AI
Lecture 1: Intro

Introduction

- Welcome to AI Class
- Text Book:
- Artificial Intelligence A Modern Approach (**Third Edition**) by Stuart Russell and Peter Norvig (by Pearson Education Inc.)
- Additional readings may be suggested over course
- Please prepare notes during class – Slides MAY NOT be accessible

A Rough Grading Structure… Thinking of

- 2 Mid Terms: 15% each = 30%
- 1 End Term: 30%
- 2-3 big assignments: 10% each (20-30%)
  - Would involve programming
- Plan for written assignments: 4-6(10%)
  - To decide if some of them should be in class or surprise assignments
  - Depends on if most people are receptive/attentive in class – Its your decision essentially
- Total: ~(30 + 30 + (20-30) + 10) = ~(90 – 100)%
  - This course is about systems that work in real world with so many uncertainties
  - Might as well start here ☺

Overview of topics we may cover (Will add/delete later)

- Introduction to AI
- Search techniques
- Constraint Satisfaction Problems (CSP)
- Probability Theory
- Bayesian Networks
- Decision Theory (MDPs, POMDPs intro)
- Topics in Learning
- May have guest lectures on Vision, NLP etc. OR introduce topics on Logic

What is AI ?

- Discussion
- Voluntary participation is ALSO encouraged !!!

Thinking humanely **Making machines that think like humans Activities associated with human thinking such as decision making, problem solving, learning,…**	**Thinking Rationally** **Computations that make it possible to perceive, reason and act**
Acting Humanely How to make computers perform functions that people typically do or are better at	Acting Rationally Design of intelligent agents that can act to achieve the best possible outcome or expected outcome

Thinking Humanely

- Machines that think like humans
- Q: How do humans think ?
- Called cognitive modeling approach
  - Computer models + Experiments from psychology
- **Cognition** is the set of all mental abilities and processes related to knowledge – attention, memory, judgment, reasoning, problem solving etc.
- An initial program named GPS (General Problem Solver) [Newell & Simon, 1959]
  - Emphasis on matching with human reasoning rather than just correctness

Thinking Rationally

- Need a mechanism to define what is right or rational thinking
- Laws of thought encoded using **logic**
- Logic based systems developed
  - Not everything in real world can be represented by logical notation ex: value of seeing a movie
  - Hard to model not so certain information
  - Becomes intractable pretty quickly

Acting Humanely

- Can a computer pass itself as a human – Turing Test
- Computer would need the following capabilities
  - Natural Language Processing
  - Knowledge Representation
  - Automated Reasoning
  - Machine Learning
  - Computer vision
  - Robotics

Acting Rationally

- Also called **rational agent** approach
- Acts to achieve the best outcome or best expected outcome under uncertainty
- More general than other definitions, more amenable to development
- Perfect rationality may be computationally intractable in many environments
- Limited rationality under computational constraints

How did AI evolve

- AI as a field evolved due to ideas and contributions from many fields
- **Philosophy**
  - Can formal rules be used to draw valid conclusions ?
  - How does the mind arise from a physical brain ?
  - Where does knowledge come from ?
  - How does knowledge lead to action ?

