Chapter 1:
Introduction to Artificial Intelligence

Agenda

- Introduction and overview of the module
- Introduction to Artificial Intelligence
- Applications of Artificial Intelligence
- History of AI

What is Artificial Intelligence?

"Intelligence: The ability to learn and solve problems" - *Webster's Dictionary.*

"Artificial intelligence (AI) is the intelligence exhibited by machines or software" - *Wikipedia.*

"The science and engineering of making intelligent machines" – *John McCarthy.*

"The study and design of *intelligent agents*, where an intelligent agent is a system that *perceives its environment* and takes actions that *maximize its chances of success*." - *Russel and Norvig AI book.*

What is Artificial Intelligence?

"Artificial Intelligence is the part of computer science concerned with designing intelligence computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior."

- Systems that think like Humans (*thought processes and reasoning*)
- Systems that think rationally (*thought processes and reasoning*)
- Systems that act like humans (*behavior*)
- Systems that act rationally (*behavior*)

- Different definitions of AI are given by different books/writers. These definitions can be divided into two dimensions.

Systems that think like Humans	System that think rationally
Systems that act like humans	Systems that act rationally

- Top dimension is concerned with **thought processes and reasoning**, where as bottom dimension addresses the **behavior**.

- The definition on the left measures the success in terms of fidelity of *human performance*, whereas definitions on the right measure an *ideal concept of intelligence*, which is called **rationality**.
- Human-centered approaches must be an empirical science, involving hypothesis and experimental confirmation. A rationalist approach involves a combination of mathematics and engineering.

Systems that think like humans

- "The exciting new effort to make computers think…..*machine with minds*, in the full and literal sense." (Haugeland, 1985)
- "[The automaton of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning….." (Bellman, 1978)

Systems that think rationally

- "The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)
- "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)

Systems that act like humans

- " The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)
- "The study of how to make computer do things at which, at the moment, people are better." (Rich and Knight, 1991)

Systems that act rationally

- "Computational Intelligence is the study of the design of intelligent agents." (Poole *et al*., 1998)
- "AI… is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Acting Humanly: The Turing Test Approach

- The **Turing test**, proposed by Alan Turing (1950) was designed to convince the people that whether a particular machine can think or not.
- He suggested a test based on indistinguishability from undeniably intelligent entities- human beings.
- **The test involves an interrogator who interacts with one human and one machine.**
- **Within a given time the interrogator has to find out which of the two the human is, and which one the machine.**
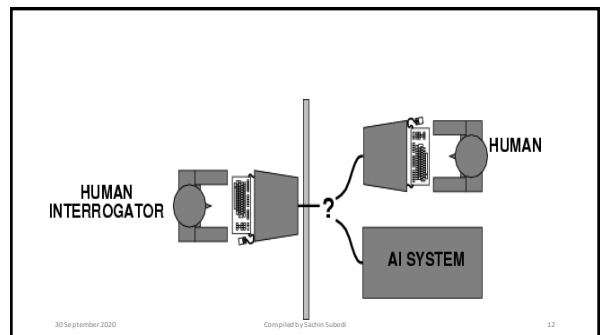
- The computer passes the test if a human interrogator after posing some written questions, cannot tell whether the written response come from human or not.
- To pass a Turing test, a computer must have following capabilities:
  - Natural Language Processing: Must be able to communicate successfully in English
  - Knowledge representation: To store what it knows and hears.
  - Automated reasoning: Answer the Questions based on the stored information.
  - Machine learning: Must be able to adapt in new circumstances.
- Turing test avoid the physical interaction with human interrogator. Physical simulation of human beings is not necessary for testing the intelligence.

- **The total Turing test** includes video signals and manipulation capability so that the interrogator can test the subject's perceptual abilities and object manipulation ability.
- To pass the total Turing test computer must have following additional capabilities:
  - Computer Vision: To perceive objects
  - Robotics: To manipulate objects and move

Thinking Humanly: Cognitive modeling approach

- If we are going to say that a given program thinks like a human, we must have some way of determining how humans think.
- We need to get inside the actual workings of human minds. There are two ways to do this:
  - **through introspection:** catch our thoughts while they go by
  - **through psychological experiments.**
- Once we have precise theory of mind, it is possible to express the theory as a computer program.
- The field of cognitive science brings together computer models from AI and experimental techniques from psychology to try to construct precise and testable theories of the workings of the human mind.

