UNIVERSITY OF LOUISVILLE
J. B. SPEED SCHOOL OF ENGINEERING

Computer Engineering and Computer Science Department

CSE545-Artificial Intelligence: Getting Started

Lecture slides for this and upcoming lectures are based on the slides by the AIMA book authors, users and competing authors.

Dr. Roman Yampolskiy

Instructor: **Dr. Roman V. Yampolskiy**

- roman.yampolskiy@louisville.edu
- **Office Hours:** (subject to change)
  - Monday: 14:00-15:00
  - Wednesday: 14:00 – 15:00
- **Appointments (**at least 24-hour notice required**)**
- Teaching Assistants:
  - **Name:** Ahmed Sharafeldeen; **Office**: Lutz Hall 429
  - **Email**: a.sharafeldeen@louisville.edu
  - **Office Hours**: M, W 11:00 - Noon

Lectures

- <u>Lectures:</u>
  - Monday & Wednesday & Friday: 1:00 – 1:50PM
  - For Section 01/02 (onsite)
  - Asynchronous online for section 50/51.

Artificial Intelligence CSE545

- Prerequisites: CSE 302 and CSE 310.
- Ability to program, knowledge of data structures and algorithms, solid mathematical background.

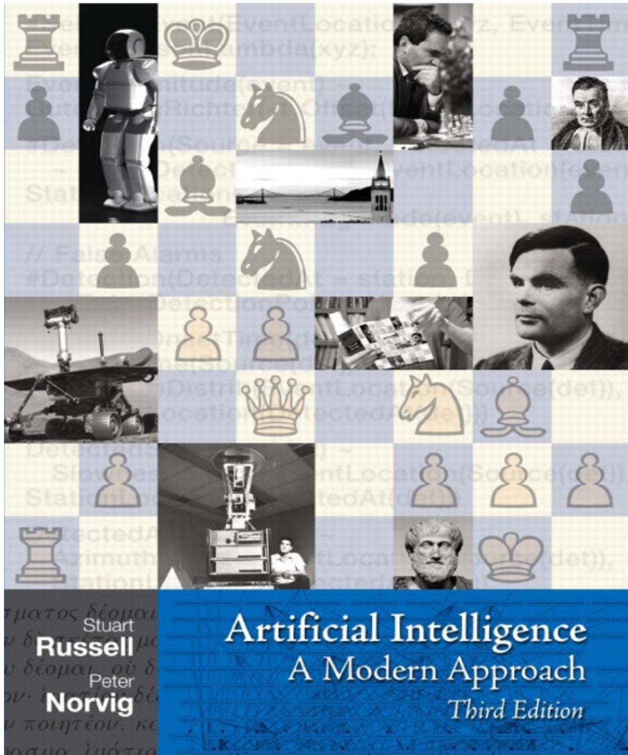
- Course Description: Topics covered will include rationale and use of heuristic approach to engineering problem solving; information processing models as an explanation of human perceptual, cognitive and affective behaviors. Applications involving the concepts and problems in artificial intelligence engineering.

Course Objectives:

- Explain the main features of an intelligent agent
- Design and implement programs for simple heuristic search problems
- Understand and explain the performance limitations of heuristic search
- Demonstrate an in-depth understanding of at least one AI application area
- Represent simple logic problems as predicate calculus formulae
- Design and implement programs for solving NP-Complete problems
- Be able to design novel algorithms and conduct experiments
- Write research papers and give public presentations
- Understand ethical and philosophical issues associated with AI research

<u>Textbooks</u>: One Book is required:

- <u>Textbook</u>: **Artificial Intelligence: A Modern Approach.** (Third edition) by Stuart Russell and Peter Norvig. Prentice Hall. ISBN-10: 0136042597.
- http://aima.cs.berkeley.edu/index.html



<u>Programming Assignments</u>:

- The course is designed to require a lot of programming.
- In total 6 programming projects will be assigned.
- Each project should be accompanied by a report describing details of the algorithm and results of any experiments performed.
- Submit your assignments via BlackBoard by combining your source code files and *.doc file into a single *.zip achieve. The archived file should be named: Project#YourLastName.zip.
- Example: my first project submission would be called **Project1Yampolskiy.zip**. Do NOT password protect your submission.

Research Paper, Presentation, …

- Research Paper: Students are expected to prepare a paper describing their work on the final Programming Assignment. The paper should be of publishable quality.
- Presentation: Students are expected to prepare and present to the class a 15-20 minute presentation about their final Programming Assignment.
- Participation: Participation in discussions, exercises, etc.

Grading:

- Programming Assignments: 55%
- Research Paper: 15%
- Presentation: 5%
- Participation: 10%
- Midterm Examination: 15%
- The grading scale is as follows:

Graduate VS Undergraduate: As this is a co-listed course Graduate Students are expected to do additional work. All *graduate students* will have to present a 30-minute lecture covering one of the chapters in the textbook.

10% out of 110%

98-100 = A+	89-87 = B+	79-77 = C+	69-67 = D+	Below 59 = F
97-94 = A	86-84 = B	76-74 = C	66-64 = D	
93-90 = A-	83-80 = B-	73-70 = C-	63-60 = D-	

*Percentages between specified ranges default to a lower grade (Ex. 97.6 is an A)

Exams:

- One mid-term exam will be administered. The exam will be based mainly on the project work you have completed as well as the reading assignments and class lectures. The exam is closed book, closed notes, unless otherwise noted.

Grading and Attendance

- Grading questions: If you have a question about a grade, you should see your instructor within one week of the day the graded work is returned to you. You lose the right to re-grading after that.
- Incompletes: Incomplete grades (I) are granted very rarely and only under extenuating circumstances.
- Absences: Attendance is optional, making up material from missed classes is your responsibility.
- Students with Special Needs: Students with special needs will be accommodated and all necessary arrangements will be made to facilitate learning the material, doing the assignments, and taking the exams.

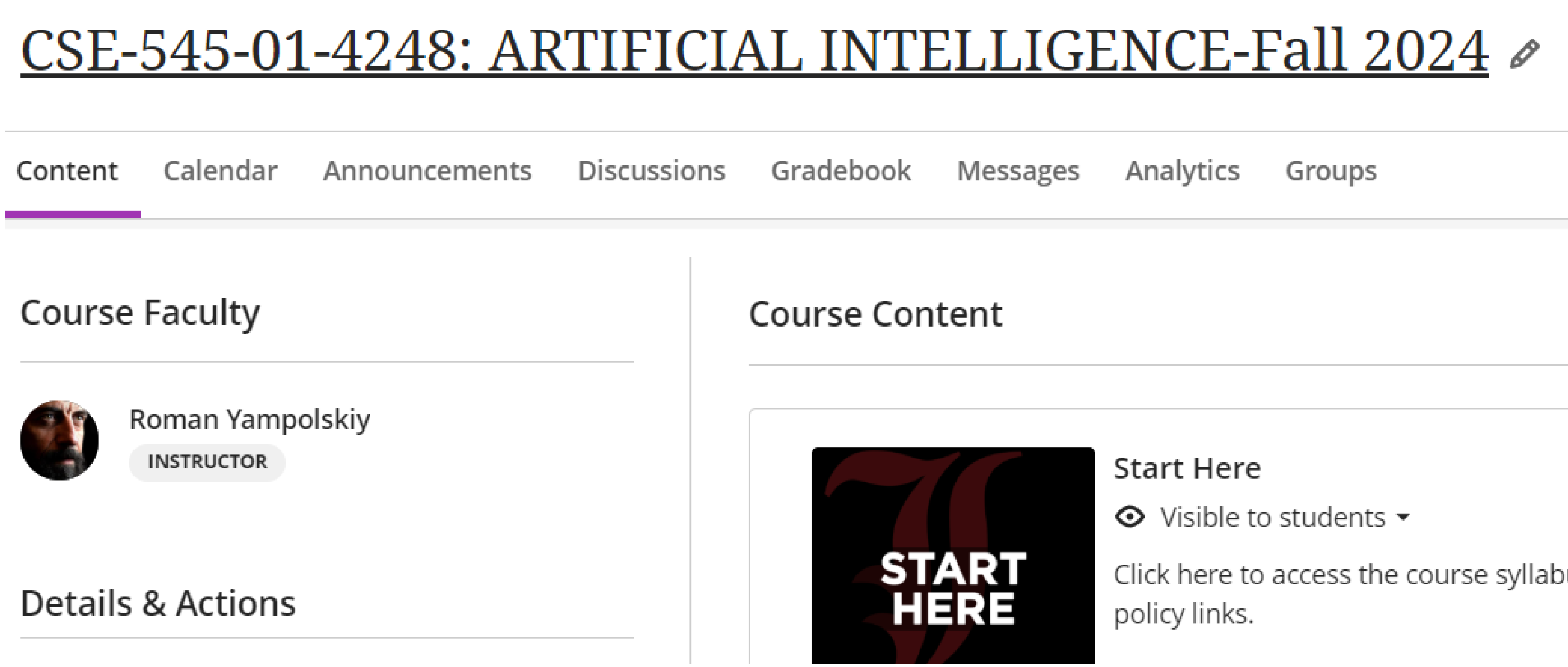
Academic dishonesty:

