# CSE 473: Artificial Intelligence
## Autumn 2014

Introduction & Agents

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With slides from
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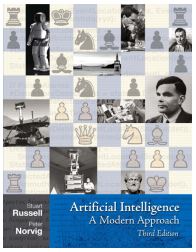
# Course Logistics

Textbook:
Artificial Intelligence: A Modern Approach, Russell and Norvig (3rd ed)




Prerequisites:
- Data Structures (CSE 326 or CSE 322) or equivalent
- Understanding of probability, logic algorithms, complexity

Work:
Readings (text & papers),
Programming assignment (55%),
Midterm (15%)
Final (30%)

# Topics

- Introduction
- Agents
- Search Methods & Heuristic Construction
- Game Playing (minimax, alpha beta, expectimax)
- Markov Decision Processes & POMDPs
- Reinforcement Learning
- Knowledge Representation & Reasoning
- Supervised Machine Learning
- Natural Language Processing

# Today

- What is (AI)?
- Agency
- What is this course?

# What is AI?

# What is AI?

The science of making machines that:

| Think like humans | Think rationally |
|---|---|
| Act like humans | Act rationally |

# Rational Decisions

We'll use the term rational in a particular way:

- Rational: maximally achieving pre-defined goals
- Rational only concerns what decisions are made (not the thought process behind them)
- Goals are expressed in terms of the utility of outcomes
- Being rational means maximizing your expected utility

A better title for this course might be:

Computational Rationality

# What is AI?

- A set of tools
  - Heuristic search
  - Machine learning algorithms
    - "deep learning"
  - Probabilistic reasoning
  - Decision-theoretic optimization

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# What is AI?

- A way of looking at the world
  - Search & problem spaces
  - Agency
  - Knowledge representation & reasoning
  - Utility optimization
  - Function approximation

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# Can We Build It?


$10^{11}$ neurons
$10^{14}$ synapses
cycle time: $10^{-3}$ sec

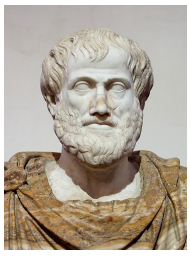
vs.

$10^{9}$ transistors
$10^{12}$ bits of RAM
cycle time: $10^{-9}$ sec

# A (Short) History of AI

# Prehistory

- Logical Reasoning: ($4^{th}$ C BC+) Aristotle, George Boole, Gottlob Frege, Alfred Tarski



## Medieval Times

- Probabilistic Reasoning: (16th C+) Gerolamo Cardano, Pierre Fermat, James Bernoulli, Thomas Bayes

## 1940-1950: Early Days

1942: Asimov: Positronic Brain; Three Laws of Robotics

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

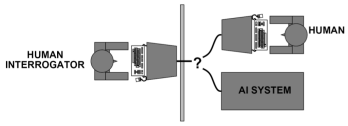
1943: McCulloch & Pitts: Boolean circuit model of brain

1946: First digital computer - ENIAC

## The Turing Test

Turing (1950) "Computing machinery and intelligence"

- "Can machines think?" ◊ "Can machines behave intelligently?"
- The Imitation Game:




- Suggested major components of AI: knowledge, reasoning, language understanding, learning

## 1950-1970: Excitement

- 1950s: Early AI programs, including
  - Samuel's checkers program,
  - Newell & Simon's Logic Theorist,
  - Gelernter's Geometry Engine
- 1956: Dartmouth meeting: "Artificial Intelligence" adopted
- 1965: Robinson's complete algorithm for logical reasoning

"Over Christmas, Allen Newell and I created a thinking machine."

*-Herbert Simon*

## 1970-1980: Knowledge Based Systems

- 1969-79: Early development of knowledge-based systems
- 1980-88: Expert systems industry booms
- 1988-93: Expert systems industry busts "AI Winter"

The knowledge engineer practices the art of bringing the principles and tools of AI research to bear on difficult applications problems requiring experts' knowledge for their solution.

- *Edward Felgenbaum* in "The Art of Artificial Intelligence"

## 1988--: Statistical Approaches

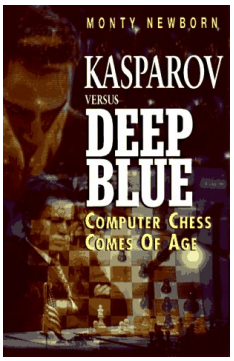
- 1985-1990: Rise of Probability and Decision Theory
  Eg, Bayes Nets
  Judea Pearl - ACM Turing Award 2011
- 1990-2000: Machine learning takes over subfields:
  Vision, Natural Language, etc.

