Introduction to Robotics & Mechatronics CMPUT 312

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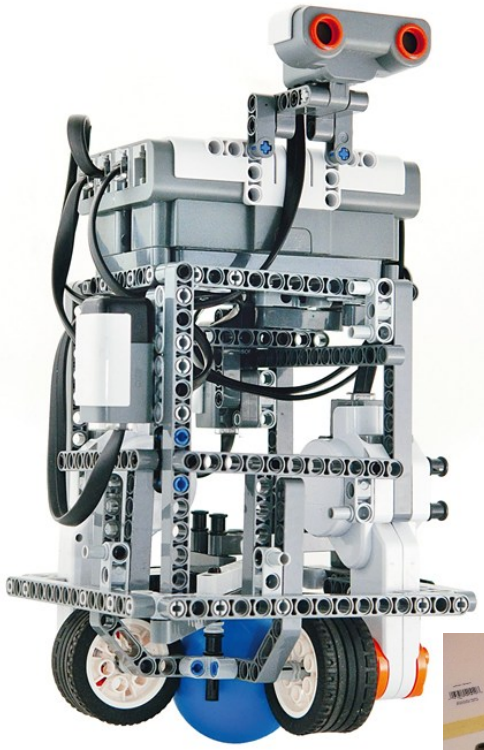
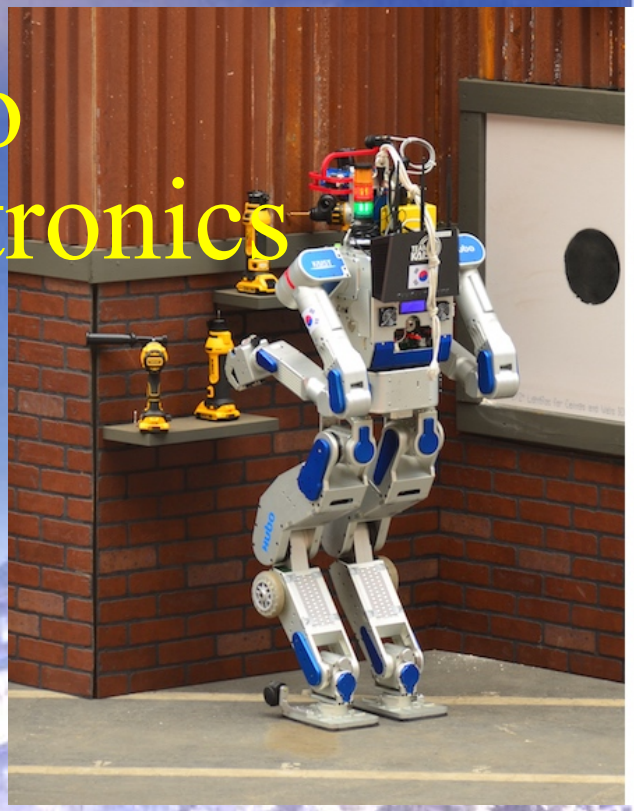
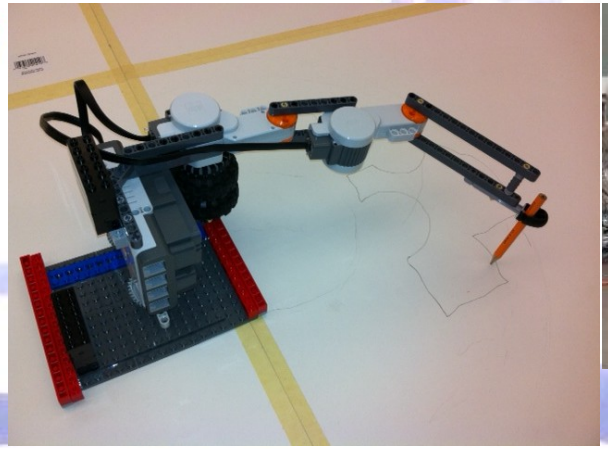






Course Questions

Why study robotics?

What, exactly, is robotics about?

What work is involved?

and other questions as well!

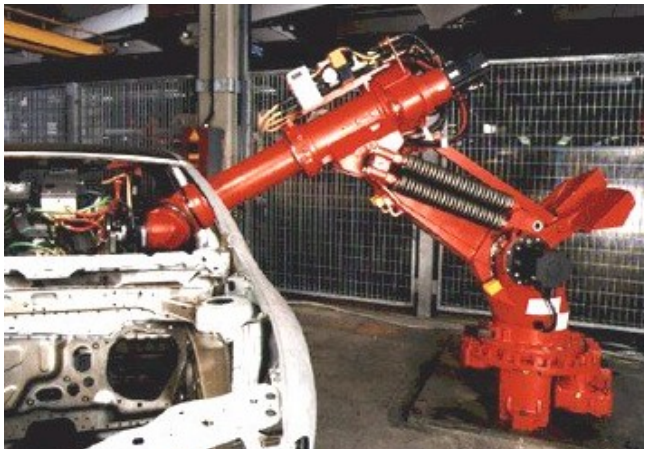
Why Robotics?

shift in robot numbers… !

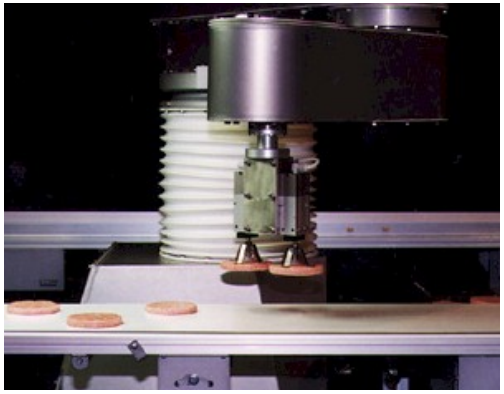
Practice

welding

assembly

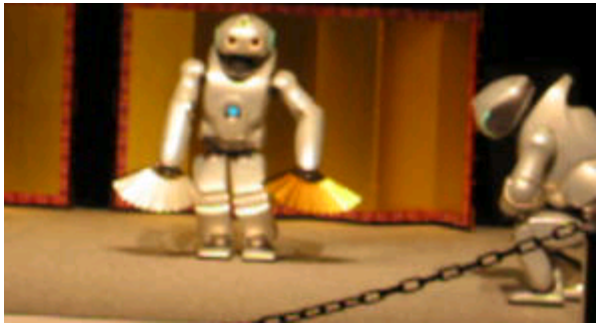


pumping gas



packaging

eating automobiles



dancing

Promise

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

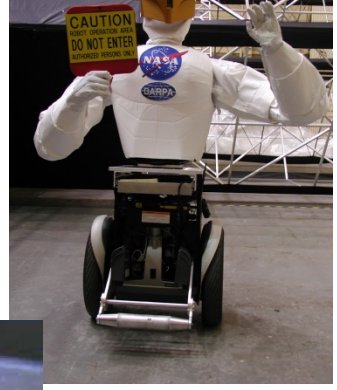
Current Robot Arm Applications Manufacturing

- Engineered environment
- Repeated motion

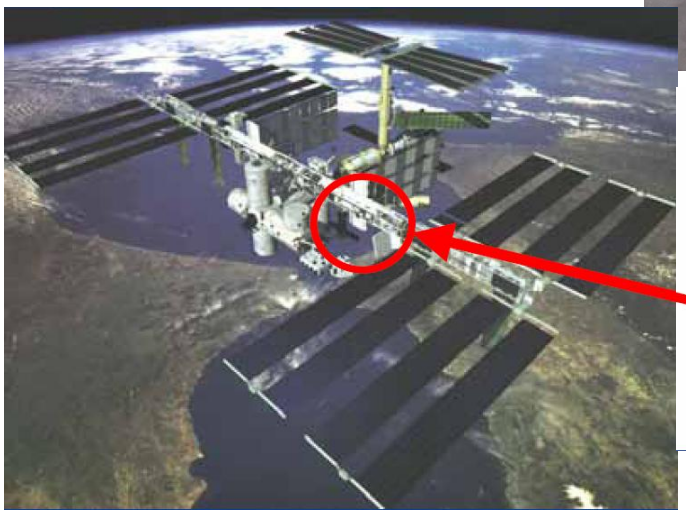
1 million arms in operation worldwide

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

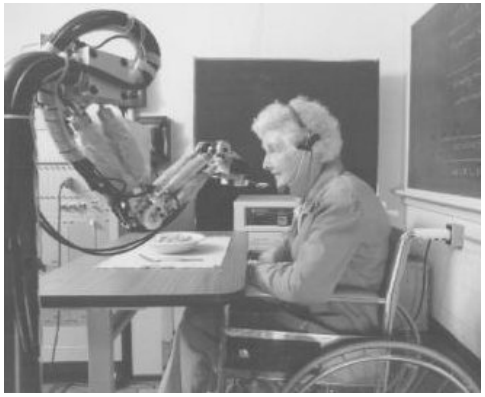
Emerging Robotics Applications



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

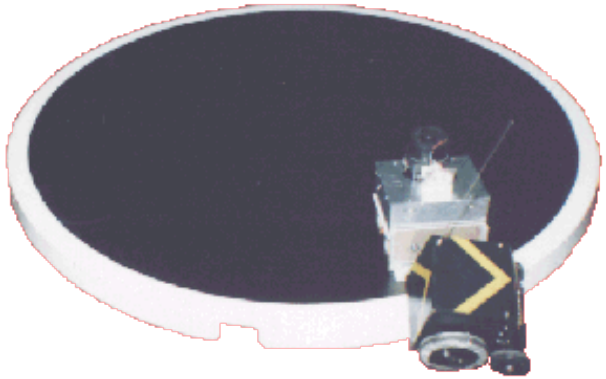
No or few robots currently operate reliably in these

kismet

Why Robotics?

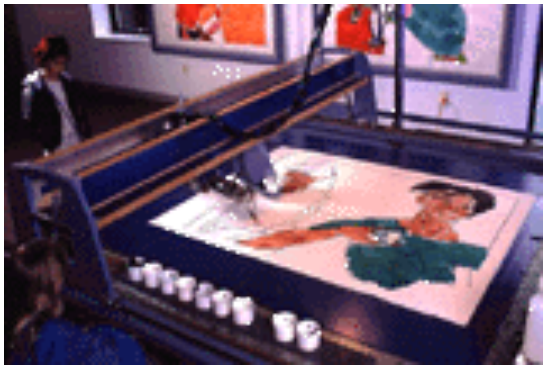
Sony Aibo dogs – had to LEARN to run

Vibrant field



other competitions

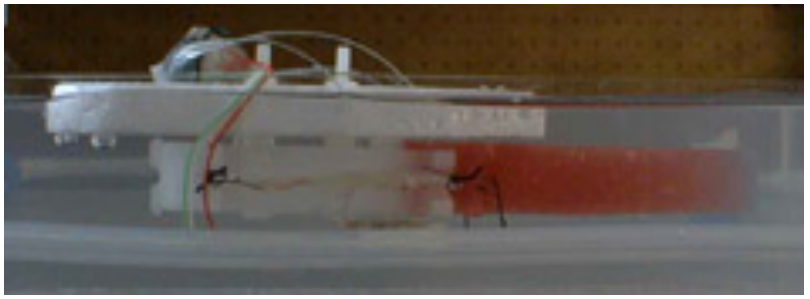
Harold Cohen's Aaron



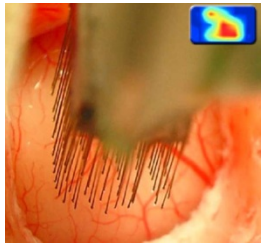
Why Robotics?

A window to the soul...