- Students are expected to do their own work.
- **Copying is strictly forbidden.**
- Academic dishonesty is defined in the Code of Student Rights and Responsibilities.
- It is the student's responsibility to become familiar with the Code.
- Allegations of academic dishonesty are handled in accordance with the Procedures for Dealing with Breaches of Academic Integrity.
- Copies of the Code are available in the Speed School Academic Affairs Office and departmental offices.

Weekly Schedule: Note that the schedule below is tentative and will be adjusted.

Week	Lecture Date	Topic	Reading	Assignments
1	Monday, 8/19	*Introduction*	Ch1	Project 1 assigned
	Wednesday, 8/21	*-TSP*		
	Friday, 8/23	Programming Project Work		
2	Monday, 8/26	*Intelligent Agents*	Ch2	**Pr1 due**
	Wednesday, 8/28	*-Exercises 2.3, 2.5, 2.6*		Pr2 assigned
	Friday, 8/30	Programming Project Work		
3	Monday, 9/2	**Labor Day**		
	Wednesday, 9/4	*Search*	Ch3	
	Friday, 9/6	Programming Project Work		**Project 2 due**
4	Monday, 9/9	*-Exercises 3.10, 3.14, 3.15a,b,c*		Project 3 assigned
	Wednesday, 9/11	*Beyond Search – GA*	Ch4	
	Friday, 9/13	Programming Project Work		
5	Monday, 9/16	*- GP*		
	Wednesday, 9/18	*Adversarial Search*	Ch5	
	Friday, 9/20	Programming Project Work		**Pr3 due**
6	Monday, 9/23	*-Exercises 5.8, 5.21*		Pr4 assigned
	Wednesday, 9/25	*CSPs, -SI(PSO, ACO)*	Ch6	
	Friday, 9/27	Programming Project Work		
7	Monday, 9/30	**Midterm Break**		
	Wednesday, 10/2	*-Exercises 6.1,6.2,6.3*	Ch7	
	Friday, 10/4	Programming Project Work		
8	Monday, 10/7	*Logical Agents*		
	Wednesday, 10/9	*First-Order Logic*	Ch8/9	
	Friday, 10/11	Programming Project Work		
9	Monday, 10/14	**Midterm Exam**		
	Wednesday, 10/16	*WOC, Exam Results*		**Project 4 due**
	Friday, 10/18 **W**	Programming Project Work		Project 5 assigned
10	Monday, 10/21	*-Exercises 8.6,8.15,8.16 (AIMA 2nd ed)*		
	Wednesday, 10/23	*Artificial Life, CA*		
	Friday, 10/25	Programming Project Work		
11	Monday, 10/28	*TBD-Student Interest*		**Pr5 due** Pr6 assigned
	Wednesday, 10/30	*TBD-Student Interest*		Paper/ppt Assigned
	Friday, 11/1	Programming Project Work		
12	Monday, 11/4	*TBD-Student Interest*		
	Wednesday, 11/6	*We Need to Talk about AI (Movie part 1)*		
	Friday, 11/8	Programming Project Work		
13	Monday, 11/11	*We Need to Talk about AI (Movie part 2)*		**Final Project (6) due**
	Wednesday, 11/13	*AI Ethics &Philosophy*	Ch26/27	
	Friday, 11/15	Student Projects **ppt**		
14	Monday, 11/18	Student Projects **ppt**		
	Wednesday, 11/20	Student Projects **ppt**		
	Friday, 11/22	Student Projects **ppt**		
15	Monday, 11/25	Student Projects **ppt**		**Research Paper due**
	Wednesday, 11/27	**Thanksgiving Break**		
	Friday, 11/29	**Thanksgiving Break**		
16	Monday, 12/2	Student Projects **ppt**		

Blackboard


CSE-545-01-4248: ARTIFICIAL INTELLIGENCE-Fall 2024
Content
Calendar
Announcements
Discussions
Gradebook
Messages
Analytics
Groups
Course Faculty
Roman Yampolskiy
INSTRUCTOR
Details & Actions
Course Content
START HERE
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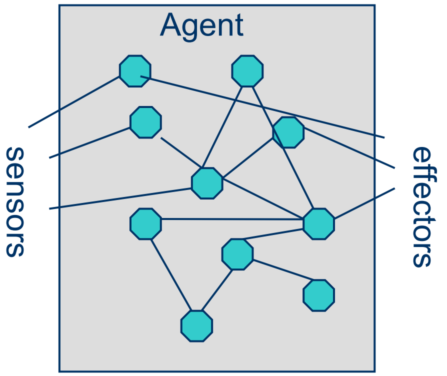
Visible to students
Click here to access the course syllabu
policy links.

Course Overview

General Introduction

- ***Introduction.*** Course Schedule. Why study AI? What is AI? The Turing test. Rationality. Branches of AI. Research disciplines connected to and at the foundation of AI. Brief history of AI. Challenges for the future.

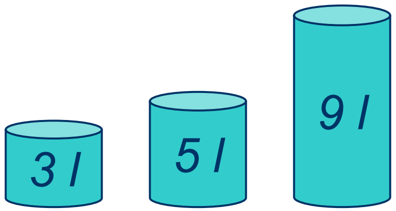
- ***Intelligent Agents.*** What is an intelligent agent? Examples. Doing the right thing (rational action). Performance measure. Autonomy. Environment and agent design. Structure of agents. Agent types. Reflex agents. Reactive agents. Reflex agents with state. Goal-based agents. Utility-based agents. Mobile agents. Information agents.



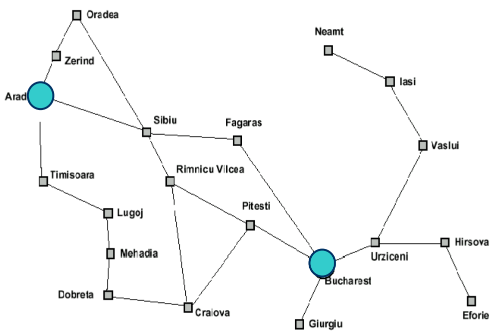
How can we solve complex problems?

Course Overview (cont.)

- ***Problem solving and search.*** Types of problems. More example problems. Basic idea behind search algorithms. Complexity. Combinatorial explosion and NP completeness.
- ***Uninformed search.*** Depth-first. Breadth-first. Uniform-cost. Depth-limited. Iterative deepening. Examples. Properties.
- ***Informed search.*** Best-first. A* search. Heuristics. Hill climbing. Problem of local extrema. Simulated annealing.



Using these 3 buckets, measure 7 liters of water.

