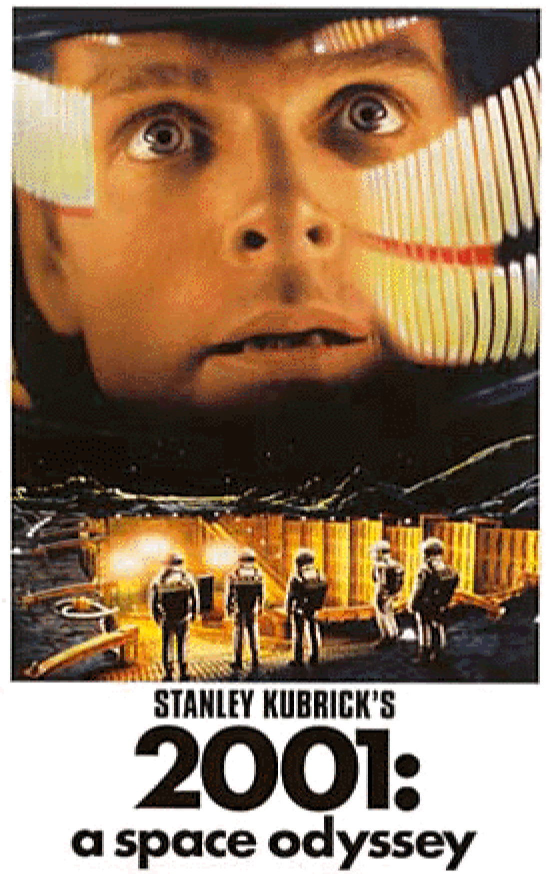
CSE 417: Artificial Intelligence

Spring 2015

Department of Computer Science and Engineering (CSE)
City University

Brief Intro

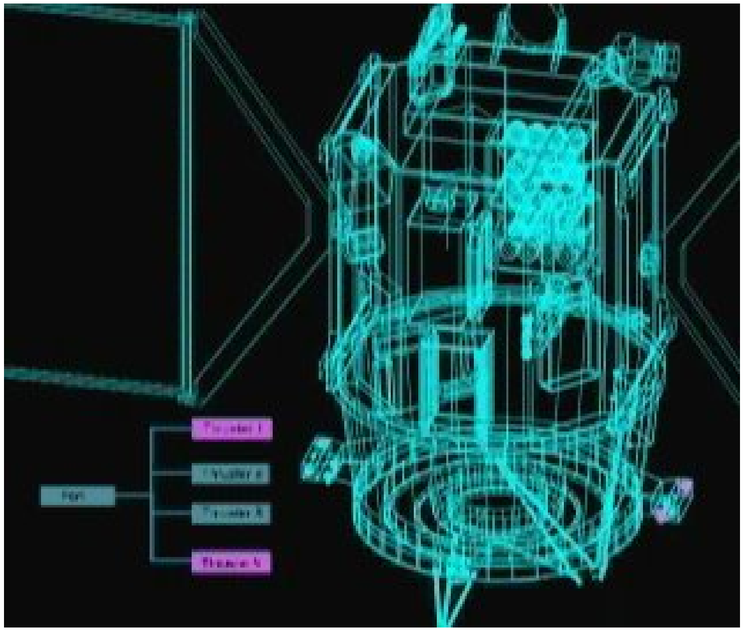
- Course that focuses on the study and design of **Intelligent Agents**