Rodney Brooks's Cog



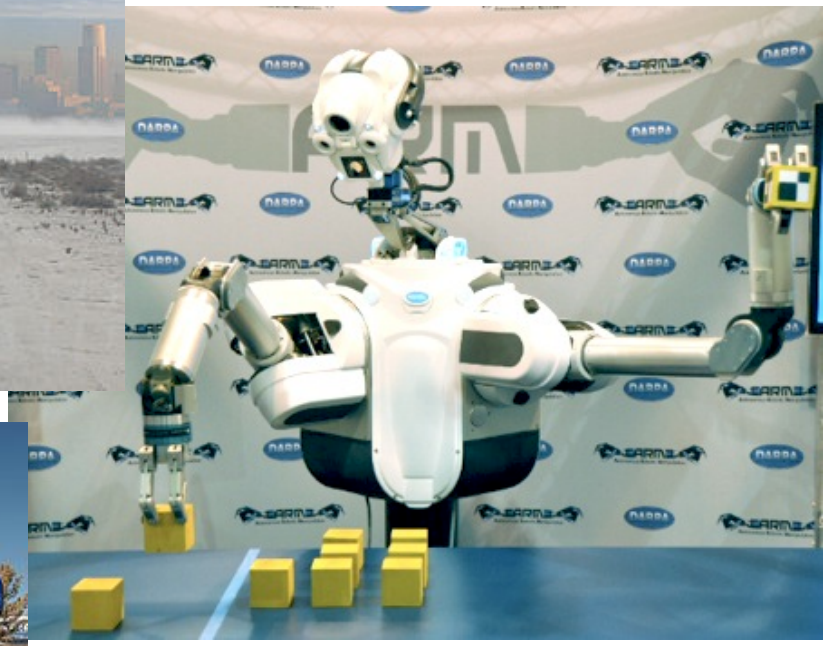
MIT's robotic fish with an unusual actuator!

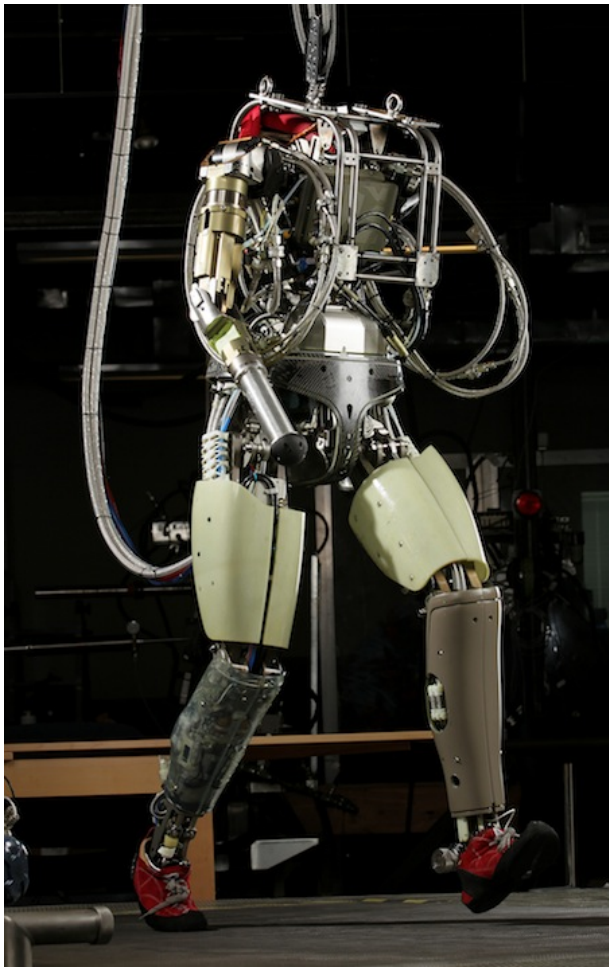


Monkey/machine interface at the Univ. of Pittsburgh

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

Robotics challenges



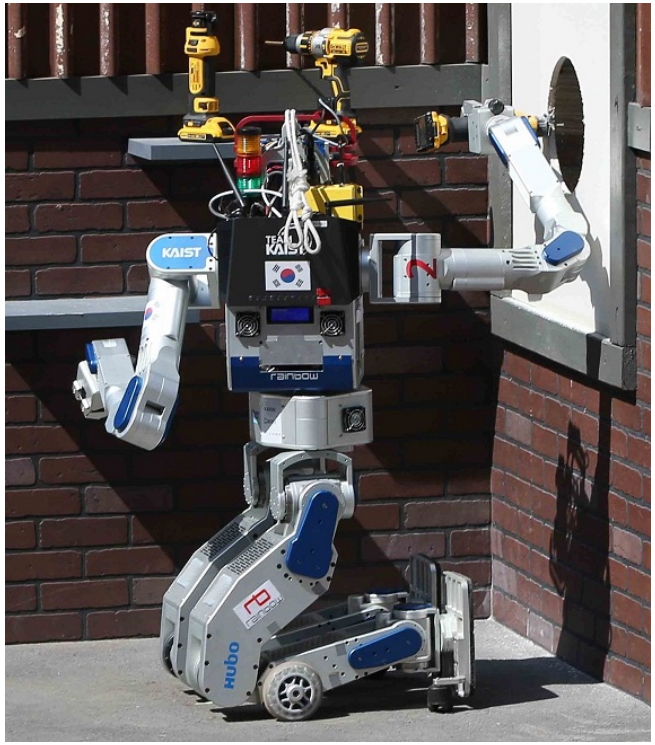


Navigation ‘05

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?

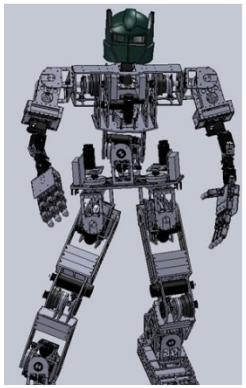
Autonomous : Robot :: Unicycling / Awake / Autonomous : Student

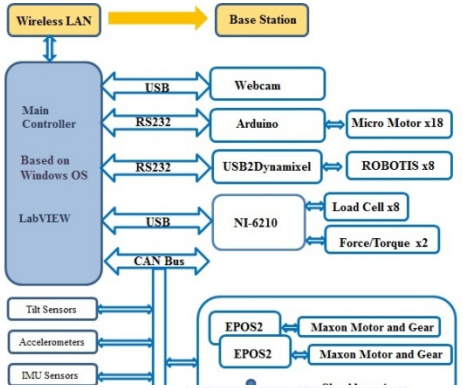
Choose one !

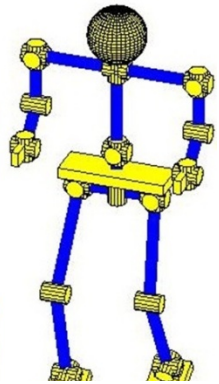
What is a robot?

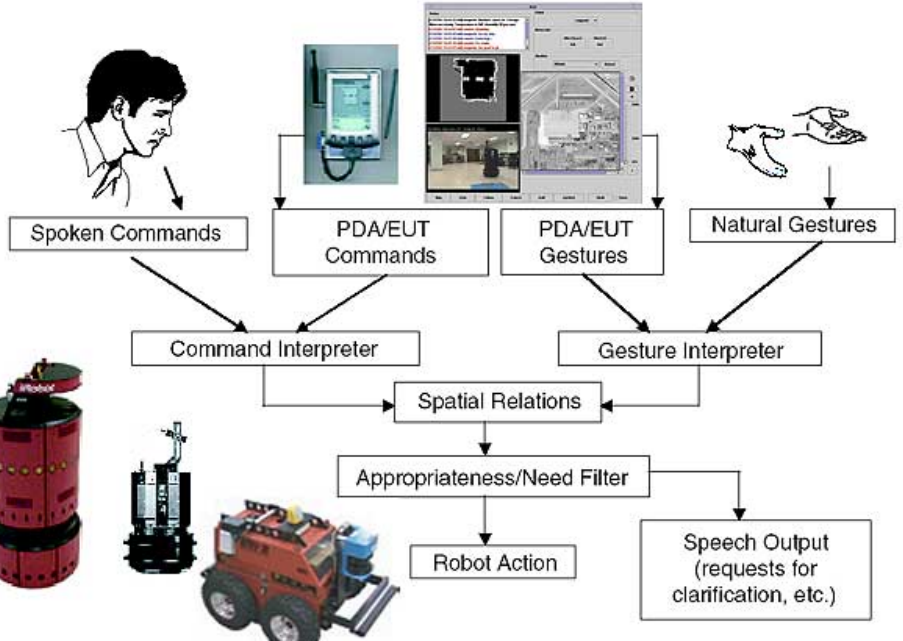
Physical instantiation (Hardware)