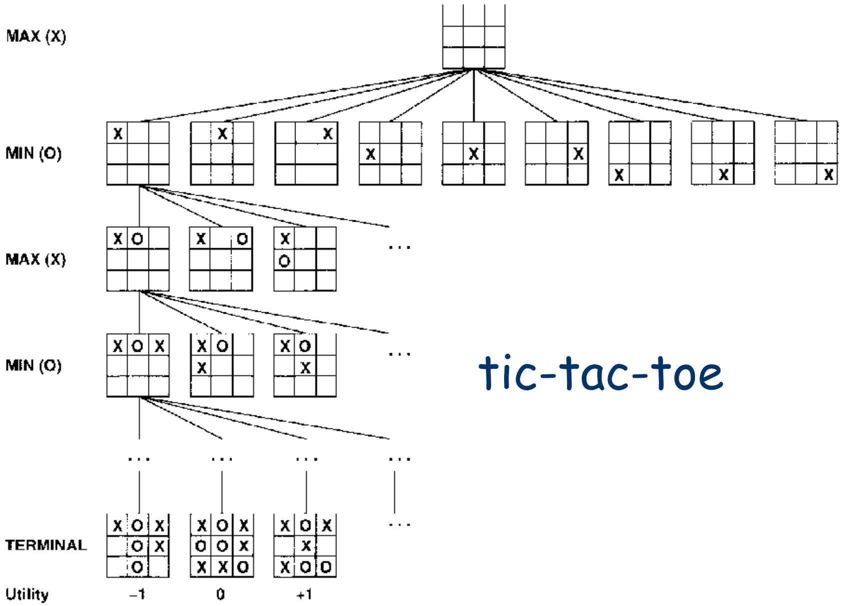


Traveling salesperson problem

Course Overview (cont.)

Practical applications of search.

- ***Game playing.*** The minimax algorithm. Resource limitations. Aplha-beta pruning. Elements of chance and non-deterministic games.

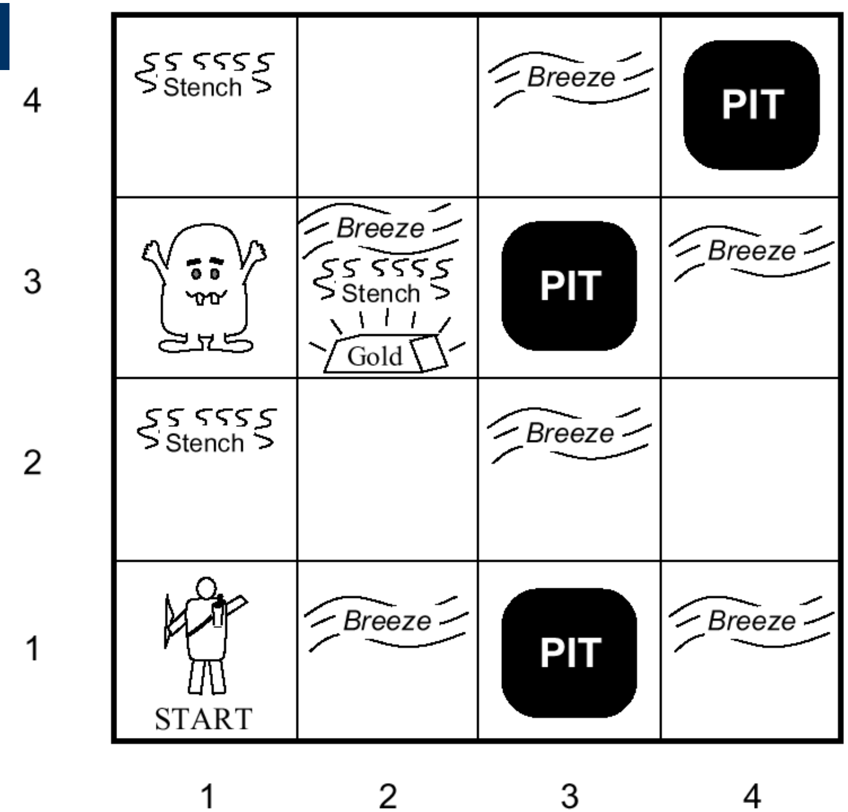


tic-tac-toe

Towards intelligent agents

Course Overview (cont.)

- ***Agents that reason logically*** Knowledge-based agents. Logic and representation. Propositional (boolean) logic. Inference in propositional logic. Syntax. Semantics. Examples.

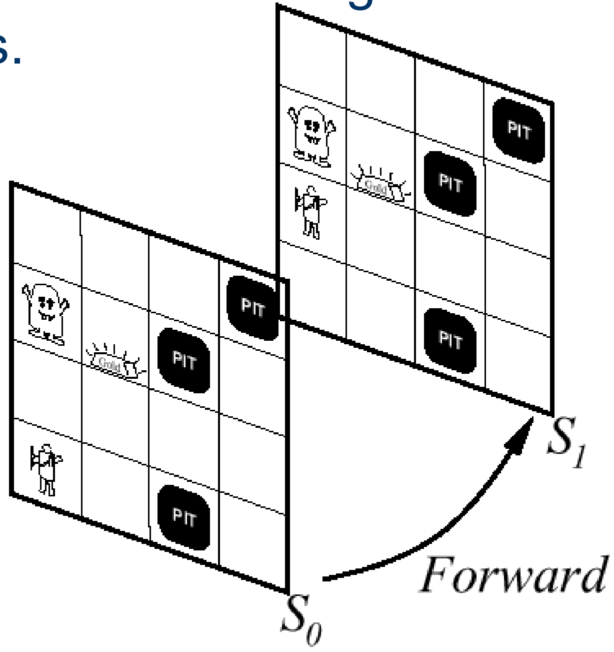


wumpus world

Course Overview (cont.)

Building knowledge-based agents: 1st Order Logic

- ***First-order logic*** Syntax. Semantics. Atomic sentences. Complex sentences. Quantifiers. Examples. FOL knowledge base. Situation calculus. Describing actions. Planning. Action sequences.

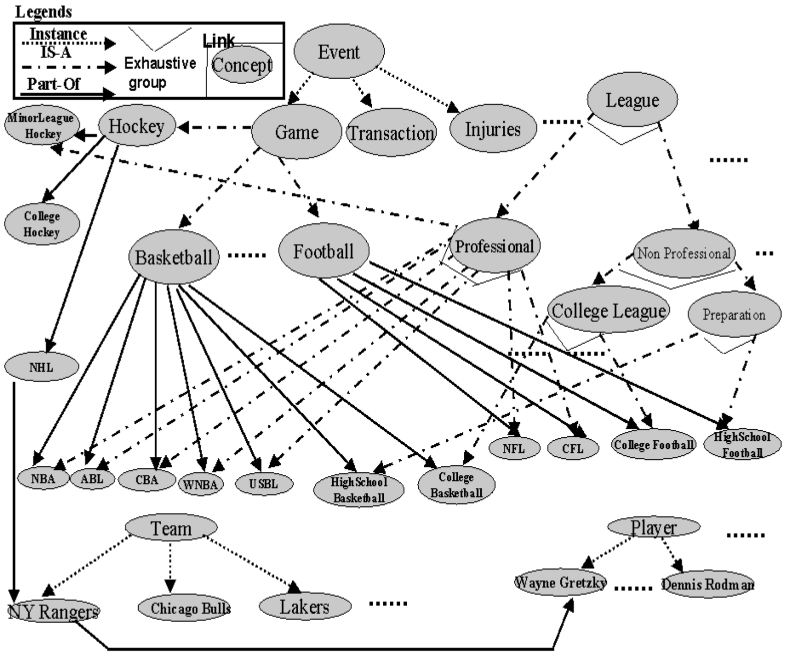


Course Overview (cont.)

Representing and Organizing Knowledge

- ***Building a knowledge base.*** Knowledge bases. Vocabulary and rules. Ontologies. Organizing knowledge.