"Every time I fire a linguist, the performance of the speech recognizer goes up"

- *Fred Jelinek*, IBM Speech Team

## 1997

"I could feel – I could smell – a new kind of intelligence across the table"
*-Gary Kasparov*




Saying Deep Blue doesn't really think about chess is like saying an airplane doesn't really fly because it doesn't flap its wings.

*– Drew McDermott*

## 2005

Stanford Car
DARPA Grand Challenge

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## Self-driving car, today

http://www.youtube.com/watch?v=csvt6JBAwBk

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## 2009

amazon Prime

More Top Picks for You



Recommendations,
Search result ordering
Ad placement,

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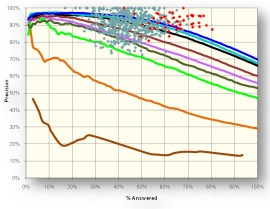
## 2011


http://www.youtube.com/watch?v=WFR3lOm_xhE

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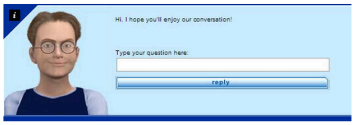
## 2014 = Momentous Times!

Fooled 29% of judges!

News > Technology

Turing Test breakthrough as super-computer becomes first to convince us it's human




Eugene Goostman, a computer programme pretending to be a young Ukrainian boy, successfully duped enough humans to pass the iconic test

ANDREW GRIFFIN | Sunday 08 June 2014

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A programme that convinced humans that it was a 13-year-old boy has become the first computer ever to pass the Turing Test. The test — which requires that computers are indistinguishable


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# Judges were Stupid

Conversation with Scott Aaronson:

Scott: Which is bigger, a shoebox or Mount Everest?

Eugene: I can't make a choice right now. I should think it out later. And I forgot to ask you where you are from…

Scott: How many legs does a camel have?

Eugene: Something between 2 and 4. Maybe, three? :-))) By the way, I still don't know your specialty – or, possibly, I've missed it?

Scott: How many legs does a millipede have?

Eugene: Just two, but Chernobyl mutants may have them up to five. I know you are supposed to trick me.

Scott: No, I need to know that you're not a chatbot. Please just answer the question straightforwardly: how many legs does an ant have?

Eugene: Something between 2 and 4. Maybe, three? :-))) Oh, what a fruitful

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# xkcd


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# What Can AI Do?

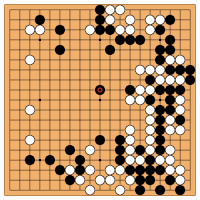
Quiz: Which of the following can be done at present?

- Play a decent game of Soccer?
- Play a winning game of Chess? Go? Jeopardy?
- Drive safely along a curving mountain road? University Way?
- Buy a week's worth of groceries on the Web? At QFC?
- Make a car? Make a cake?
- Discover and prove a new mathematical theorem?
- Perform a complex surgical operation?
- Unload a dishwasher and put everything away?
- Translate Chinese into English in real time?

# Mathematical Calculation


$$\begin{aligned}
\partial_r^2 u &= -\left[E' - \frac{l(l+1)}{r^2} - r^2\right] u(r) \\
e^{-2s}\left(\partial_s^2 - \partial_s\right) u(s) &= -\left[E' - l(l+1)e^{-2s} - e^{2s}\right] u(s) \\
e^{-2s}\left[e^{\frac{1}{2}s}\left(e^{-\frac{1}{2}s}u(s)\right)'' - \frac{1}{4}u\right] &= -\left[E' - l(l+1)e^{-2s} - e^{2s}\right] u(s) \\
e^{-2s}\left[e^{\frac{1}{2}s}\left(e^{-\frac{1}{2}s}u(s)\right)''\right] &= -\left[E' - \left(l+\frac{1}{2}\right)^2 e^{-2s} - e^{2s}\right] u(s) \\
v'' &= -e^{2s}\left[E' - \left(l+\frac{1}{2}\right)^2 e^{-2s} - e^{2s}\right] v
\end{aligned}$$

# Game Playing

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# Robocup

## Brownies Anyone?

BakeBot:
Motion Planning for Cooking

Mario Bollini and Daniela Rus
CSAIL, MIT

CSAIL

## Bakebot

http://www.youtube.com/watch?v=CjJH1XSnVVY

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## What is AI?