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

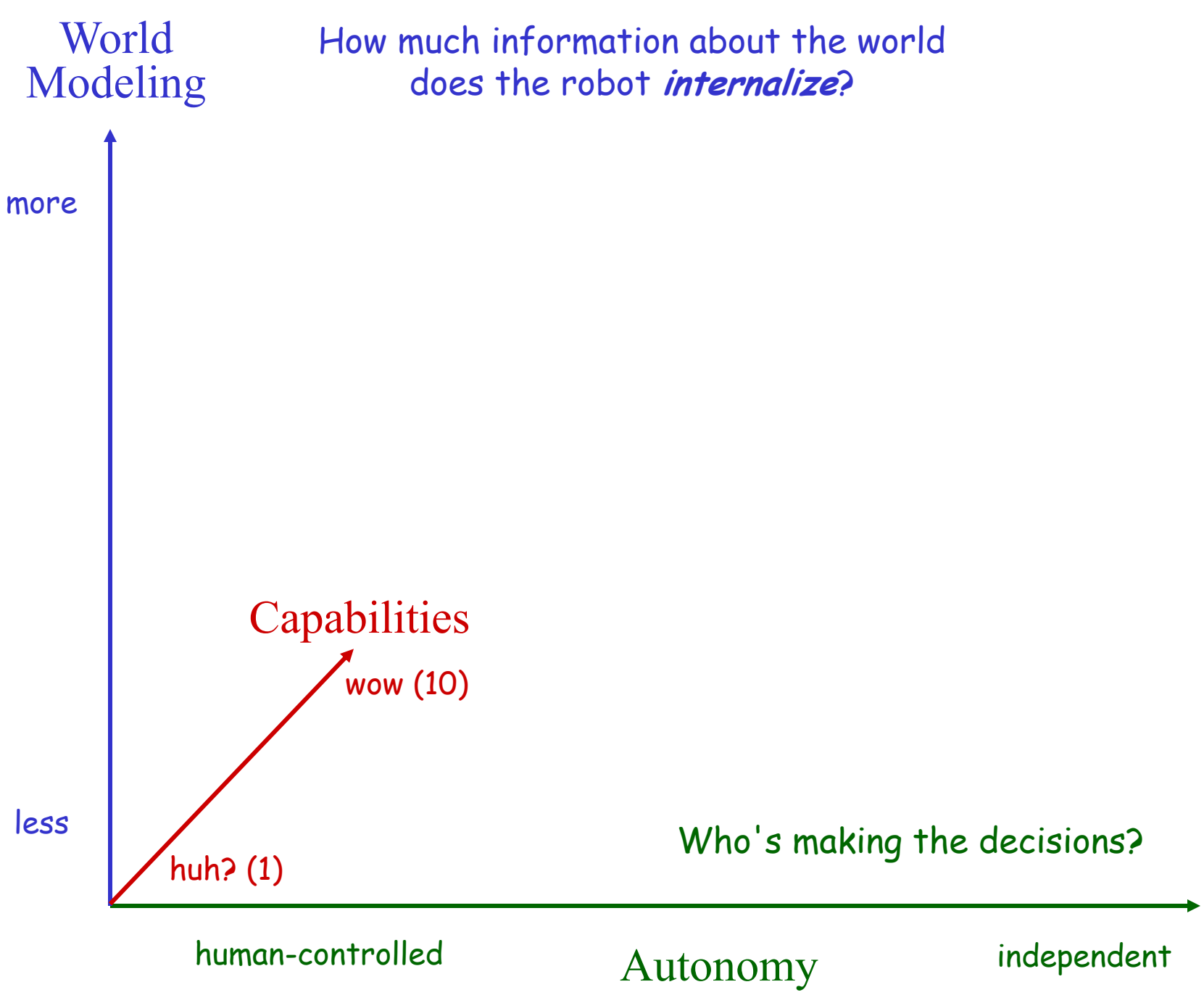
none → **full**

Robot Wars, Battlebots

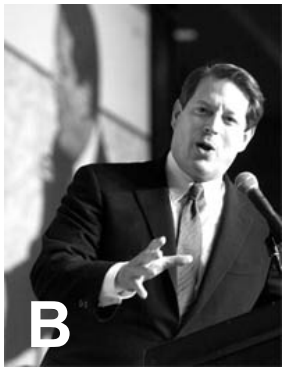
FIRST Robotics

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

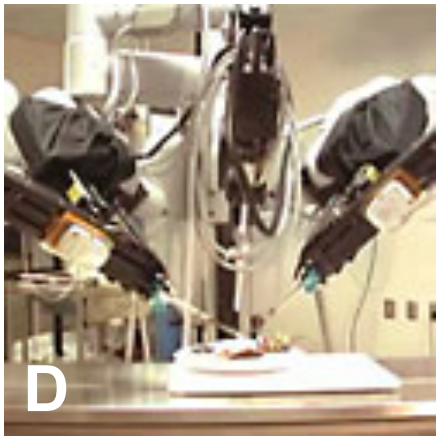
Bar Monkey



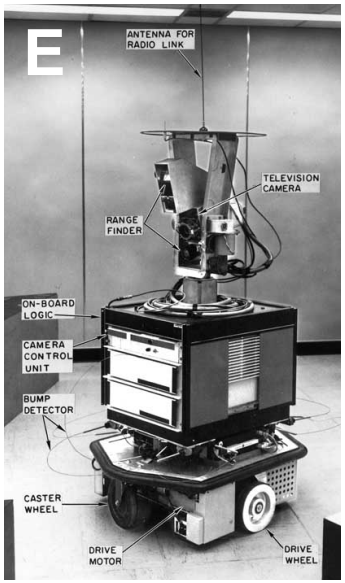
Al Gore
ex-VP, Nobelian

Genghis Robotic Insect

da Vinci
Robotic Surgeon



11 "robotic" systems



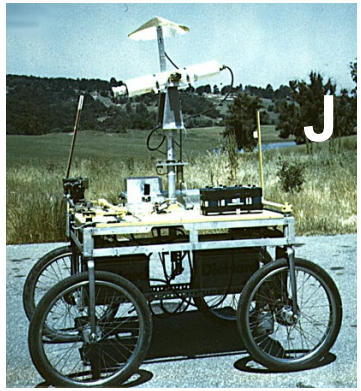
Shakey
object-"manipulator" (pusher) from SRI (1969)

Roomba
Robotic vacuum cleaner

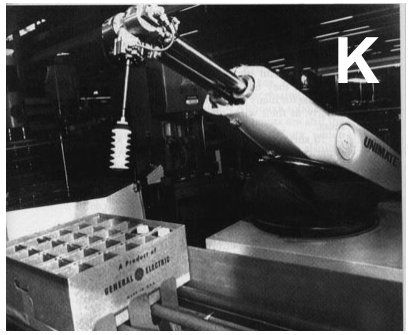
Sims
now with professor!

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

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



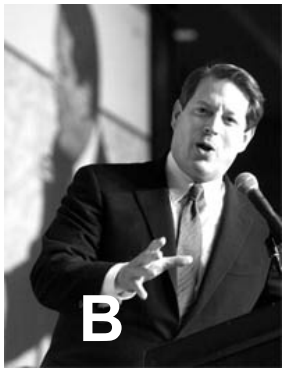
Stanford Cart
vision-based obstacle-avoider (1976)



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

Perhaps include a robot of your own choosing…

World Modeling



Al Gore (11)

more

less

Capabilities

wow (10)

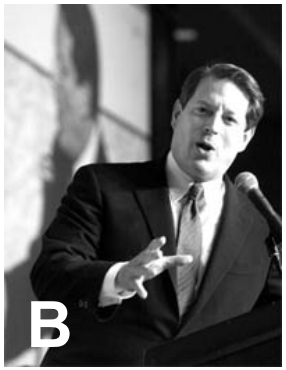
huh? (1)

human-controlled

Autonomy

independent

Bar Monkey
robotic barkeep



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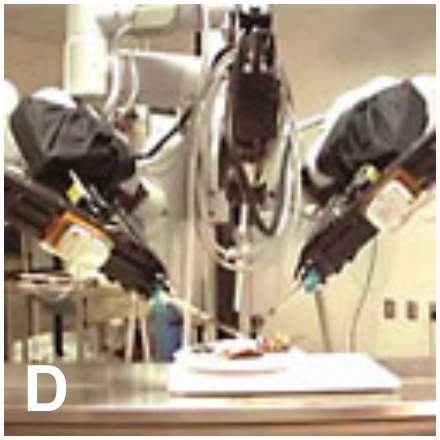

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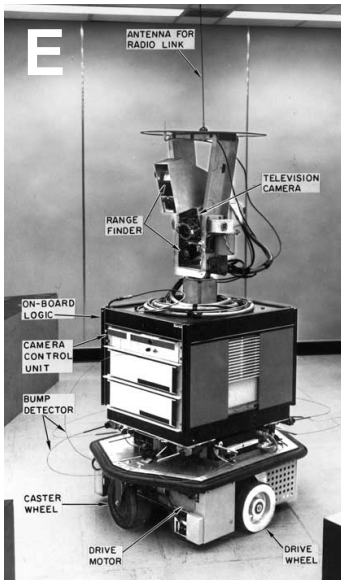

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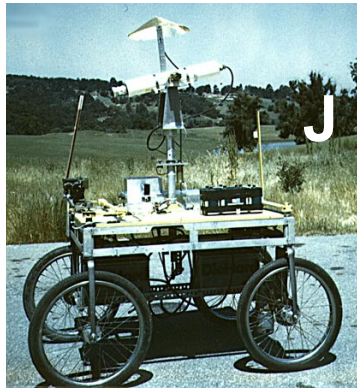

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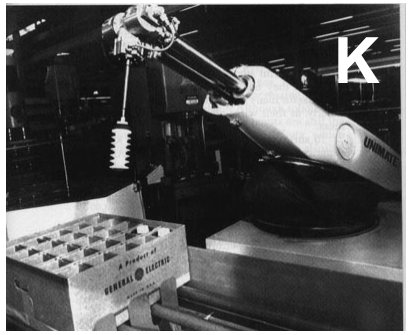

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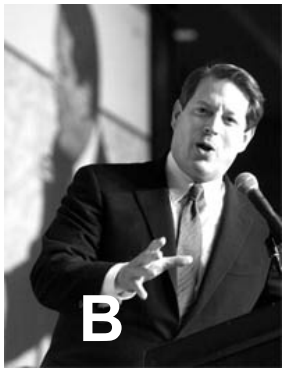
Robot Plot

World Modeling

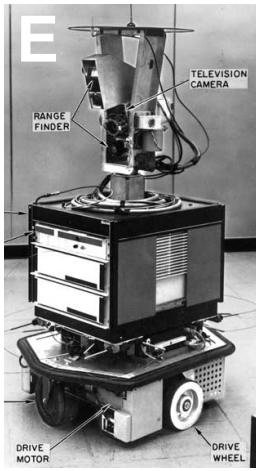
more

less

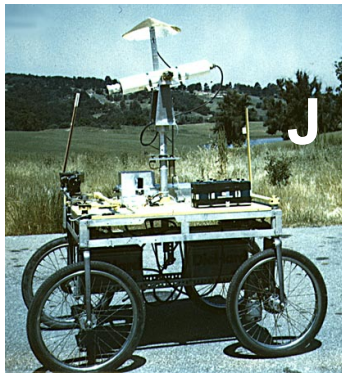
Capability (0-10)



Al Gore (11)



Shakey (3)



Stanford Cart (3)

Capabilities

wow (10)

huh? (1)

Genghis (3)

human-controlled

Autonomy

independent

Robot Plot

World Modeling

Capability (0-10)

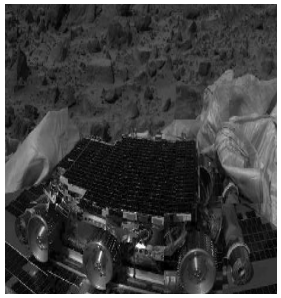
more

less

Al Gore (11)

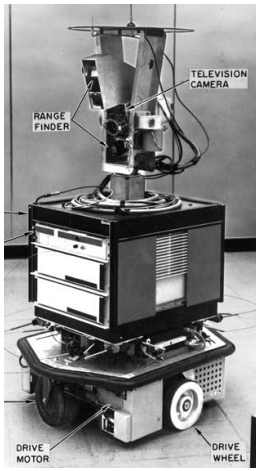
Sims (5)

Bar Monkey (9)

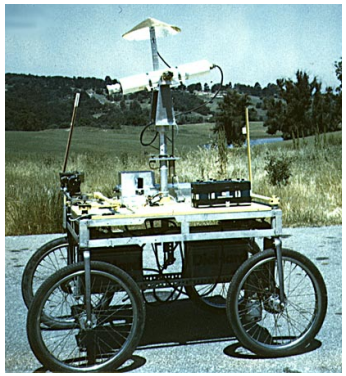


MERs (8)

Stanley/Boss (9)

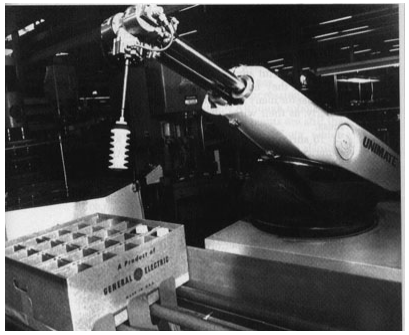


Shakey (3)



Stanford Cart (3)

da Vinci (2)



Unimate (4)

Roomba (7)

Genghis (3)

human-controlled

Autonomy

independent

Robot Plot

World Modeling

Capability (0-10)

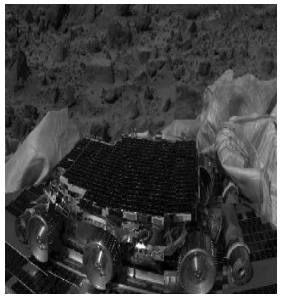
more

less

Al Gore (11)

Sims (5)

Bar Monkey (9)



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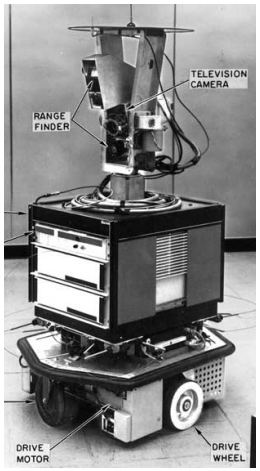
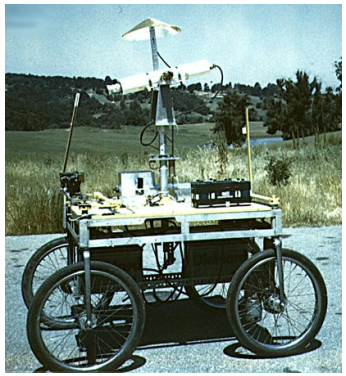
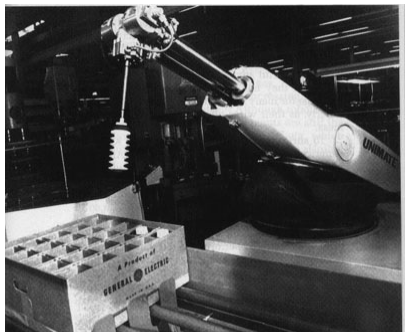


Shakey (3)



Stanford Cart (3)

da Vinci (2)



Unimate (4)

Roomba (7)

Genghis (3)

human-controlled

Autonomy

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

399 Course topics

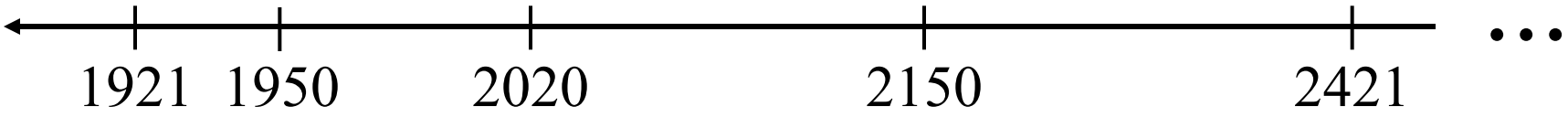
- **Introduction**
- **Robot hardware for mobile robots, arms and UAV's**
- **Reactive robotics**
- **Modeling mobile robots, kinematics, navigation**
- **Robot sensors**
- **Motor Control**
- **Robot arm types and kinematics**
- **Analytic and numerical arm inverse kinematics**
- **Machine vision and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

What am I? robots ~ bodies…

where am I?
how do I get there?