An ontology for the sports domain

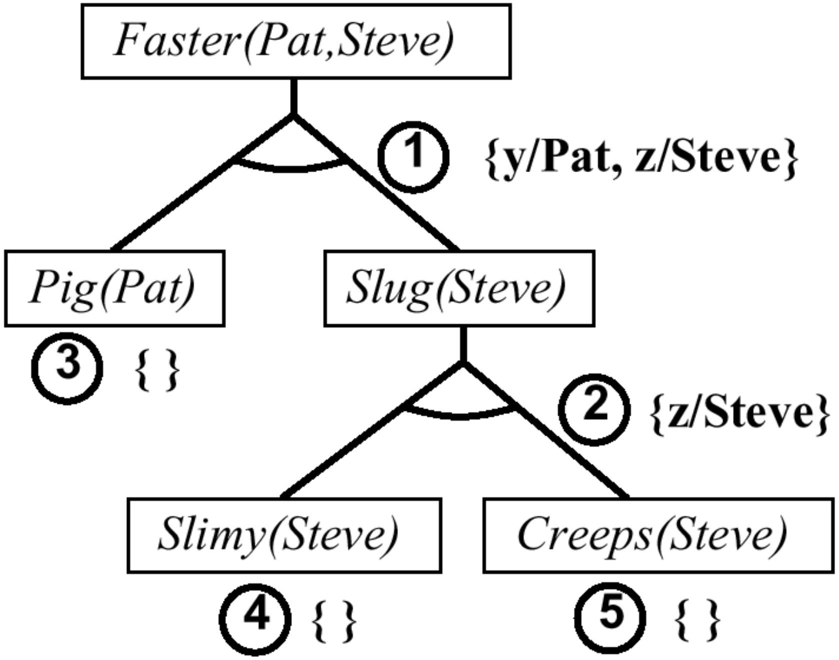


Course Overview (cont.)

Reasoning Logically

- ***Inference in first-order logic.*** Proofs. Unification. Generalized modus ponens. Forward and backward chaining.

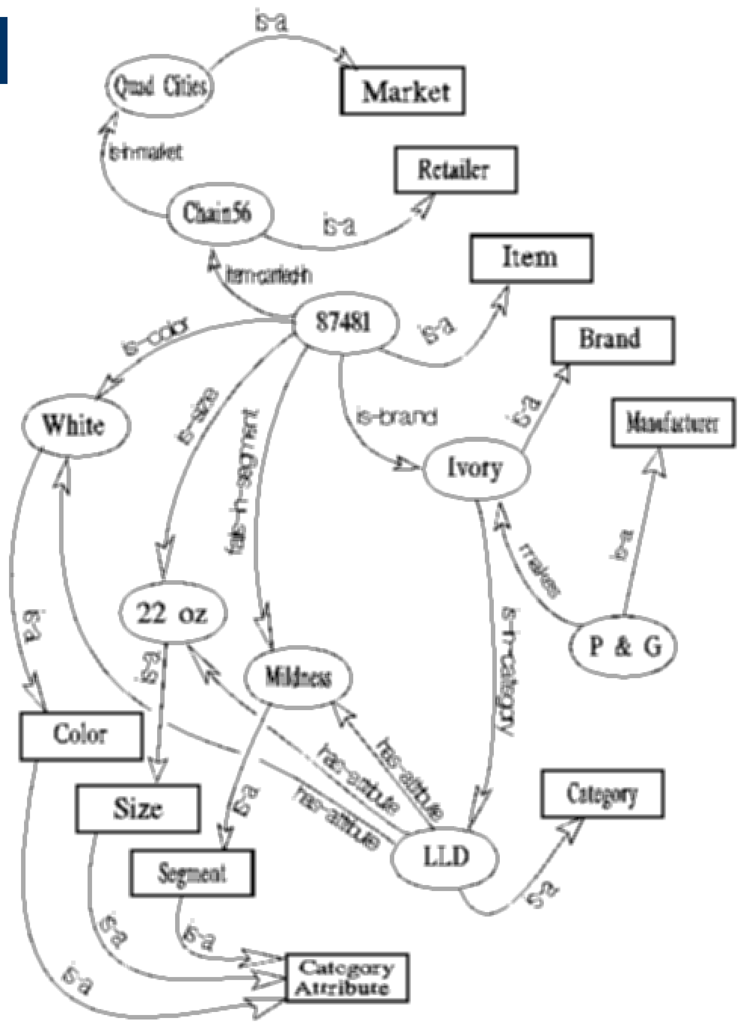
Example of backward chaining



Course Overview (cont.)

Examples of Logical Reasoning Systems

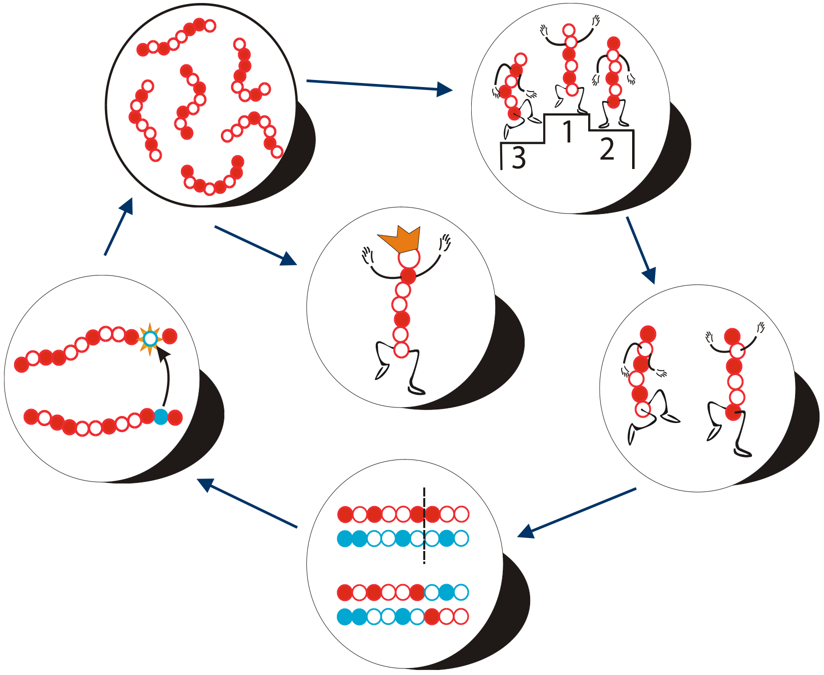
- ***Logical reasoning systems.***
  Indexing, retrieval and unification.
  Theorem provers. Semantic networks.



Semantic network used in an insight generator (Duke university)

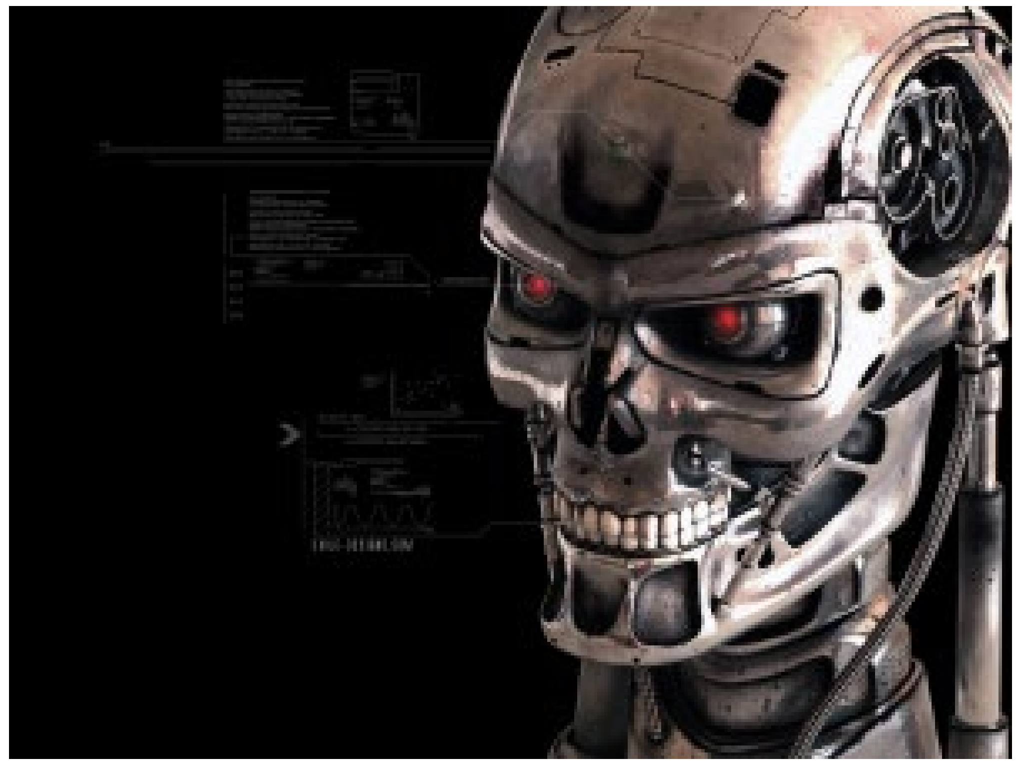
Course Overview (cont.)

