4701

- Course home page: http://www.cs.columbia.edu/~jvoris/AI
Who are we?

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Who Are We?

• Teaching Assistants:
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Who Are We?

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More about Jon

• Graduated from the Ph.D. Program at Polytechnic Institute of New York University
• Currently a Postdoctoral Research Scientist in the Columbia Intrusion Detection Systems Lab
• Research in computer security, privacy, and usability
• Web site: https://www.cs.columbia.edu/~jvoris/
Outline

• Course overview
• What is AI?
• A brief history
• The state of the art
Tentative Grading Scheme

- 4 Projects/1 Midterm/1 Final

<table>
<thead>
<tr>
<th>Assignment/Test</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Project #1</td>
<td>15%</td>
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<tr>
<td>Project #2</td>
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<td>Project #3</td>
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<td>Midterm</td>
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<td>Final</td>
<td>20%</td>
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<tr>
<td>Class Participation</td>
<td>5%</td>
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</table>
Grading Policy

• Submit:
  – Source code
  – Documentation
  – Test run input and output

• General criteria:
  – Correctness: 75%
  – Design/Structure: 15%
  – Documentation: 10%
Late Policy

• 10 points deducted immediately
• 10 points per day thereafter
  – 10/24 points deducted per hour
• No submissions accepted after the next project due date
Academic Honesty

• Read and understand the department’s policy here:
  – http://www.cs.columbia.edu/education/honesty
Course Overview

• Introduction and Agents (chapters 1,2)
• Search (chapters 3,4,5,6)
• Mathematical Logic (chapters 7,8,9)
• Uncertainty (chapters 13)
• Learning (chapters 18,20)

• 4 Projects/1 Midterm/1 Final
What is Artificial Intelligence?

• Loaded question...let’s back up a little here
What is Artificial Intelligence?

• Loaded question…let’s back up a little here
• What is a computer?
What is Artificial Intelligence?

• Loaded question...let’s back up a little here

• What is a computer?
  – Hrmm...
  – Let’s start with these easier questions....
What is a Hammer?
What is a Hammer?

A hammer is an AMPLIFIER for….
What is a Phone?
What is a Phone?

A phone is an AMPLIFIER for....
What is a Car?
What is a Car?

A car is an AMPLIFIER for….
What is a Computer?
What is a Computer?

A computer is an AMPLIFIER for....
The Brain!

- 50-100B of these:
- 10,000’s connections each!
- ~10B critical pyramidal cells involved with cognition
- 1000 trillion (1 quadrillion) connections!

- Why is it so wrinkled?
- Frontal lobes oversized by mammalian standards
- Vision processing oversized
- Three times larger than next average mammal
The Brain!

• What does it do?

• Remembers stuff:

  • Semantic memory: General knowledge, trivia and facts are stored in the temporal lobe and the cortex.
  • Episodic memory: New data and recent events are stored in the prefrontal cortex and the temporal lobe.
  • Working memory: Information and knowledge required for daily life – such as telephone numbers and learned skills like driving -- are stored in the prefrontal cortex.
  • Procedural memory: Secondhand skills, things we take for granted, such as walking and cycling, are stored in the cerebellum.
The Mind!

• Is it physical?

• Where is it?

• Is it real or imagined? 😊

• Mind-Body Problem
  – Descartes, Plato, Aristotle, Asian philosophy
  – Dualism: separate from each other
  – Monism: rationalists, two aspects of an underlying reality

• Let’s just deal with our own reality for now….
What is AI?

Views of AI fall into four categories:

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The textbook advocates "acting rationally"
What is AI?

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Acting humanly: Turing Test

- Turing (1950) "Computing machinery and intelligence":  
  "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game

- Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes
- Anticipated all major arguments against AI in following 50 years
- Suggested major components of AI: knowledge, reasoning, language understanding, learning
Turing Test: Relevance?

• Strengths of this approach?
• Weaknesses of this approach?
Turing Test: Relevance?

