Artificial Intelligence
ADC503

Lecture 1

Prof. Smita S. Mane

Asst. Prof.

Dept. of AI & DS,

VESIT,Chembur

- W hen you
- E nter this class
- L earning is Fun And
- C ooperation is Expected
- O ur Positive Attitude and
- M utual respect are part of
- E verything We do and Say....

V.E.S.
Since 1962

Curriculum

Course Outcomes

At the completion of course student should be able to

1) **Identify the characteristics of the environment and differentiate between various agent architectures.**
2) **Apply the most suitable search strategy to design problem solving agents.**
3) **Represent a natural language description of statements in logic and apply the inference rules to design Knowledge Based agents.**
4) **Apply a probabilistic model for reasoning under uncertainty.**
5) **Comprehend various learning techniques.**
6) **Describe the various building blocks of an expert system for a given real word problem.**

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Module		Detailed Content	Hours
1		**Introduction to Artificial Intelligence**	3
	1.1	Artificial Intelligence (AI), AI Perspectives: Acting and Thinking humanly, Acting and Thinking rationally	
	1.2	History of AI, Applications of AI, The present state of AI, Ethics in AI	

Artificial Intelligence
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Lecture 2

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Introduction to AI

Data, Information, and Knowledge

- What is Data and Information? Are they different from Knowledge?

- **Data:** Unorganized and unprocessed facts; static; a set of discrete facts about events
- **Information:** Aggregation of data that makes decision making easier
- **Knowledge** is derived from information in the same way information is derived from data; it is a person's range of information

What is Knowledge

- Knowledge includes facts about the real world entities and the relationship between them
  - It is an Understanding gained through experience
  - familiarity with the way to perform a task
  - an accumulation of facts, procedural rules, or heuristics

- Characteristics of Knowledge:
  - It is voluminous in nature and requires proper structuring.
  - It may be incomplete and imprecise.
  - It may keep on changing (dynamic).

Knowledge base systems (KBSs)

- Deal with treating **knowledge** and ideas on a computer.
  - Emphases to the importance of knowledge.
- Use **inference** to solve problems on a computer.
  - Knowledge-based systems describes programs that reason over extensive knowledge bases.
- Have the ability to **learn** ideas so that they can obtain information from outside to use it appropriately.
  - The value of the system lies in its ability to make the workings of the human mind understandable and executable on a computer.

Attributes of KBS

- Learn
  - The more you use knowledge, the smarter they get and the smarter you get, too
- Improve with use
  - Knowledge is enhanced rather than depleted when used and they grow up instead of being used up
- Anticipate
  - Knowing what you want, KBS recommend what you want next
- Interactive
  - There is two-way communication between you and KBS
- Remember
  - KBS record and recall past actions to develop a profile
- Customize
  - KBS offer unique configuration to your individual specifications in real time at no additional cost