Artificial Intelligence in Real Life

NASA: Deep Space One spacecraft

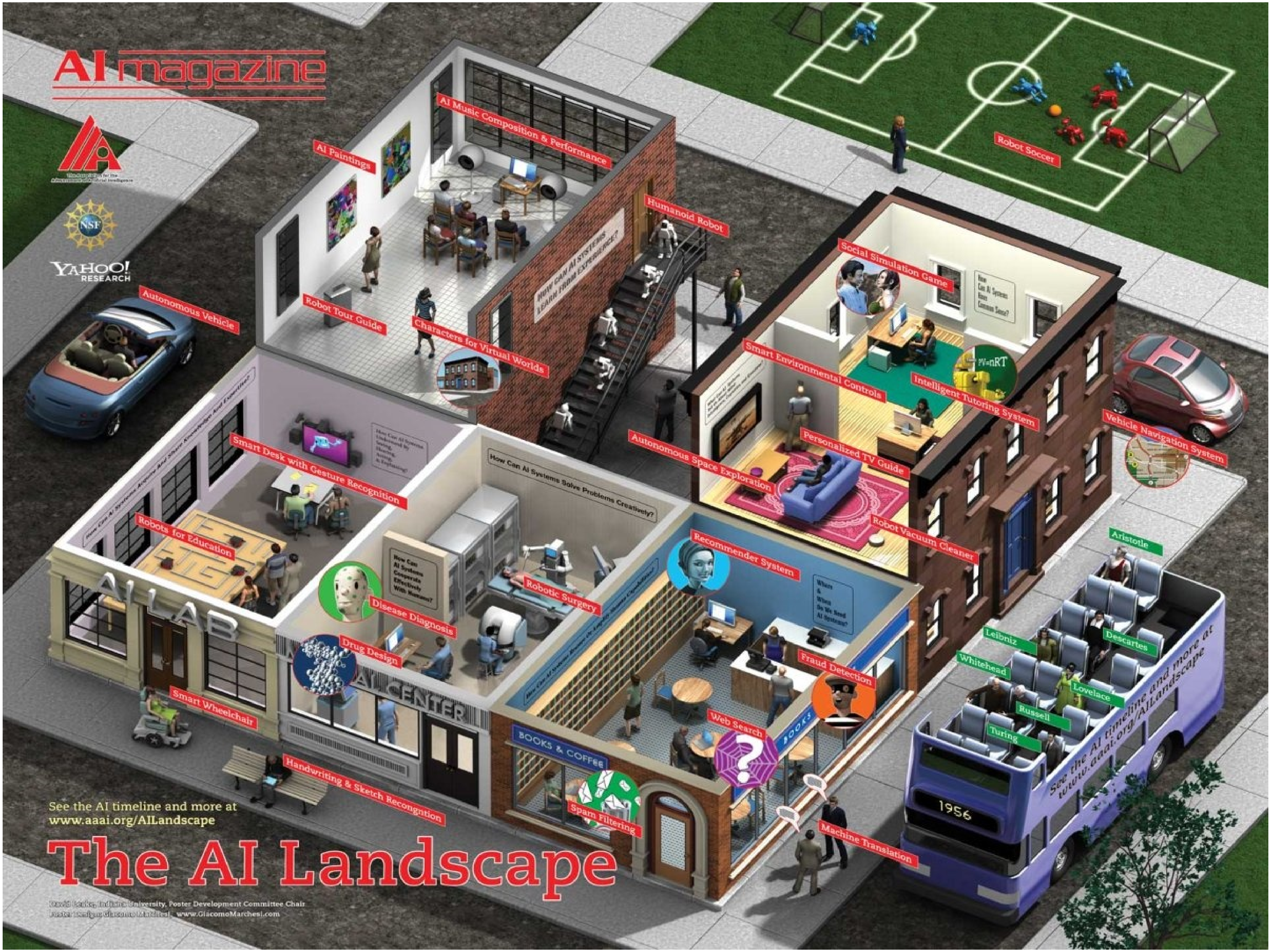
It's one small step in the history of space flight. But it was one giant leap for computer-kind, with a state of the art artificial intelligence system being given primary command of a spacecraft. Known as Remote Agent, the software operated NASA's Deep Space 1 spacecraft and its futuristic ion engine during two experiments that started on Monday, May 17, 1999. For two days Remote Agent ran on the on-board computer of Deep Space 1, more than 60,000,000 miles (96,500,000 kilometers) from Earth. The tests were a step toward robotic explorers of the 21st century that are less costly, more capable and more independent from ground control.