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- Weaknesses of this approach?
- Practical applications?
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Thinking humanly: cognitive modeling
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• Well, how do humans think anyway?
  – Introspection
  – Psychological / physiological experiments
• Develop *theory* of human thought
• Implement *theory* as a *program*
  – Its as simple as that!
• Check similarities to human behavior
Thinking humanly: cognitive modeling

• 1960s "cognitive revolution": information-processing psychology
• Requires scientific theories of internal activities of the brain
• -- How to validate? Requires
  1) Predicting and testing behavior of human subjects (top-down)
  or 2) Direct identification from neurological data (bottom-up)

• Both approaches (roughly, Cognitive Science and Cognitive Neuroscience) are now distinct from AI
Thinking humanly: cognitive modeling

• Relationship between “good” algorithms and “human” algorithms

• Separation has formed two distinct fields:
  – Cognitive Science
  – Cognitive Neuroscience
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Thinking rationally: "laws of thought"

- Aristotle: what are correct arguments/thought processes?
  - Sought *irrefutable* reasoning
  - Correct premises -> correct conclusions

- Several Greek schools developed various forms of *logic*: *notation* and *rules of derivation* for thoughts; may or may not have proceeded to the idea of mechanization
Thinking rationally: "laws of thought"

- Logicism: Direct line through mathematics and philosophy to modern AI
- 19th Century: Precise notations for logical relations
  - Arithmetic for things
- 1965: Problem solving programs
- Problems:
  1. Expressing things in formal notation
  2. Uncertainty
  3. Theory vs practice
     1. Efficiency
     2. Ordering
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Acting rationally: rational agent

- **Rational** behavior: doing “the right thing”
- The right thing: that which is expected to maximize goal achievement, given the available information
- Doesn't necessarily involve thinking – e.g., blinking reflex – but thinking should be in the service of rational action
Rational agents

• An agent is an entity that perceives and acts
• This course is about designing rational agents
• Abstractly, an agent is a function from percept histories to actions:
  \[ f: P^* \rightarrow A \]
• For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
• Caveat: computational limitations make perfect rationality unachievable
  \[ \rightarrow \text{design best program for given machine resources} \]
The Secret Origin of AI

• AI has a long academic pedigree
• Was born out of ideas from many fields
The Secret Origin of AI

• Philosophy: pre-computer AI
  – Logic
  – Methods of reasoning
  – Mind as physical system
  – Foundations of learning
  – Language
  – Rationality

• Ramon Lull 1315: Can a device reason?
• Already talked about Aristotle
• Da Vinci: plans for an unbuilt mechanical calculator
• Early 1600s: Schickard, Pascal, Leibinz actually construct them
• Mind-body problem
The Secret Origin of AI

• Logical positivism
  – All knowledge formed by *logical theories* which connect *observation*
  – Sound familiar?
  – Read works of:
    • Hume
    • Wittgenstein
    • Russell
The Secret Origin of AI

• Mathematics: transition of AI into a formal science
  – Formal representation and proof algorithms
  – Computability, (un)decidability, (in)tractability
  – Probability / uncertainty

• Math and logic: 1800s: George Boole

• Algorithms: Euclid & GCD

• 1931: Goedel’s incompleteness theory
  – Some things are true but unprovable

• 1900s: Turing is the man
  – Some functions cannot be programmed

• 1700s: Bayes – Calculating probabilities from observations
The Secret Origin of AI

- **Economics**: practical aspects of AI
  - 1776: Smith – Wealth of Nations – turned economics into a science
    - “Invisible Hand”
- **Utility**: Association of value to event outcomes
- **Decision theory**: probability + utility
  - Framework for analyzing decisions made with imperfect knowledge
- 1944: von Neumann and Morgenstern: Game Theory
  - Ways to model interactions between rational agents
The Secret Origin of AI

• A few other fields:
  • Neuroscience
    – How does the brain work?
    – Physical substrate for mental activity
  • Psychology
    – How do humans think, and why?
    – Phenomena of perception and motor control
    – Experimental techniques
  • Computer engineering
    – Improving hardware
  • Control theory
    – Design systems that maximize an objective function over time
  • Linguistics
    – How does language affect thought (or vice versa)?
    – Knowledge representation
    – Grammar
A Brief History of AI

- 1943-1955: Getting warmer…
- 1943: McCulloch & Pitts neuron model blends
  - Neurology
  - Propositional logic
  - Theory of computation
- 1950: First “neural network”
  - Computer simulating 40 neurons
- Turing in the house
  - "Computing Machinery and Intelligence"
  - “Child program” idea
A Brief History of AI

