http://www.youtube.com/watch?v=3E5jCIe6XYg

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Robotic

CS311, Spring 2013
David Kauchak
Some material adapted from slides from Zach Dodds

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Admin

- Assignment 5 graded
- Exam #2 available later today
- To be done by Sunday at midnight

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What is a robot?

"I can’t define a robot, but I know one when I see one.”
--Joseph Engelberger (1966)

Justice Potter Stewart wrote in Jacobellis v. Ohio (1964), "I can’t define pornography, but I know it when I see it.”
Word robot was coined by a Czech novelist Karel Capek in a 1920 play titled Rossum’s Universal Robots (RUR). Robota in Czech is a word for worker or servant.

**Definition of robot:**
- Any machine made by one of our members: Robot Institute of America
- A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks: Robot Institute of America, 1979

**What is a Robot**
- Manipulator
- Legged Robot
- Wheeled Robot
- Autonomous Underwater Vehicle
- Unmanned Aerial Vehicle
Robot Plot

Capability (0-10)
- Turing [1]
- MERs [8]
- Shakey [3]
- Unimate [4]
- da Vinci [2]
- Roomba [7]
- Stanford Cart [3]
- Simms [5]
- Stanely/Boss [9]
- Genghis [3]
- Bar Monkey [9]

World Modeling
- more
- less

Robot timeline?

1921 1950 2020 2150 2421

Fictional Robot timeline

Put these robots in chronological order?

1921 2020 2150 2421
### Real robot timeline

- **1951**: Tortoise “Elsie” by Neurophysiologist Grey Walter
  - [http://www.frc.ri.cmu.edu/~hpm/talks/revo.slides/1950.html](http://www.frc.ri.cmu.edu/~hpm/talks/revo.slides/1950.html)
- **1968**: Nils Nilsson @ Stanford Research Inst.
- **1968**: first “general-purpose” mobile platform

### Shakey

- **1968**: Nils Nilsson @ Stanford Research Inst.

### Robotics’s Shakey start

- **START**:
  - At(sh,L) ∧ At(sp,L) ∧ At(rem,L) ∧ At(tv,L)
  - At(sh,K) ∧ At(sp,K) ∧ At(rem,L) ∧ At(tv,K)

- **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)
Shakey in video

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

Stanford Cart: SPA

Hans Moravec @ SAIL
“functional” task decomposition
“horizontal” subtasks

SENSING
PERCEPTION
PLANNING
TASK EXECUTION
MOTOR CONTROL

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

What are the challenges?
How do these relate to AI?

AI
Search
planning
Game playing
CSFs
Bayesian
HMMs
Machine learning
neural nets
Knowledge representation
Natural Language processing
Computer vision

Autonomy/behavior

how much of the world do we need to represent internally?

how should we internalize the world?
what outputs can we effect?
what inputs do we have?
what algorithms connect the two?

how do we use this “internal world” effectively?
Robot Architecture

how much / how do we represent the world internally?

As much as possible
SPA paradigm

Not at all
Reactive paradigm

Task-specific
Behavior-based architecture

As much as possible.
Hybrid approaches

Sense - Plan - Act

Robot Architecture

how much / how do we represent the world internally?

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Task-specific
Behavior-based architecture

As much as possible.
Hybrid approaches
**Biological Inspiration**

*Ethology*: describing animal behavior

- Getting to the ocean?
- Digger wasp nest-building sequence

AI reasoning systems abstract too much away: *frame problem*

"The world is its own best model"

Decision-making is based only on current sensor inputs.

**Analog reactive robots**

- “Tortoise”: Gray Walter
- “BEAM”: Mark Tilden
- “light-headed” behavior: Valentino Braitenberg

1951
1984
1989

Robot Architecture

- **how much / how do we represent the world internally?**

  - As much as possible!
  - SPA paradigm
  - Not at all
  - Reactive paradigm
  - Task-specific
    - Behavior-based architecture
      - Subsumption paradigm
      - Potential Fields
      - different ways of composing behavior
  
- As much as possible.
- Hybrid approaches

**Behavior-based control**

- **Behavior**: a direct mapping of sensory inputs to a pattern of task-specific motor actions

  - “Vertical” task decomposition
    - planning and reasoning
      - identify objects
      - build maps
      - explore
      - wander
    - avoid objects

  - stimulus – response ≈ "behavior"
  - little explicit deliberation except through system state

  - “Vertical” task decomposition

  - Genghis

  - 1985

1951
1984
1989
Subsumption builds intelligence incrementally in layers.