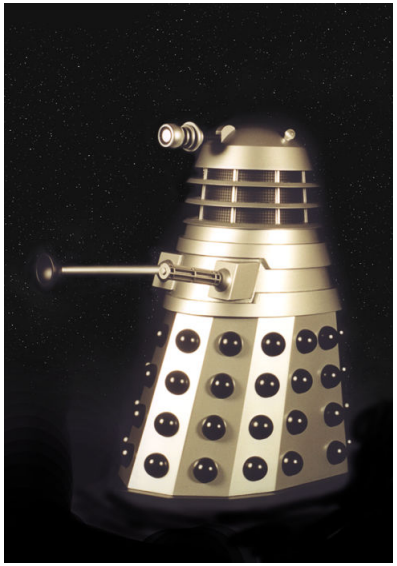
is seeing believing?

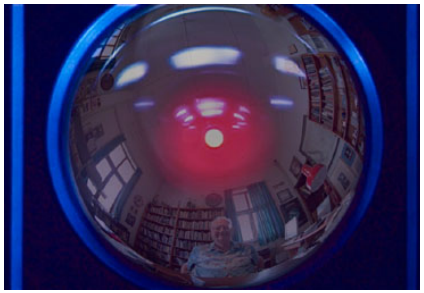
Robot timeline?

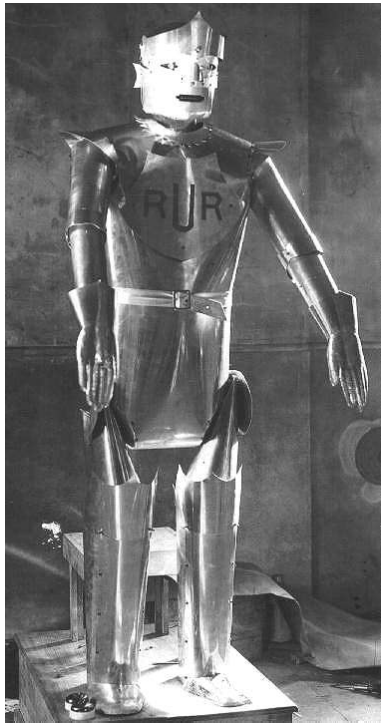


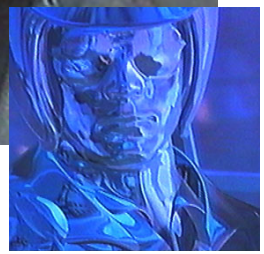
Fictional Robot timeline

Putting these robots in chronological order?







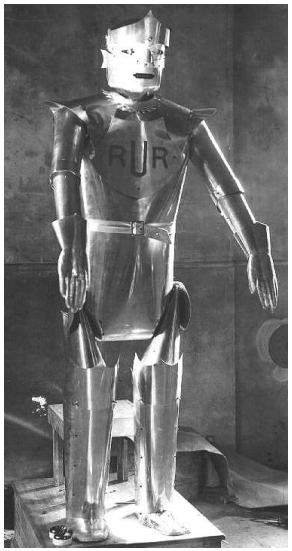


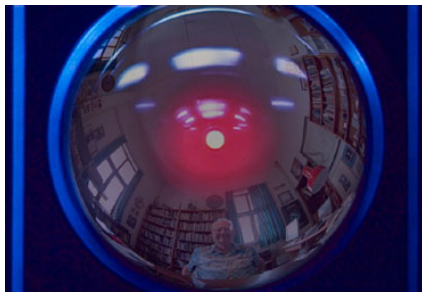
1921 2020 2150 2421 • • •

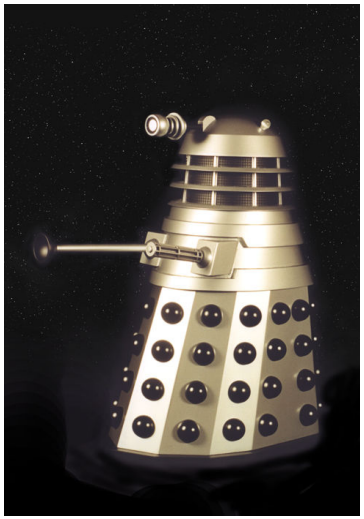
Fictional robot timeline

Karl Capek

Rossum's Universal Robots







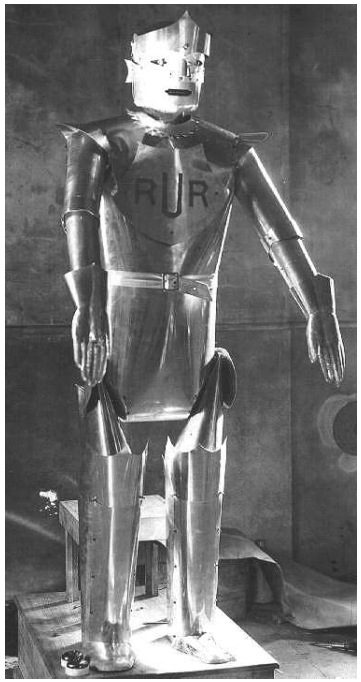
I, Robot **Asimov**

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.

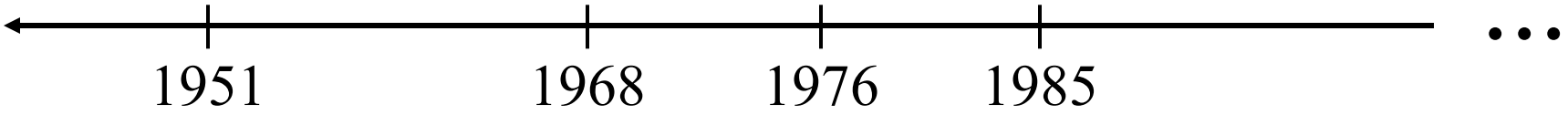
Third Law:

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

I, Robot

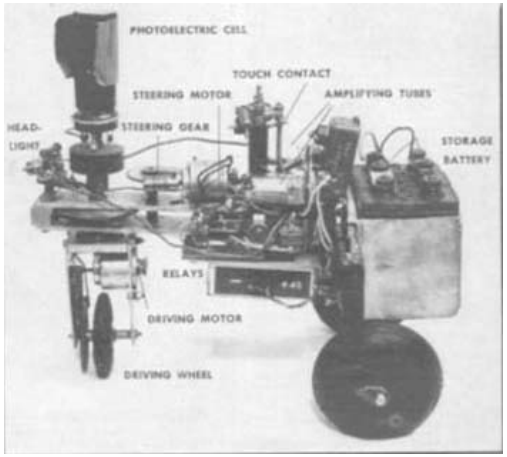
1921 1950 • • •

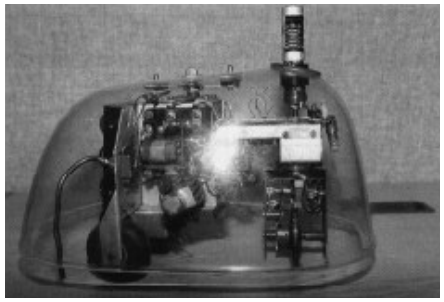
Real robot timeline

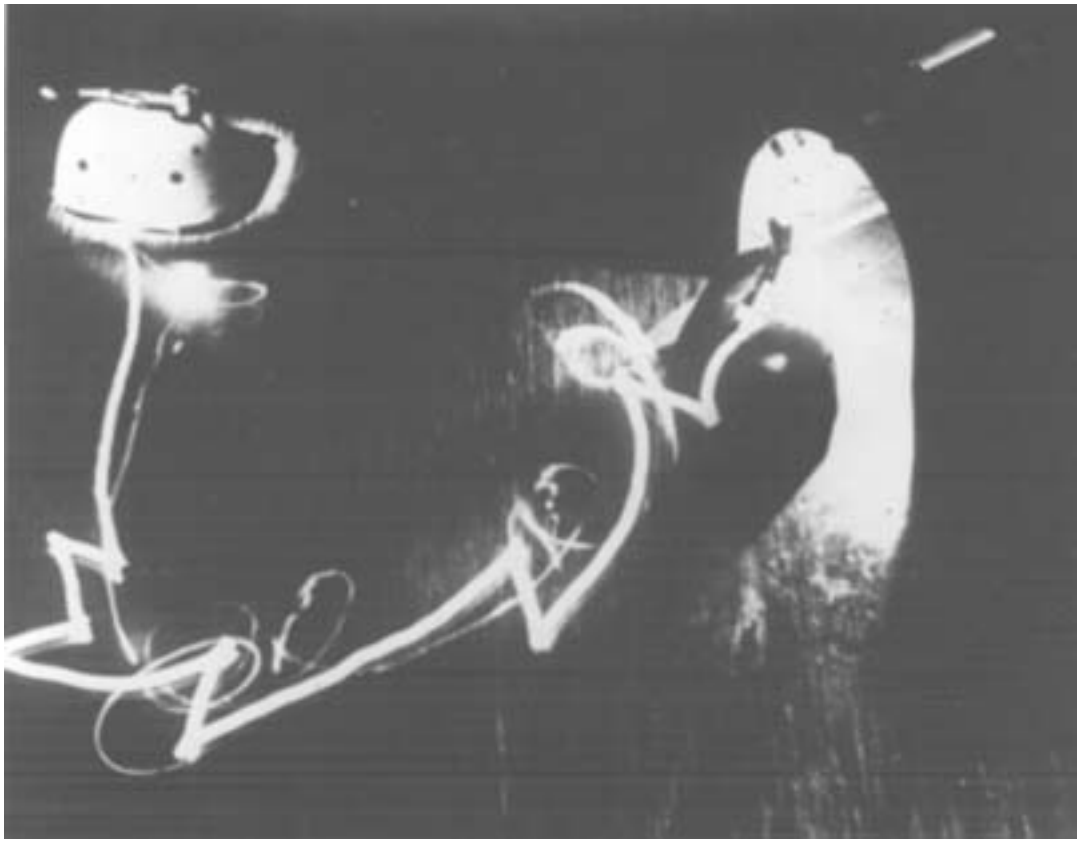


Real robot timeline

Tortoise “Elsie”