- ***Genetic Algorithms.*** Introduction to genetic algorithms and their use in optimization problems.



Course Overview (cont.)

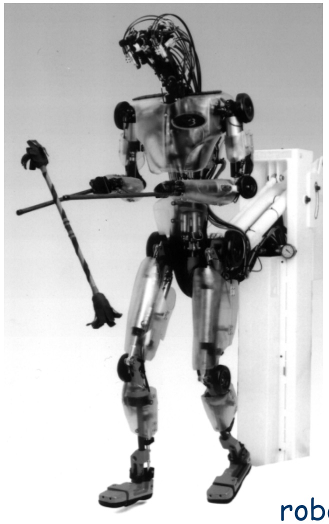
- *AI philosophy*
- *Ethics*
- *Safety*



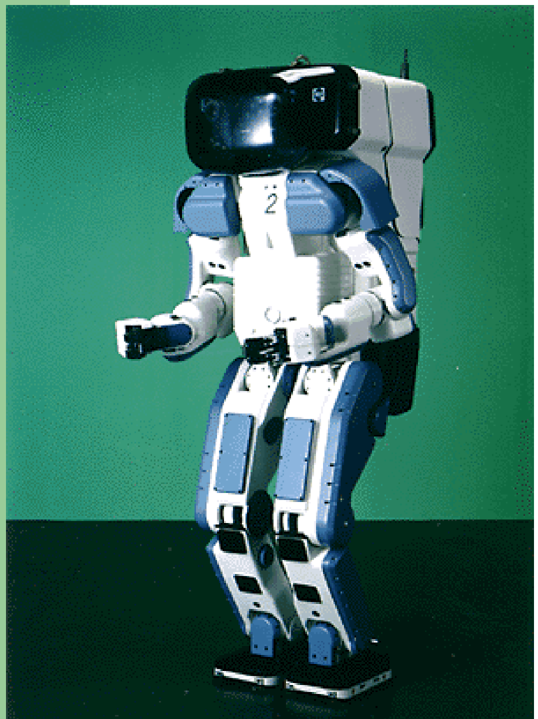
Course Overview (cont.)

What challenges remain?

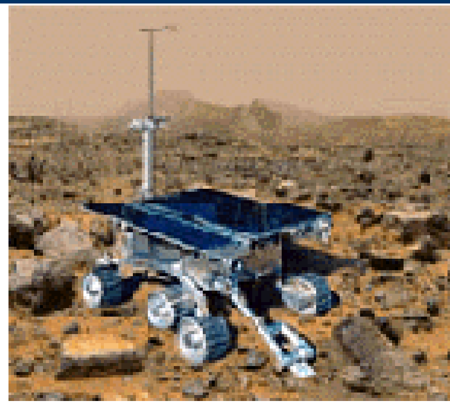
- ***Towards intelligent machines.*** The challenge of robots: with what we have learned, what hard problems remain to be solved? Different types of robots. Tasks that robots are for. Parts of robots. Architectures. Configuration spaces. Navigation and motion planning. Towards highly-capable robots.
- ***Overview and summary.*** What have we learned. Where do we go from here?



Why study AI?



Labor



Science

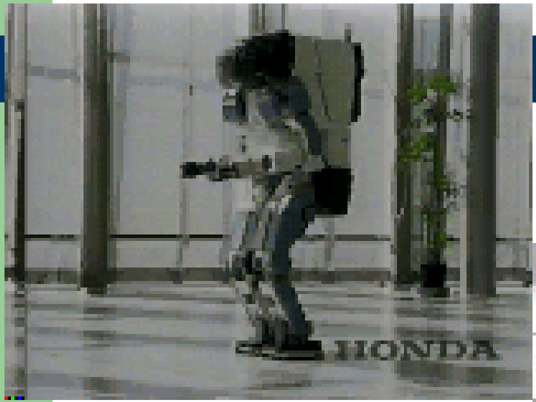
Search engines

Medicine/
Diagnosis

Appliances

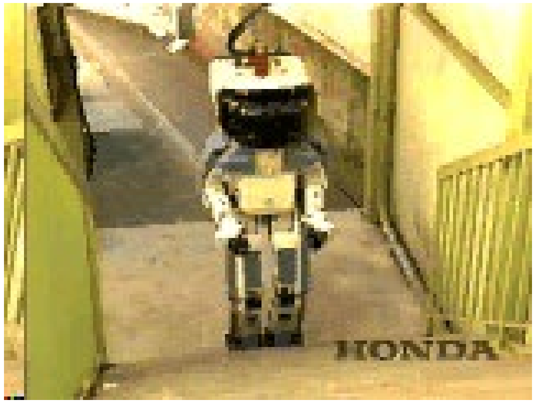
What else?

Honda Humanoid Robot



Walk

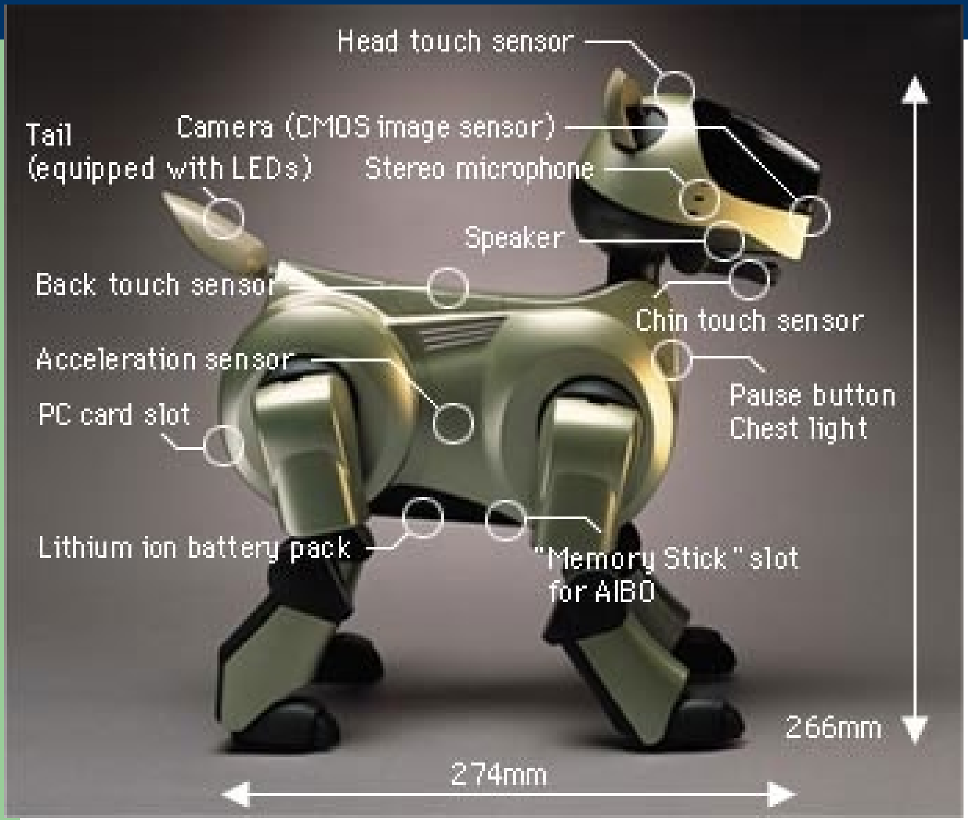
Turn



Stairs

http://world.honda.com/robot/

Sony AIBO



http://www.aibo.com

Natural Language Question

http://aimovie.warnerbros.com http://www.ai.mit.edu/projects/infolab/

Robot Teams

USC robotics Lab

What is AI?

