What do SpamAssassin, Gene Sequencing, Google, and Deep Blue have in common?

Artificial Intelligence
Introduction: What is AI?

CSPP 56553
Artificial Intelligence
January 7, 2004
Agenda

• Course goals

• Course machinery and structure

• What is Artificial Intelligence?

• What is Modern Artificial Intelligence?
Course Goals

- Understand reasoning, knowledge representation and learning techniques of artificial intelligence
- Evaluate the strengths and weaknesses of these techniques and their applicability to different tasks
- Understand their roles in complex systems
- Assess the role of AI in gaining insight into intelligence and perception
Instructional Approach

• Readings
  – Provide background and detail

• Class sessions
  – Provide conceptual structure

• Homework
  – Provide hands-on experience
  – Explore and compare techniques
Course Organization

• Knowledge representation & manipulation
  – Reasoning, Planning,..

• Acquisition of new knowledge
  – Machine learning techniques

• AI at the interfaces
  – Perception - Language, Speech, and Vision
Artificial Intelligence

• Understand and develop computations to
  – Reason, learn, and perceive

• Reasoning:
  – Expert systems, planning, uncertain reasoning
  – E.g. Route finders, Medical diagnosis, Deep Blue

• Learning:
  – Identifying regularities in data, generalization
  – E.g. Recommender systems, Spam filters

• Perception:
  – Vision, robotics, language understanding
  – E.g. Face trackers, Mars rover, ASR, Google
Course Materials

• Textbook
  – Artificial Intelligence: A Modern Approach
    • 2nd edition, Russell & Norvig
    • Seminary Co-op

• Lecture Notes
  – Available on-line for reference
Homework Assignments

• Weekly
  – due Wednesdays in class

• Two options:
  – All analysis
  – Combined implementation and analysis
    • Choice of programming language

• TAs & Discussion List for help
  – http://mailman.cs.uchicago.edu – Cssp56553
Homework: Comments

• Homework will be accepted late
  – 10% off per day

• Collaboration is permitted on homework
  – Write up your own submission
  – Give credit where credit is due

• Homework is required to pass the course
Grading

- Homework: 40%
- Class participation: 10%
- Midterm: 25%
- Final Exam: 25%
Course Resources

• Web page:
  – http://people.cs.uchicago.edu/~levow/courses/cspp56553
    • Lecture notes, syllabus, homework assignments,..

• Staff:
  – Instructor: Gina-Anne Levow, levow@cs
    • Office Hours: By appointment, Ry166
  – TA: Leandro Cortes, leandro@cs, Ry177
  – TA: Vikas Sindhwani, vikass@cs, Ry 177
Questions of Intelligence

• How can a limited brain respond to the incredible variety of world experience?
• How can a system learn to respond to new events?
• How can a computational system model or simulate perception? Reasoning? Action?
What is AI?

• Perspectives
  – The study and development of systems that
    • Think and reason like humans
      – Cognitive science perspective
    • Think and reason rationally
    • Act like humans
      – Turing test perspective
    • Act rationally
      – Rational agent perspective
Turing Test

- Proposed by Alan Turing (1950)
  - Turing machines & decidability
- Operationalize intelligence
  - System indistinguishable from human
    - Canonical intelligence
  - Required capabilities:
    - Language, knowledge representation, reasoning, learning (also vision and robotics)
Imitation Game

• 3 players:
  – A: Human; B: Computer; C: Judge

• Judge interrogates A & B
  – Asks questions with keyboard/monitor
    • Avoid cues by appearance/voice

• If judge can’t distinguish,
  – Then computer can “think”
Question

• What are some problems with the Turing Test as a guide to building intelligent systems?
Challenges I

Eliza (Weizenbaum)

• Appearance: an (irritating) therapist
• Reality: Pattern matching
  – Simple reflex system
    No understanding
    “You can fool some of the people…” (Barnum)
Challenges II

– Judge: How much is 10562 * 4165?
– B: (Time passes…) 4390730.
– Judge: What is the capital of Illinois?
– B: Springfield.

• Timing, spelling, typos…
• What is essential vs transient human behavior?
Challenges III

• Understanding?