Think rationally: The laws of thought approach

- Aristotle was one of the first who attempt to codify the *right thinking* that is irrefutable reasoning process. He gave Syllogisms that always yielded correct conclusion when correct premises are given.
- For example:
  - Ram is a man
  - All men are mortal
    - Ram is mortal
- These law of thought were supposed to govern the operation of mind: This study initiated the field of logic.

- The logicist tradition in AI hopes to create intelligent systems using logic programming.
- However there are two obstacles to this approach.
  - First, It is not easy to take informal knowledge and state in the formal terms required by logical notation, particularly when knowledge is not 100% certain.
  - Second, solving problem principally is different from doing it in practice. Even problems with certain dozens of fact may exhaust the computational resources of any computer unless it has some guidance as which reasoning step to try first.

Acting Rationally: The rational Agent approach:

- Agent is something that acts.
- Computer agent is expected to have following attributes:
  - Autonomous control
  - Perceiving their environment
  - Persisting over a prolonged period of time
  - Adapting to change
  - And capable of taking on another's goal
- **Rational behavior**: doing the right thing.
- **The right thing**: that which is expected to maximize goal achievement, given the available information.
- **Rational Agent** is one that acts so as to achieve the best outcome or, when there is uncertainty, the best expected outcome.

- In the "laws of thought" approach to AI, the emphasis was given to correct inferences.
- Making correct inferences is sometimes part of being a rational agent, because one way to act rationally is to reason logically to the conclusion and act on that conclusion.
- On the other hand, there are also some ways of acting rationally that cannot be said to involve inference. *For Example, recoiling from a hot stove is a reflex action that usually more successful than a slower action taken after careful deliberation.*
- Advantages:
  - It is more general than laws of thought approach, because correct inference is just one of several mechanisms for achieving rationality.
  - It is more amenable to scientific development than are approaches based on human behavior or human thought because the standard of rationality is clearly defined and completely general.

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What is Artificial Intelligence?

- *Intelligence* is:
  - the ability to reason
  - the ability to understand
  - the ability to create
  - the ability to learn from experience
  - the ability to plan and execute complex tasks
- "Giving machines ability to perform tasks normally associated with *human* intelligence."
- AI is intelligence of machines and branch of computer science that aims to create it.

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Why AI?

"Just as the Industrial Revolution freed up a lot of humanity from physical drudgery, I think AI has the potential to free up humanity from a lot of the mental drudgery." - *Andrew Ng.*

"Artificial Intelligence is the New Electricity." - *Andrew Ng.*

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Various Terminologies used in AI

Knowledge
- Knowledge is the sum of what is known: the body of truth, information, and principles acquired by mankind.
- "Knowledge is "information combined with experience, context, interpretation, and reflection. It is a high-value form of information that is ready to apply to decisions and actions." (T. Davenport et al., 1998)
- Knowledge is information evaluated and organized by the human mind so that it can be used purposefully, e.g., conclusions or explanations." (Rousa, 2002)
- Knowledge is more than just data, it consist of: facts, ideas, beliefs, heuristics, associations, rules, abstractions, relationships, customs.

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Various Terminologies used in AI

Knowledge Representation
- Knowledge representation (KR) is the study of how knowledge about the world can be represented and what kinds of reasoning can be done with that knowledge.
- Knowledge Representation is the method used to encode knowledge in Intelligent Systems.
- Since knowledge is used to achieve intelligent behavior, the fundamental goal of knowledge representation is to represent knowledge in a manner as to facilitate inferencing (i.e. drawing conclusions) from knowledge.
- Ways of knowledge representations:
  - Logical Representation (propositional logic and predicate logic)
  - Semantic Network Representation
  - Frame Representation
  - Production Rules (condition-action pair)

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Various Terminologies used in AI

Searching
- Search is the systematic examination of states to find path from the start/root state to the goal state.
- The set of possible states, together with *operators* defining their connectivity constitute the *search space*.
- The output of a search algorithm is a solution, that is, a path from the initial state to a state that satisfies the goal test.
- In general, searching refers to as finding information one needs.