Artificial Intelligence in Real Life

A young science (≈ 50 years old)

- Exciting and dynamic field, impressive success stories
- Lots uncharted territory left
- “Intelligent” in specialized domains
- Many application areas



AI magazine
YAHOO! RESEARCH
NSF
AI Music Composition & Performance
AI Paintings
Humanoid Robot
How Can AI Systems Learn From Experience?
Robot Soccer
Social Simulation Game
How Can AI Systems Have Common Sense?
Autonomous Vehicle
Robot Tour Guide
Characters for Virtual Worlds
Smart Environmental Controls
Intelligent Tutoring System
PV=nRT
Vehicle Navigation System
Personalized TV Guide
Autonomous Space Exploration
Smart Desk with Gesture Recognition
How Can AI Systems Solve Problems Creatively?
Robot Vacuum Cleaner
Robots for Education
Recommender System
Where & When Do We Need AI Systems?
Aristotle
Robotic Surgery
How Can AI Systems Cooperate Effectively With Humans?
Disease Diagnosis
Leibniz
Descartes
Whitehead
Drug Design
Fraud Detection
Lovelace
Russell
Turing
AI LAB
AI CENTER
Smart Wheelchair
Web Search
BOOKS
BOOKS & COFFEE
Handwriting & Sketch Recongnition
Spam Filtering
Machine Translation
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www.aaai.org/AILandscape
The AI Landscape
University, Poster Development Committee Chair
www.GiacomoMarchesi.com

This Course

- “Breadth" introduction to artificial intelligence.
  - It will make a broad coverage of modern AI.
  - Focus on core concepts
    - Apply to wide variety of applications
    - Will mention example applications but without the gory details
- Suitable for those with
  - no AI background,
  - with only one undergraduate course in AI (or Machine Learning).
- Designed for computer science students, but is also suitable for students from other programs
  - (e.g., cognitive science, engineering)
  - Required: familiarity with algorithms, complexity, logic, probability

This Course (cont.)

- There are many specialized subfields in AI
- Each of them is a separate course (not all offered every year)
  - Machine learning
  - Computer vision
  - Natural language processing
  - Robotics
  - Intelligent User Interfaces
  - ....
- If you have already taken two or more AI-related courses, these specialized courses are likely more suitable for you than 502

Textbooks

- **Required course textbook:**
  - Artificial Intelligence : A Modern Approach, by Russell and Norvig, 3rd Edition (Prentice-Hall, 2010)
- **Recommended textbook:**
  - Artificial Intelligence: Foundations of Computational Agents. by D. Poole and A. Mackworth. Cambridge University Press, 2010
  - A selection of research papers from recent conferences/journals in Artificial Intelligence

What is Artificial Intelligence?

- Some definitions that have been proposed
  1. Systems that think like humans
  2. Systems that act like humans
  3. Systems that think rationally
  4. Systems that act rationally

Thinking Like Humans

Model the cognitive functions and behaviors of humans

- Human beings are our best example of intelligence
- We should use that example!

