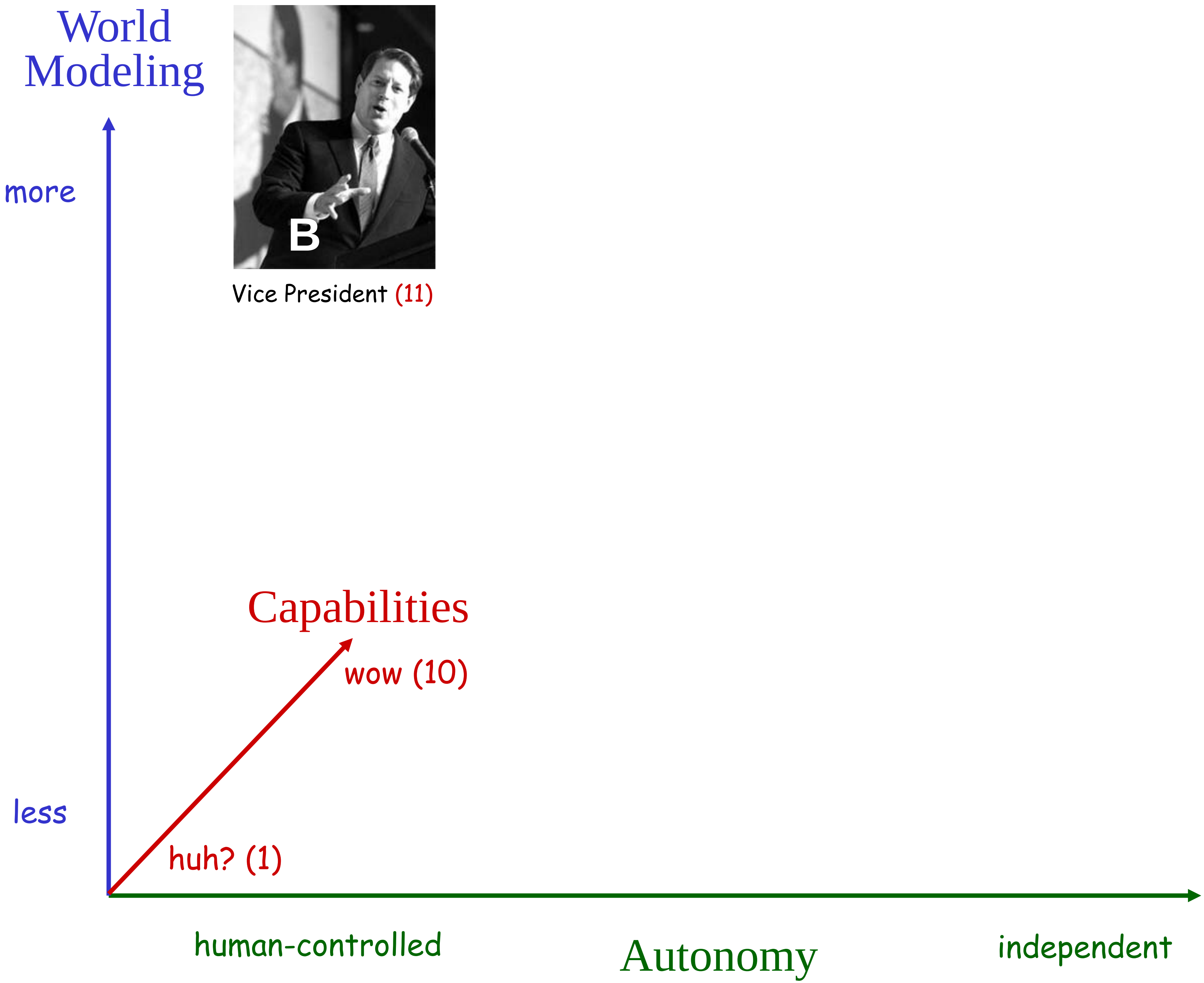
vision-based obstacle-avoider (1976)



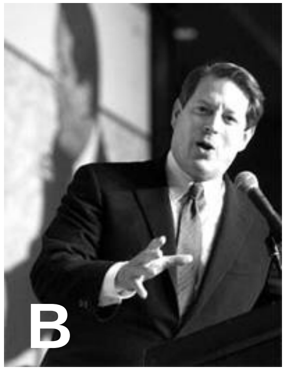
Unimate

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

Perhaps include a robot of your own choosing…

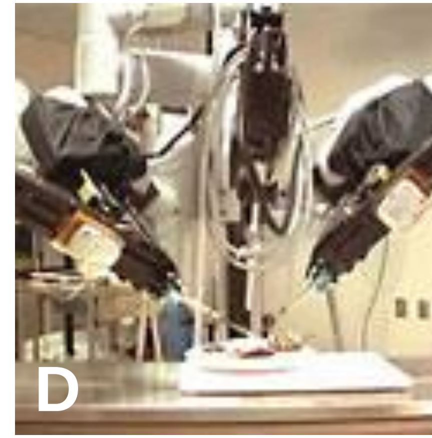

World Modeling
more
B
Vice President (11)
Capabilities
wow (10)
less
huh? (1)
human-controlled
Autonomy
independent

Bar Monkey
robotic barkeep



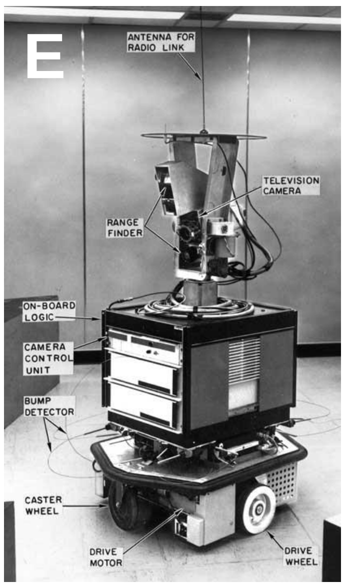
Al Gore
ex-VP, Nobelian

Genghis Robotic Insect



da Vinci
Robotic Surgeon

11 "robotic" systems



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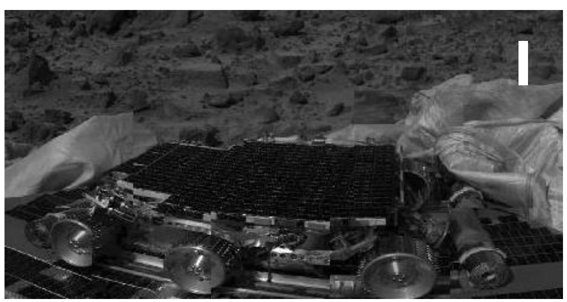
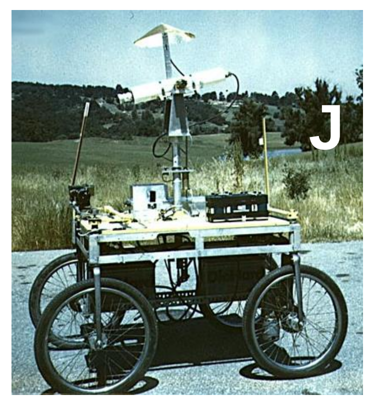


Sojourner/Spirit/Opportunity
Mars Exploration Rovers: 1997, 2004-now



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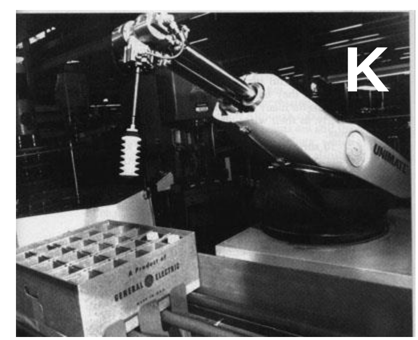


Unimate
first industrial robotic arm, '61
(now in the hall of fame)

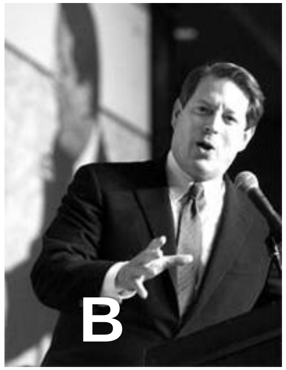
Perhaps include a robot of your own choosing…

Robot Plot

World Modeling

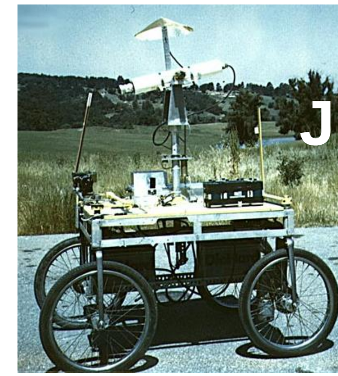
Capability (0-10)

more



Al Gore (11)

Shakey (3)



Stanford Cart (3)

Capabilities

wow (10)

huh? (1)

Genghis (3)

less

human-controlled

Autonomy

independent

Robot Plot

World Modeling

Capability (0-10)

more

Al Gore (11)