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Various Terminologies used in AI

Searching
- Searching is the most commonly used technique of problem solving in artificial intelligence.
- The searching algorithm helps us to search for solution of particular problem.
- Two kinds of search:
  - *Uninformed Search* (use no domain knowledge)
  - *Informed Search* (use domain knowledge reach the goal faster)

Various Terminologies used in AI

Learning
- Learning is acquiring new or modifying existing knowledge, behaviors, skills and may involve synthesizing different types of information.
- Learning denotes changes in the system that are adaptive in the sense that they enable the system to do the same task more effectively the next time." - Herbert Simon
- "Learning is constructing or modifying representations of what is being experienced." - Ryszard Michalski
- "Learning is making useful changes in our minds." - Marvin Minsky
- The *general learning approach* is to generate potential improvements, test them, and discard those which do not work.

Various Terminologies used in AI

Machine Learning
- Machine learning is a branch of AI that uses algorithm to allow computer to evolve behaviors based on data collected from databases or gathered through sensors.
- Machine learning usually refers to the changes in systems that perform tasks associated with artificial intelligence (AI).
- Machine learning focuses on prediction based on known properties learned from the training data.
- For example, when the performance of a speech-recognition machine improves after hearing several samples of a person's speech, we feel quite justified in that case saying that the machine has learned.

Various Terminologies used in AI

Neural Networks
- An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information.
- It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems.
- An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.
- Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques.
- A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze.

Various Terminologies used in AI

Expert Systems
- An Expert system is a set of program that manipulates encoded knowledge to solve problem in a specialized domain that normally requires human expertise.
- A computer system that simulates the decision-making process of a human expert in a specific domain.
- An expert system's knowledge is obtained from expert sources and coded in a form suitable for the system to use in its inference or reasoning processes.
- **Examples:**
  - **MYCIN:**
    - It could identify various bacteria that could cause acute infections.
    - It could also recommend drugs based on the patient's weight.
  - **DENDRAL:**
    - Expert system used for chemical analysis to predict molecular structure.

Various Terminologies used in AI

Natural Language Processing
- Natural Language Processing (NLP) is the process of computer analysis of input provided in a human language (natural language), and conversion of this input into a useful form of representation.
- NLP is one of field of AI that processes or analyzes written or spoken language.
- NLP involve processing of speech, grammar and meaning.

Various Terminologies used in AI

Machine Vision

- Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images.
- Duplicates the abilities of human vision by electronically perceiving and understanding an image
- Theory for building artificial systems that obtain information from images.
- Image data can take many forms, such as a video sequence, depth images, views from multiple cameras, medical scanner, satellite sensors etc.
- The goal of Machine Vision is to create a model of the real world from image

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Applications of AI

Speech Recognition

- Speech recognition is the ability of a machine or p words and phrases in spoken language and conver machine-readable format.
- Virtual assistants: Siri (Apple), Echo (Amazon), God Cortana (Microsoft)
- "They" help get things done: send an email, make find a restaurant, tell you the weather and more
- Leverage *deep neural networks* to handle *speech r natural language understanding*

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Applications of AI

Handwriting recognition

- Handwriting recognition is the ability of a computer handwriting as actual text.
- Handwriting recognition is the ability of a computer input handwriting from sources such as printed phys pictures and other devices, or to use handwriting as touchscreen and then interpret this as text.
- The input is –
  - usually in the form of an image such as a picture of handwritten text that is fed to a pattern-recognition software,
  - or as real-time recognition using a camera for optical scanning.

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Applications of AI

Machine Translation

- Machine translation (MT) refers to fully automated software that can translate source content into target languages.
- Humans may use MT to help them render text and speech into another language, or the MT software may operate without human intervention.

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Applications of AI

Machine Tr

100+ languages

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Applications of AI

Robotics

- Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing.
- These technologies are used to develop machines that can substitute for humans and replicate human actions.
- AI is arguably the most exciting field in robotics.
- First, the AI robot or computer gathers facts about a situation through sensors or human input. The computer compares this information to stored data and decides what the information signifies. The computer runs through various possible actions and predicts which action will be most successful based on the collected information.

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Applications of AI

Robotics

- Learning robots recognize if a certain action (moving its legs in a certain way, for instance) achieved a desired result (navigating an obstacle). The robot stores this information and attempts the successful action the next time it encounters the same situation.
- Some robots can interact socially. Kismet, a robot at M.I.T's Artificial Intelligence Lab, recognizes human body language and voice inflection and responds appropriately.