Some Examples

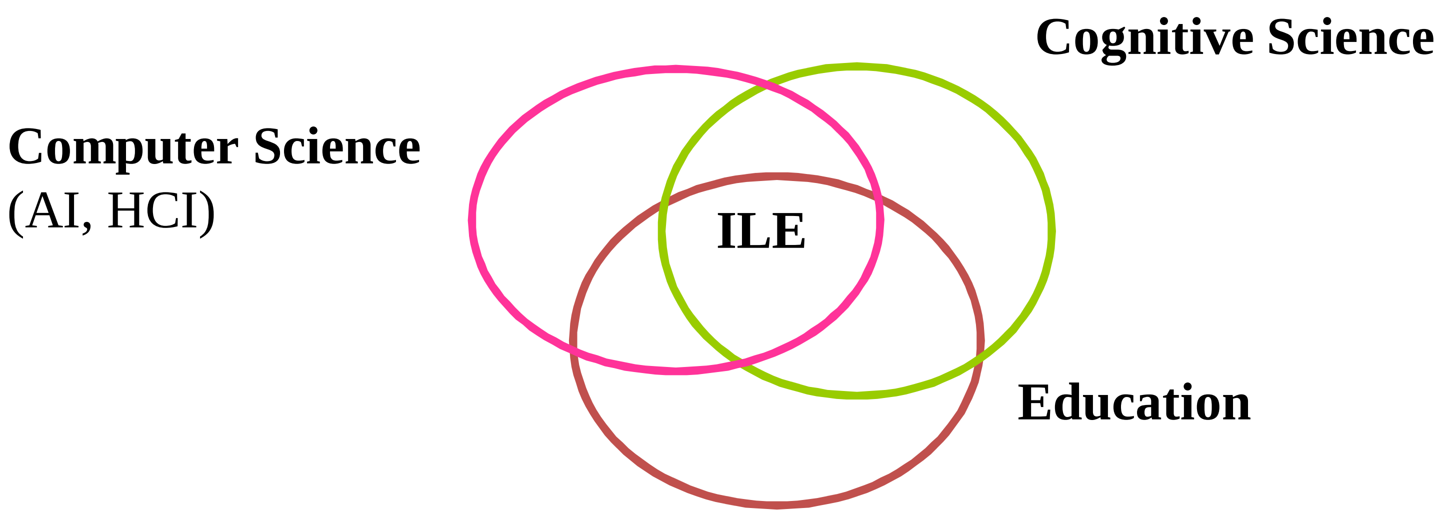
- Newell and Simon's GPS (General Problem Solver, 1961) to test means-end approach as general problem solving strategy

- John Anderson's ACT-R cognitive architecture (http://act-r.psy.cmu.edu/)
  - Anderson, J. R. & Lebiere, C. (1998). *The atomic components of thought*. Erlbaum;
  - Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y . (2004). An integrated theory of the mind. *Psychological Review 111*, (4). 1036-1060.

- SOAR cognitive architecture (http://sitemaker.umich.edu/soar)
  - Newell, A. 1990. *Unified Theories of Cognition*. Cambridge, Massachusetts: Harvard University Press.

ACT-R Models for Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS)



- Intelligent agents that support human learning and training
- By *autonomously* and *intelligently* adapting to learners' specific needs, like good teachers do

ACT-R Models for Intelligent Tutoring Systems

- One of ACT-R main assumptions:
    - Cognitive skills (procedural knowledge) are represented as production rules:

      IF *this situation is TRUE,* ***THEN*** *do X*

- ACT-R model representing expertise in a given domain:
    - set of production rules mimicking how a human would reason to perform tasks in that domain

- An ACT-R model for an ITS encodes all the reasoning steps necessary to solve problems in the target domain
    - Example: rules describing how to solve

$$5x+3=30$$

ACT-R Models for Intelligent Tutoring Systems

Eq: 5x+3=30 ; Goals: [Solve for x]

- Rule: To solve for x when there is only one occurrence, unwrap (isolate) x.

Eq:5x+3=30 ; Goals: [Unwrap x]

- Rule: To unwrap ?V, find the outermost wrapper ?W of ?V and remove ?W

Eq: 5x+3=30; Goals: [Find wrapper ?W of x; Remove ?W]

- Rule: To find wrapper ?W of ?V, find the top level expression ?E on side of equation containing ?V, and set ?W to part of ?E that does not contain ?V

Eq: 5x+3=30; Goals: [Remove "+3"]

- Rule: To remove "+?E", subtract "+?E" from both sides

Eq: 5x+3=30; Goals: [Subtract "+3" from both sides]

- Rule: To subtract "+?E" from both sides ….