AI vs. KBS

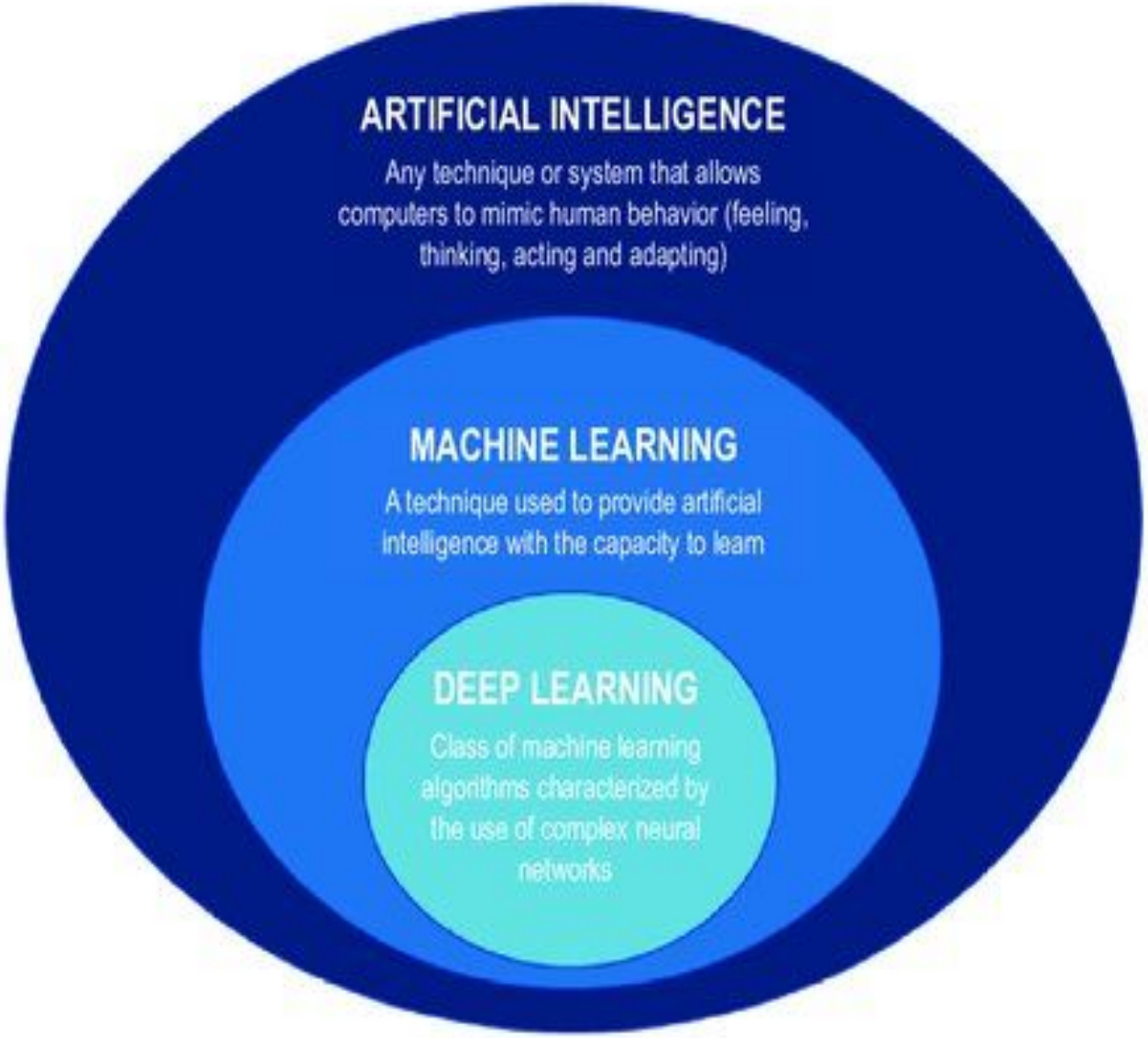
- Knowledge based system is part of Artificial Intelligence
- AI also requires extensive knowledge of the subject at hand.
  - AI program should have knowledge base
  - Knowledge representation is one of the most important and most active areas in AI.
  - AI programs should be learning in nature and update its knowledge accordingly.

Intelligence

- Intelligence is the capability of observing, learning, remembering and reasoning.
  - Intelligence is a general mental capability that involves the ability to reason, plan, solve problems, think abstractly, comprehend ideas and language, and learn.
- Intelligence draws on a variety of mental processes, including *memory, learning, perception, decision-making, thinking, and reasoning.*
- Memory of Intelligent system is used to store knowledge base which is the key for success for artificial intelligent systems.
- AI attempts to develop intelligent agents.

Characteristics of Intelligent system

- Use vast amount of knowledge
- Learn from experience and adopt to changing environment
- Interact with human using language and speech
- Respond in real time
- Tolerate error and ambiguity in communication


ARTIFICIAL INTELLIGENCE
Any technique or system that allows computers to mimic human behavior (feeling, thinking, acting and adapting)
MACHINE LEARNING
A technique used to provide artificial intelligence with the capacity to learn
DEEP LEARNING
Class of machine learning algorithms characterized by the use of complex neural networks