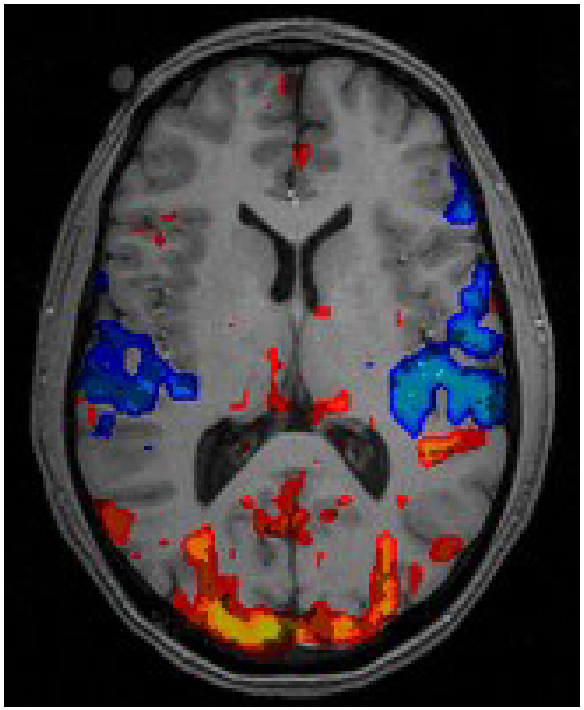
Mathematics

- **Mathematics**
  - What are the formal rules to draw valid conclusions?
  - What can be computed ?
  - How do we reason about uncertain information ?
- Some issues similar to philosophy but Math's provides rigor and a leap to formal science
  - Logic : Boolean Logic
  - Computation : Notion of algorithms, decidability, computability, tractability etc.
  - Theory of Probability : Bayes Rule for uncertainty reasoning

Economics

- **Economics**
  - How should we make decisions to maximize payoff ?
  - How should we do this when others may not go along ?
  - How should we do this when the payoff maybe far in future ?
- Economics is a study of **how people make choices** that lead to preferred outcomes
- Notion of utility was introduced
- Decision theory = Probability + Utility theory
- Payoffs from actions may not be immediate but a result of several actions in sequence – Operations Research

Neuroscience



- How do brains process information ?
- Study of nervous system esp. brain
- Long way to understand the brain
- fMRI (functional Magnetic Resonance Imaging) gives detailed images of brain activity
- Raw computational resources of supercomputers increasing rapidly (Processor speeds, memory available etc.)
- **Singularity** – Emergence of superhuman intelligence
  - Event where AI will exceed human intellectual capability and control
  - https://www.youtube.com/v/jY-cc1MLAI4
- https://www.youtube.com/v/oYqXQw2CryI

Psychology

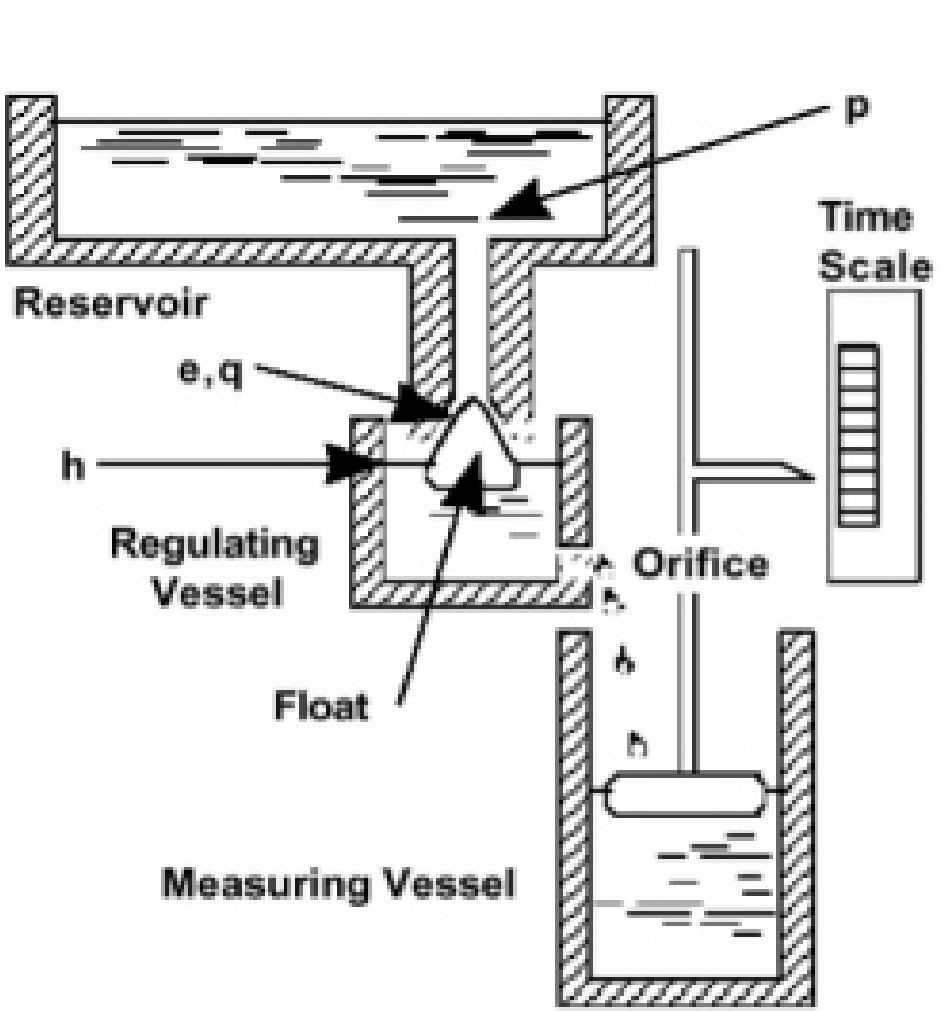
- How do humans and animals think and act ?
- Careful experiments that would perform carefully chosen tasks and introspect thought processes
  - Subjective in nature
- **Behaviorism**: Study objective measures of percepts and resulting actions
- Cognitive psychology : Views brain as information processing device
  - Stimulus translated to internal representation
  - Derive new representation through cognitive process
  - Retranslate back to action