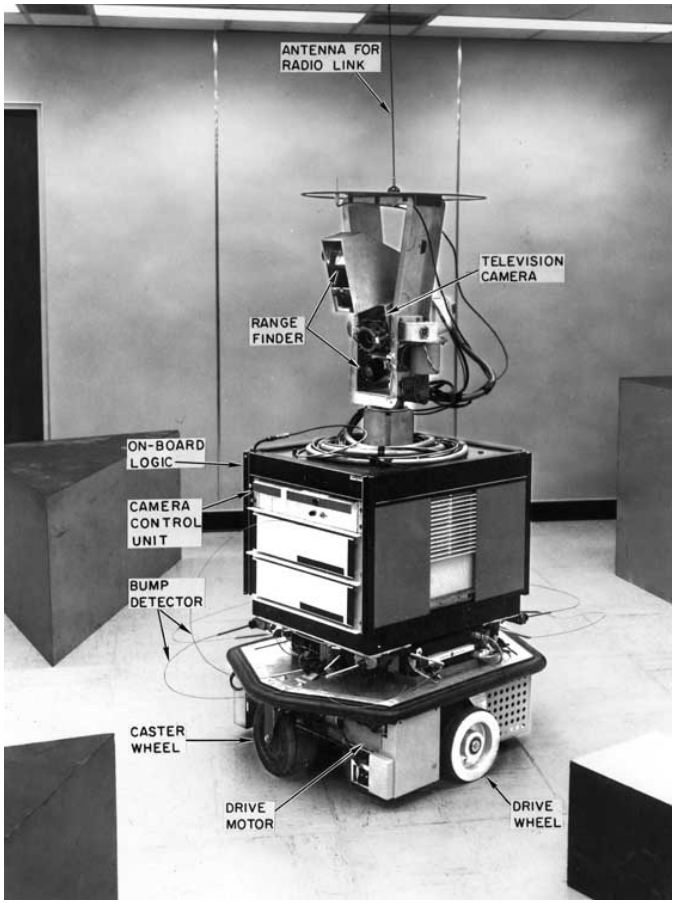




by Neurophysiologist Grey Walter

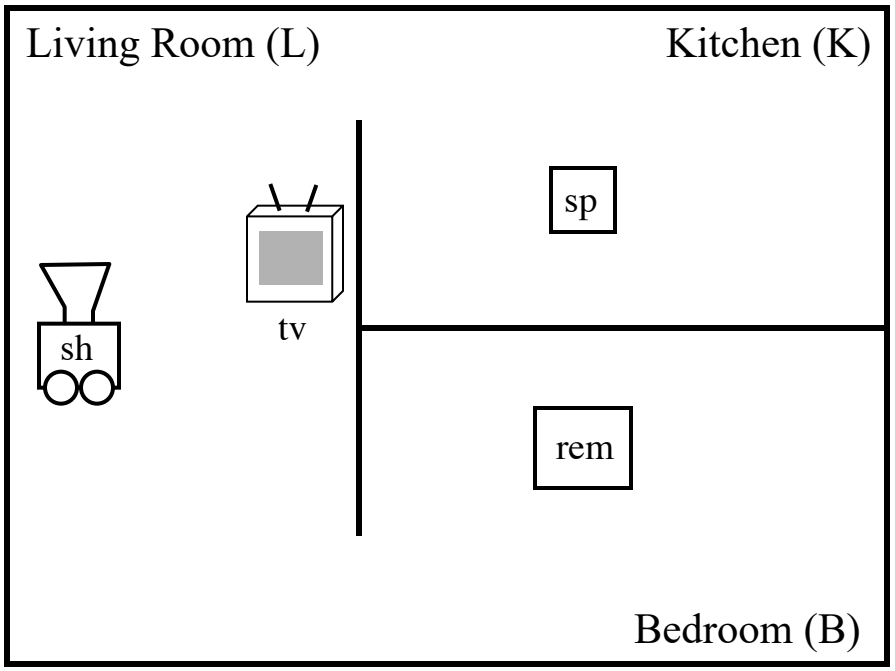
1951 • • •

Shakey



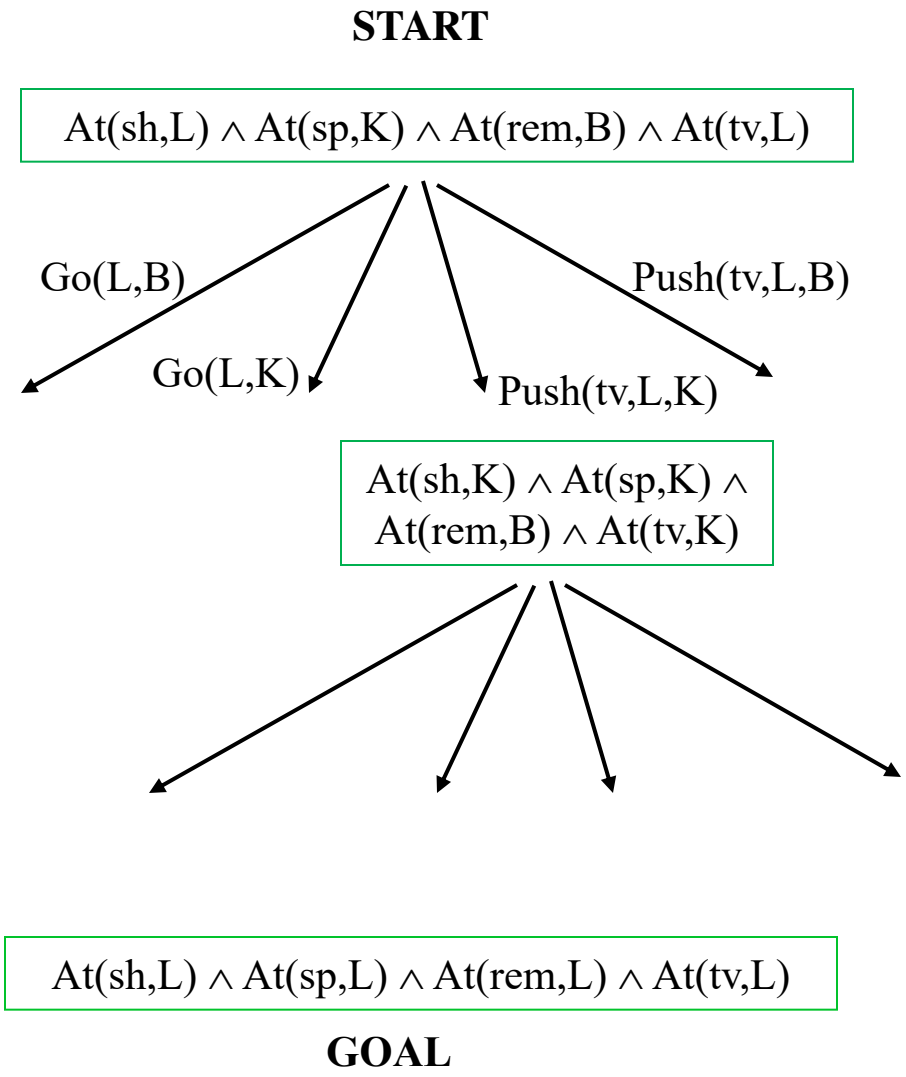
Nils Nilsson @ Stanford Research Inst.

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!

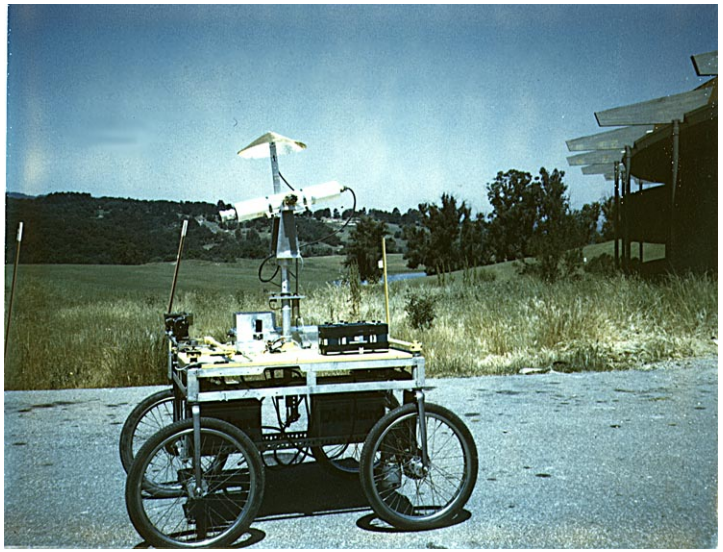
Stanford Cart: *SPA*

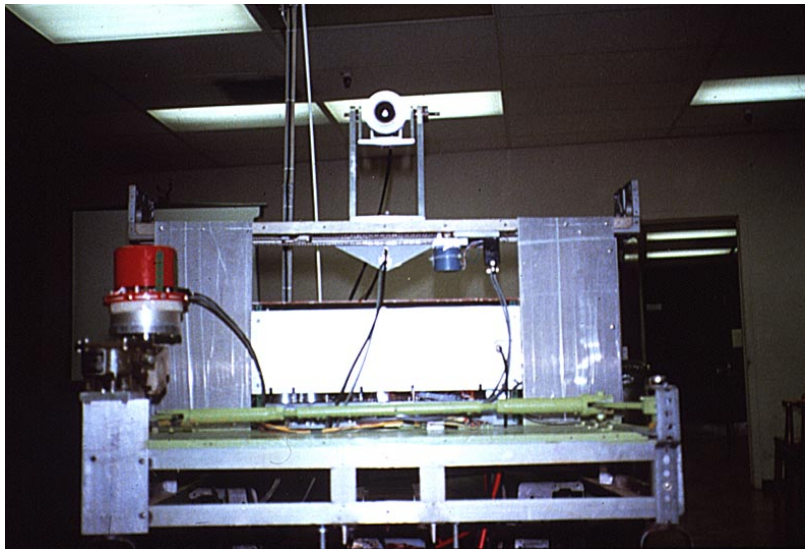
Hans Moravec @ SAIL

"functional" task decomposition

"horizontal" subtasks

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





1976

Cartland (outdoors)

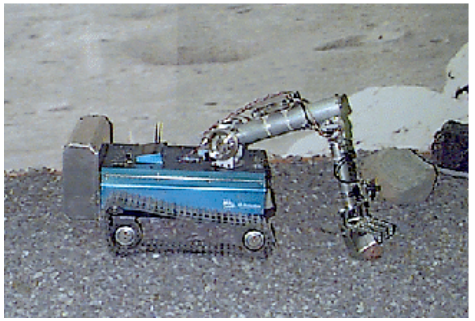
Cartland (indoors)

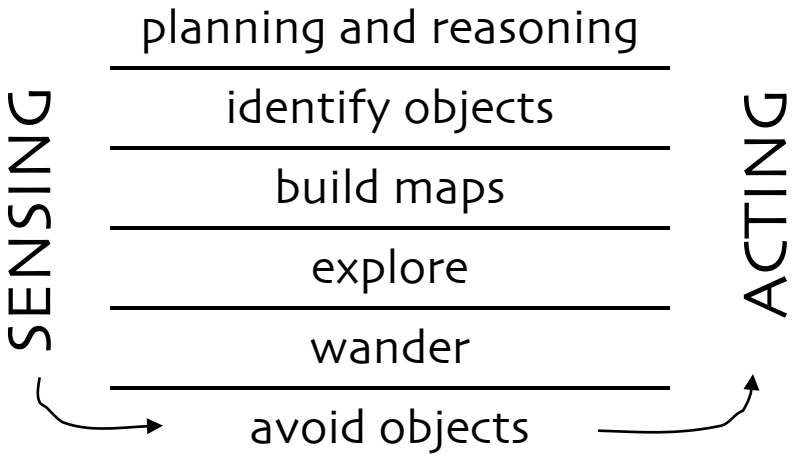
“Robot Insects”

Rodney Brooks @ MIT

“behavioral” task decomposition

“vertical” subtasks





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

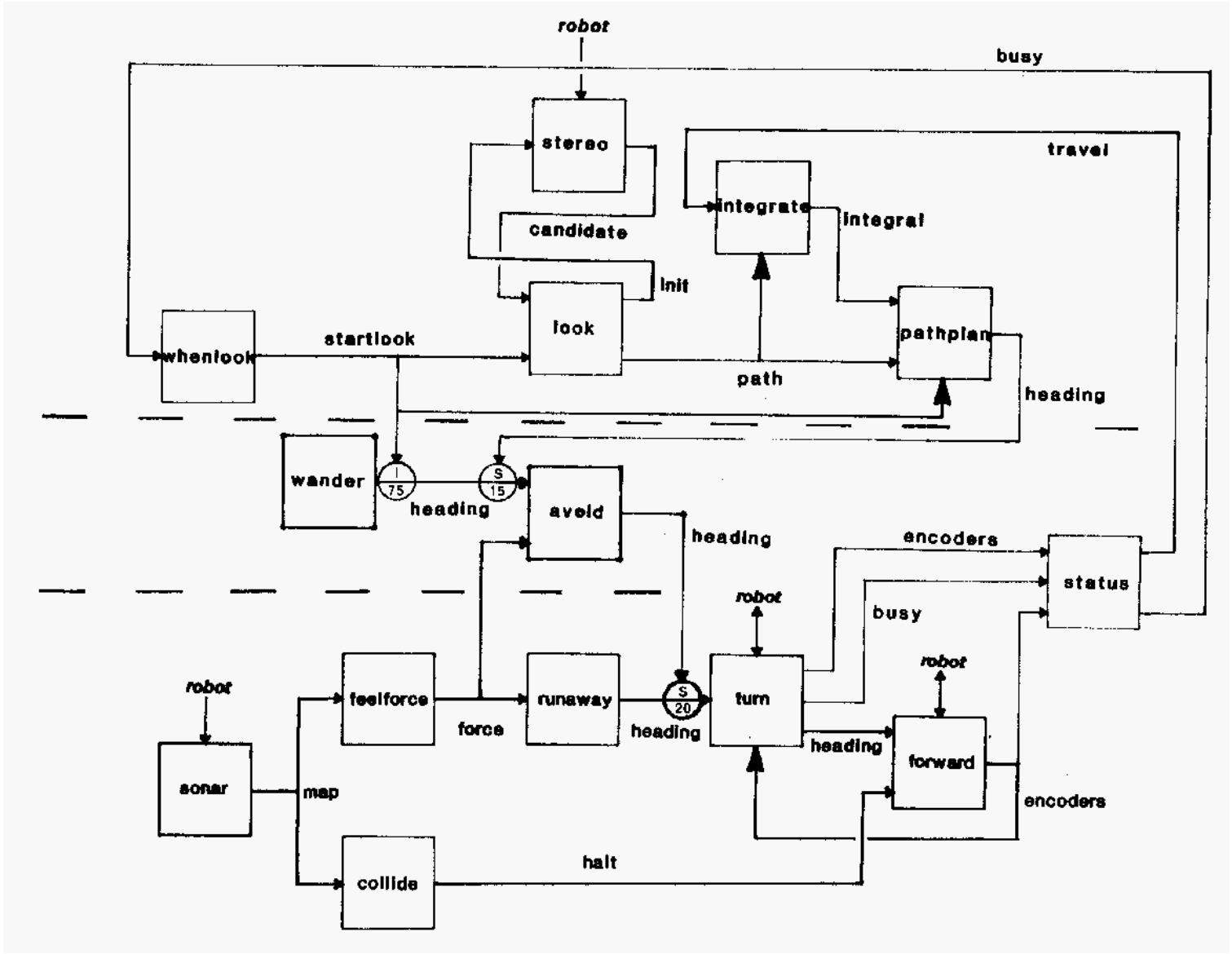
6) *Pitch stabilization*: uses an inclinometer to stabilize fore/aft pitch