Applications of AI

Robotics: Awesome robots today!

Applications of AI

Recommendation Systems

- A recommendation system, or recommender system tries to make predictions on user preferences and make recommendations which should interest customers.
- Recommendation systems typically appear on many e-commerce sites because of providing better conversion rates.
- According to some articles you can find on the Internet, 35% of Amazon's sales are result of its recommendation engine.

Applications of AI

Recommendation Systems

- There are basically two approaches to make recommendations:
  - Collaborative filtering (or social filtering)
  - Content-based filtering
- Collaborative filtering uses the known behavior of a group of users to make recommendations for the others. (using the data of other users who have similar preferences about items.)
- Content-based filtering makes use of the comparison between items and the past preferences of a particular user. (the items which have similar properties to the ones that the user liked or checked previously are likely to be recommended.)
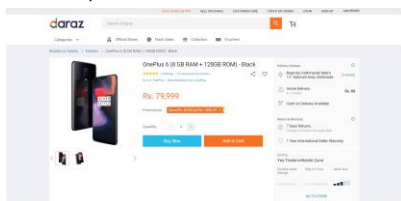
Applications of AI

Recommendation Systems

Applications of AI

Recommendation Systems
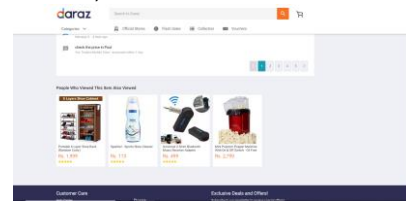
Applications of AI

Search Engines

- Google and Bing started using AI to improve the search algorithms to help customers find better search results.
- This includes deep neural networks, networks of hardware and software that approximate the web of neurons in the human brain.
- By analyzing vast amounts of digital data, these neural nets can learn all sorts of useful tasks, like identifying photos, recognizing commands spoken into a smartphone, and, as it turns out, responding to Internet search queries.
- In some cases, they can learn a task so well that they outperform humans. They can do it better. They can do it faster. And they can do it at a much larger scale.

Applications of AI

Search Engines
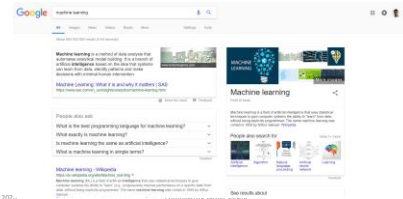
Applications of AI

Email (spam detection)

- An Machine Learning-based spam filter can learn in several ways, but it has to be trained by using a large amount of data from already recognized spam emails and identifying patterns.
- The ML algorithm then automatically creates a new rule for the spam filter.
- The best possible spam filter at the moment still relies on human beings and machines working together, rather than in isolation.
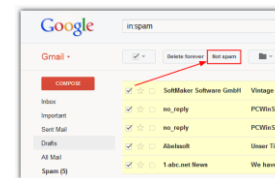
Applications of AI

Email (spam detection)

Applications of AI

Chess (1997): Kasparov vs IBM Deep Blue
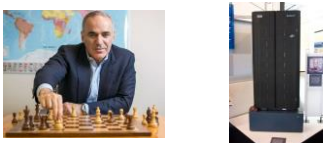
Powerful search algorithms !!

Applications of AI

Chess (1997): Kasparov vs IBM Deep Blue

- In 1997, IBM's Deep Blue computer defeated world chess champion Garry Kasparov, the first time a human chess grandmaster had ever been defeated in such a match.
- Deep Blue employed all of its massive computing power to work out every possible scenario available to it in the three minutes it was allowed for each move.

Applications of AI

Jeopardy! (2011): Humans vs. IBM Watson

Natural Language Understanding and information extraction!

Applications of AI

Jeopardy! (2011): Humans vs. IBM Watson

- Watson is a question-answering computer system capable of answering questions posed in natural language, developed in IBM's DeepQA project by a research team led by principal investigator David Ferrucci.
- Watson was named after IBM's first CEO, industrialist Thomas J. Watson.
- The computer system was initially developed to answer questions on the quiz show Jeopardy! and, in 2011, the Watson computer system competed on Jeopardy! against legendary champions Brad Rutter and Ken Jennings, winning the first place prize of $1 million.