- 1956: The birth of AI
- Dartmouth College
- Two month workshop
- 10 attendees
- Newell and Simon’s “Logic Theorist” Program
  - Creates a shorter proof for one of Russell’s theorems
  - Original paper rejected!
- Firmly planted AI in CS
- Introduced all the field’s main players
A Very Brief History of AI

• 1952-1969: This new AI thing is great!
• Low expectations
• Early “successes” showing computers >> calculators
• Physical Symbol System hypothesis: intelligent systems must operate on structures of symbols
• IBM: Early AI programs
  – Samuel’s checkers program outwits its creator
  – Gelernter's Geometry Engine
• 1958: Lisp is born at MIT! (much more about this soon)
• Study of domain limited microworlds
  – Calculus integration
  – Algebra problems
  – “Blocks world”
A Very Brief History of AI

• 1966-1973: Maybe not all its cracked up to be…
  - Herbert Simon: computer will beat chess champion by late 60s
    - It actually took until the late 90s – whoops…
  - Research runs into problems of **scalability** and **complexity**
  - Solutions to simple problems don’t apply well to more challenging ones
  - Syntax ≠ knowledge
  - Example: translation
    - “The spirit is willing but the flesh is weak”
    - “The vodka is good but the meat is rotten”
• Difference between theory and practice
• No progress in genetic algorithms
  - Data represented poorly
• Governments start to cut funding
• Neural network research almost disappears
A Very Brief History of AI

• 1969-1979: Knowledge based systems
  • Instead of generic problem solvers
    – Attack narrower problems
    – Leverage domain specific information
    – Knowledge from lots of special rules
• 1969: DENDRAL program for inferring molecular structure
• Expert systems: attempts to copy human decision making
  – MYCIN: medical diagnosis
• Return of translation efforts
  – Natural Language Processing
  – Less emphasis on language and more on knowledge representation
A Very Brief History of AI

• 1980 – Now: AI sells out
  • Companies realize this AI thing can save them money
  • R1: Expert system for computer orders
    – A computer in charge of ordering computers!
• DuPont develops and uses hundreds of expert systems
• Nations launch competing AI efforts
  – 1981: Japan’s “Fifth Generation” project
  – US: Microelectronics and Computer Technology Corporation (MCC)
  – UK restores funding
  – None of these efforts were fruitful by the way…
• 1988: AI is a billion dollar industry
  – Yet companies still have trouble delivering on claims
A Very Brief History of AI

• 1986 – Now: AI grows up
• The return of neural networks – split into
  – Modeling organic neurons
  – Creating and analyzing effective networks
• Embraces scientific methods
  – Formal hypotheses
  – More rigorous experiments
  – Statistical analysis of results
  – Replication!
• Developments in use today:
  – Data mining
  – Bayesian networks

“My CPU is a neural net processor; a learning computer. But Skynet pre-sets the switch to read-only when we're sent out alone.”
A Very Brief History of AI

• 1995 – Now: Intelligent agents
• New debate over whether AI should
  – Continue to focus on concrete domain specific tasks, or
  – “Human level AI”
• The Internet comes in to play
  – Search algorithms
  – Recommendation systems
• The rise of “bots”
  – Where is Turing when you need him!? 
A Very Brief History of AI

• 2001 – Now: Rise of big data
• Advent of the internet provides plenty of data to practice on
• Maybe the problem isn’t bad algorithms, but insufficient data?
  – Certain algorithms perform much better with huge data
• AI is here to stay
Where is AI now?

• In games:
  – Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
  – Proverb solves crossword puzzles better than most humans
  – Jeopardy!! Watson wipes the floor with the humans in 2011

• In cars:
  – No hands across America (driving autonomously 98% of the time from Pittsburgh to San Diego)

• In math:
  – Proved a mathematical conjecture (Robbins conjecture) unsolved for decades

• In war:
  – During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
  – Savings repaid DARPA’s entire investment in AI research

• In space:
  – NASA’s on-board autonomous planning program controlled the scheduling of operations for a spacecraft

• AI Knowledge based system components are embedded in many real-world applications
Where is AI now?

Everywhere!