The science of making machines that:

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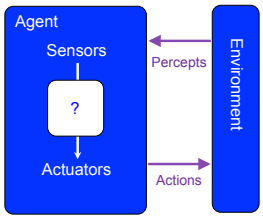
| Act like humans | **Act rationally** |

## Agent *vs.* Environment

- An agent is an entity that perceives and acts.
- A rational agent selects actions that maximize its utility function.
- Characteristics of the percepts, environment, and action space dictate techniques for selecting rational actions.

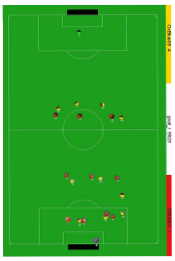



## Types of Environments

- Fully observable *vs.* partially observable
- Single agent *vs.* multiagent
- Deterministic *vs.* stochastic
- Episodic *vs.* sequential
- Discrete *vs.* continuous

## Fully observable vs. Partially observable

Can the agent observe the complete state of the environment?



vs.

## Single agent vs. Multiagent

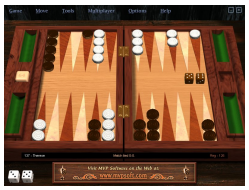
Is the agent the only thing acting in the world?


vs.


Aka static *vs.* dynamic

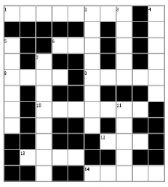
## Deterministic vs. Stochastic

Is there uncertainty in how the world works?


vs.


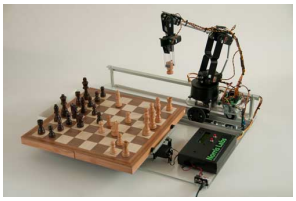
## Episodic vs. Sequential

Episodic: next episode doesn't depend on previous actions.


vs.


## Discrete vs. Continuous

- Is there a finite (or countable) number of possible environment states?


vs.


## Types of Agent

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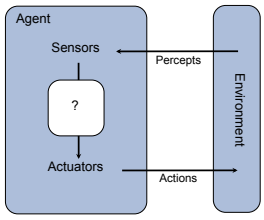



## Reflex Agents

- Reflex agents:
  - Choose action based on current percept (and maybe memory)
  - Do not consider the future consequences of their actions
  - Act on how the world IS


Can a reflex agent be rational?
Can a non-rational agent achieve goals?

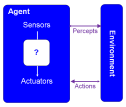
## Goal Based Agents

- Plan ahead
- Ask "what if"
- Decisions based on (hypothesized) consequences of actions
- Must have a model of how the world evolves in response to actions
- Act on how the world WOULD BE

## Utility Based Agents

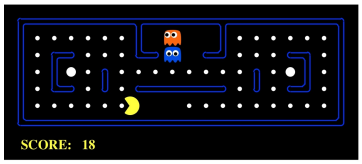
- Like goal-based, but
- Trade off multiple goals
- Reason about probabilities of outcomes
- Act on how the world will LIKELY be

## Pacman as an Agent




Utility Function?

Implementation?

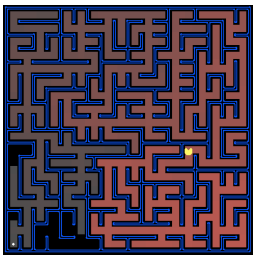



Originally developed at UC Berkeley:
http://www-inst.eecs.berkeley.edu/~cs188/pacman/pacman.html

## PS1: Search

Goal:
- Help Pac-man find his way through the maze

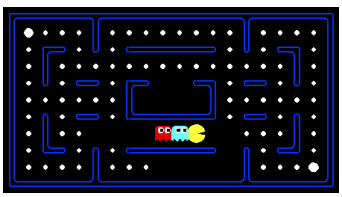
Techniques:
- Search: breadth-first, depth-first, etc.
- Heuristic Search: Best-first, A*, etc.



## PS2: Game Playing

Goal:
- Play Pac-man!

Techniques:
- Adversarial Search: minimax, alpha-beta, expectimax, etc.



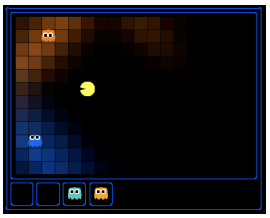
## PS3: Planning and Learning

Goal:
- Help Pac-man learn about the world

Techniques:
- Planning: MDPs, Value Iterations
- Learning: Reinforcement Learning

# PS4: Ghostbusters

Goal:
- Help Pac-man hunt down the ghosts



Techniques:
- Probabilistic models: HMMS, Bayes Nets
- Inference: State estimation and particle filtering

# Starting… Now!

- Assign 0: Python Tutorial
  - Online, but not graded
- Assign 1: Search
  - Coming soon…
  - Start early and ask questions. It's longer than most!