Artificial Intelligence

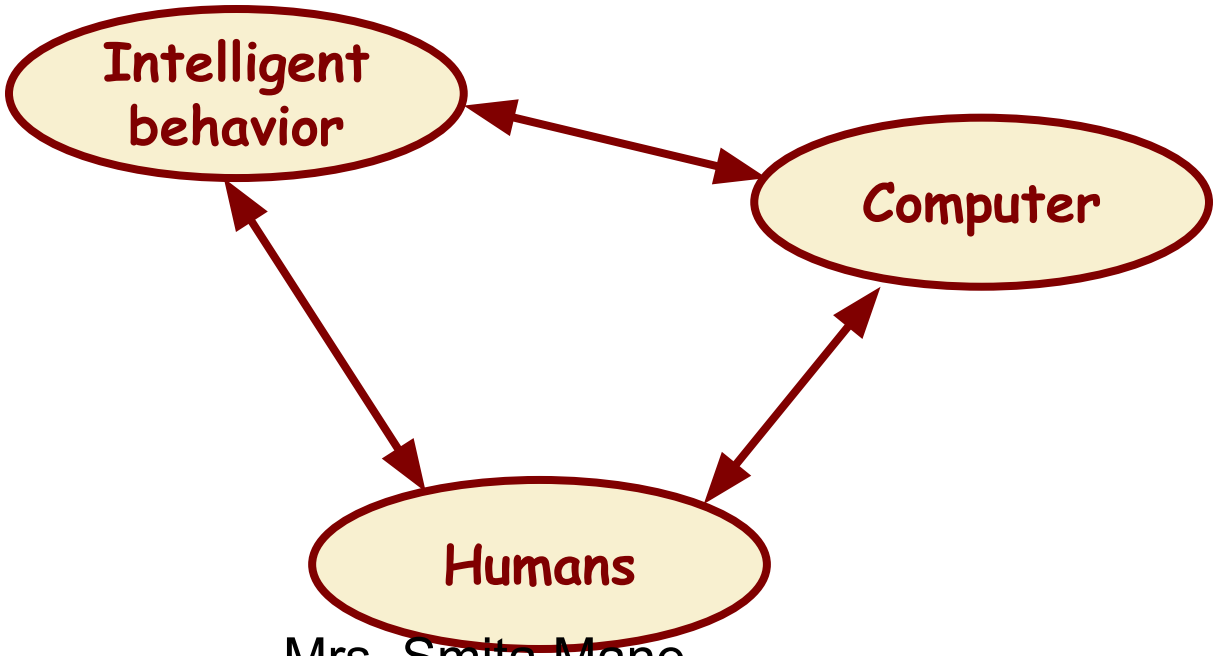
- AI is the branch of Computer Science that deals with ways of:
  - representing knowledge using symbol rather than numeric value and with rule-of-thumb and method of processing information

- AI is the effort to develop computer based system that behave as human.
  - Such system should be able to learn Natural Language.
  - Able to do text processing, communicate in natural language and speech

What is AI?

an attempt of

- AI is ~~the~~ reproduction of human reasoning and intelligent behavior by computational methods



Views of AI

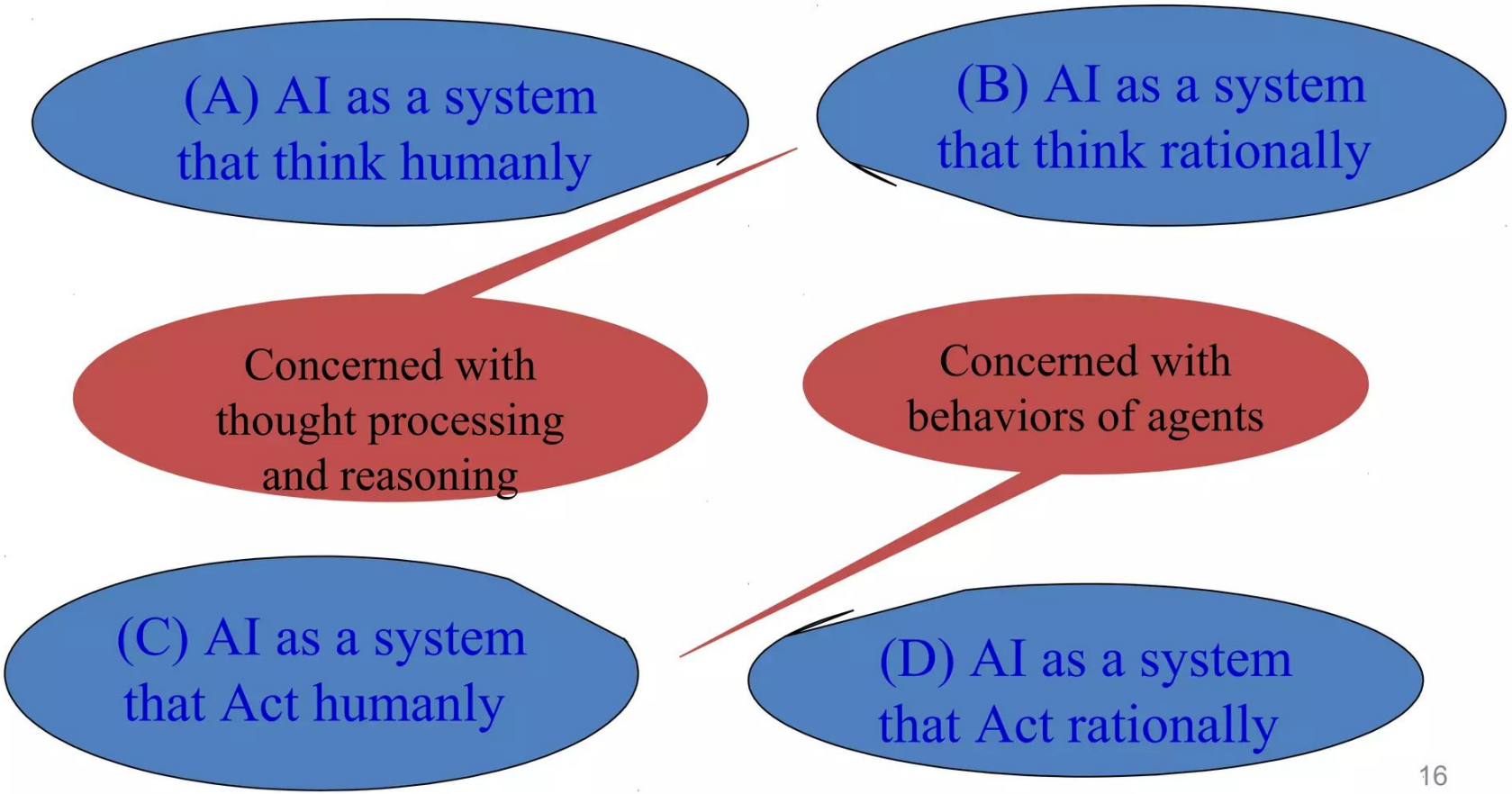
- AI is found on the premise that:
  - workings of human mind can be explained in terms of computation, and
  - computers can do the right thing given correct premises and reasoning rules.