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

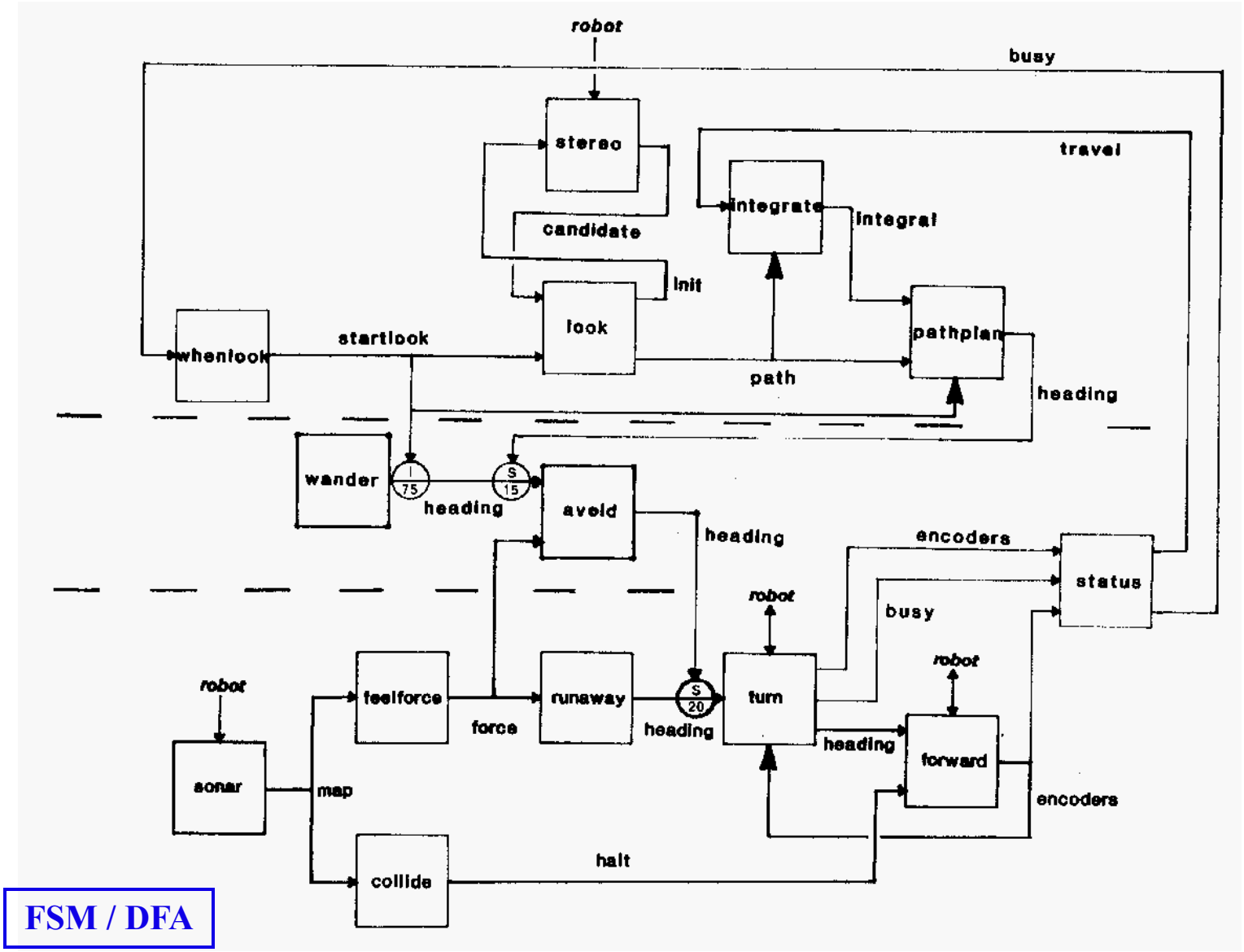
8) *Steering*: uses the difference in two IR sensors to follow

57 modules wired together !