Applications of AI

Autonomous Driving

- Autonomous vehicles are being fitted with cameras, sensors and communication systems to enable the vehicle to generate massive amounts of data which, when applied with AI, enables the vehicle to see, hear, think and make decisions just like human drivers do.
- AI-based systems will become a standard in new vehicles especially in these two categories:
  - Infotainment human-machine interface, including speech recognition and gesture recognition, eye tracking and driver monitoring, virtual assistance and natural language interfaces.
  - Advanced Driver Assistance Systems (ADAS) and autonomous vehicles, including camera-based machine vision systems, radar-based detection units, driver condition evaluation and sensor fusion engine control units (ECUs).

Applications of AI

Autonomous Driving

State-of-the-art Applications

- Speech recognition
- Autonomous planning and
- Scheduling
- Financial forecasting
- Game playing, video games
- Spam fighting
- Logistics planning
- Robotics (household, surgery, navigation)
- Machine translation
- Information extraction
- Automatic assembly
- Sentiment analysis
- Fraud detection
- Recommendation systems
- Web search engines
- Autonomous cars
- Energy optimization
- Question answering systems
- Social network analysis
- Medical diagnosis, imaging
- Route finding
- Traveling salesperson
- Document summarization
- Transportation/scheduling
- Computer animation

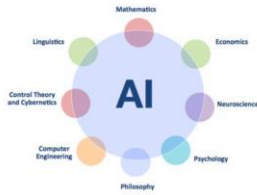*Many more !!*

Applications of AI

What will AI allow us to automate?

We'll be able to automate everything that we can describe. The problem is: *it's not clear what we can describe*. - *Stephen Wolfram, MIT*

Foundation of AI

Foundation of AI

- *Philosophy*
  - Logic, methods of reasoning.
  - Mind as physical system that operates as a set of rules.
  - Foundations of learning, language, rationality.
- *Mathematics*
  - Logic: Formal representation and proof.
  - Computation, algorithms.
  - Probability.

Foundation of AI

- *Economics*
  - Formal theory of rational decisions.
  - Combined *decision theory* and *probability theory* for decision making under *uncertainty*.
- *Neuroscience*
  - Study of brain functioning.
  - How brains and computers are (dis)similar.

Foundation of AI

- *Psychology*
  - How do we think and act?
  - Cognitive psychology perceives the brain as an information processing machine.
  - Led to the development of the field *cognitive science*: how could computer models be used to study *language, memory, and thinking* from a psychological perspective.
- *Computer engineering*
  - Cares about how to build *powerful machines* to make AI possible.
  - E.g., Self-driving cars are possible today thanks to advances in computer engineering.

Foundation of AI

- *Control theory*
  - Design simple *optimal agents* receiving *feedback* from the environment.
  - Modern control theory design systems that maximize an objective function over time.
- *Linguistics*
  - How are language and thinking related.
  - Modern linguistics + AI = Computational linguistics (*Natural language processing*).

History of AI

- 1940-1950: Gestation of AI
  - McCulloch & Pitts: Boolean circuit to model of brain
  - Turing's Computing Machinery and Intelligence
  http://www.turingarchive.org/browse.php/B/9
- 1950-1970: Early enthusiasm, great expectations
  - Early AI programs, Samuel's checkers program
  - Birth of AI @ Dartmouth meeting 1956.
  - Check out the MIT video "The thinking Machine" on youtube
  https://www.youtube.com/watch?v=aygSMgK3BEM

History of AI

- 1970-1990: Knowledge-based AI
  - Expert systems, AI becomes an industry
  - AI winter
- 1990-present: Scientific approaches
  - Neural Networks: le retour (the return)
  - The emergence of intelligent agents
  - AI becomes "scientific", use of probability to model uncertainty
  - AI Spring!
  - The availability of very large datasets.
  - *Big Data will drive future discoveries and alleviate the complexity in AI.*

Summary

- AI is a hard (computational complexity, language, vision, etc), and a broad field with high impact on humanity and society.
- What can AI do for us is already amazing!
- AI systems do *not have to model* human/nature *but can act like* or be inspired by human/nature.
- Rational (do the right thing) agents are central to our approach of AI.
- Note that rationality *is not always possible* in complicated environment but we will still aim to build rational agents.
- AI is a flourishing and exciting field: everyone can contribute.

Thank you !
Any questions ?