The exciting new effort to make computers think … *machine with minds,* in the full and literal sense" (Haugeland 1985)	"The study of mental faculties through the use of computational models" (Charniak et al. 1985)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990)	A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkol, 1990)

Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that act rationally

What is AI again?: descriptive approach

- Although the term of AI has been widely used for quite a long time with steadily increasing amount of research and applications, there is no anonymously accepted definition. AI can mean many things to different people and various techniques are considered as belonging to AI.
- The term coined in 1956 by J. McCarthy at MIT
- Two branches: engineering discipline dealing with the creation of intelligent machines and empirical science concerned with the computational modelling of human intelligence
- The goal of AI is developing methods, which allow producing thinking machines that can solve problems
- Which problems?

- ill-defined and ill-structured
- complicated taxonomy or classifying
- Combinatorial optimisation

What is AI again?:

- The great variety of AI techniques have been developed and applied over the history for solving the problems mentioned above.
- Some of these methodologies are"conventional" or "old" methods (1950s):

- search algorithms,
- Probabilistic reasoning,
- natural language processing,
- belief networks, etc.

- Others are "new" (1960s) – soft computing and computational intelligence

What is AI again?
Systematic approach

- **Four Categories of Systemic Definitions**
  - **1. Think like humans**
  - **2. Act like humans**
  - **3. Think *rationally***
  - **4. Act *rationally***

What is AI again? Systematic approach

- Thinking Like Humans
  - *Machines with minds* (Haugeland, 1985)
  - Automation of "decision making, problem solving, learning…" (Bellman, 1978)
- Acting Like Humans
  - *Functions* that *require intelligence when performed by people* (Kurzweil, 1990)
  - Making computers do things *people currently do better* (Rich and Knight, 1991)
- Thinking Rationally
  - Computational models of mental faculties (Charniak and McDermott, 1985)
  - Computations that make it possible to *perceive*, *reason*, and *act* (Winston, 1992)
- Acting Rationally
  - Explaining, emulating intelligent behavior via computation (Schalkoff, 1990)
  - Branch of CS concerned with automation of intelligent behavior (Luger and Stubblefield, 1993)

What tasks require AI?

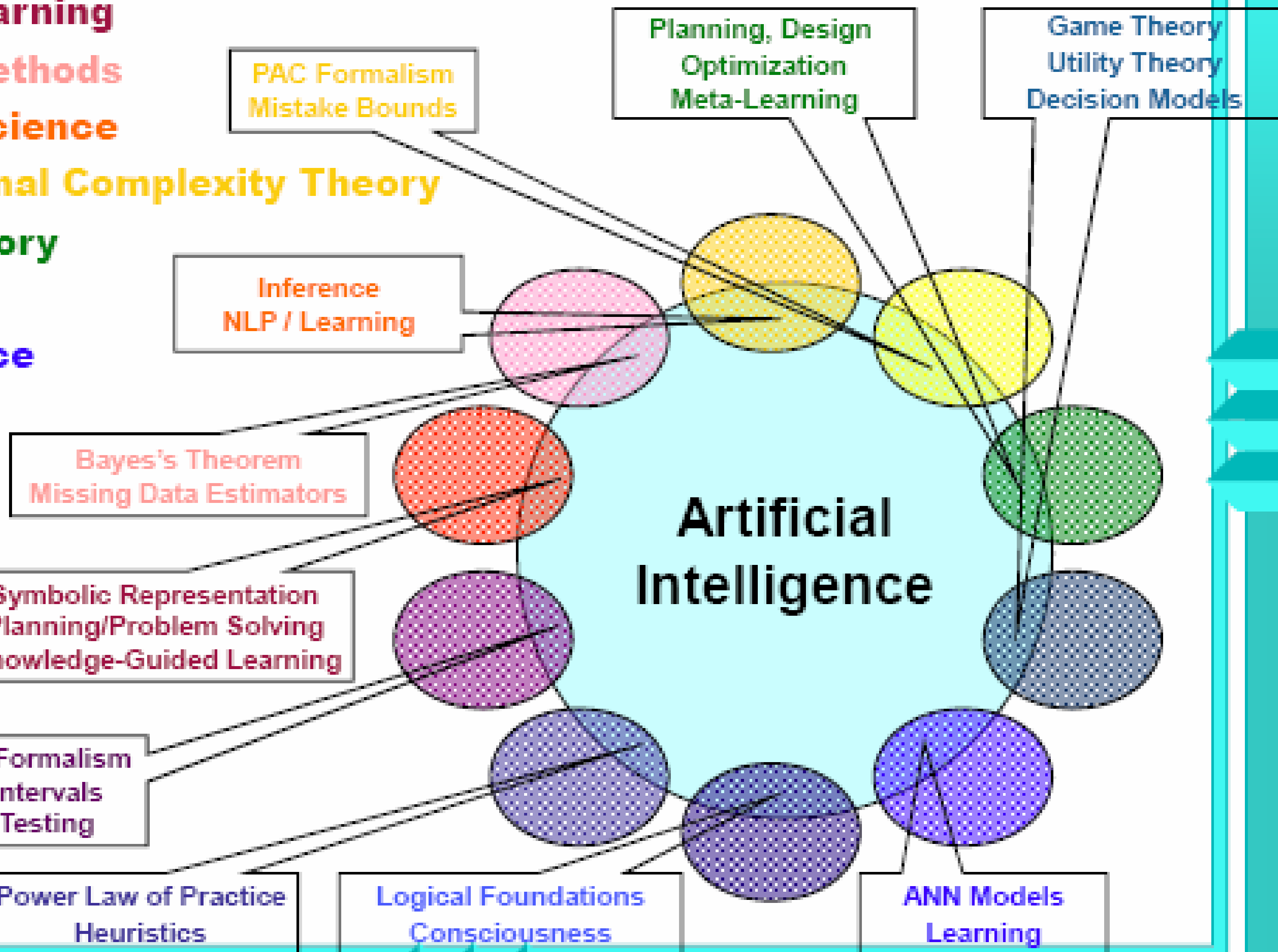
- Tasks that require AI:
  - Solving a differential equation
  - Brain surgery
  - Inventing stuff
  - Playing Jeopardy
  - Playing Wheel of Fortune
  - What about walking?
  - What about grabbing stuff?
  - What about pulling your hand away from fire?
  - What about watching TV?
  - What about day dreaming?

AI prehistory

Philosophy	logic, methods of reasoning
	mind as physical system
	foundations of learning, language, rationality
Mathematics	formal representation and proof
	algorithms, computation, (un)decidability, (in)tractability
	probability
Psychology	adaptation
	phenomena of perception and motor control
	experimental techniques (psychophysics, etc.)
Economics	formal theory of rational decisions
Linguistics	knowledge representation
	grammar
Neuroscience	plastic physical substrate for mental activity
Control theory	homeostatic systems, stability
	simple optimal agent designs

Relevant Disciplines

- Machine Learning
- Bayesian Methods
- Cognitive Science
- Computational Complexity Theory
- Control Theory
- Economics
- Neuroscience
- Philosophy
- Psychology
- Statistics