Computer Engineering

- How can we build an efficient computer ?
- AI needs intelligence + an artifact ex: computer to act on the intelligence
- Efficient computing also involves s/w
- Ideas from AI in mainstream CS
- Time sharing, Interactive interpreters, Linked lists, concepts of symbolic (Lisp, Prolog), functional (built on lambda calculus) and object oriented programming (smalltalk) and others

Control Theory

- How can artifacts operate under their own control ?
- Considered first self-controlling device: Water clock with a regulator to maintain constant flow rate
- Others: Steam engine governor, thermostat



- Control theory formalizes self regulating mechanisms ex: minimize error computed as difference between current and goal state
- Problems relating to language, vision and planning may not be amenable to control theoretic techniques

Linguists

- How does language relate to thought ?
- Modern linguists and AI intersect in a field called Natural Language Processing
- Early on understanding language => understanding structure of sentences
- Requires understanding of subject matter and context
  - Knowledge representation

Pre-cursor to AI (1943-55)

- Model of Artificial Neurons [McCulloch and Pitts, 1943]
  - Showed any computable function could be computed by some network of connected neurons
- A simple updating rule (Hebbian Learning) for modifying connection strengths between neurons [Donald Hebb, 1949]
- First neural network computer in 1950 [Marvin Minsky, Dean Edmonds]
- Turing Test by Alan Turing [1950]

Birth of AI

- Workshop in Dartmouth College in **1956**
- 2 month, 10 man study of artificial intelligence to be carried out
- **Basis of the study:** Any aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can simulate it
- Many of the attendees became key figures in AI
- Newell and Simon introduced Logic Theorist – Could prove theorems

AI as a new field

- Many fields have overlapping objectives with AI
- **Why need AI as a new field ?**

1. AI from the start embraced idea of duplicating human faculties such as creativity, self-improvement and language use
2. AI was clearly a branch of CS with emphasis on computer simulations
3. AI attempts to build machines that function autonomously in complex, challenging environments

Further developments

- Newell and Simon **GPS** (General Problem Solver) – Designed to imitate humans
  - Order in which program considered sub goals and possible actions similar to humans
  - Probably first program to embody thinking human approach
- Success of GPS led to formulation of **physical symbol system hypothesis** [1976]: It states a physical symbol system has the necessary and sufficient means for general intelligent action
  - Any system exhibiting intelligence must operate by manipulating data structures composed of symbols
  - Examples of Physical Symbol Systems: Formal logic (symbols like and, or, not, for all), Algebra (+, -, 1, 2, 3, x, y, z, …)etc.

Further developments

- Geometry Theorem Prover (1959)
- Solving checkers (1952)
- By 90's, checkers program beating humans
- Checkers solved by Jonathan Schaeffer in 2007 after **18 years** of computation (Chinook)
  - Will result in draw if no player makes mistake
- John McCarthy
  - Defined LISP
  - Time sharing concept
  - Described **Advice Taker** a hypothetical program that embodies key principles of knowledge representation and reasoning
    - Uses knowledge to search for solutions (ex: axioms to generate a plan to drive to airport)
    - Has formal explicit representation of world and axioms to deduce