• Searle’s Chinese Room argument
  – Judge submits question in Chinese
  – B is person who doesn’t know Chinese
    • But, B has a book mapping Chinese to Chinese
  – B doesn’t understand Chinese, but simulates

• Problem??
Question

• Does the Turing Test still have relevance?
Modern Turing Test

• “On the web, no one knows you’re a….”
• Problem: ‘bots’
  – Automated agents swamp services
• Challenge: Prove you’re human
  – Test: Something human can do, ‘bot can’t
• Solution: CAPTCHAs
  – Distorted images: trivial for human; hard for ‘bot
• Key: Perception, not reasoning
Questions

• Why did expert systems boom and bomb?

• Why are techniques that were languishing 10 years ago booming?
Classical vs Modern AI

Shakey and the Blocks-world

Versus

Genghis on Mars
Views of AI: Classical

• Marvin Minsky
• Example: Expert Systems
  – “Brain-in-a-box”
  – (Manual) Knowledge elicitation and engineering
  – Perfect input
  – Complete model of world/task
  – Symbolic
Issues with Classical AI

- Oversold!
- Narrow: Navigate an office but not a sidewalk
- Brittle: Sensitive to input errors
  - Large complex rule bases: hard to modify, maintain
  - Manually coded
- Cumbersome: Slow think, plan, act cycle
Modern AI

• Situated intelligence
  – Sensors, perceive/interact with environment
  – “Intelligence at the interface” – speech, vision

• Machine learning
  – Automatically identify regularities in data

• Incomplete knowledge; imperfect input

• Emergent behavior

• Probabilistic
Issues in Modern AI

• Benefits:
  – More adaptable, automatically extracted
  – More robust
  – Faster, reactive

• Issues:
  – Integrating with symbolic knowledge
    • Meld good model with stochastic robustness

• Examples: Old NASA vs gnat robots
  – Symbolic vs statistical parsing
Key Questions

- **AI advances:**
  - How much is technique?
  - How much is Moore’s Law?
- **When is an AI approach suitable?**
  - Which technique?
- **What are AI’s capabilities?**
- **Should we model human ability or mechanism?**
Challenges

• Limited resources:
  – Artificial intelligence computationally demanding
  • Many tasks NP-complete
  • Find reasonable solution, in reasonable time
  • Find good fit of data and process models
  • Exploit recent immense expansion in storage, memory, and processing
AI’s Biggest Challenge

“Once it works, it’s not AI anymore. It’s engineering.” (J. Moore, Wired)
Studying AI

- Develop principles for rational agents
  - Implement components to construct
- Knowledge Representation and Reasoning
  - What do we know, how do we model it, how we manipulate it
    - Search, constraint propagation, Logic, Planning
- Machine learning
- Applications to perception and action
  - Language, speech, vision, robotics.
Roadmap

• Rational Agents
  – Defining a Situated Agent
  – Defining Rationality
  – Defining Situations
    • What makes an environment hard or easy?
  – Types of Agent Programs
    • Reflex Agents – Simple & Model-Based
    • Goal & Utility-based Agents
    • Learning Agents
  – Conclusion
Situated Agents

- Agents operate in and with the environment
  - Use sensors to perceive environment
    - Percepts
  - Use actuators to act on the environment

- Agent function
  - Percept sequence -> Action
    - Conceptually, table of percepts/actions defines agent
    - Practically, implement as program
Situated Agent Example

- Vacuum cleaner:
  - Percepts: Location (A,B); Dirty/Clean
  - Actions: Move Left, Move Right; Vacuum

- A,Clean  ->  Move Right
- A,Dirty  ->  Vacuum
- B,Clean  ->  Move Left
- B,Dirty  ->  Vacuum
- A,Clean, A,Clean  ->  Right
- A,Clean, A,Dirty  ->  Vacuum.....
What is Rationality?

• “Doing the right thing”
• What's right? What is success???
• Solution:
  – Objective, externally defined performance measure
    • Goals in environment
    • Can be difficult to design
  – Rational behavior depends on:
    • Performance measure, agent's actions, agent's percept sequence, agent's knowledge of environment
Rational Agent Definition

• For each possible percept sequence,
  – A rational agent should act so as to maximize performance, given knowledge of the environment

• So is our agent rational?