Questions

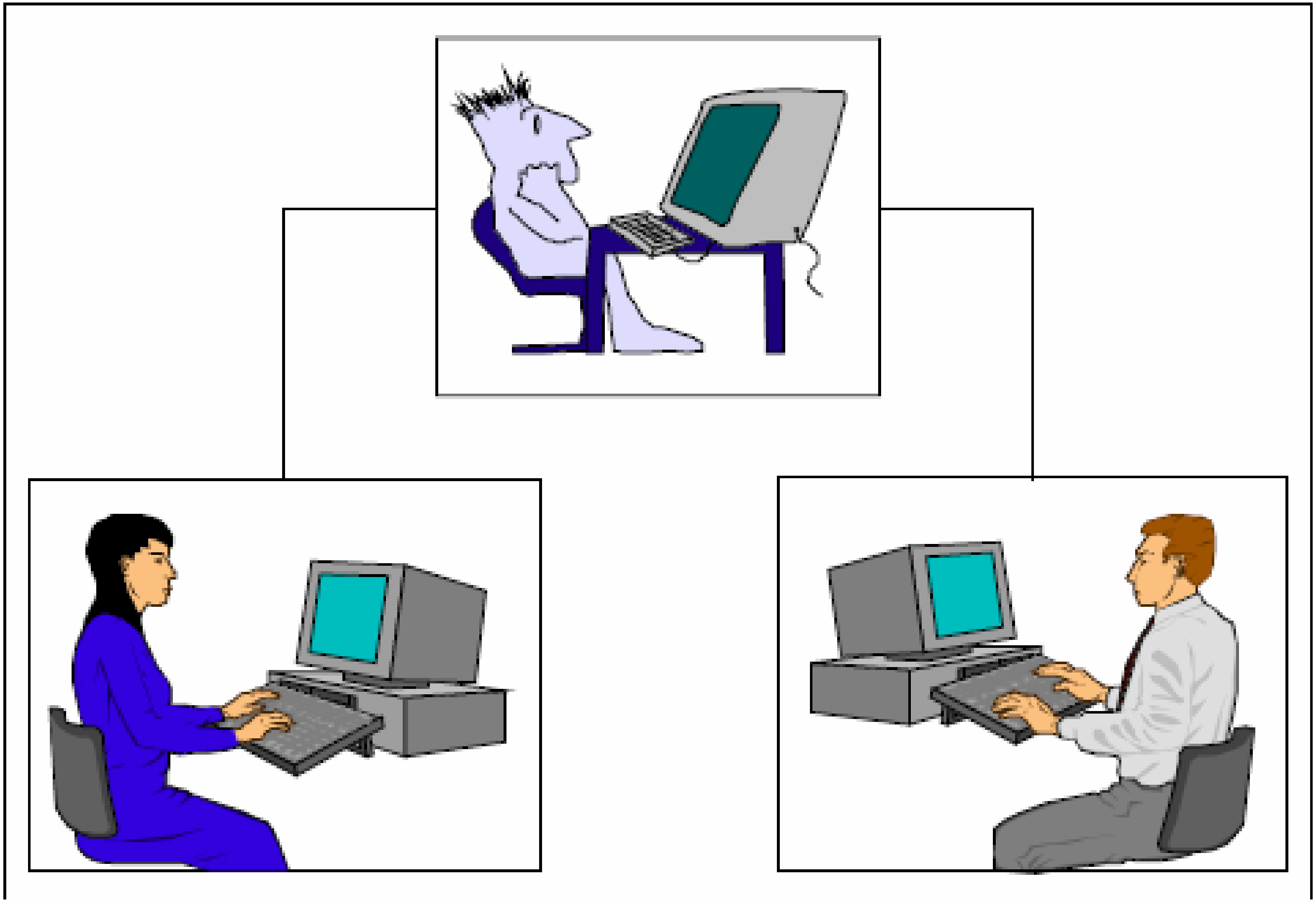
- What tasks are machines good at doing that humans are not?
- What tasks are humans good at doing that machines are not?
- What tasks are both good at?
- What does it mean to learn?
- How is learning related to intelligence?
- What does it mean to be intelligent? Do you believe a machine will ever be built that exhibits intelligence?
- Have the above definitions changed over time?
- If a computer were intelligent, how would you know?
- What does it mean to be conscious?
- Can one be intelligent and not conscious or vice versa?

One of the most significant papers on machine intelligence, ***"Computing Machinery and Intelligence"***, was written by the British mathematician ***Alan Turing*** over fifty years ago . However, it still stands up well under the test of time, and the Turing's approach remains universal.

He asked: ***Is there thought without experience? Is there mind without communication? Is there language without living? Is there intelligence without life?*** All these questions, as you can see, are just variations on the fundamental question of artificial intelligence, ***Can machines think?***

- Turing did not provide definitions of machines and thinking, he just avoided semantic arguments by inventing a game, the ***Turing Imitation Game***.
- The imitation game originally included two phases. In the first phase, the interrogator, a man and a woman are each placed in separate rooms. The interrogator's objective is to work out who is the man and who is the woman by questioning them. The man should attempt to deceive the interrogator that *he* is the woman, while the woman has to convince the interrogator that *she* is the woman.

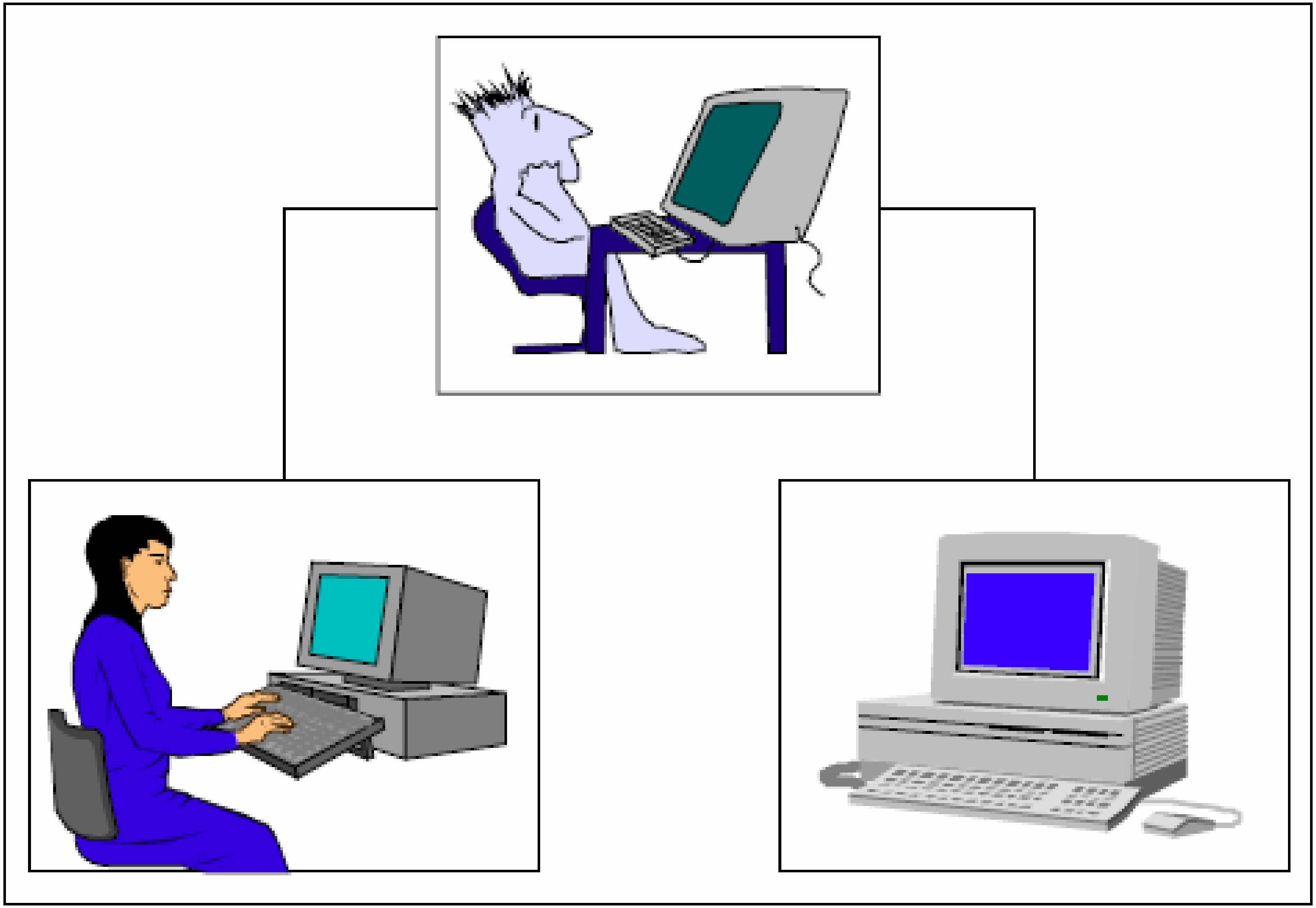
Turing Imitation Game: Phase 1



Turing Imitation Game: Phase 2

- In the second phase of the game, the man is replaced by a computer programmed to deceive the interrogator as the man did. It would even be programmed to make mistakes and provide fuzzy answers in the way a human would. If the computer can fool the interrogator as often as the man did, we may say this computer has passed the intelligent behaviour test.