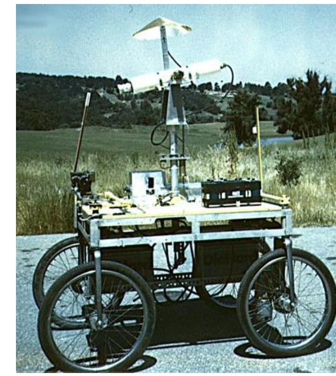
Sims (5)

Bar Monkey (9)

MERs (8)

Stanley/Boss (9)

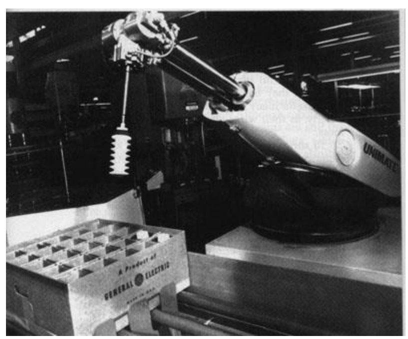
Shakey (3)



Stanford Cart (3)

less

da Vinci (2)



Unimate (4)

Roomba (7)

Genghis (3)

human-controlled

Autonomy

independent

312 Course topics

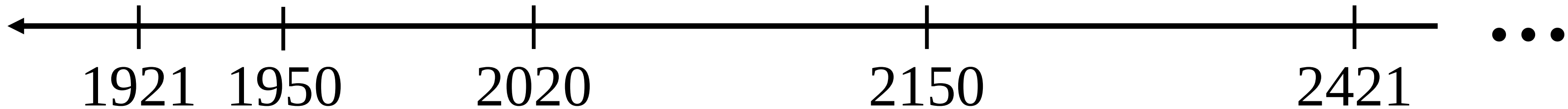
- **Introduction**
- **Robot hardware for mobile roobots, arms and UAV's**
- **Reactive robotics**
- **Modeling mobile robots, kinematics, navigation**
- **Robot sensors**
- **Robot arm types and kinematics**
- **Analytic and numerical arm inverse kinematics**
- **Machine vision and image processing**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

What am I? robots ~ bodies…

where am I?
how do I get there?

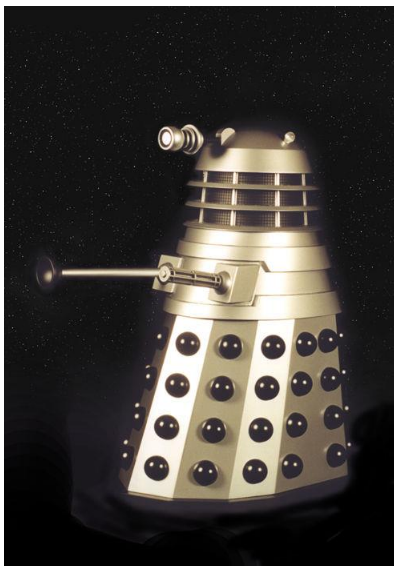
is seeing believing?

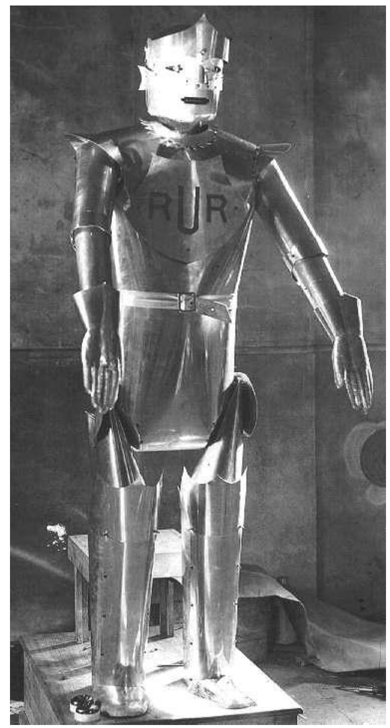
Robot timeline?



Fictional Robot timeline

Putting these robots in chronological order?



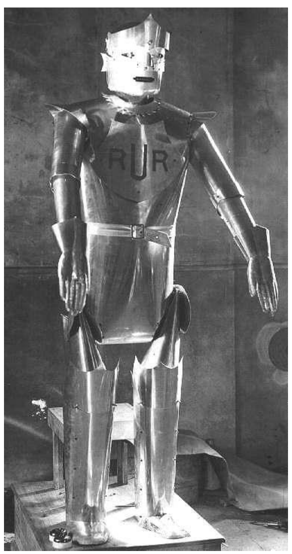


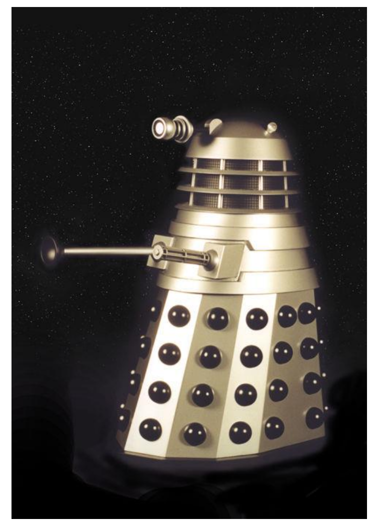
1921 2020 2150 2421 …

Fictional robot timeline

Karl Capek

Rossum's Universal Robots





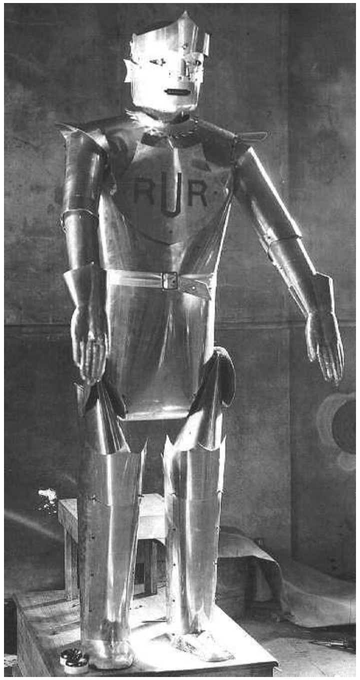
I, Robot **Asimov**

1921 1950 2020 2150 2421 . . .

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.

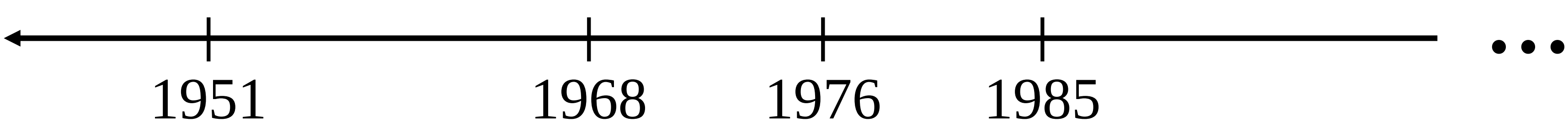
Third Law:

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

I, Robot

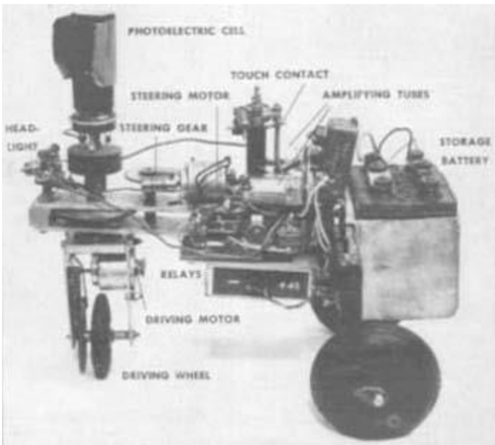
1921 1950 …

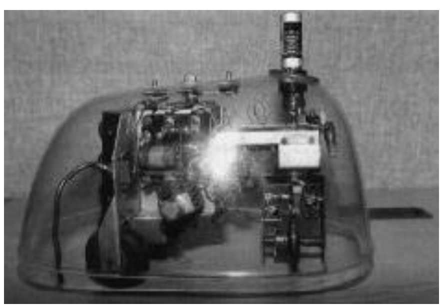
Real robot timeline

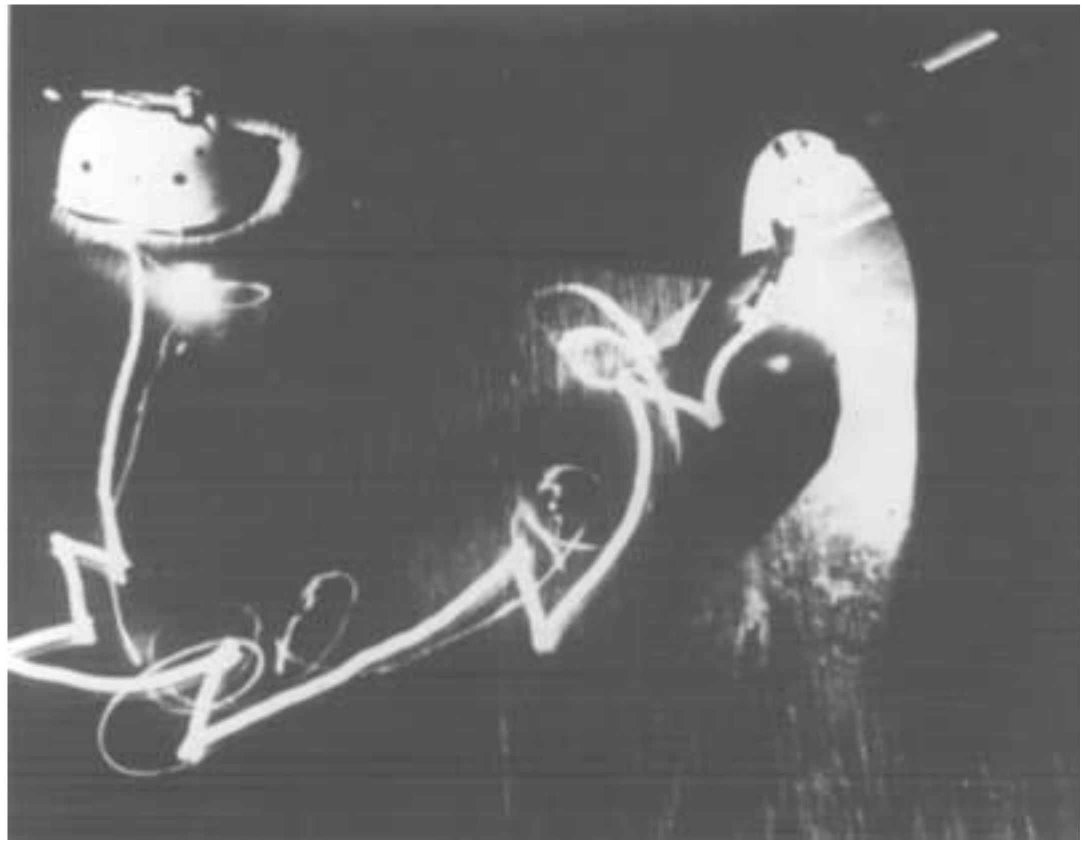


Real robot timeline

Tortoise "Elsie"



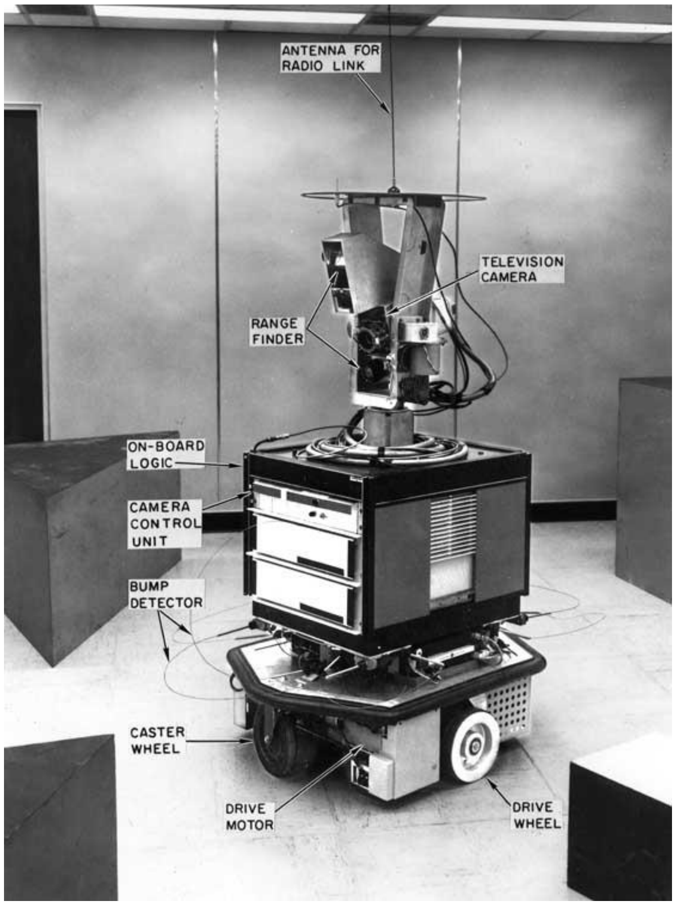




by Neurophysiologist Grey Walter

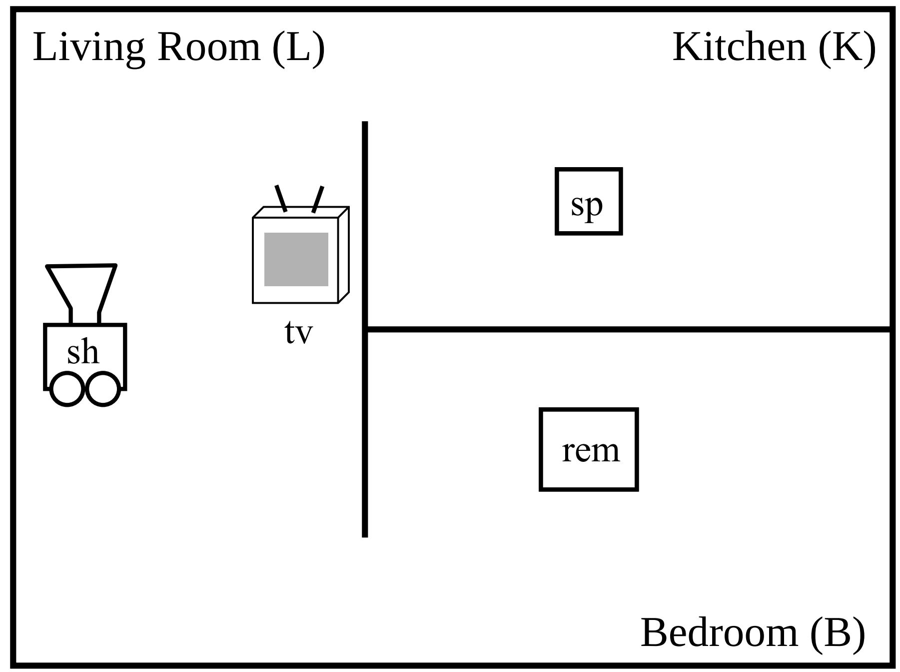
1951 …

Shakey



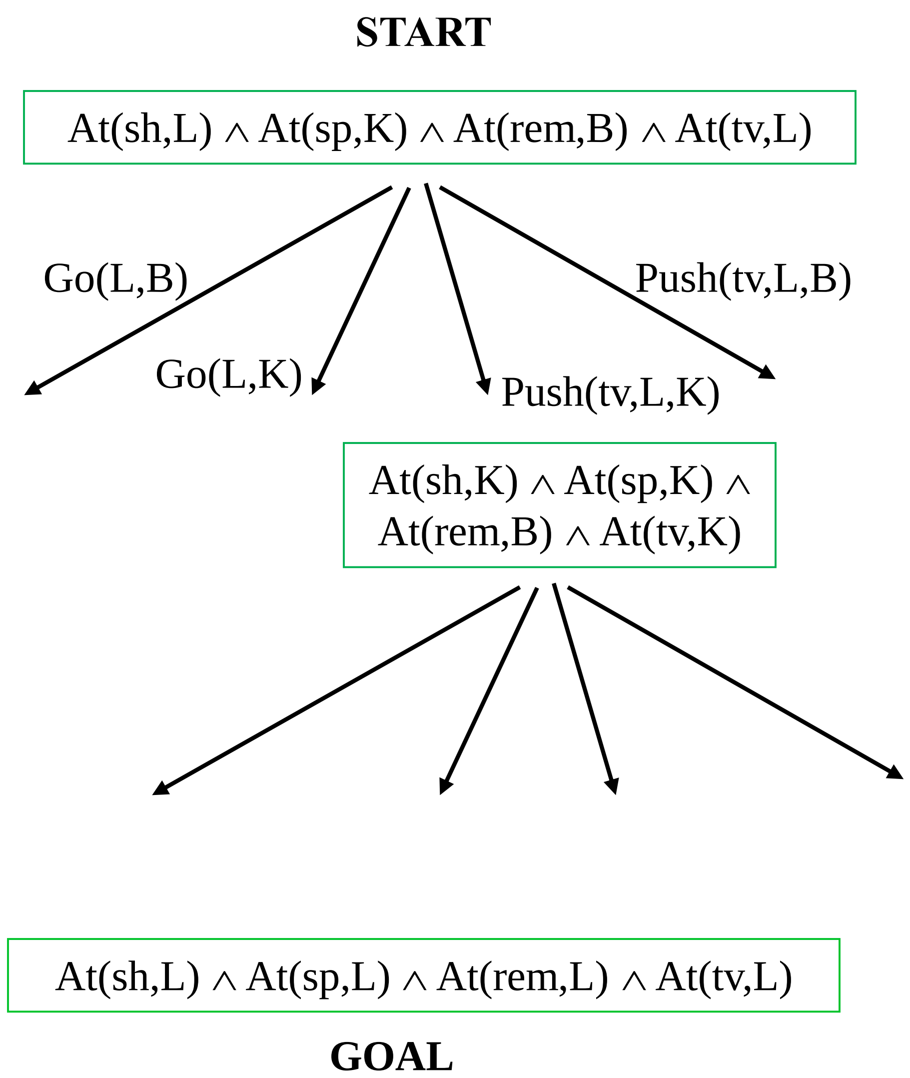
Nils Nilsson @ Stanford Research Inst.

