Artificial Intelligence

• More than any other subfield of computer science, artificial intelligence, or AI for short, has probably caught the imagination of the general public the most.

• Amidst science fiction visions of droids, robots, and evil computers taking over the world, the real-world subfield of AI includes a variety of concepts and endeavors, each of which hopes to enable machines to exhibit behavior that we would classify as “intelligent”.

• AI is also highly multidisciplinary, integrating psychology, neurology, linguistics, and other fields.

Central Concept: Agents

• AI focuses on the notion of an intelligent agent — a “device” (not necessarily physical) that responds to stimuli in a manner that we interpret as “intelligent”.

• AI seeks to develop agents that respond to their stimuli in a sensible and rational manner.
  ◊ Perception enables agents to “understand” or process incoming data effectively.
  ◊ Reasoning handles the formation of appropriate responses to the perceived stimuli.

• Another aspect of AI explores learning — the ability for an agent to improve upon its behavior over time, either through procedural or declarative knowledge.
The Turing Test

- The notion of “intelligent” agents begs the question — what counts as “intelligence?”
- An early (and still somewhat popular) benchmark was proposed by (who else) Alan Turing in 1950
- The idea behind the Turing test is to have an interrogator converse with another entity purely by typing and reading (not unlike today’s instant messaging)
- If the interrogator could not tell whether the entity was a human or machine, then the behavior exhibited can be viewed as “intelligent”

Strong vs. Weak AI

- The Turing test is based on the idea that intelligence is based on external behavior; however, some argue that intelligence lies in consciousness or sentience
- The weak AI camp contends that humans are fundamentally different from machines, and that machines can only act intelligently, not be intelligent
- The strong AI camp views that machines can ultimately achieve consciousness — it’s a matter of making the right parts and putting them together in the right way
- Where would you stand?
Perception

- Regardless of the final result (strong AI vs. weak AI), certain problems remain to be solved no matter what.
- *Perception* presents some key challenges: how can we make an agent “sense” its surroundings?
- Current technology has produced a wide variety of sensors that can quantify and digitize a variety of real-world phenomena:
  - *Light sensors* can measure and digitize brightness and color.
  - *Sound sensors* can measure and digitize sound pitch and volume; pairs of sound sensors at ultrasonic frequencies use triangulation to measure distances to physical objects.
  - *Touch and motion sensors* can measure and digitize physical pressure, speed, and movement.

- While machines can have a range of artificial “sensory organs,” they continue to lack the ability to *interpret* or *understand* these digitized sights and sounds.
- *Image understanding* seeks to develop algorithms that facilitate machine interpretation of raw digital images into meaningful objects, shapes, patterns, and symbols.
  - Image understanding can be viewed as two steps: *image processing* (manipulating and transforming pictures) and *image analysis* (deriving meaning from the resulting content).

- *Natural language processing* (NLP) is concerned with algorithms that can derive meaning from the languages that we use — English, Spanish, Latin, etc.
  - NLP also has a number of accepted phases: *syntactic analysis* identifies the roles taken by words and phrases; *semantic analysis* attaches meanings to the roles; and *contextual analysis* integrates associated information (surrounding words, real-world knowledge).
  - NLP assumes that the words are already represented digitally (i.e., text) — to understand the spoken word, we need *speech recognition* to translate digitized sound into text first.
Reasoning

- Once an agent’s environment has been adequately perceived, the agent must then do some reasoning in order to make decisions, solve problems, or exhibit intelligent behavior.

- Like perception, this area of AI also encompasses a variety of distinct approaches.

- Production systems represent problem solving as a set of states, one of which is the goal state, over which a control system applies rules or productions that move from one state to another, eventually reaching the goal.

- Inference engines constitute a form of production system, with sets of assertions making up a state, and inference rules serving as productions for deriving new assertions based on the previous ones.

  - Inference engines form the core of expert systems, which seek to simulate human reasoning for a specific domain or problem area.

- Drawing out a production system’s transitions from state to state yields a directed graph of all possible states; starting from an initial state outward forms a search tree of possibilities as we try to reach the goal.

- Still, many problems remain too large (chess!) for a system to exhaustively search every single possibility; to narrow our choices, systems often apply heuristics that quantifies how “good” a decision might be.
Knowledge Bases

- An issue that underlies both perception and reasoning is the concept of knowledge — what is it, and how can it be effectively represented within a machine?

- We can represent numbers, words, pictures, and sounds as bits…but how does one represent something like “Being sick reduces productivity” or “High reward sometimes motivates high risk”

- Beyond representation, can we make machines identify implied knowledge, or even derive or extract knowledge from pre-existing information?

[Machine] Learning

- Thoughts on representing and manipulating knowledge naturally leads to the idea that machines might be able to acquire new knowledge — a.k.a. machine learning

- A wide variety of approaches have been tried:
  - With imitation, a machine “watches” and records how a person accomplishes a task
  - Supervised training takes human choices that are made for some training set and uses these choices to influence the machine’s later behavior and decisions
  - In learning by reinforcement, machines are given a method to evaluate success or failure; the machine undergoes a trial-and-error phase and tracks successful attempts
  - Genetic algorithms try to develop solutions by “evolving” them from a pool of possibilities — candidate algorithms are repeatedly pruned then “re-mixed” into new “generations”
Artificial Neural Networks

- One approach to AI focuses on the nature of the machine itself: since we are trying to replicate the abilities of the human brain, then why not build a machine that resembles it?

- Artificial neural networks (ANNs) try to mimic the known structure of the human brain: interconnected cells that hold electrical charges and are influenced by the charges of the cells that surround them

- ANNs aren’t explicitly programmed but trained: test scenarios adjust how cells affect each other

Associative Memory

- The human brain is capable of association — moving quickly from one idea to another, such as a song to fond memories, or a scent to a particular individual

- This observation leads to associative memory, which is another approach to mimicking the brain

- Associative memory can be implemented using ANNs; the approach is to define “stable” and “unstable” cell values, and to let the network transition from one stable state to another in response to some input

◊ The idea here is to make certain input lead the ANN from one state to another, similar to how catching a scent may remind us of someone we know
Robotics

- Recall that many agents don’t have a physical presence — they can be pure software, such as a chess-playing program or an expert system.
- The area of robotics explores the idea of physical and possibly autonomous agents in the real world.
- Robots (from the Russian robota, for “work”) respond physically to physical stimuli (motion, sound, lights).
- All prior AI notions apply to robots, with the addition of mechanical subsystems for real-world interaction, which may or may not mimic the human body.