Eq: 5x+3-3=30-3

Cognitive Tutors

- ITS that use Act-R models of target domains (e.g. algebra, geometry), in order to
  - trace student performance by firing rules and do a stepwise comparison of rule outcome with student action
  - Mismatches signal incorrect student knowledge that requires tutoring
- These models showed good fit with student performance, indicating value of the ACT-R theory
- Cognitive Tutors are great examples of AI success – used in thousands of high schools in the USA (http://www.carnegielearning.com/success.cfm)

Thinking Like Humans

Model the cognitive functions and behaviors of humans

- Human beings are our best example of intelligence
- We should use that example!
- But ... really hard to measure thought
  - We would have to spend most of our effort on studying how people's minds operate (Cognitive Science)
  - Rather than thinking about what intelligence ought to mean in various domains

What is Artificial Intelligence?

- Some definitions that have been proposed
  1. Systems that think like humans
  2. Systems that act like humans
  3. Systems that think rationally
  4. Systems that act rationally

Acting Like Humans

- Turing test (1950)
  - operational definition of intelligent behavior
  - Can a human interrogator tell whether (written) responses to her (written) questions come from a human or a machine?
- No system has yet passed the test
  - Yearly competition: http://www.loebner.net/Prizef/loebner-prize.html
  - Can play with best entry from 2008: Chatbot Elbot (www.elbot.com)
- Is acting like humans really what we want?
  - Humans often think/act in ways we don't consider intelligent
  - Why?

So, Why Replicate Human Behavior, Including its “Limitations”?

- AI and Entertainment
  - E.g. *Façade*, a one-act interactive drama
    http://www.quvu.net/interactivestory.net/#publications
- Sometime these limitations can be useful, e.g.
  - Supporting Human Learning via teachable agents

    (Leelawong, K., & Biswas, G. Designing Learning by Teaching Agents: The Betty's Brain System, *International Journal of Artificial Intelligence in Education*, vol. 18, no. 3, pp. 181-208, 2008

What is Artificial Intelligence?

- Some definitions that have been proposed
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Thinking Rationally

- Rationality**:** an abstract ideal of intelligence, rather than “whatever humans think/do”
  - Ancient Greeks invented syllogisms: argument structures that always yield correct conclusions given correct premises
  - This led to logic, and probabilistic reasoning which we'll discuss in this course

- Is rational thought enough?
  - A system that only thinks and doesn’t do anything is quite useless
  - Any means of communication would already be an action
  - And it is hard to measure thought in the first place …