Wake up slide

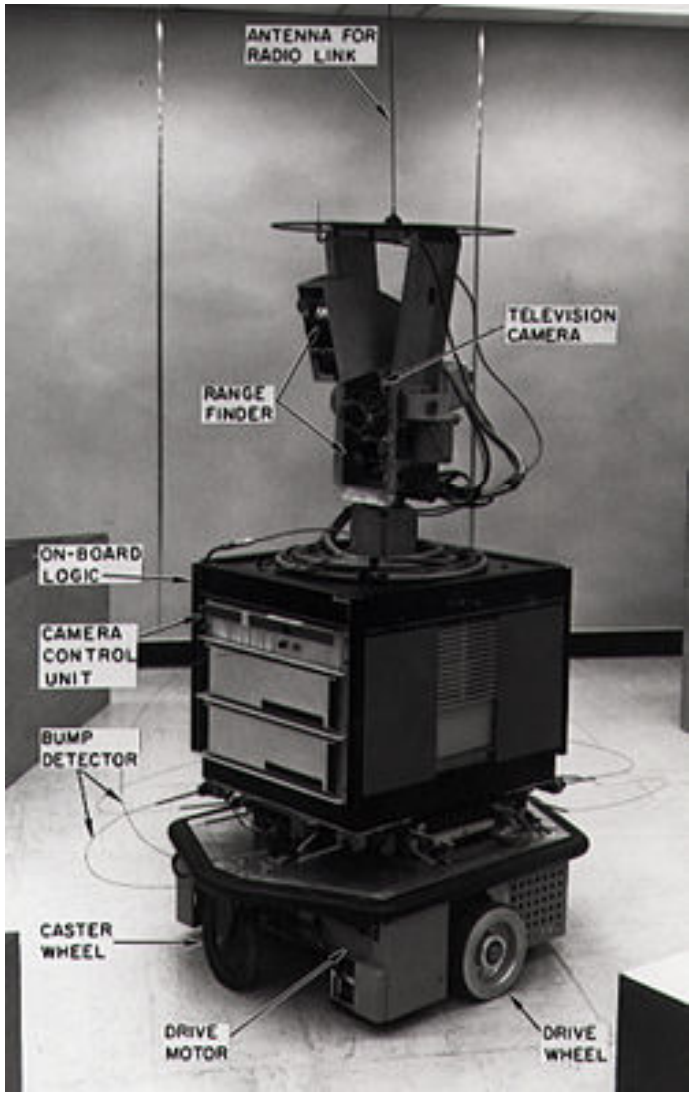
https://www.youtube.com/v/SlZMVAydqaE

WAKE UP

Checkers game

Shakey Robotics Project

- Developed at SRI (1966-72)
- First general purpose mobile robot
- Could analyze commands and break it down
- Notable results from the project:
  - **A* Search Algorithm** (will study later as a Search algorithm)
  - **Hough transform** (Feature extraction technique in Image Processing)
  - **Visibility graph method** (In computational geometry and robot motion planning)



Further developments

- Shakey robotics project at Stanford
  - Integrated logical reasoning and physical activity
  - https://www.youtube.com/v/RhrLHkVuerc
  - (Please go through this video carefully)
- Marvin Minsky developed an anti-logic outlook
  - Get programs to work
  - Developed solutions for microworlds (specific and limited domains)
  - Ex: Blocks World Problem
  - Set of solid blocks on a table top
  - Rearrange blocks in specific ways
  - Robot hand that picks one block at a time

Further Developments

- Instead of using general purpose knowledge, use more powerful domain specific knowledge
- **DENDRAL** program to infer molecular structure or **MYCIN** to diagnose blood infections at Stanford
- Knowledge intensive system with expertise derived from special purpose rules
- Useful to develop what we call expert systems
- Too much optimism led to AI Winter
  - Many companies shut down or downsized

MYCIN Expert System

- An early expert system that used AI to
  - Identify bacteria causing severe infections such as bacteremia and meningitis
  - Recommend antibiotics
  - Also used for diagnosis of blood clotting systems
- Was good in 69% percent of cases
- Developed in early 70's at Stanford
- **A simple inference engine + knowledge base of ~600 rules**
- Wasn't used in practice due to legal and ethical issues