Where would a light-seeking behavior/layer connect?

Subsumption - Limits

Success of behavior-based systems depends on how well-tuned they are to their environment. This is a huge strength, but it's also a weakness...
Subsumption limits: Genghis

- Navigate behavior
- Wander behavior
- Runaway behavior

Unwieldy!

Larger example -- 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/range sensors to follow

57 modules wired together!

Robot Architecture

- How much / how do we represent the world internally?
  - As much as possible!
    - SPA paradigm
      - Sense
      - Plan
      - Act
    - Reactive paradigm
      - Sense
      - Act
  - Not at all

Potential Fields

- Potential fields compose simple behaviors by adding the outputs that each sensor/input sends the robot
- Individual potential fields (motor schemas) contain state

A sequencing process (FSM/DFA) updates the potential fields and/or decides which ones to run next.

As much as possible.
- Hybrid approaches

Ron Arkin @ Georgia Tech
Motor Schemas / Potential Fields

Direct mapping from the environment to a control signal

obstacle-avoiding schema goal-seeking schema

note that the complete environmental vector fields are only for visualization!

Behavior Summer

path taken by a robot controlled by the resulting field

vector sum of the avoid and goal motor schemas

Implementation details

the extent to which potential field force drops off with distance...

what crucial assumption is being made here?

corridor-following schema(s)?

Additional behavior primitives

corridor-centering schema
go! schema
A more complex task

Direct mapping from the environment to a control signal

- How many individual fields are summed in this task?
- Not necessarily all at one time!

larger composite task

Local minima

A potential-field-based system can get stuck?

- What would happen if a robot came in in the middle on the left?
- a solution?

the problem

Local minima

A potential-field-based system can get stuck!

- Why is the “local minimum” problem, as illustrated to the left, not likely to actually cause a robot to get stuck in practice?
- robots controlled by summing goal/obstacle potential fields can get stuck in practice — draw an example of an environment with both obstacle(s) and goal(s) in which getting stuck might actually occur.
- Suggest how a robot might overcome the problem of getting stuck in such cases…

the problem
Bigger deadends...

How to get out of larger wells?

Bigger deadends...

Uses memory of where the robot has been

Another example

Keeping away from past locations...

Pfields in Practice

Steathy navigation @ USC (Ashley Tews, Gaurav S. Sukhatme, and Maja J. Matarić)

Part of the potential field... What's going on here?
Docking with potential fields

Why might a simple attractive force not be sufficient for docking (plugging-in, etc.)?

How does the idea of docking, e.g., with an electrical outlet change the requirements for a potential field?

The key insight is the need to establish an approach direction.

Review

- Machine learning
- General learning concepts
- Supervised vs. unsupervised
- Feature-based problems/feature space
- Bias/variance
- Overfitting
- Hyperplanes/linear separability
- Supervised learning
- Applications
- Approaches
  - k-NN
  - Decision trees
  - SVM (Large margin classifiers)
  - Ensemble approaches (boosting)
Review

- Machine learning (continued)
  - unsupervised learning
    - application
    - issues
    - number of clusters
    - flat vs. hierarchical
    - soft vs. hard clustering
    - approaches
    - k-means
    - EM
    - word alignment
    - clustering (mixture of gaussians)
    - spectral clustering (min-cut)

- Neural networks (Machine learning?)
  - perceptrons/neurons
    - activation functions (threshold vs. sigmoid)
  - perceptron learning
  - multi-layer networks
- Knowledge representation
  - basic logic
  - ontology
  - NELL

Review

- CSPs
  - problem formulation
    - variables
    - domain
    - constraints
    - why CSPs? applications?
  - constraint graph
  - CSP as search
    - backtracking algorithm
  - forward checking
  - arc consistency
  - heuristics
    - most constrained variable
    - least constrained value
  - ...

Review

- Natural language processing
  - Applications
  - Problem areas
  - Why it's hard?
  - Machine translation setup
Guest speaker

- Rodney Brooks
  - Professor at MIT (was previous director of CSAIL)
  - Founder of iRobot

- http://www.youtube.com/watch?v=B79D9tnW2AFA