Acting Rationally

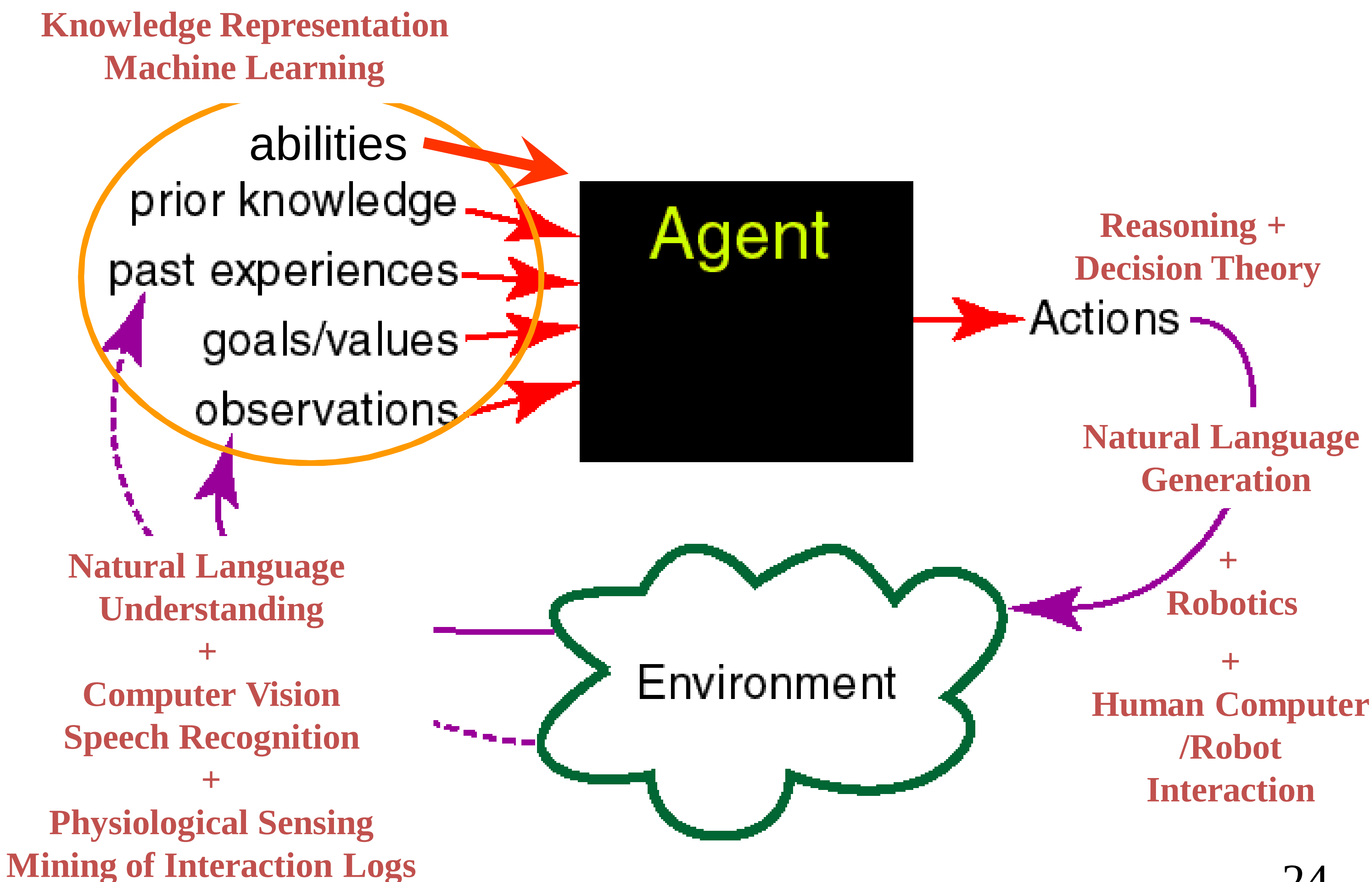
We will emphasize this view of AI

- Rationality is more cleanly defined than human behaviour, so
  - it's a better design objective
  - in cases where human behaviour is not rational, often we'd prefer rationality
    - Example: you wouldn't want a shopping agent to make impulsive purchases!
  - And once we have a rational agent, we can always tweak it to make it irrational!
- It's easier to define rational action than rational thought

AI as Study and Design of Intelligent Agents

- Intelligent agents: artifacts that act rationally in their environment
  - Their actions are appropriate for their goals and circumstances
  - There are flexible to changing environments and goals
  - They learn from experience
  - They make appropriate choices given perceptual limitations and limited resources
- This definition drops the constraint of *cognitive plausibility*
  - Same as building flying machines by understanding general principles of flying (aerodynamic) vs. by reproducing how birds fly
- Normative vs. Descriptive theories of Intelligent Behavior

