Notes for Meeting 1. Introduction and Background

What is artificial intelligence?

- This course is about the field of artificial intelligence (AI).
  What does that phrase mean?
- Artificial intelligence is the computational study of structures
  and processes that support intelligent behavior.
- The name accurately reflects the fact that most work in the area
  involves the creation of computational artifacts.
- But other names - complex information processing, computational
  intelligence, cognitive systems - have been proposed.

What does artificial intelligence study?

- Any scientific field must commit to some phenomena it aims to
  understand and explain.
- Any engineering field must commit to some capabilities that it
  aims to produce and support.
- Artificial intelligence focuses on phenomena and abilities that,
  informally, we recognize as intelligent in humans.
- However, this includes many (apparently) distinct functionalities.

What are some examples of intelligent behavior?

- Can you carry out transitive reasoning?
  [Joe shorter Sam, Bob taller Tom, Joe taller Bob, who is tallest?]
- Can you prove that two triangles are similar?
- Can you draw plausible inferences from a sentence like:
  "John needed money. He got his gun. He drove to the bank."
  Would you make different inferences from a sentence like:
  "John needed money. He got his gun. He drove to the pawn shop."
- Can you compute the sum of 647 and 359?
- Can you give directions to a familiar place?
- Can you follow such directions to reach the place? Can you adapt
  them if a road is closed?
- Can you solve crossword or sudoku puzzles?
- Can you carry out a dialogue to support joint activity?

Some questions about intelligence

- Can animals handle any of the tasks we just discussed?
- Can a young child handle any of the tasks just discussed?
- Are some aspects of intelligence be learned?
- Could intelligence be what makes us distinctively human?
- Should AI focus on these distinctive capabilities?

Why is it important to study intelligence?

- Basic science
  - Understanding the nature of mind is a grand challenge equivalent
    to understanding the universe, matter, life, and society.
  - Computational models of mental abilities can give insights into
    human psychology.
- Engineering
  - AI can support more effective educational processes
  - AI can automate or assist complex tasks
  - AI can provide more interactive entertainment

A brief history of artificial intelligence

- AI officially launched at 1956 Dartmouth Conference, which recently celebrated its 50th anniversary.
- That year also saw the first AI system and the first programming language for symbolic processing (the same year as Fortran).
- AI has been so successful that its influence is seldom recognized; its ideas underlie:
  - spreadsheets and tax software
  - digital road maps and route finders
  - data mining and recommender systems
- However, the past 20 years has seen AI diverge from some themes that guided early research, and that we will emphasize in class.

Artificial intelligence and high-level cognition

- Early AI research revolved around the study of high-level cognition.
- When we say that humans exhibit intelligence, we do not mean they can perceive objects, recognize concepts, or execute motor skills.
- Rather, we mean they can carry out multi-step reasoning, solve novel problems, and use natural language to interact with others.
- Recent AI work has moved away from these challenges or, at best, focused on greatly reduced versions of them.
- This shift has produced short-term gains in narrow areas, but it has not brought us closer to understanding the mind.

Symbolic representations and processes

- The central insight that launched AI was that computers are not just number crunchers, but rather general symbol manipulators.
- Intelligence is enabled by, and depends on, symbolic processing.
- This activity requires ways to represent symbolic structures, to interpret them, and to manipulate them.
- Much of AI’s five decades of progress has relied on advances in symbolic representations and mechanisms that operate on them.
- Recent excitement in AI about statistical approaches has not made this insight any less valid or important.

The role of knowledge in intelligent behavior

- Another important assumption in early AI was that knowledge plays a key role in high-level cognition.
- Studies of human experts revealed that their abilities came from domain-specific content acquired over time.
- Techniques for representing and utilizing such knowledge led to the subfield of expert systems.
- This produced many knowledge-based systems that business and government groups adopted to replace or augment human experts.
- These systems typically encoded knowledge in terms of modular symbolic structures.

Satisficing and heuristics in complex cognition

- Early AI research recognized that, when confronted with complex problems, a cognitive system cannot find optimal solutions.
- Any resource-limited agent must satisfice, that is, focus on finding acceptable solutions in reasonable time.
- Satisficing results naturally from the use of heuristic methods rather than algorithmic ones.
- Psychological studies have shown that people satisfice, and it is the only practical way for AI to approach complex cognitive tasks.
- The field’s increasing focus on finding optimal solutions in restricted settings does not counter these facts.