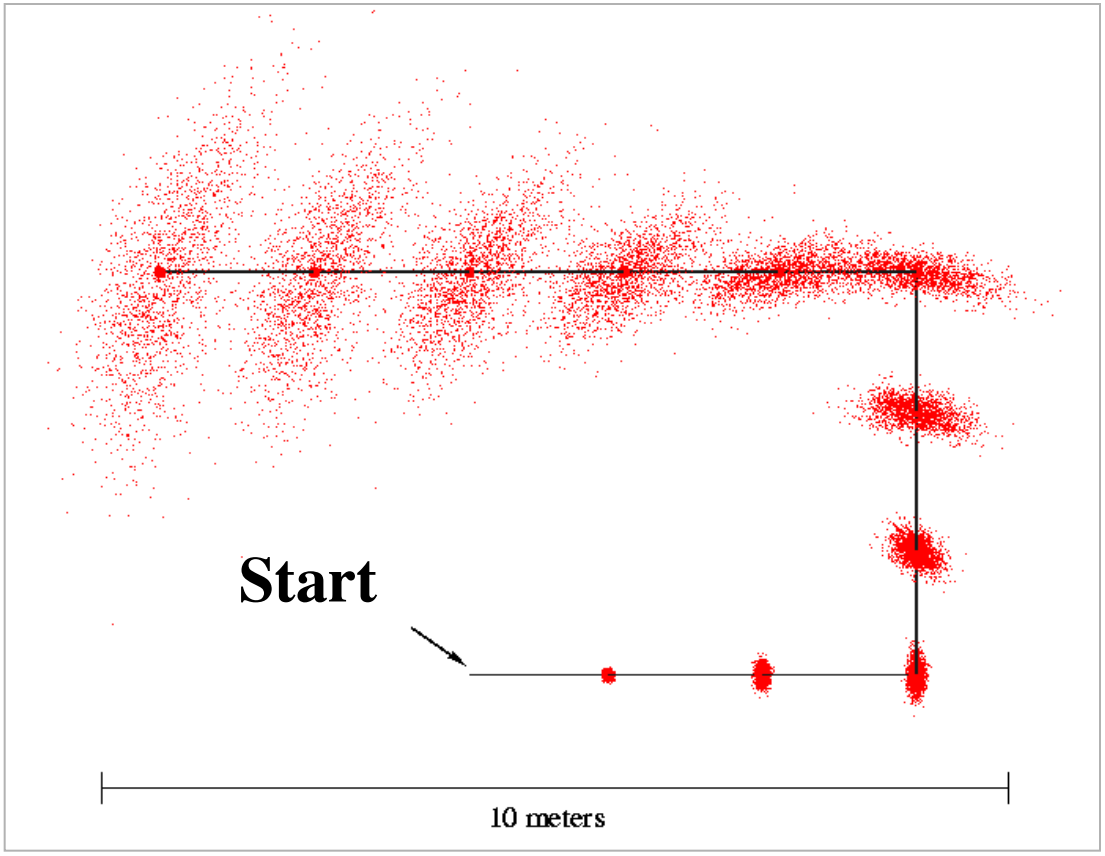
Subsumption Architecture



Finite-state Architecture

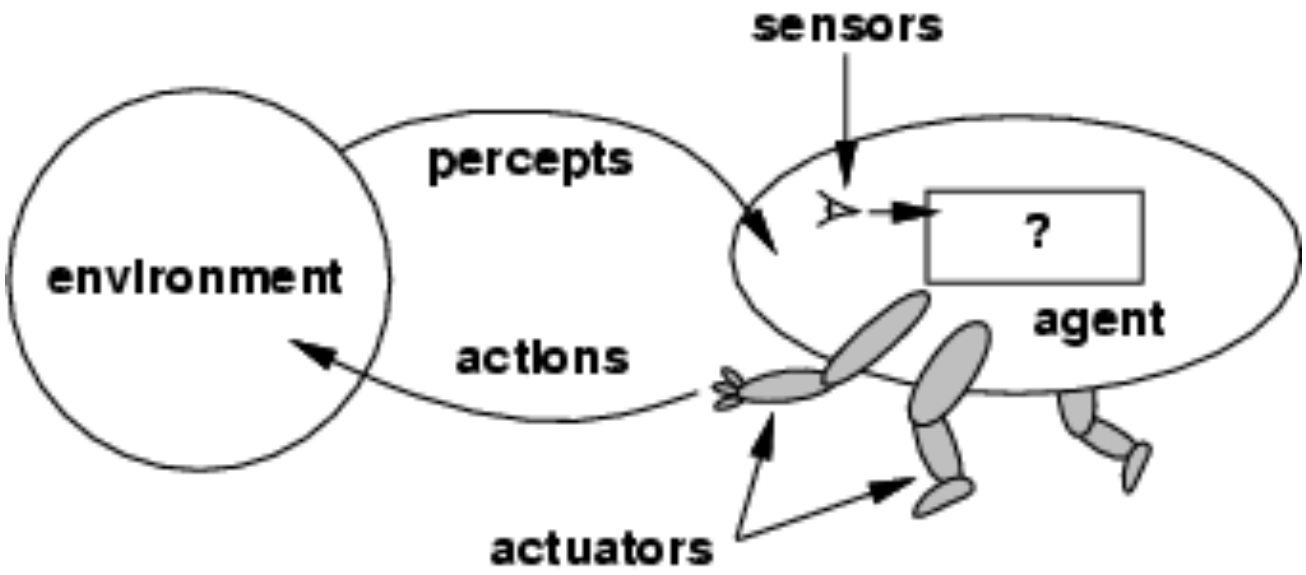


Probabilistic robotics



Sensory guided robotics

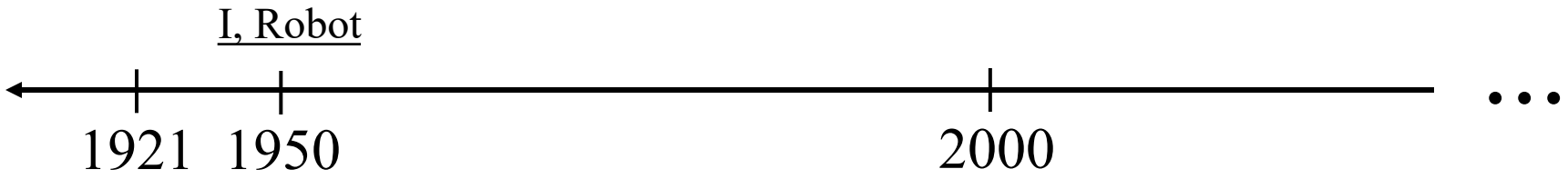
- Camera or Kinect vision



Robot timeline

Robots - a 50 year journey [Video @ ICRA 2000]
https://vimeo.com/137042620

The journey continues:
https://vimeo.com/173394878

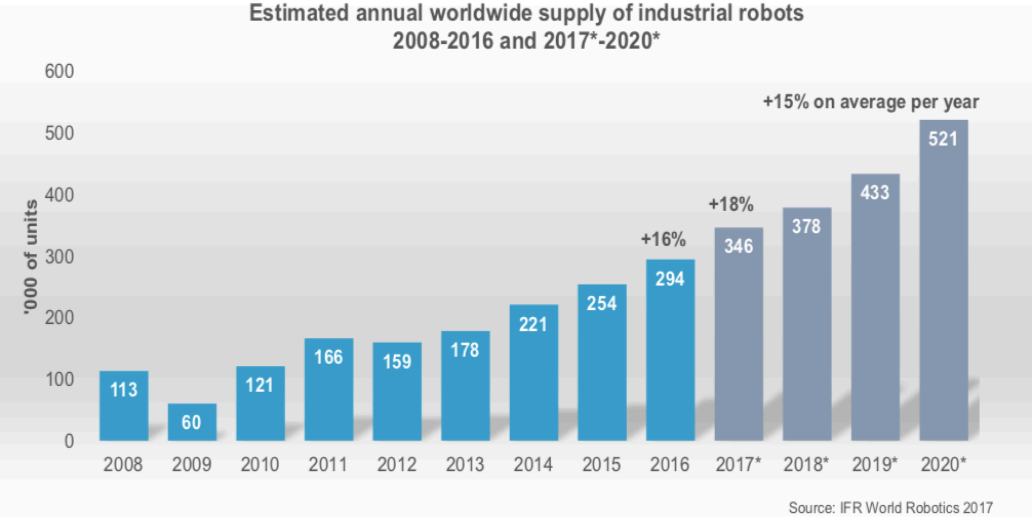


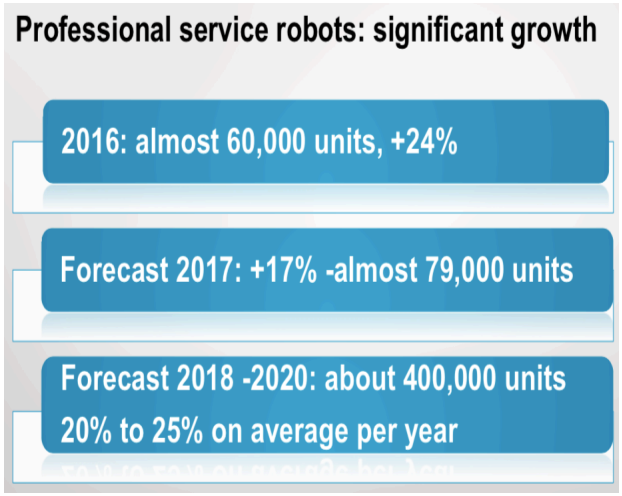
Robotics (turnover over **$40 billion***)

Industrial Robotics - Service Robotics

*IFA robotics, 2016

Trends in robotics



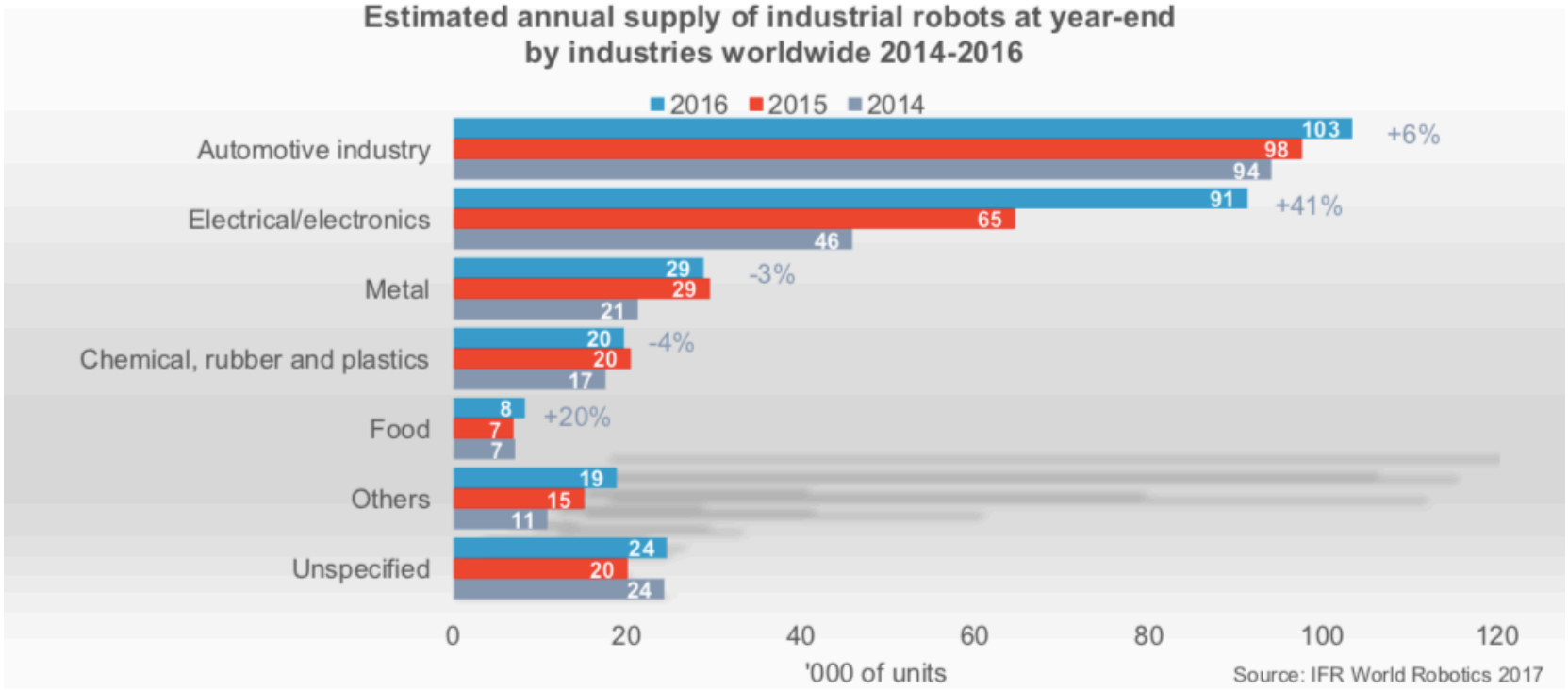


1.7 million new industrial robots by 2020

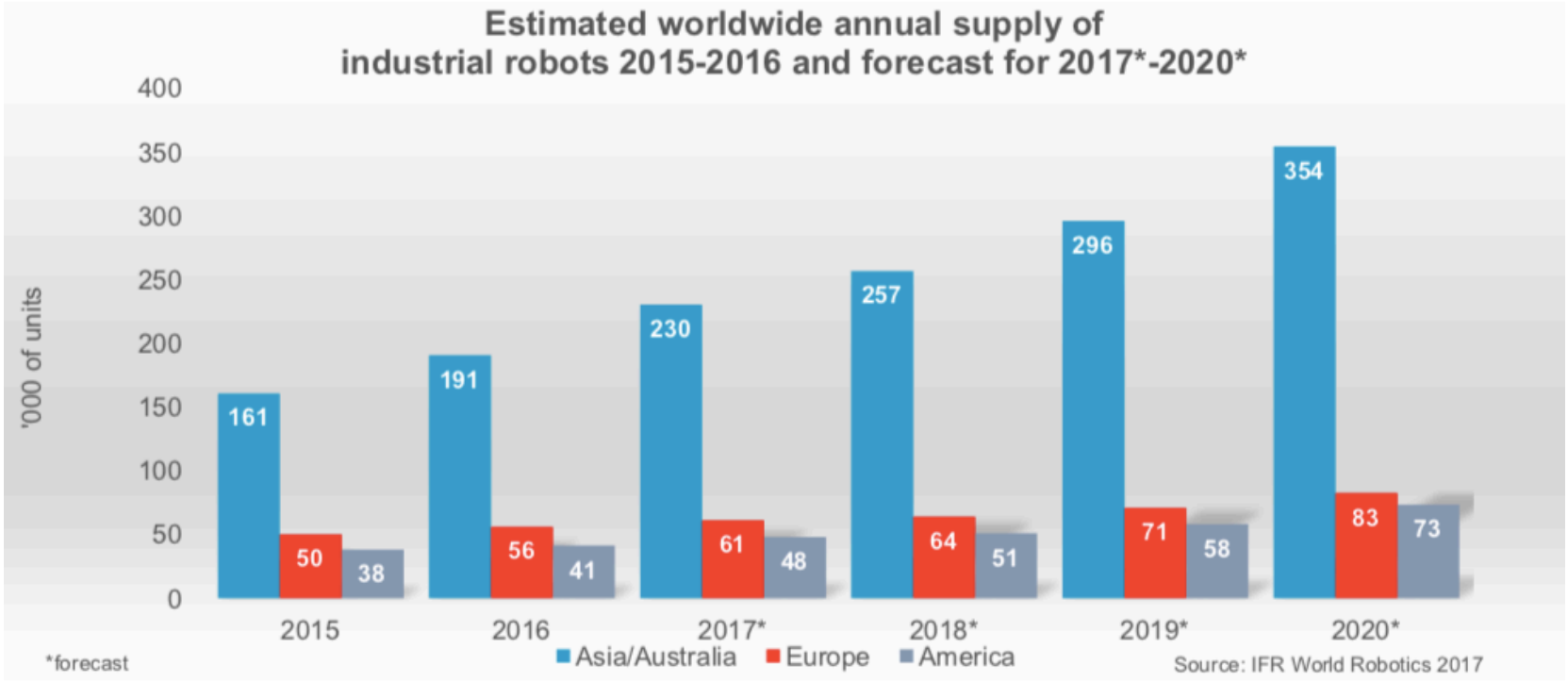
Double-digit average annual increase

Trends in robotics

Continued increase in major industries



Trends in industrial robotics



Trends in service robotics

Fresh fruit picking robot

FF Robotics (Israel)

Platform for vineyard maintenanc

WALL-YE (France)

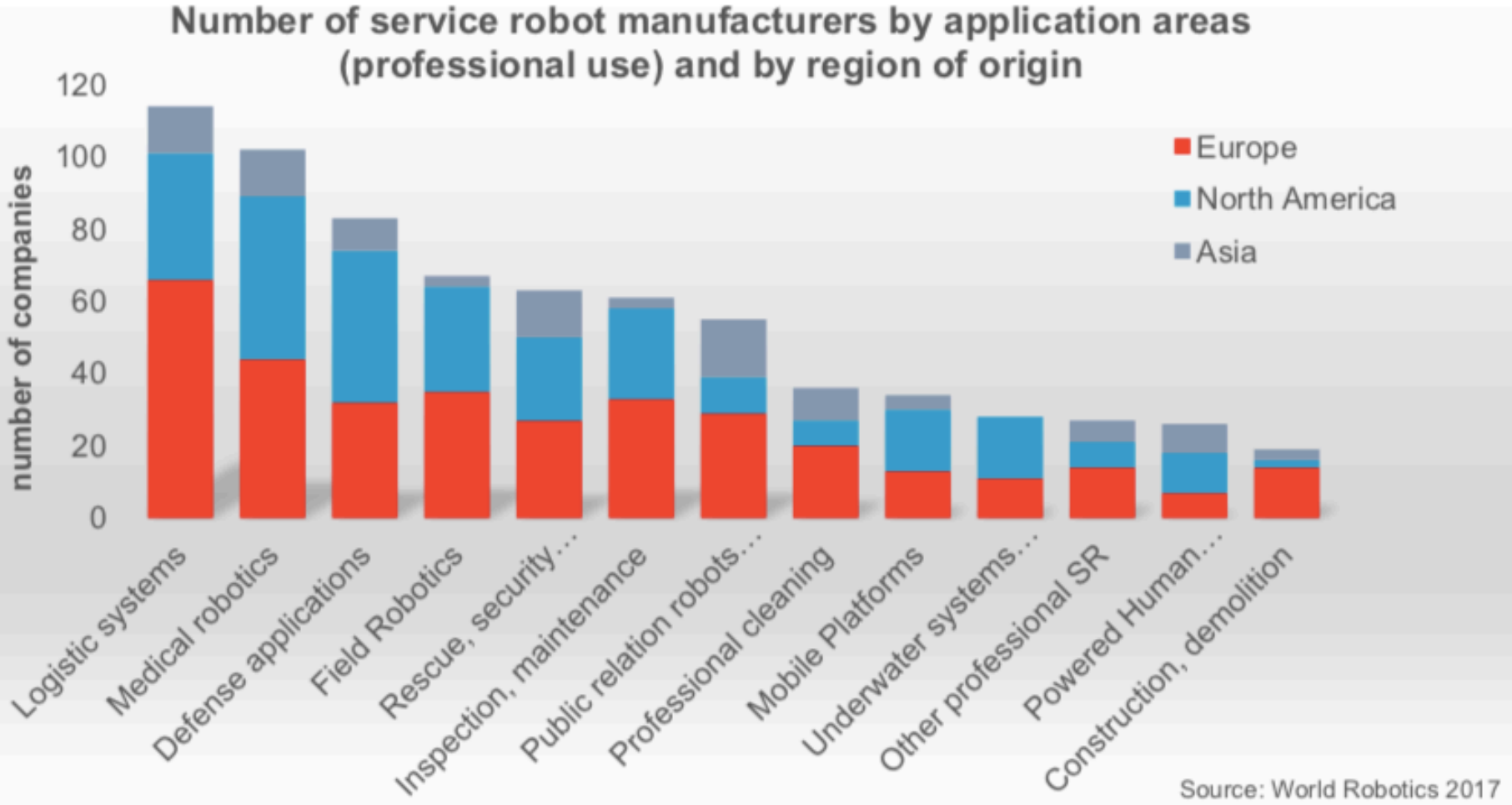
Unity Robotics (D)