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)

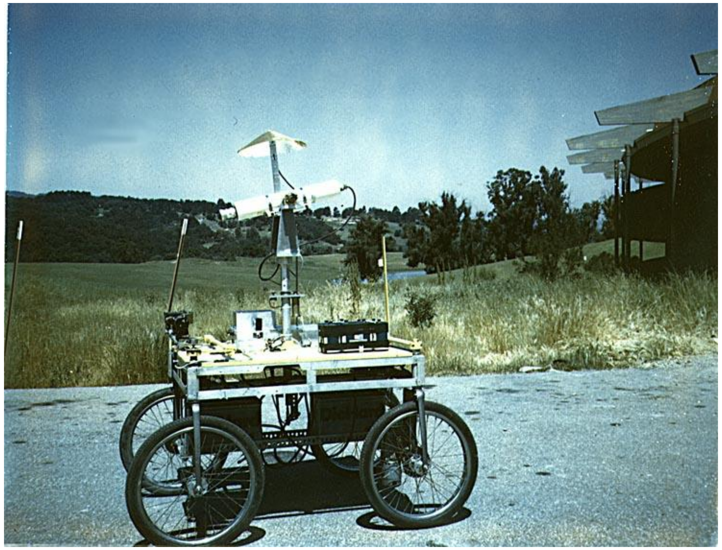
for details, see CS 151!

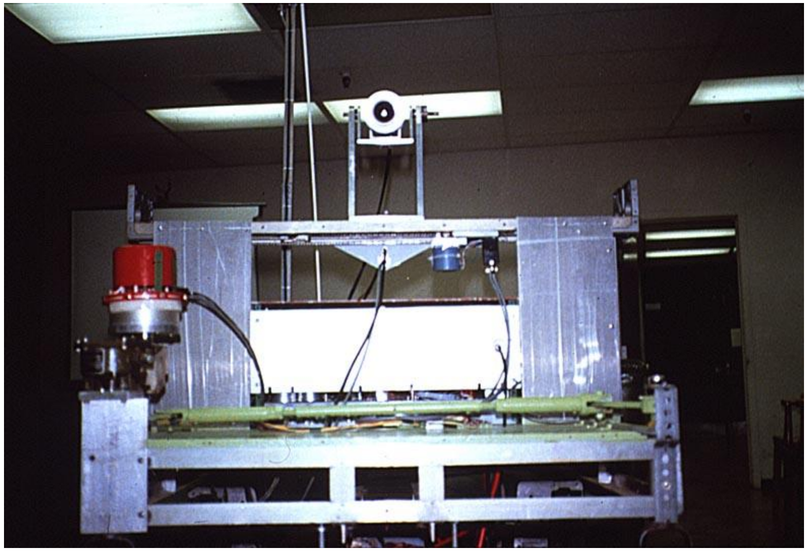
Stanford Cart: *SPA*

Hans Moravec @ SAIL

"functional" task decomposition →
"horizontal" subtasks

SENSING | perception | world modeling | Planning | task execution | motor control | ACTING





… 1976 …

Cartland (outdoors)

Cartland (indoors)

"Robot Insects"

Rodney Brooks @ MIT

"behavioral" task decomposition →
"vertical" subtasks

SENSING

planning and reasoning

identify objects

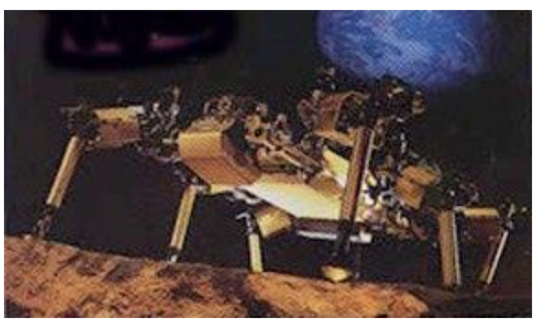
build maps

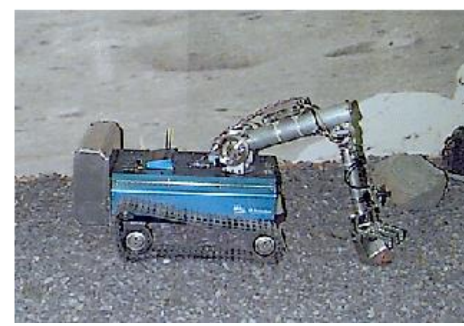
explore

wander

avoid objects

ACTING





• • • 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

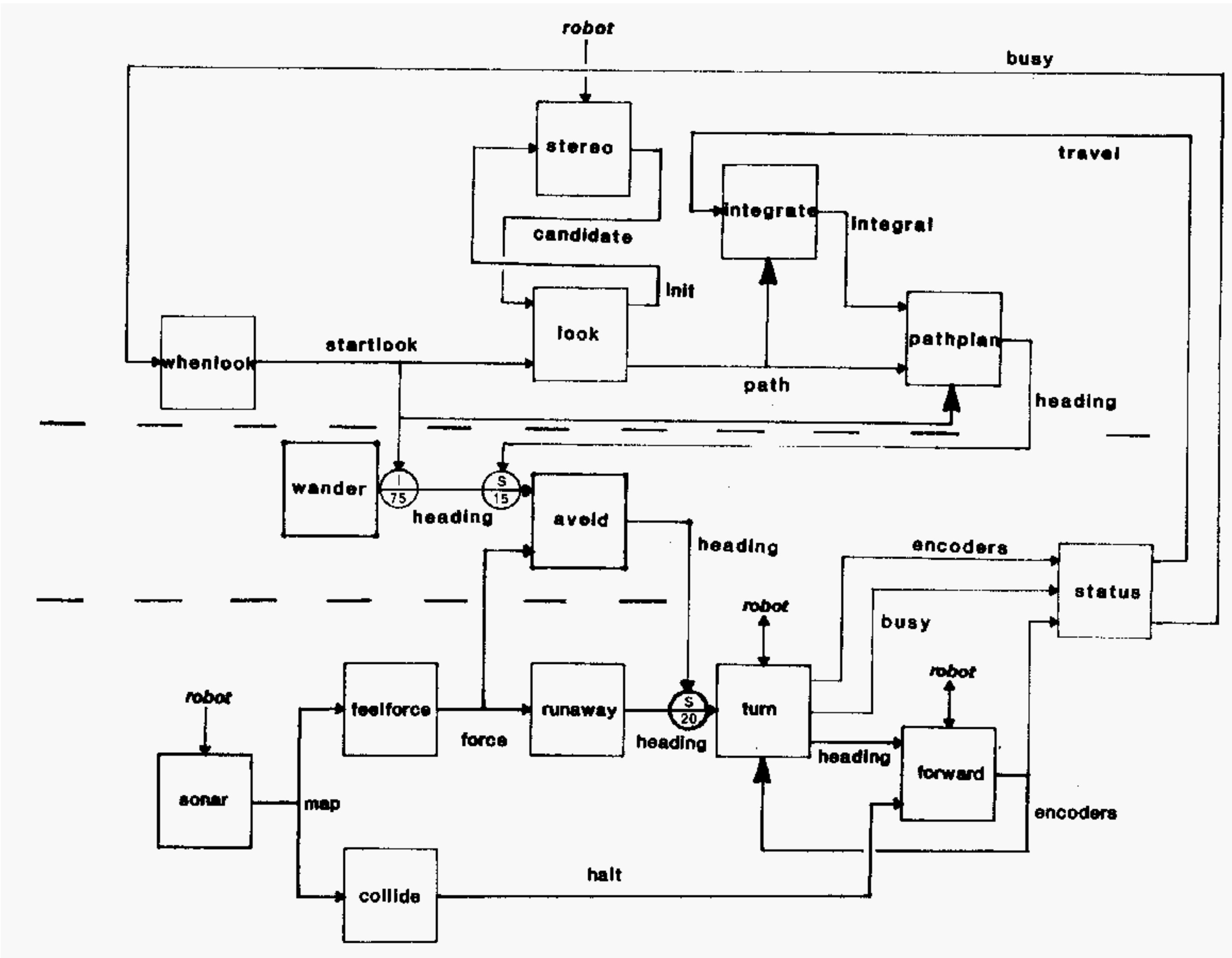
6) *Pitch stabilization*: uses an inclinometer to stabilize fore/aft pitch