Artificial intelligence and cognitive psychology

- Much initial AI work was motivated by, and incorporated insights from, studies of human cognition.
- Examining high-level cognition in humans suggests challenge tasks for AI, as well as promising methods for machine cognition.
- Moreover, AI systems can serve as computational models of human cognitive processing.
- Most modern AI researchers have abandoned this connection, as have most cognitive psychologists.
- But the current divide between AI and psychology does not lessen the potential benefits of further interaction.

Complete cognitive systems

- Although early AI focused on components of intelligence, its aim was to develop complete cognitive systems.
- Many efforts focused on general mechanisms that could support such intelligent agents.
- Research on cognitive architectures began to explore ways to combine these components into unified theories of cognition.
- However, over the past 20 years, AI has become increasingly fragmented, with most studying components in isolation.
- This piecemeal emphasis, even when leading to commercial success, does not make AI’s original vision any less important.

High-level languages for intelligent systems

- Early AI research also favored developing high-level programming languages that could speed creation of intelligent systems.
- Some encodings, like list structures and rules, arise repeatedly in many aspects of cognition.
- Certain mechanisms, like relational pattern matching and heuristic search, also occur in many cognitive tasks.
- Embedding these ideas in high-level programming constructs supports compact code, rapid programming, and effective debugging.
- The current emphasis on Java and C, and their associated libraries, does not make these insights any less viable.

Summary of main themes

- Early research on artificial intelligence often favored:
  - focusing on challenging, high-level cognitive tasks
  - incorporating symbolic representations and processes
  - developing knowledge-based systems with domain expertise
  - using heuristic methods that satisfice on complex tasks
  - drawing on results from psychology for tasks and mechanisms
  - attempting to construct complete cognitive systems
  - using high-level programming languages to support development
- Recent AI work has often diverged from these themes, but they are still valid and we will emphasize them in this course.

Metaphors for research in AI and cognitive systems

- Artificial intelligence researchers draw on a number of distinct metaphors for mental processing:
  - Thinking as logical reasoning.
  - Thinking as search through a problem space.
  - Thinking as retrieval from memory.
- Each metaphor suggests different ways of thinking about the mind, emphasizes different tasks, and has different communities.
- These metaphors are not mutually exclusive and can be combined.
- All share the view that cognition involves symbolic processing, and they appear in both AI and cognitive psychology.

The mind and the brain

- Many identify the mind with the brain, but they are not the same.
- We can specify theories of the mind that are independent of the specific hardware or wetware on which they operate.
- A given program can run on many different types of computers; the same holds for cognitive systems.
- Chemistry predated quantum physics by 100 years, and the former still offers a useful level of description.
- This does not mean that brain science cannot suggest insights about the mind, but they are not required.

Emphases of the course

- Although the course focuses on integrated intelligent systems, we must still examine their component mechanisms.
- We will start with processes for inference, execution, and problem solving, then consider their use in high-level abilities.
- Exercises will embed these ideas in the context of a cognitive architecture for complex cognition.
- The course has a historical flavor, so many readings will involve classic papers and survey articles.
- Many early results on AI and cognitive systems are still valid and more important than recent developments.
- Exercises and project will emphasize the creation of intelligent agents that operate in virtual environments.

Details of course Operation

- Assignments include reading papers, preparing comments or questions, and discussing them; this is not a traditional lecture class.
- One simple Lisp exercise, six programming exercises using the Icarus language, Prolog, or Lisp, and one class project.
- Grading policy
  - Each student has a total of four free late days.
  - Once exhausted, 20 percent off per (fractional) day late.
- Auditors are welcome but should limit their class discussion.
- Offices and office hours
  - Pat Langley, BYENG 446
    - Mondays 6:15PM-7:15PM or by appointment
  - Glen Hunt, BYENG 443 AB

Assignments for meeting 2
Frameworks and metaphors for intelligent systems

Read the article:

- Newell, A., & Simon, H. A. (1976). Computer science as empirical enquiry: Symbols and search. Communications of the ACM, 19, 113-126.
- This paper introduces two key ideas:
  - The notion of physical symbol systems
  - The idea of heuristic search through a problem space
- Newell and Simon claim both are key features of intelligent systems.