Views of AI fall into four categories:

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

Views of defining AI

- What is AI (Artificial Intelligence)
  - Different scholars define AI differently



Thinking humanly: The Cognitive Modeling

- Reasons like humans do
  - Programs that behave like humans
- Requires understanding of the internal activities of the brain
  - see how humans behave in certain situations and see if you could make computers behave in that same way.

Example. write a program that plays chess.

- Instead of making the best possible chess-playing program, you would make one that play chess like people do.

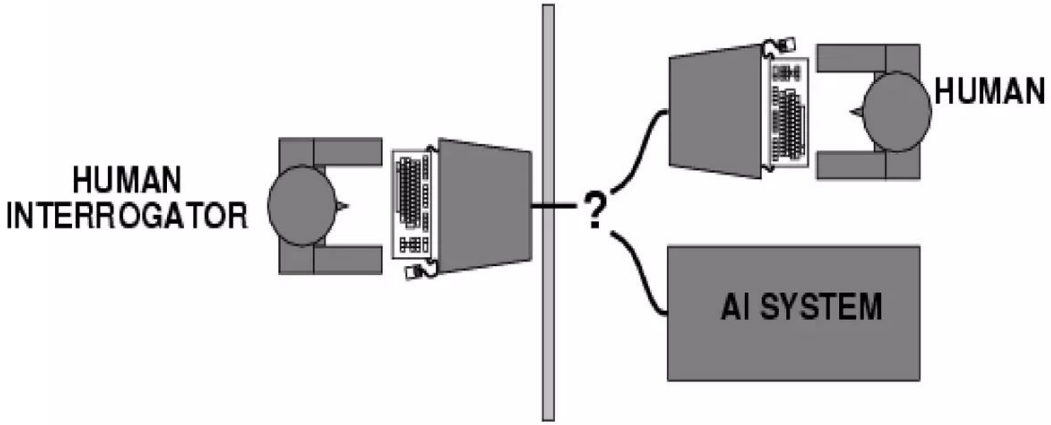
Acting humanly: The Turing Test

Can machines act like human do? Can machines behave intelligently?

- Turing Test: Operational test for intelligent behavior
  - do experiments on the ability to achieve human-level performance,
  - Acting like humans requires AI programs to interact with people
- Suggested major components of AI: knowledge, reasoning, language understanding, learning

Acting humanly: Turing Test

- Turing (1950) on his famous paper "Computing machinery and intelligence":
- "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game



- Predicted that by 2000, a machine might have a 30% chance of fooling a person for 5 minutes
- Anticipated all major arguments against AI in following 50 years
- Active areas of research to achieve this: Machine learning, NLP, Computer vision, etc

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Lecture 3

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Thinking Rationally: The Laws of Thought

- A system is rational if it thinks/does the right thing through correct reasoning.

- **Aristotle**: provided the correct arguments/ thought structures that always **gave correct conclusions given correct premises**.
  - Abebe is a man; all men are mortal; therefore Abebe is mortal
  - These Laws of thought governed the operation of the mind and initiated the field of **Logic**.