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

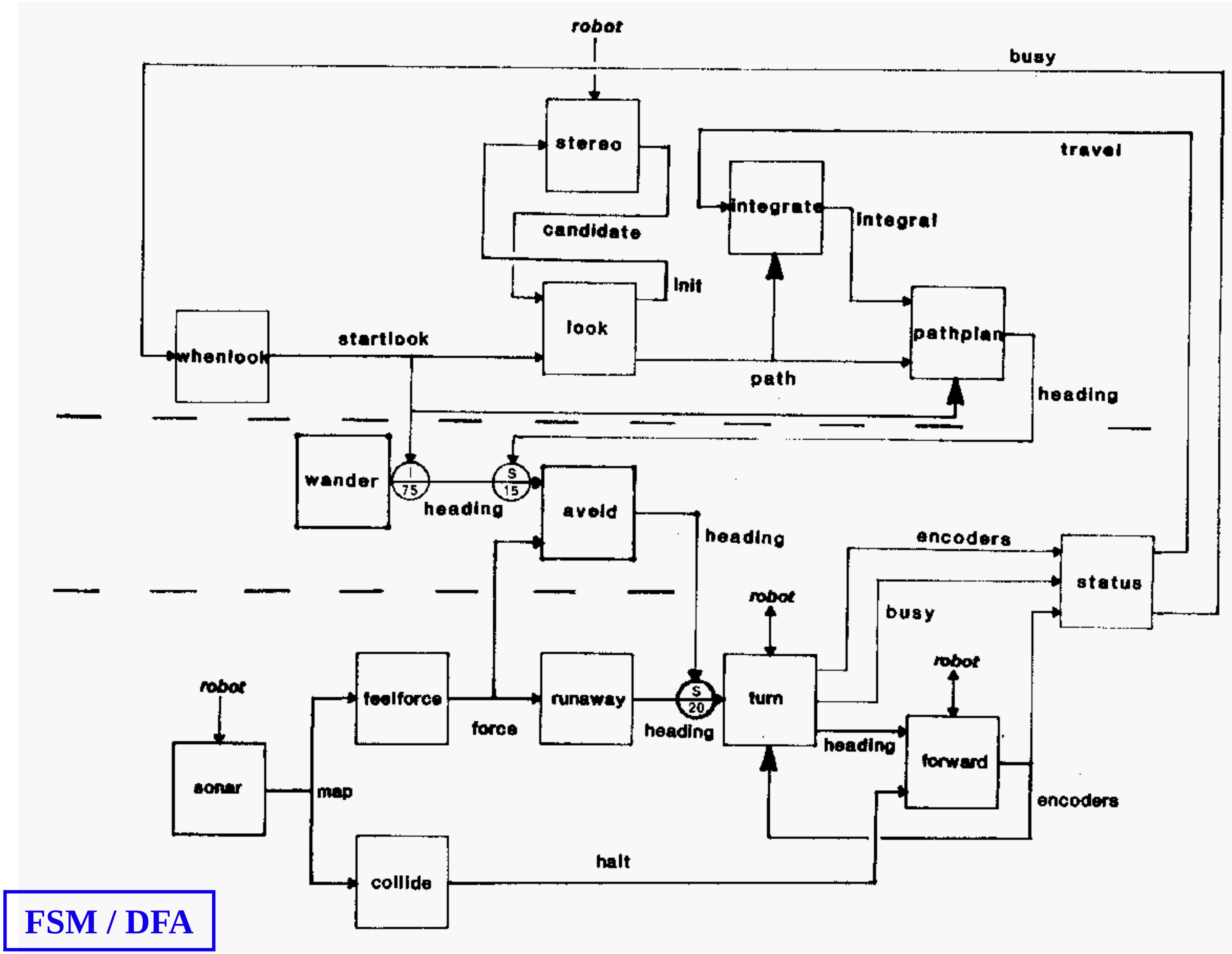


navigate behavior

wander behavior

runaway behavior

Finite-state Architecture



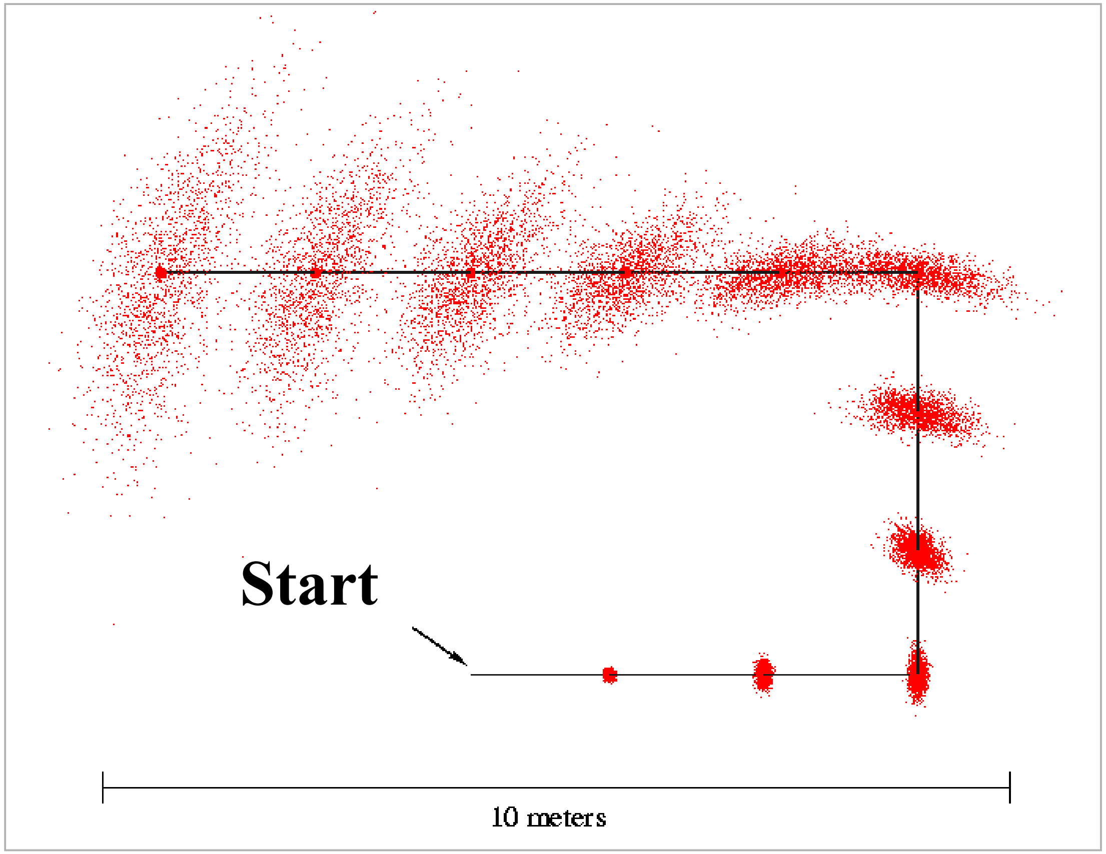
navigate behavior

wander behavior

runaway behavior

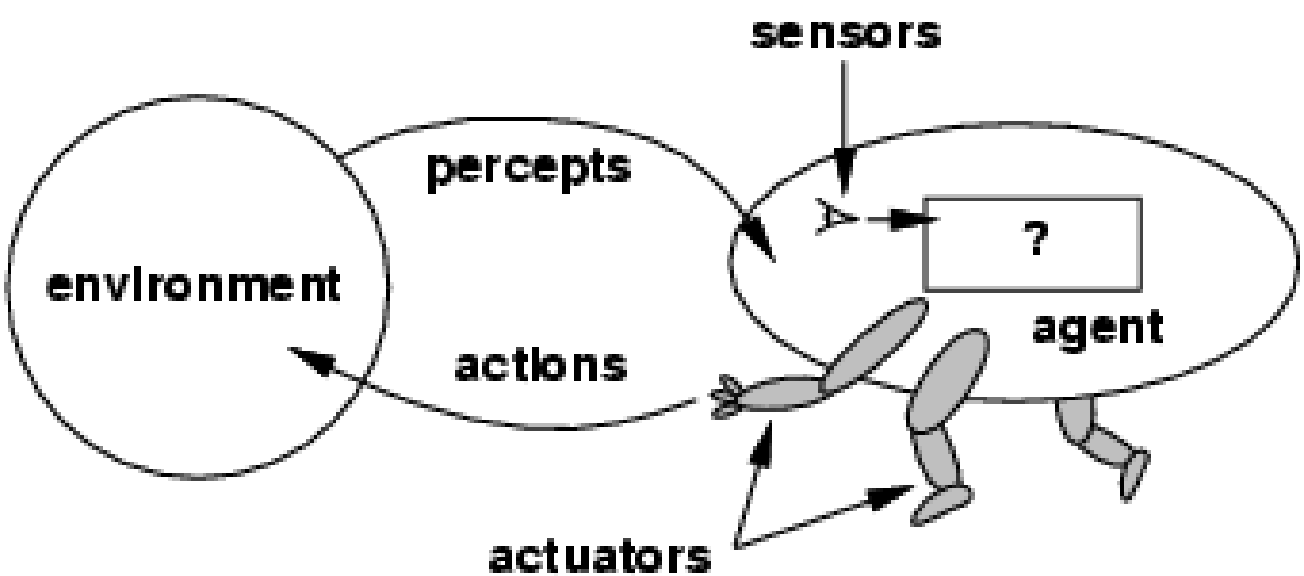
FSM / DFA

Now: Intelligent Robotics: Probabilistic robotics

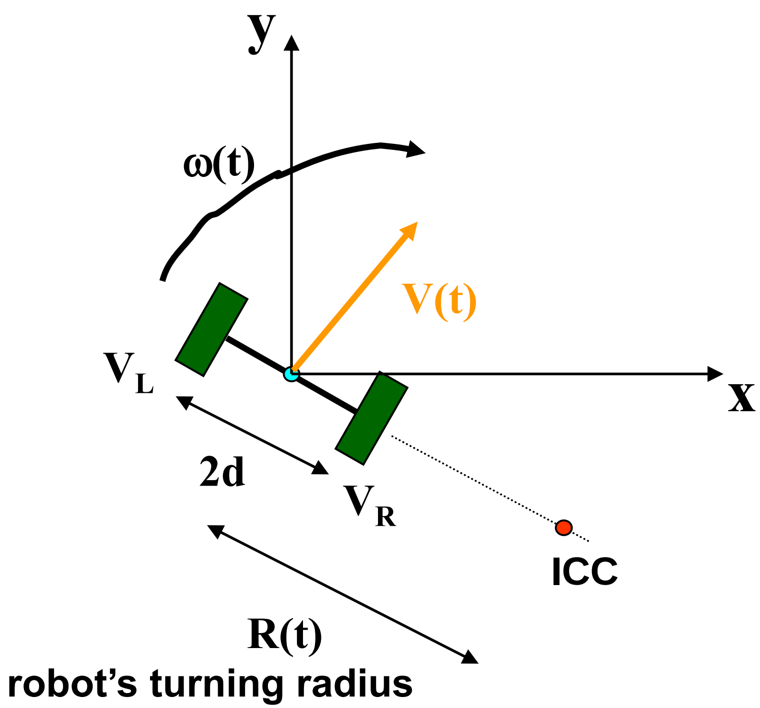


Now: Intelligent Robotics: Sensory guided robotics

- Camera or Kinect vision



Lecture 3: Modeling 1: Differential drive



What has to happen to change the ICC ?

things have to change over time, t

4) Integrate to obtain position

$$V_x = V(t)\cos(\theta(t))$$

$$V_y = V(t)\sin(\theta(t))$$

Thus,

$$x(t) = \int V(t)\cos(\theta(t))\,dt$$