AI in recent years

- Moving towards scientific method
  - Rigorous theorems or hard experimental evidence rather than intuition.
  - Examples include the following:
  - **Hidden Markov Models** for speech recognition
  - Principles of information theory in **machine translation** to translate text/speech from one machine language to another
  - **Bayesian networks** for reasoning with uncertainty
  - **Normative expert systems** based on laws of decision theory ex: Windows OS has diagnostic normative expert systems to correct problems

AI in recent years

- Emergence of intelligent systems
- More focus on **whole agent** problem
  - Ex: SOAR architecture [Newell, Laird & Rosenbloom]
- Bots in web-based applications
- Need to reorganize isolated subfields
  - Ex: Sensory systems are faulty
  - Need to handle uncertainty due to sensor faults while building reasoning and planning systems
- Emphasis on data rather than algorithms
- Availability of large data sets
- Ex: Trillions of words or millions of images on internet
- Learning methods gaining prominence

SOAR Architecture

- **Cognitive architecture** created by John Laird, Allen Newell and Paul Rosenbloom at CMU
- Cognitive architecture as a blue print for intelligent systems
  - Proposes computational processes that acts like a person
- Goal of SOAR is to handle full range of capabilities of an intelligent agent
- SOAR uses a **set of rules** (called productions) to govern its behavior (roughly of form if…then…)
- Uses a **learning technique** to transform a course of action taken into a new rule (Knows action to take when a similar situation is encountered)

Question of the day

- **What is Artificial Intelligence and why do you think you should study this field ?**

AI Applications

DARPA Grand Challenge

- Driverless robotic car **STANLEY** developed @ Stanford
- Won the first DARPA Grand Challenge in 2005, 132-mile course finished driverless
- Vehicle fitted with cameras, radar and laser rangefinders to sense environment
- Onboard software performs steering, braking and acceleration
- Google's driverless car was first issued license in the state of Nevada in US !!!
- Driverless cars are a reality sooner than later
- https://www.youtube.com/v/cdgQpa1pUUE

Speech Recognition

Autonomous Planning & Scheduling

- Most companies of late have a speech recognition system as a front desk receptionist
- Many times hard to tell if talking with a person or a human (Passed Turing Test ??)
  - [Note: Initial turing test was limited to text only channel]
- Humungous savings for companies using these systems

- **NASA's Remote Agent Program** : Autonomous planning program to control scheduling of operations for a spacecraft (Successor MAGPEN plans the daily operations for NASA's Mars Exploration Rovers)
- Generated plans from high level goals specified from ground and monitored execution of those plans – detecting, diagnosing and recovering from problems

Game Playing & Spam Fighting

- **IBM's DEEP BLUE** defeated world champion Garry Kasparov in chess match
- Smart heuristics + brute force ability of computer to perform computations
- Automated checkers, Robotic soccer agents and other

- **Spam** was a huge problem just a few years before
- Inboxes were inundated with spam mails
- Learning algorithms could differentiate between genuine and spam mails
- Static approaches may be circumvented by spammers

Robotics

- **iRobot Roomba** : Smart robot that vacuums rooms without knowing their maps or topology
- https://www.youtube.com/v/hZFlrYMrKCE

- **Boston Dynamic Big Dog** : A quadraped robot capable of traversing difficult terrain
  - Runs at 6.4 kmph, carrying 150kgs and climbing 35 degree incline
- Honda ASIMO (Advanced Step in Innovative Mobility) robot – A Humanoid robot

Robotics

- **Da Vinci** Robot for Spinal Surgery
  - Used in 100's of locations worldwide
  - Enables surgeons to be precise
  - Surgeon views actual image in real time
  - Minimally invasive surgery : Performed through tiny incisions instead of one large one
- https://www.youtube.com/v/C17-bGquIjI

Improving Security

- **Security via strategy randomization** (Paruchuri'07)
  - Gave birth to the **ARMOR** security system deployed at LAX airport since 2007
  - Allocate checkpoints on roads and canine patrol routes at terminals
- Game theoretic system that can explicitly model adversaries and reason about their strategies

- Principles behind ARMOR led to development of newer systems deployed at many locations [Prof. Tambe @ USC]
  - ARMOR Protect for US Coast Guard : Patrol randomization for boats and ships
  - ARMOR Iris for Federal Air Marshals : Randomize in-flight security personnel and many others…..
  - https://www.youtube.com/v/2f4XUy5c4N0