Turing Imitation Game: Phase 2



The Turing test has two remarkable qualities that make it really universal.

- By maintaining communication between the human and the machine via terminals, the test gives us an objective standard view on intelligence.
- The test itself is quite independent from the details of the experiment. It can be conducted as a two-phase game, or even as a single-phase game when the interrogator needs to choose between the human and the machine from the beginning of the test.

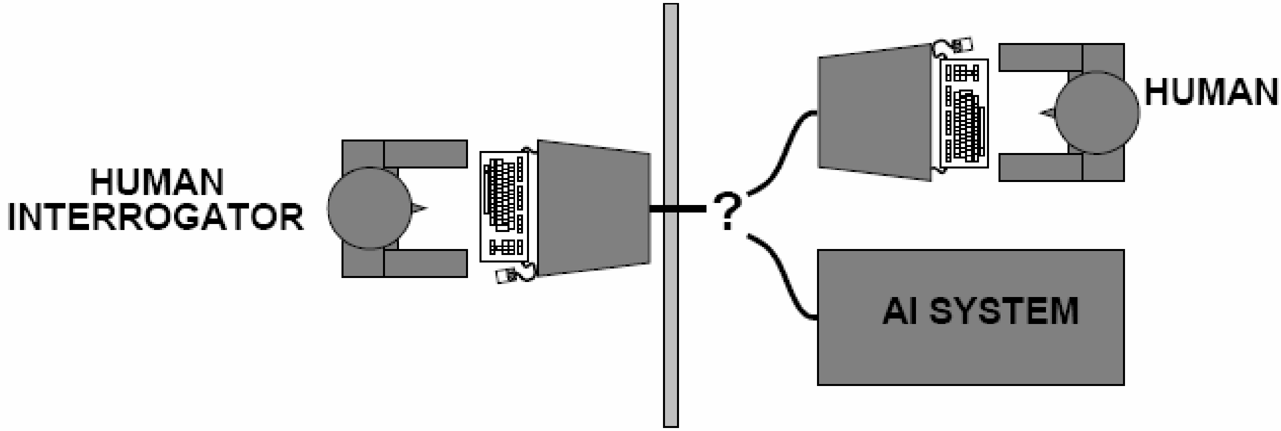
- Turing believed that by the end of the 20th century it would be possible to program a digital computer to play the imitation game. Although modern computers still cannot pass the Turing test, it provides a basis for the verification and validation of knowledge-based systems.
- **A program thought intelligent in some narrow area of expertise is evaluated by comparing its performance with the performance of a human expert.**
- To build an intelligent computer system, we have to capture, organise and use human expert knowledge in some narrow area of expertise.

Acting humanly: The 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

Problem: Turing test is not **reproducible**, **constructive**, or amenable to **mathematical analysis**

Thinking humanly: Cognitive Science

1960s "cognitive revolution": information-processing psychology replaced prevailing orthodoxy of behaviorism

Requires scientific theories of internal activities of the brain

- What level of abstraction? "Knowledge" or "circuits"?
- 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

Both share with AI the following characteristic:

the available theories do not explain (or engender) anything resembling human-level general intelligence

Hence, all three fields share one principal direction!

Thinking rationally: Laws of Thought

Normative (or prescriptive) rather than descriptive

Aristotle: what are correct arguments/thought processes?

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

Direct line through mathematics and philosophy to modern AI

Problems:
1) Not all intelligent behavior is mediated by logical deliberation
2) What is the purpose of thinking? What thoughts **should** I have
out of all the thoughts (logical or otherwise) that I **could** have?

Acting rationally

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

Aristotle (Nicomachean Ethics):

> Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good

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:

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

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**

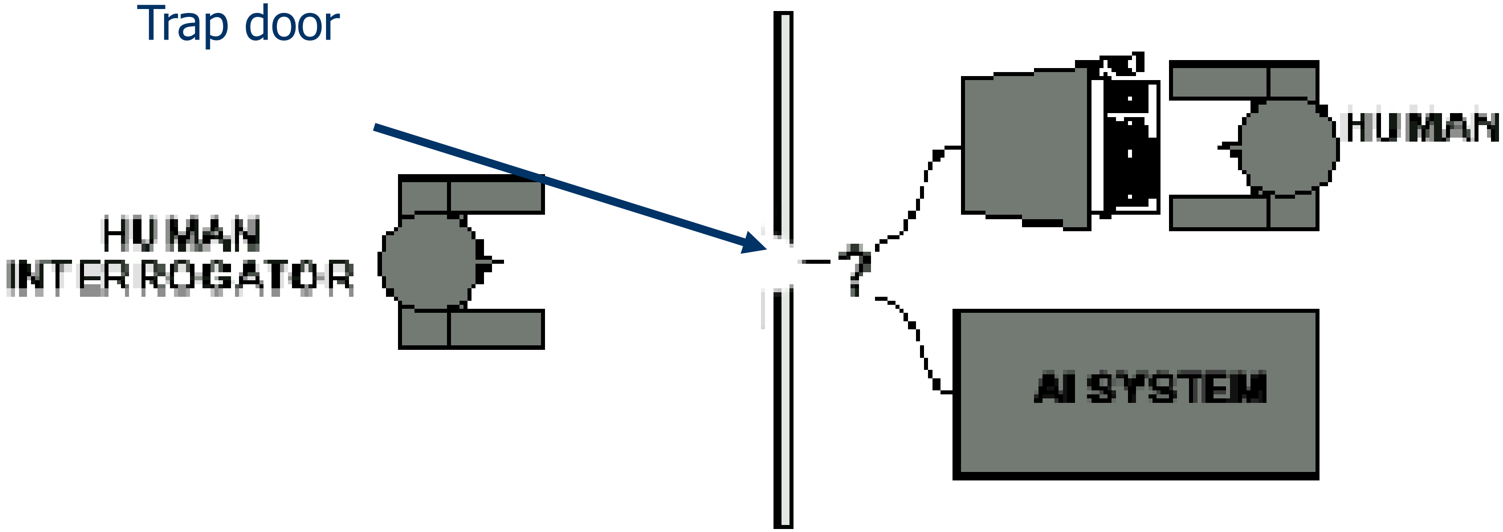
$\rightarrow$ design best program for given machine resources

Acting Humanly: The Full Turing Test

<u>Problem:</u>

What about physical interaction with interrogator and environment?

Trap door



What would a computer need to pass the Turing test?

- Natural language processing: to communicate with examiner.
- Knowledge representation: to store and retrieve information provided before or during interrogation.
- Automated reasoning: to use the stored information to answer questions and to draw new conclusions.
- Machine learning: to adapt to new circumstances and to detect and extrapolate patterns.

What would a computer need to pass the Turing test?

- Vision (for Total Turing test): to recognize the examiner's actions and various objects presented by the examiner.
- Motor control (total test): to act upon objects as requested.
- Other senses (total test): such as audition, smell, touch, etc.

How to achieve AI?

- How is AI research done?
- AI research has both theoretical and experimental sides. The experimental side has both basic and applied aspects.
- There are two main lines of research:
  - One is biological, based on the idea that since humans are intelligent, AI should study humans and imitate their psychology or physiology.
  - The other is phenomenal, based on studying and formalizing common sense facts about the world and the problems that the world presents to the achievement of goals.
- The two approaches interact to some extent, and both should eventually succeed. It is a race, but both racers seem to be walking. [**John McCarthy]**

Branches of AI

- **Logical AI**
- **Search**
- **Natural language processing**
- **pattern recognition**
- **Knowledge representation**
- **Inference** From some facts, others can be inferred.
- **Automated reasoning**
- **Learning from experience**
- **Planning** To generate a strategy for achieving some goal
- **Epistemology** Study of the kinds of knowledge that are required for solving problems in the world.
- **Ontology** Study of the kinds of things that exist. In AI, the programs and sentences deal with various kinds of objects, and we study what these kinds are and what their basic properties are.
- **Genetic programming**
- **Emotions???**
- …

The End!