$$y(t) = \int V(t)\sin(\theta(t))\,dt$$

$$\theta(t) = \int \omega(t)\,dt$$

Kinematics

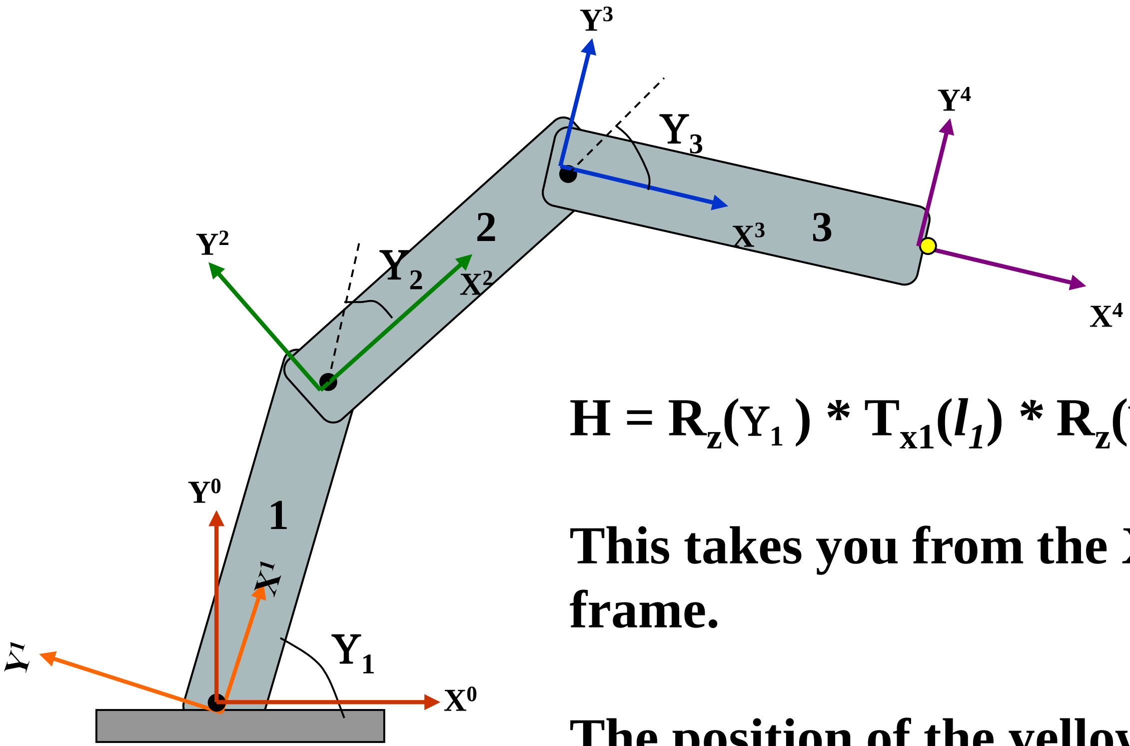
with

$$\omega = (V_R - V_L) / 2d$$

$$R = d\,(V_R + V_L) / (V_R - V_L)$$

$$V = \omega R = (V_R + V_L) / 2$$

Mid course: Modeling 2: Forward kinematics and homogenous transforms



$$H = R_z(Y_1) * T_{x1}(l_1) * R_z(Y_2) * T_{x2}(l_2) * R_z(Y_3) * T_{x3}(l_3)$$

This takes you from the X^0Y^0 frame to the X^4Y^4 frame.

The position of the yellow dot relative to the X^4Y^4 frame is (0,0).

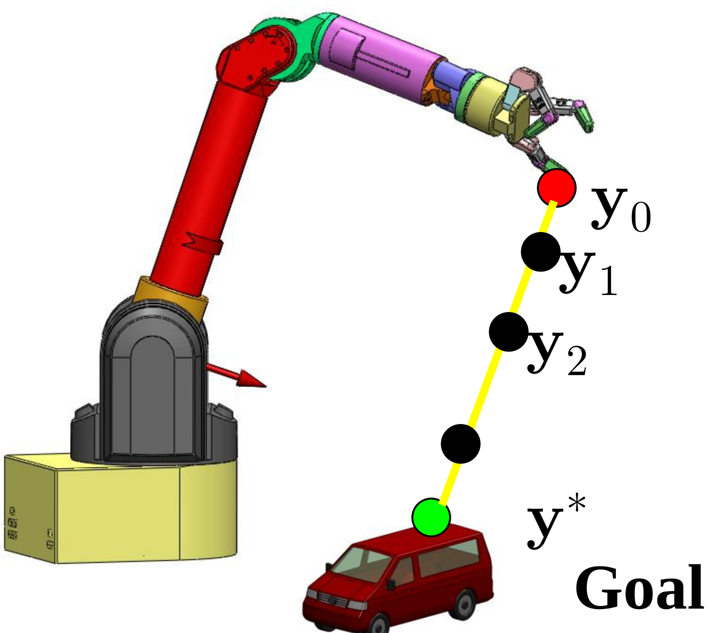
$$\begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} = H \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

Notice that multiplying by the (0,0,0,1) vector will equal the last column of the H matrix.