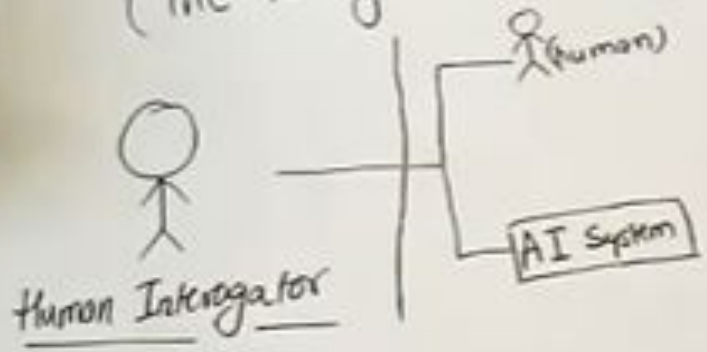
Acting rationally: The rational agent

- **Doing the right thing** so as to achieve one's goal, given one's beliefs.
- **AI** is the study and construction of rational agents (an agent that perceives and acts)
- Rational action requires the ability to represent knowledge and reason with it so as to reach good decision.
  - Learning for better understanding of how the world works

Artificial Intelligence

(1) Acting Humanly –

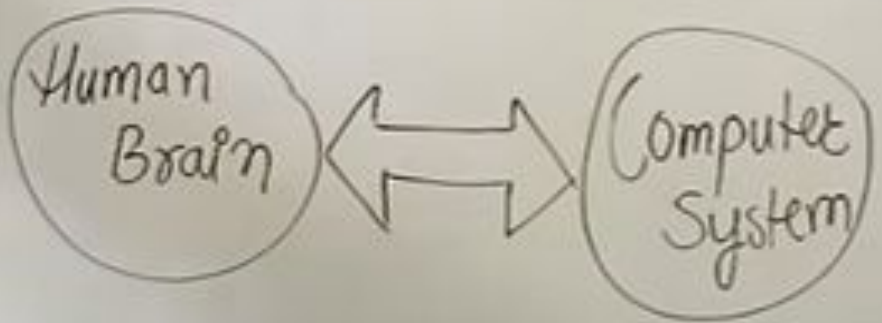
(The Turing test approach)



(2) Thinking Humanly :–

(The Cognitive Modelling Approach)

→ Conginitive science



(3) Acting Rationally :–

(Rational agent approach)

→ Doing / Behaving Rightly

→ Generalized Approach.

→ Maximizing expected performance.

(4) Thinking Rationally :–

(The Laws of Thought approach)

→ "Right Thinking"

→ Requires 100% Knowledge.

→ Too many computations Required.

Different AI Perspectives

2. Systems that *think like humans*	3. Systems that *think rationally (optimally)*
"The exciting new effort to make computers think … *machines with minds*, in the full and literal sense" (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning …" (Bellman, 1978)	"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)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)	"A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkoff, 1990) "The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)

1. Systems that *act like humans* 4. Systems that *act rationa lly*

What is AI?
(R&N)

Discipline that systematizes and automates reasoning processes to create machines that:

Act like humans	Act rationally
Think like humans	Think rationally

A human Centered approach must be an empirical Science, involving Hypothesis and Experimental Confirmation.
A rationalist approach involves a combination of mathematics and engineering.

A system is rational if it does the "right thing" given what it knows.

Act like humans	Act rationally
Think like humans	Think rationally

- The goal of AI is to create computer systems that perform tasks regarded as requiring intelligence when done by humans
- AI Methodology: Take a task at which people are better, e.g.:
  - Prove a theorem
  - Play chess
  - Plan a surgical operation
  - Diagnose a disease
  - Navigate in a building

  and build a computer system that does it automatically
- But do we want to duplicate human imperfections?

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History of AI

- 1943: early beginnings
  - McCulloch & Pitts: Boolean circuit model of brain
- 1950: Turing
  - Turing's "Computing Machinery and Intelligence“ ,there in introduced tuning test , machine learning , genetic and reinforcement learning algo
- 1956: birth of AI
  - **McCarthy** : Dartmouth college meeting: "Artificial Intelligence“ name adopted
- 1950s: initial promise
  - Early AI programs, including
  - Samuel's checkers program
  - Newell & Simon's Logic Theorist
- 1955-65: “great enthusiasm”
  - Newell and Simon: GPS, general problem solver
  - Gelertner: Geometry Theorem Prover
  - McCarthy: invention of LISP

History of AI

- 1966—73: Reality dawns
  - Realization that many AI problems are intractable
  - Limitations of existing neural network methods identified
    - Neural network research almost disappears

- 1969—85: Adding domain knowledge
  - Development of knowledge-based systems
  - Success of rule-based expert systems,
    - E.g., DENDRAL, MYCIN
    - But were brittle and did not scale well in practice

- 1986-- Rise of machine learning
  - Neural networks return to popularity
  - Major advances in machine learning algorithms and applications

- 1990-- Role of uncertainty
  - Bayesian networks as a knowledge representation framework

- 1995-- AI as Science
  - Integration of learning, reasoning, knowledge representation
  - AI methods used in vision, language, data mining, etc