Mobile Industrial Robots MiR (DK)

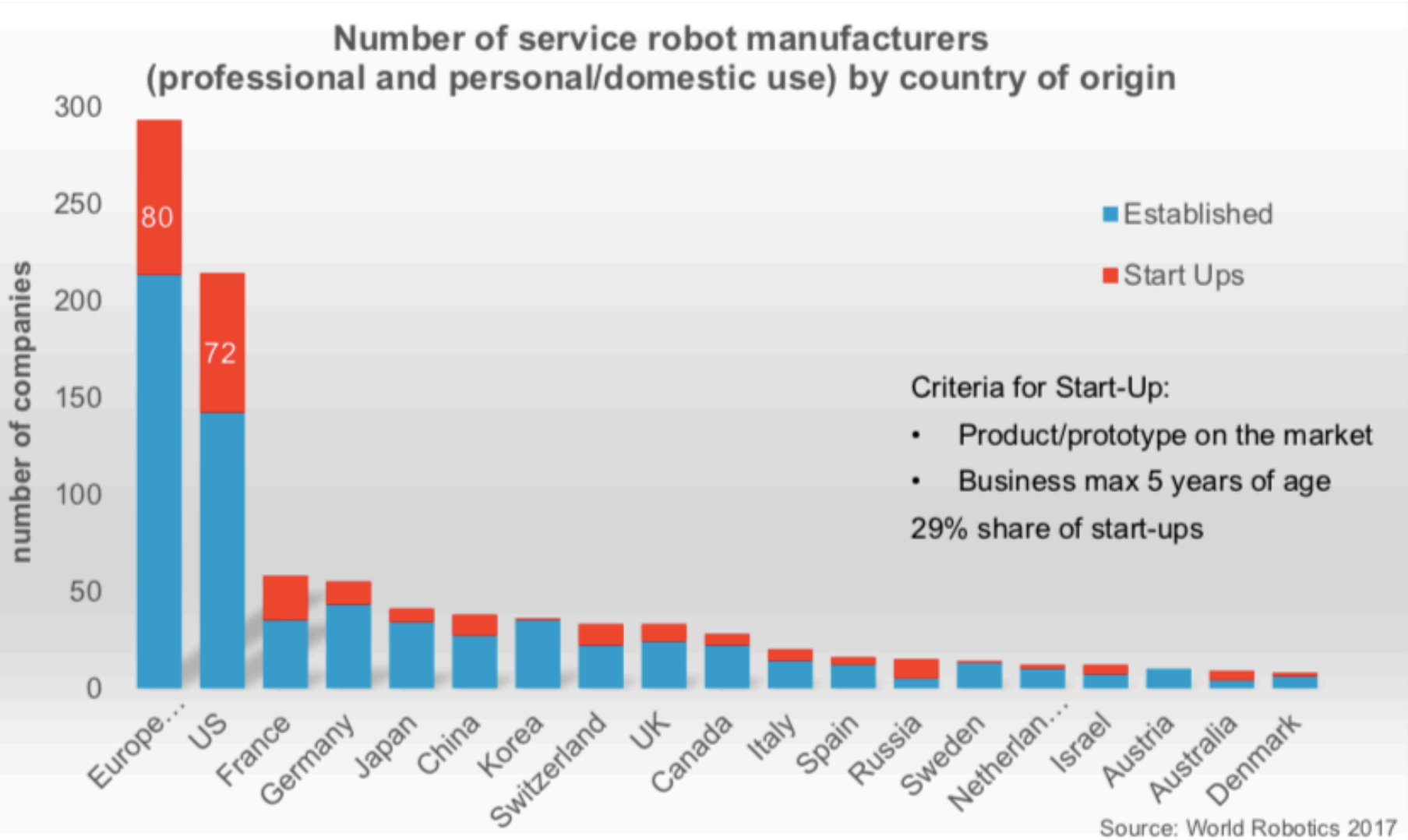
Fetch Robotics (USA)

Robotnik (ES)

Trends in service robotics



Trends in service robotics



Canadian Robotic Startups

- Kinova robotics (2006): assistive robotic platform
  - $25M funding Sept., 2017
  - Brain-controlled robot arm https://www.youtube.com/watch?time_continue=52&v=-Vh0IJRbOsY
- RobotiQ (2008): Adaptive Grippers (Laval Uni.)
- Clearpath Robotics (2009): self-driving mobile robots (U-waterloo)
  - from 365K VC founding … $30 million in a Series B (2016)
- SkyX (2015): Drone for monitoring pipelines in oil and gas sector (Ontario)
- Kindred.ai (2014): AI grasping technology based on techniques in deep learning and reinforcement learning
  - ($28 million)

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:	M 5:00-7:50 pm
real office hours:	after class or W,F by appt

Web Page

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

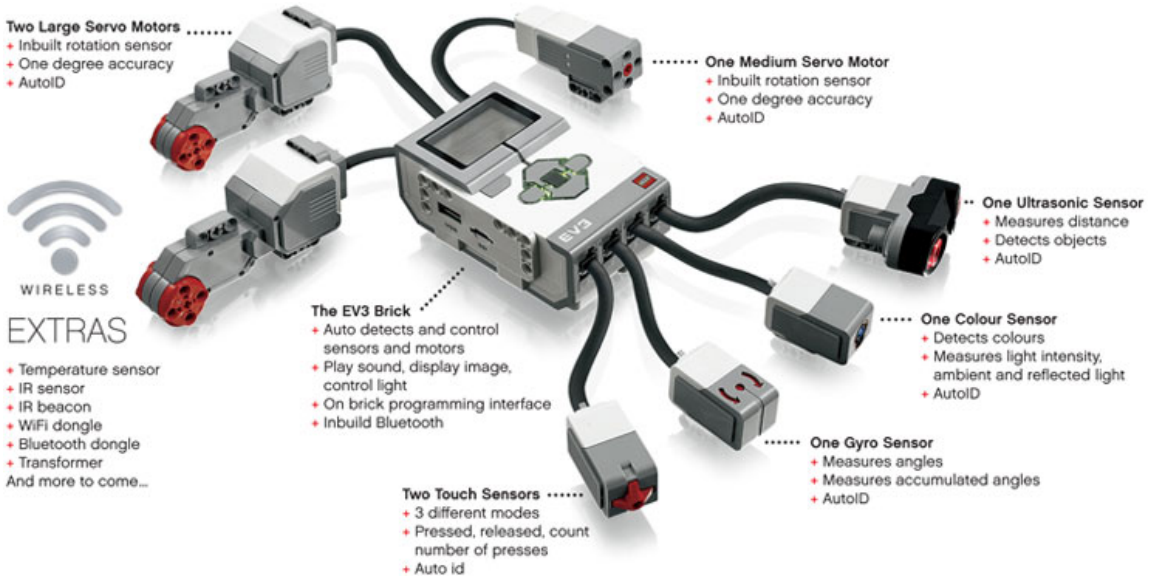
Assignments ...

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

Lab Projects - Options

Choose a platform

Default **Lego EV3** →



The EV3 Lego Robot Kit

Other possibilities:

Robot arm

AIBO dog

Pioneer

UAV

Others… !

Choose a task

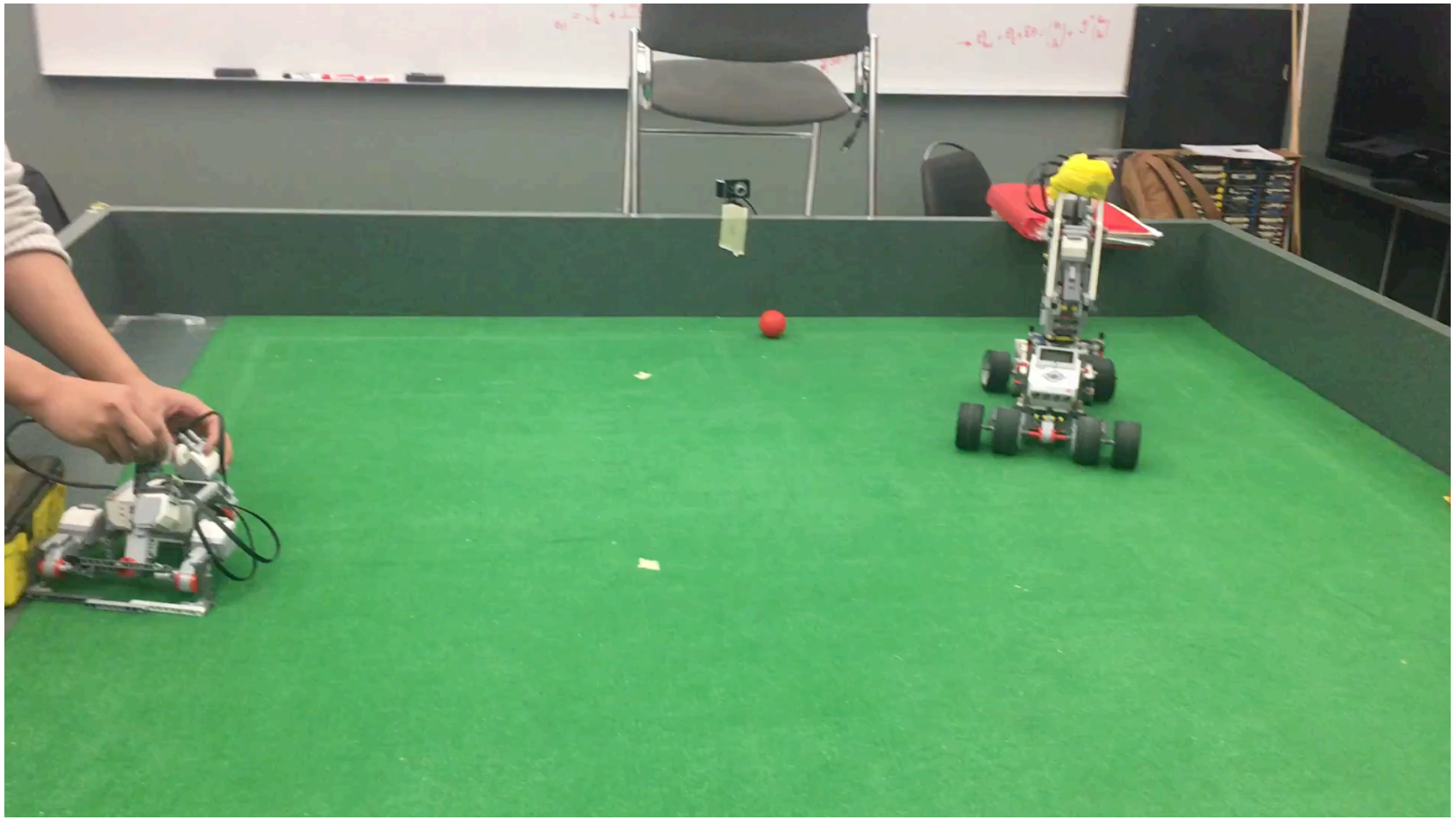
spatial reasoning

- tag / hide & seek
- Beyond Botball
-

itself publishable…

- fire extinguisher
- Vision guided motion
- Tele-operation

Robot and Project Options



Robot and Project Options