Numerical Inverse Kinematics

repeat

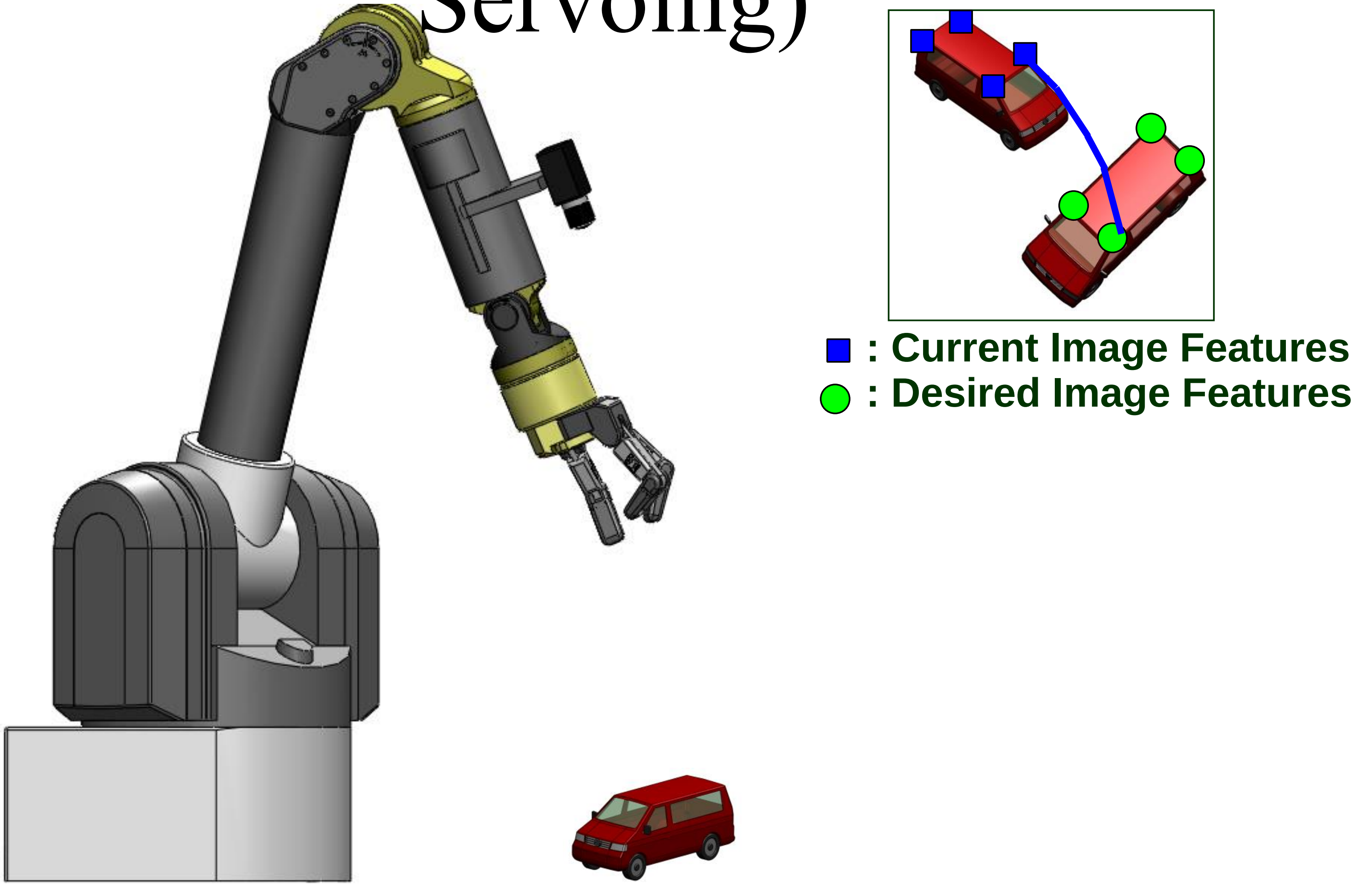
1. Solve for motion: $[\mathbf{y}^* - \mathbf{y}_k] = \mathbf{J_k}\Delta\mathbf{x}$
2. Move robot joints: $\mathbf{x}_{k+1} = \mathbf{x}_k + \Delta\mathbf{x}$
3. Read actual Cartesian move $\Delta\mathbf{y}$
4. Update Jacobian: $\hat{J}_{k+1} = \hat{J}_k + \frac{(\Delta\mathbf{y} - \hat{J}_k\Delta\mathbf{x})\Delta\mathbf{x}^T}{\Delta\mathbf{x}^T\Delta\mathbf{x}}$



Move the robot to each subgoal in sequence $\mathbf{y}_k$

Iterate until convergence at final goal

Vision-Based Control (Visual Servoing)



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 105:	M 5:00-7:50 pm
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

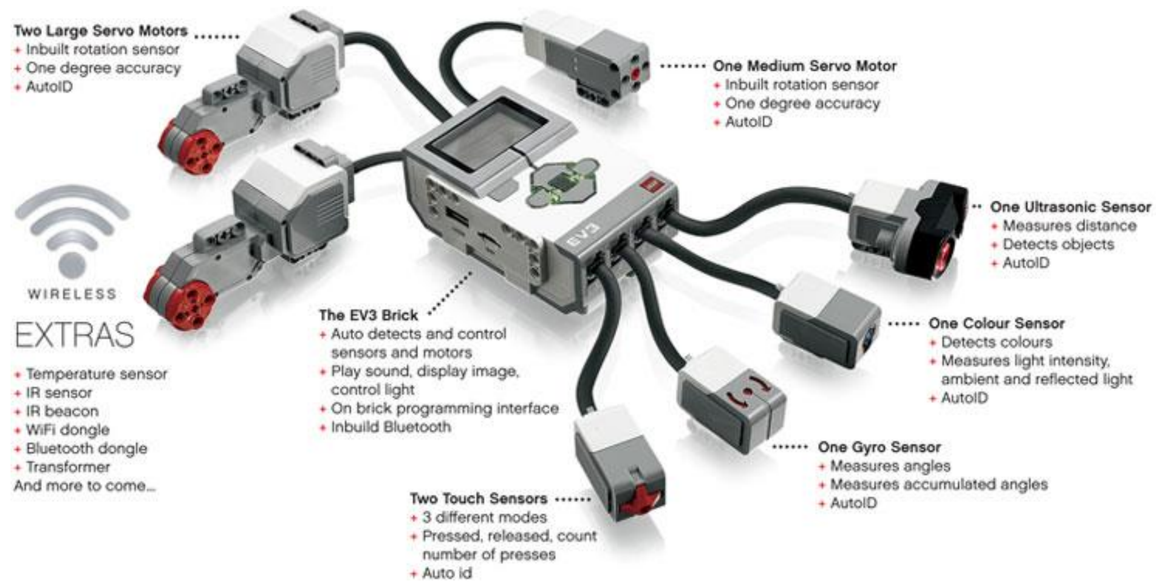
AIBO dog

Pioneer

UAV

Others… !