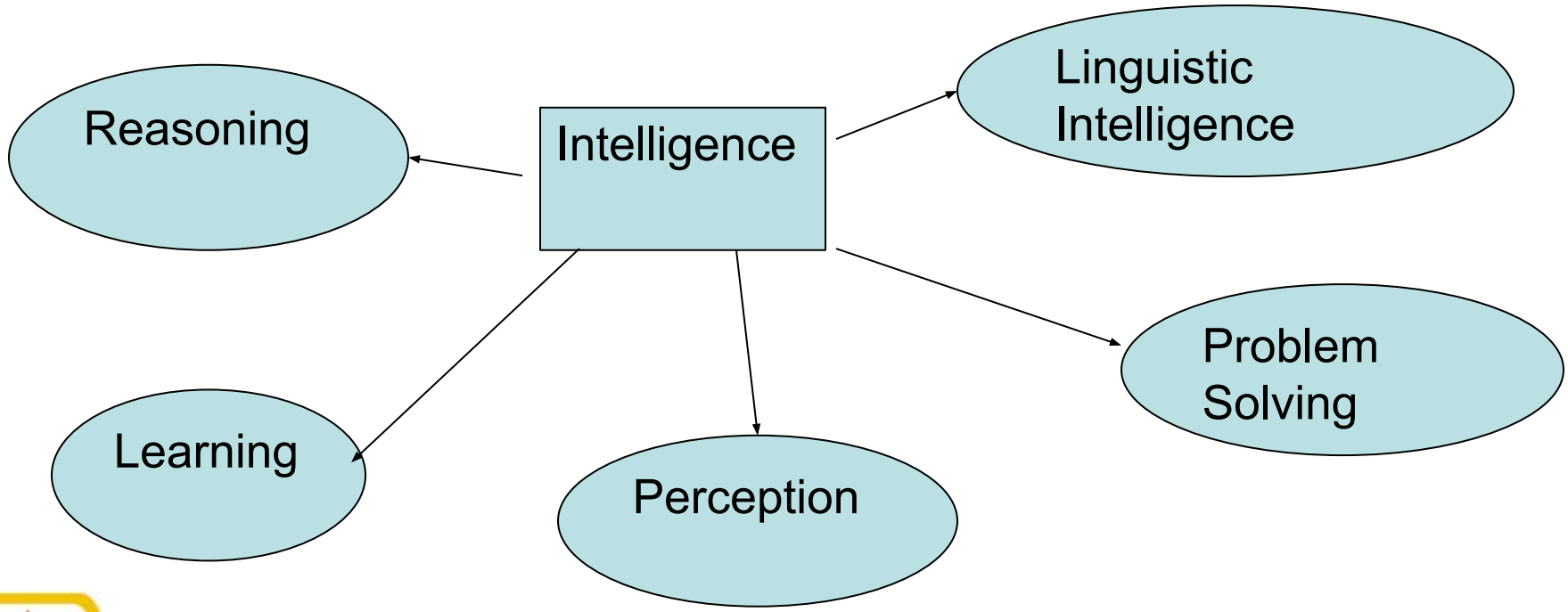
Why AI

- Solve real world problems very easily and accurately such as health issue , marketing, traffic issue etc.
- Create personal virtual assistant like siri, google assistance.
- Robot which can work in a environment where survival of human can be at risk

Goals of AI

- Replicate Human Intelligence
- Solve Knowledge –intensive task
- An intelligent connection of perception and action
- Building a m/c which can perform task that requires human intelligence such as:
  - Providing theorem
  - Playing chess
  - Plan surgical operation
  - Driving a car

Intelligence Composed of



Applications of AI:-

1. AI in Gaming:
2. AI in NLP:
3. AI in HealthCare:
4. AI in Finance:
5. AI in Data Security:
6. Expert System:
7. Computer Vision:
8. Speech Recognition:
9. Robotics:
10. AI in e-Commerce:

Applications of AI:-

(1) AI in Gaming: Chess, Poker, tic-toe.
↳ machine can think large no. of moves.

(2) AI in NLP: Natural lang. Processing
↳ Machine can understand human lang.

(3) AI in HealthCare: Fast diagonsis
↳ Robotic Surgery.

(4) AI in Finance: Adaptive Intelligence.
↳ automatic chatbots, algorithm trading.

(5) AI in Data Security: Helps in making data/appln more secure.
↳ AEG bot, AI2

(6) Expert System: Integration of s/w, machine and special infon to provide reasoning & advise.

(7) Computer Vision: Understand the visual automatically by machine.

(8) Speech Recognition: Extract the meaning of sentence by human talk. [slang removal, noise rem..]

(9) Robotics:
Talk and behave like humans.
↳ Erica and Sophia.