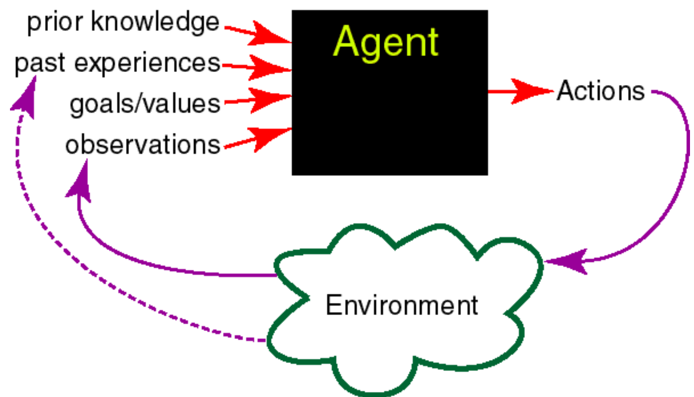
Intelligent Agents in the World



Robots vs. Other Intelligent Agents

- In AI, artificial agents that have a physical presence in the world are usually known as robots
  - Robotics is the field primarily concerned with the implementation of the physical aspects of a robot
    - I.e., perception of and action in the physical environment
    - Sensors and actuators
- Agents without a physical presence: software agents
  - E.g. desktop assistants, decision support systems, web crawlers, text-based translation systems, intelligent tutoring systems, etc
  - They also interact with an environment, but not the physical world
- Software agents and robots
  - differ in their interaction with the environment
  - share all other fundamental components of intelligent behavior

Representation and Reasoning



To use these inputs an agent needs to ***represent*** them

⇒ ***knowledge***

One of AI goals: specify how a system can

- Acquire and represent knowledge about a domain ***(representation)***
- Use the knowledge to solve problems in that domain ***(reasoning)***

What do we need to represent ?

- The environment /world :
  - What different configurations (states / possible worlds) can the world be in, and how do we denote them?
  - *E.g., Chessboard, Info about a patient, Robot Location*
- How the world works: we will focus on
  - Constraints: *sum of electric current into a node = 0*
  - Causal: *what are the causes and the effects of brain disorders?*
  - Actions' preconditions and effects: *when can I press this button? What happens if I press it?*

Representation and Reasoning (R&R) System

problem $\Longrightarrow$ representation $\Longrightarrow$ computation $\Longrightarrow$ representation $\Longrightarrow$ solution

- A representation language to describe
  - The environment
  - Problems (questions/tasks) to be solved
- Computational reasoning procedures to compute a solution to a problem
  - E.g., an answer, sequence of actions
- Choice of an appropriate R&R system depends on various dimensions, e.g. properties of
  - the environment, the type of problems, the agent, the computational resources, etc.

Representational Dimensions

- **Environment**

Deterministic Stochastic

Problem Type

Static

Sequential

We'll start by describing dimensions related to the problem and environment

Then we'll include in each cell the various R&R systems covered in the course, and discuss some more dimensions

Problem Types

- **Static:** finding a solution does not involve reasoning into the future (time is ignored)
  - One-step solution
- **Sequential:** finding a solution requires looking for a number of steps into the future, e.g.,
  - *Fixed horizon* (fixed number of steps)
  - *Indefinite horizon* (finate, but unknown number of steps)

Problem Types

- Constraint Satisfaction – Find state that satisfies set of constraints (static).
  - *e.g., what is a feasible schedule for final exams?*
- Answering Query – Is a given proposition true/likely given what is known? (static).
  - *e.g., does the patient suffers from viral hepatitis?*
- Planning – Find sequence of actions to reach a goal state / maximize outcome (sequential).
  - *e.g., Navigate through an environment to reach a particular location*

Representational Dimensions

- **Environment**

Problem Type

		Deterministic	Stochastic
Static	Constraint Satisfaction		
	Query		
Sequential	Planning		

Deterministic vs. Stochastic (Uncertain) Environment

- **Sensing Uncertainty**: Can the agent fully observe the current state of the world?

	Sensing Uncertainty?
Doctor's diagnosis	yes
Poker	yes
Chess	NO

- **Effect Uncertainty**: Does the agent know for sure what the effects of its actions are?

	Effect Uncertainty?
Soccer Player Kick	yes
Teacher's explanation	yes
Chess	NO

Deterministic vs. Stochastic Domains

- Historically, AI has been divided into two camps:
  - those who prefer representations based on logic
  - those who prefer probability.

However: Some of the most exciting current research in AI is actually building bridges between these camps.