The EV3 Lego Robot Kit



Choose a task

spatial reasoning

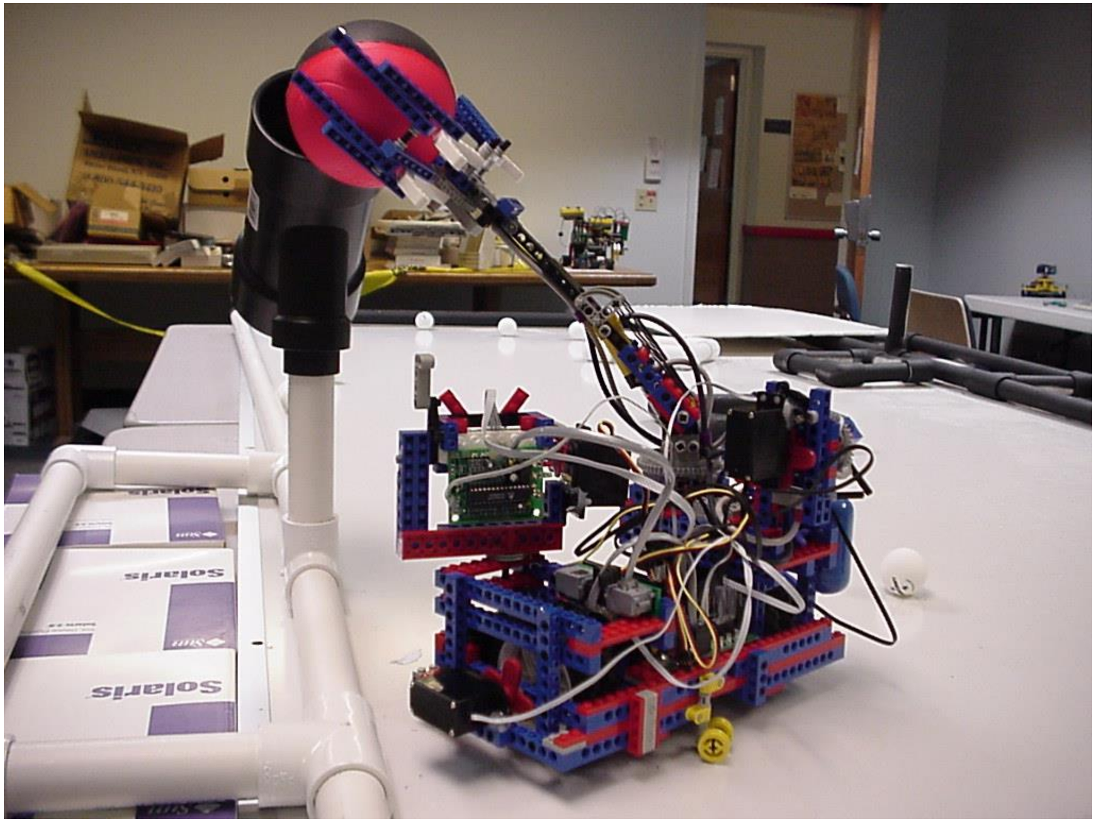
- tag / hide & seek
- Beyond Botball
-

itself publishable…

- fire extinguisher
- Vision guided motion
- Tele-operation

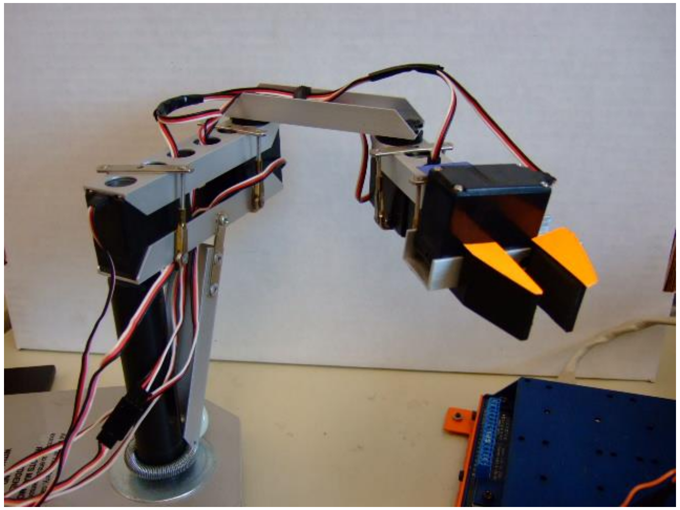
Robot and Project Options

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

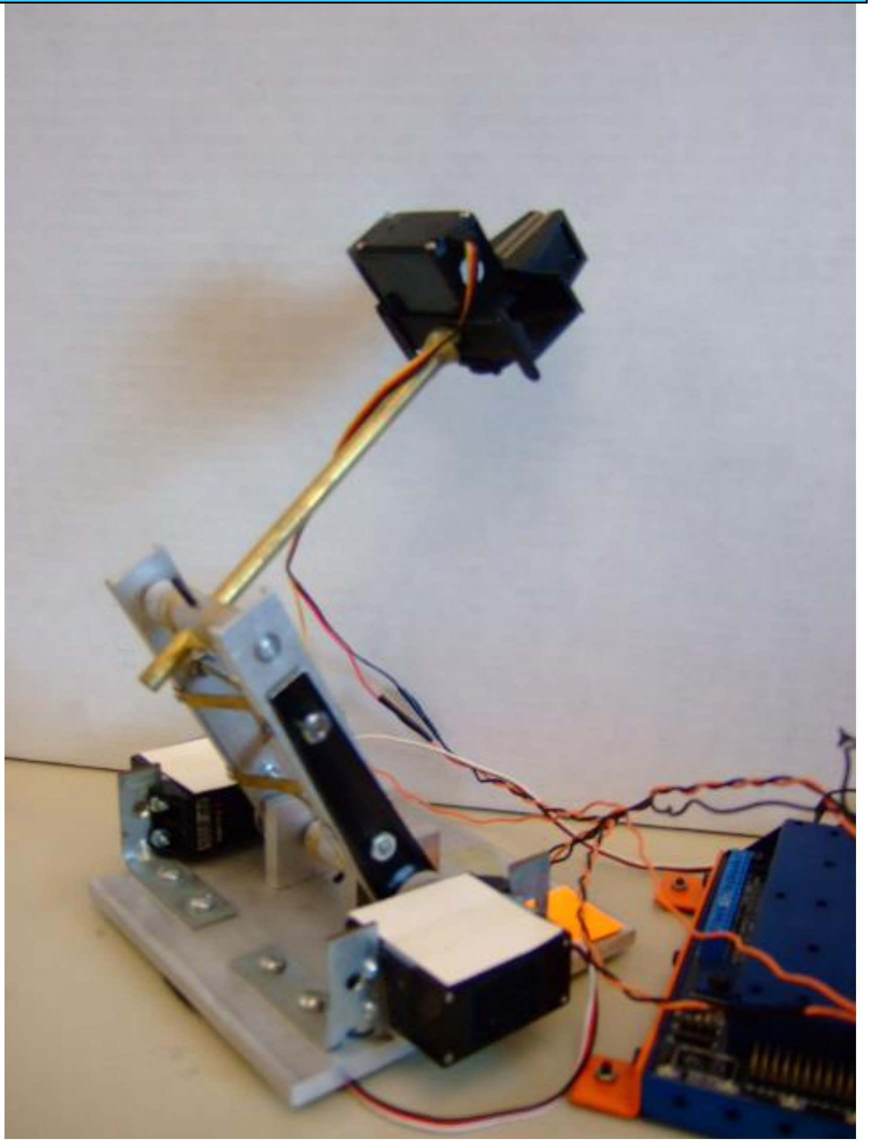


Lego Mapping?

Robot and Project Options



- Home built arm

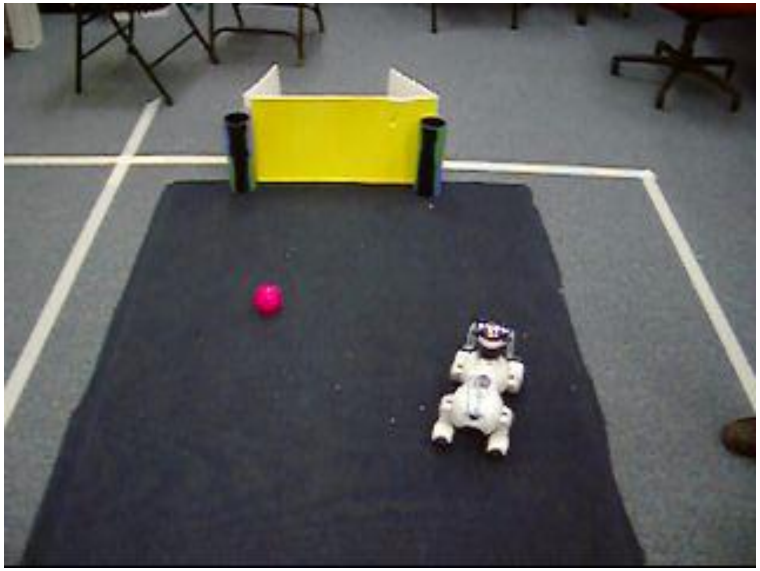


Robot and Project Options

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

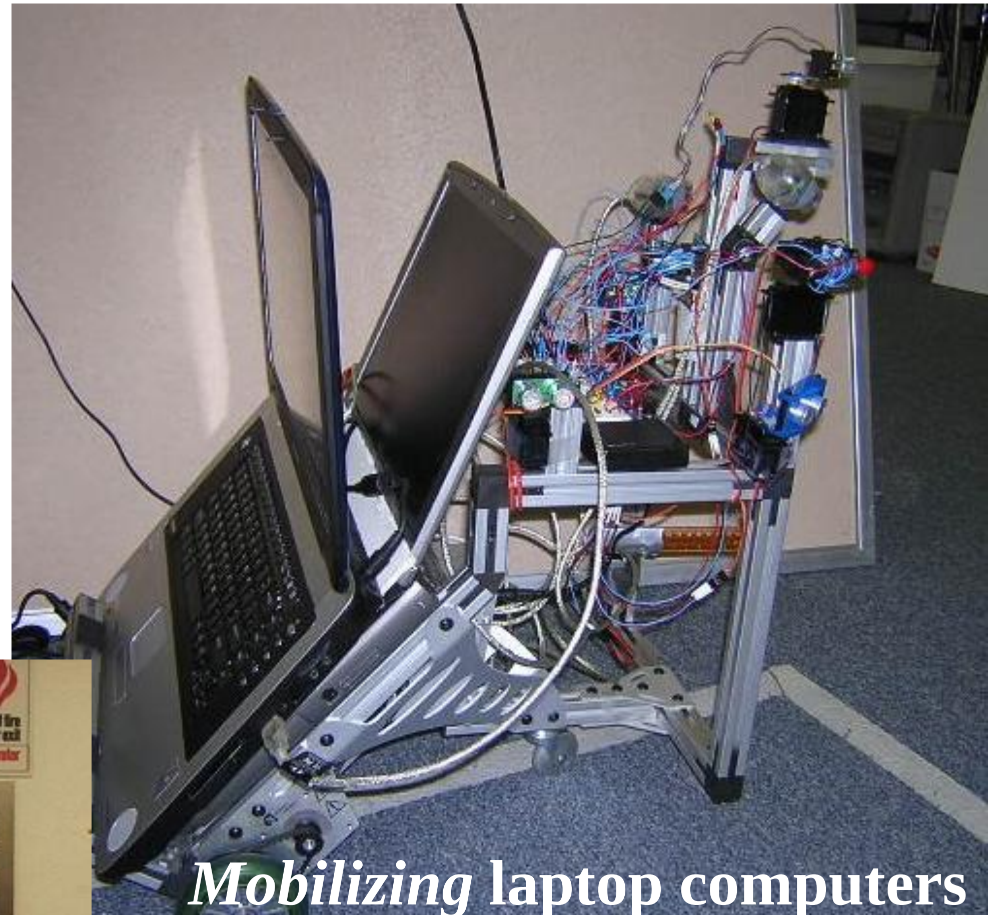
Heading Outdoors…

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

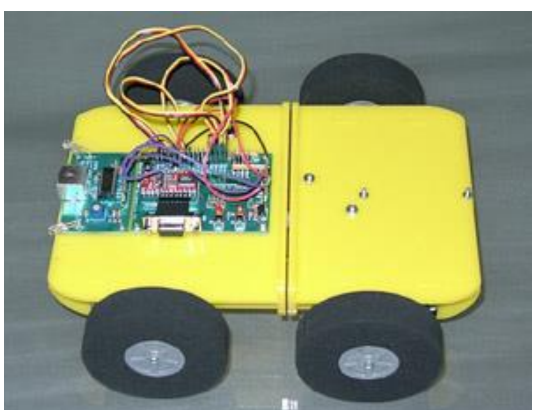
Other Options…

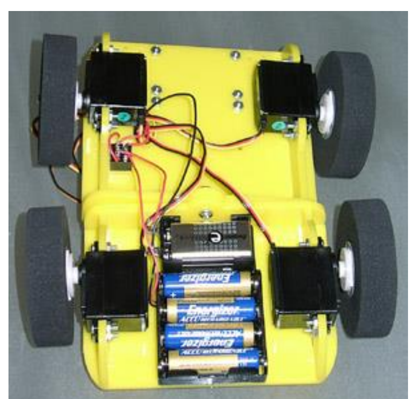
'04: NES Duck Hunt

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…)***