(10) AI in e-Commerce: Automatic recommendation of p

Applications of AI and KBS

Solving problems that required thinking by humans:

- Playing games (chess, checker, cards, ...)
- Proving theorems (mathematical theorems, laws of physics, …)
- Classification of text (Politics, Economic, sports, etc,)
- Writing story and poems; solving puzzles
- Giving advice in medicine, law, … (diagnosing diseases, consultation, …)

How to make computers act like humans?

The following sub-fields are emerged

- **Natural Language processing** (enable computers communicate in human language, English, Amharic, ..)
- **Knowledge representation** (schemes to store information, both facts and inferences, before and during interrogation)
- **Automated reasoning** (use stored information to answer questions and to draw new conclusions)
- **Machine learning** (adapt to new circumstances and accumulate knowledge)
- **Computer vision** (recognize objects based on patterns in the same way as the human visual system does)
- **Robotics** (produce mechanical device capable of controlled motion; which enable computers to see, hear & take actions)

- Is AI equals human intelligence ?

WHERE WE ARE TODAY?

- SIRI (Apple Personal Assistant)
- ALEXA
- VIDEO STREMING AND TRANSCODING
- GAMES
- DRIVER LESS TRANSPORATION
- AUTOMATED ASSEMBLY LINES AND DANGEROUS JOBS
- SURGERY AID ROBOTS
- NEXT GENERATION CONTROL

SIRI (APPLE PERSONAL ASSISTANT)

- Actually engineered and co founded by Adam Cheyer , dag kittlaus and tom .in stanford research institute.siri means A beautiful women who guide you to victory.Siri is based on the based on the fields of Artificial Intelligence and Natural Language Processing, and it is comprised of three components -a conversational interface, personal context awareness and service delegation. Siri launched in iphone in oct 4 2011 and job died the next day.

ALEXA

- The smart speaker from Amazon is playing music one time and is helping you with recipe ideas the other time.The better sound quality and a less industrial design of Amazon echo have contributed significantly to its success.Alexa indeed took the world by storm when it was introduced,and it soon reached a safe place in the living room of most of the houses.You can shop, set alarms, browse the web for information, switch off the lights, schedule appointments and what not? This most significant tech breakout in recent memoryis ready to follow your instructions and control your smart home devices.

GAMES

- Techniques used in AI game programming include decision trees and path finding.

DRIVER LESS TRANSPORT:

- Google has been investing in a driverless car, and has completed to drive a driverless car accident free.
- Through the use of cameras, sensors and special software built into vehicles manufacturers have been able to build cars that park themselves at the touch of bottom.
- Driverless trains carry passengers from city to city in Japan without the need for human help.

SURGICAL AID ROBOTS:

- Cedars-Sinai Medical Center relies on special software to examine the heart and stop heart attacks before they occur.
- Artificial muscles feature smart technology that allows them to function more like real muscles.
- Penelope, a Robotics Surgery Assistance developed at Columbia University can not only pass the correct tools to doctors, but also keep track of these tools and learn about doctors preference through AI.

- The most advanced surgical robots are programmed to perform the entire surgery on their own, except for the cutting . In these operations , a surgeon stands by just in case something goes wrong.
- Miniature intelligent robot are being developed for eye surgeries.