• Check conditions
  – What if performance measure differs?
Limits and Requirements of Rationality

• Rationality isn't perfection
  – Best action given what the agent knows THEN
    • Can't tell the future

• Rationality requires information gathering
  – Need to incorporate NEW percepts

• Rationality requires learning
  – Percept sequences potentially infinite
    • Don't hand-code
  – Use learning to add to built-in knowledge
    • Handle new experiences
Defining Task Environments

- Performance measure
- Environment
- Actuators
- Sensors
Characterizing Task Environments

• From Complex & Artificial to Simple & Real

• Key dimensions:
  – Fully observable vs partially observable
  – Deterministic vs stochastic (strategic)
  – Episodic vs Sequential
  – Static vs dynamic
  – Discrete vs continuous
  – Single vs Multi agent
## Environment types

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Examples

Vacuum cleaner

Assembly line robot

Language Tutor

Waiter robot
Agent Structure

- Agent = architecture + program
  - Architecture: system of sensors & actuators
  - Program: Code to map percepts to actions

- All take sensor input & produce actuator command

- Most trivial:
  - Tabulate agent function mapping
    - Program is table lookup

- Why not?
  - It works, but HUGE
    - Too big to store, learn, program, etc..
Simple Reflex Agents

• Single current percept
• Rules relate
  – “State” based on percept, to
  – “action” for agent to perform
  – “Condition-action” rule:
    • If a then b: e.g. if in(A) and dirty(A), then vacuum
• Simple, but VERY limited
  – Must be fully observable to be accurate
Model-based Reflex Agent

- Solution to partial observability problems
  - Maintain state
    - Parts of the world can't see now
  - Update previous state based on
    - Knowledge of how world changes: e.g. Inertia
    - Knowledge of effects of own actions
    - \( \Rightarrow \) “Model”

- Change:
  - New percept + Model+Old state \( \Rightarrow \) New state
  - Select rule and action based on new state
Goal-based Agents

- Reflexes aren't enough!
  - Which way to turn?
    - Depends on where you want to go!!

- Have goal: Desirable states
  - Future state (vs current situation in reflex)

- Achieving goal can be complex
  - E.g. Finding a route
  - Relies on search and planning
Utility-based Agents

• Goal:
  – Issue: Only binary: achieved/not achieved
  – Want more nuanced:
    • Not just achieve state, but faster, cheaper, smoother,...

• Solution: Utility
  – Utility function: state (sequence) -> value
  – Select among multiple or conflicting goals
Learning Agents

• Problem:
  – All agent knowledge pre-coded
    • Designer can't or doesn't want to anticipate everything

• Solution:
  – Learning: allow agent to match new states/actions
  – Components:
    • Learning element: makes improvements
    • Performance element: picks actions based on percept
    • Critic: gives feedback to learning about success
    • Problem generator: suggests actions to find new states
Conclusions

- Agents use percepts of environment to produce actions: agent function
- Rational agents act to maximize performance
- Specify task environment with
  - Performance measure, action, environment, sensors
- Agent structures from simple to complex, more powerful
  - Simple and model-based reflex agents
  - Binary goal and general utility-based agents
  - + Learning
Focus

• Develop methods for rational action
  – Agents: autonomous, capable of adapting
    • Rely on computations to enable reasoning, perception, and action
    • But, still act even if not provably correct
  – Require similar capabilities as Turing Test
    • But not limited human style or mechanism
AI in Context

• Solve real-world (not toy) problems
  – Response to biggest criticism of “classic AI”

• Formal systems enable assessment of psychological and linguistic theories
  – Implementation and sanity check on theory
Solving Real-World Problems

- **Airport gate scheduling:**
  - Satisfy constraints on gate size, passenger transfers, traffic flow
  - Uses AI techniques of constraint propagation, rule-based reasoning, and spatial planning

- **Disease diagnosis (Quinlan’s ID3):**
  - Database of patient information + disease state
  - Learns set of 3 simple rules, using 5 features to diagnose thyroid disease
Evaluating Linguistic Theories

- Principles and Parameters theory proposes a small set of parameters to account for grammatical variation across languages
  - E.g. S-V-O vs S-O-V order, null subject
- PAPPI (Fong 1991) implements theory
  - Converts English parser to Japanese by switch of parameter and dictionary