Representational Dimensions

- **Environment**

Deterministic Stochastic

Problem Type

Static

Sequential

We described dimensions related to the problem and environment

Now we include in each cell the various R&R systems covered in the course, and discuss some more dimensions

Representational Dimensions

- **Environment**

Representation
Reasoning Technique

Problem Type

		Deterministic	Stochastic
Static	Constraint Satisfaction	*Vars + Constraints* Arc Consistency Search	
	Query	*Logics* Search	*Belief Nets* Variable Elimination Approximate Inference Temporal Inference
Sequential	Planning	*STRIPS* Search	*Decision Nets* Variable Elimination *Markov Processes* Value Iteration

Other Representational Dimensions

We've already discussed:

- Problem Types (Static vs. Sequential)
- Deterministic versus stochastic domains

Some other important dimensions

- Knowledge given versus knowledge learned from experience
- Representation scheme: Explicit state or features or relations
- Flat or hierarchical representation
- Goals versus complex preferences
- Single-agent vs. multi-agent

Knowledge given vs. knowledge learned from experience

- The agent is provided with a model of the world once and far all vs.
- The agent can learn how the world works based on experience
  - in this case, the agent often still does start out with some prior knowledge
- This course will provide an intro to
  - Supervised Machine Learning
  - Unsupervised Machine Learning
  - Reinforcement Learning

Explicit State vs Features

How do we model the environment?

- You can enumerate the **states** of the world.
- A state can be described in terms of **features**
  - Often a more natural description
  - 30 binary features (also called *propositions*) can represent

2^{30}=1,073,741,824 states

Explicit State vs Features

Mars Explorer Example

`Weather`	{S, C}
`Temperature`	[-40, 40]
`Longitude`	[0, 359]
`Latitude`	[0, 179]

One possible state

{S, -30, 320, 210}

Number of possible states (mutually exclusive)

2 x 81 x 360 x 180

Explicit State vs. Features vs. Relations

- States can be described in terms of objects and relationships
- There is a proposition for each relationship on each tuple (n > 1) of objects
- University Example:
  - Students (S) = {s1, s2, s3, …, s200)
  - Courses (C) = {c1, c2, c3, …, c10}
  - Registered (S, C)

  - Number of Relations: 1
  - Number of Propositions: 200*10
  - Number of States: 2^{2000}

Flat vs. hierarchical

- Should we model the whole world on the same level of abstraction?
  - Single level of abstraction: flat
  - Multiple levels of abstraction: hierarchical
- *Example: Planning a trip from here to a resort in Cancun*

  Going to the airport
  - ***Take a cab***
    - ***Call a cab***
      - ***Lookup number***
      - ***Dial number***
    - ***Ride in the cab***
    - ***Pay for the cab***

  Check in

  ....
- This course: mainly flat representations
  - Hierarchical representations required for scaling up.

Goals vs. (complex) preferences

- An agent may have a goal that it wants to achieve, e.g.,
  - there is some state or set of states that the agent wants to be in
  - there is some proposition or set of propositions that the agent wants to make true
- An agent may have preferences
  - a preference/utility function describes how happy the agent is in each state of the world
  - Agent's task is to reach a state which makes it as happy as possible
- Preferences can be complex

What beverage to order?

- *The sooner I get one, the better*
- *Cappuccino yummier than Espresso, but…*

- This course: goals and simple preferences

Single-agent vs. Multi-agent domains

- Does the environment include other agents?
- If there are other agents whose actions affect us, it can be useful to explicitly model
  - their goals and beliefs,
  - how they react to our actions
- Other agents can be: cooperative, competitive, or a bit of both

- This course: only single agent scenario

Summary

Would like most general agents possible, but in this course we need to restrict ourselves to:

- Flat representations (vs. hierarchical)
- Knowledge given and intro to knowledge learned
- Goals and simple preferences (vs. complex preferences)
- Single-agent scenarios (vs. multi-agent scenarios)

We will look at

- Deterministic and stochastic domains
- Static and Sequential problems

•As see examples of representations using

- Explicit state or features or relations