SURGICAL ROBOT

MINIATURE INTELLIGENT ROBOT

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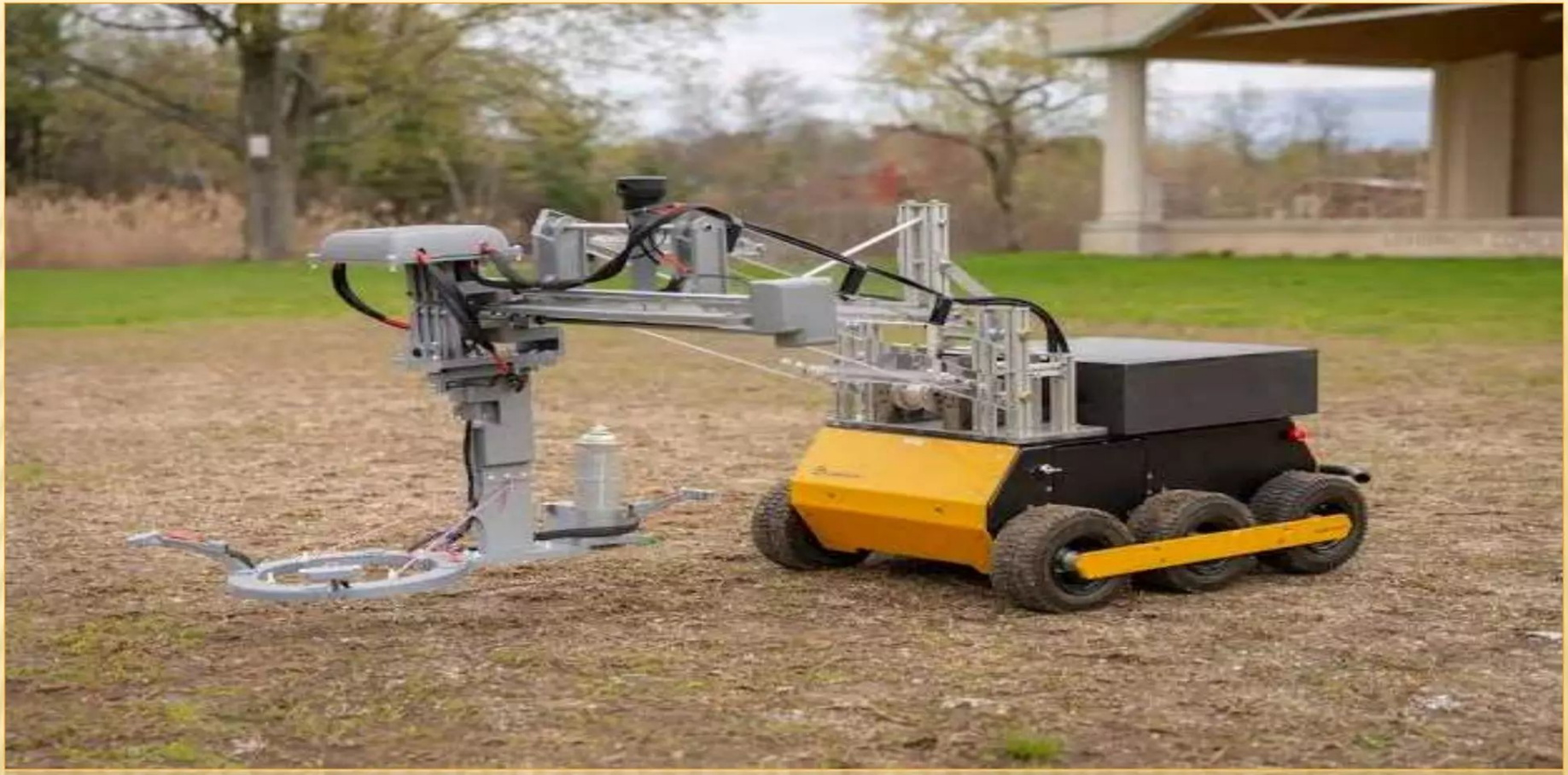


ROBOTS USING FOR DISABLING LAND-MINES

Expert system

- **Examples**:
  - Dendral, MYCIN, PUFF, ELIZA, BTDS, etc.

- Dendral expert system:
  - The primary aim to aid organic chemists with identification of unknown organic molecules by analyzing information from *mass spectrometry* graphs and the knowledge of chemistry

Expert system

- **MYCIN**:
  - Written in LISP around 1970s and derived from Dendral expert system
  - was designed to diagnose infectious blood diseases and recommend antibiotics, with the dosage adjusted for patient's body weight
  - It would query the physician/patient running the program via a long series of simple yes/no or textual questions.
  - At the end, it provides
    - a list of possible cause bacteria ranked from high to low based on the probability of each diagnosis,
    - its confidence in each diagnosis' probability
    - the reasoning behind each diagnosis
  - It has around ~50 rules

Expert system

- **PUFF**:
  - PUFF can diagnose the presence and severity of lung disease and produce reports for the patient's file
  - Is an Expert System that interprets lung function test data and has become a working tool in the pulmonary physiology lab of a large number of hospital

Expert system

- **ELIZA** :
  - ELIZA is a very well-known artificial intelligence program designed to emulate a Rogerian psychotherapist.
  - The basic elements of Carl Rogers' new way of therapy was to have a more personal relationship with the patient, to help the patient reach a state of realization that they can help themselves
  - ELIZA was showcased for a number of years at the **MIT AI Laboratory**.
  - ELIZA has no reasoning ability, cannot learn
  - ELIZA only appears to understand because "she" uses canned responses based on keywords, as well as string substitution

THE DIFFERENCE BETWEEN HUMAN BEINGS AND ARTIFICIALLY INTELLIGENT SYSTEMS

Human Brain

- Natural device
- Self-willed and creative
- Basic unit – neuron
- Storage device – electrochemical
- Low crunching
- Advanced detective reasoning
- Lower speed
- Emotion-driven
- Limited volume
- Fuzzy logic

Computers

- Non-natural device
- Limited creativity
- Basic unit – RAM
- Storage device is electromechanical
- High crunching
- Elementary detective reasoning
- High speed
- Non-emotional
- Higher volume
- Numeric (binary) logic

Problems of AI:

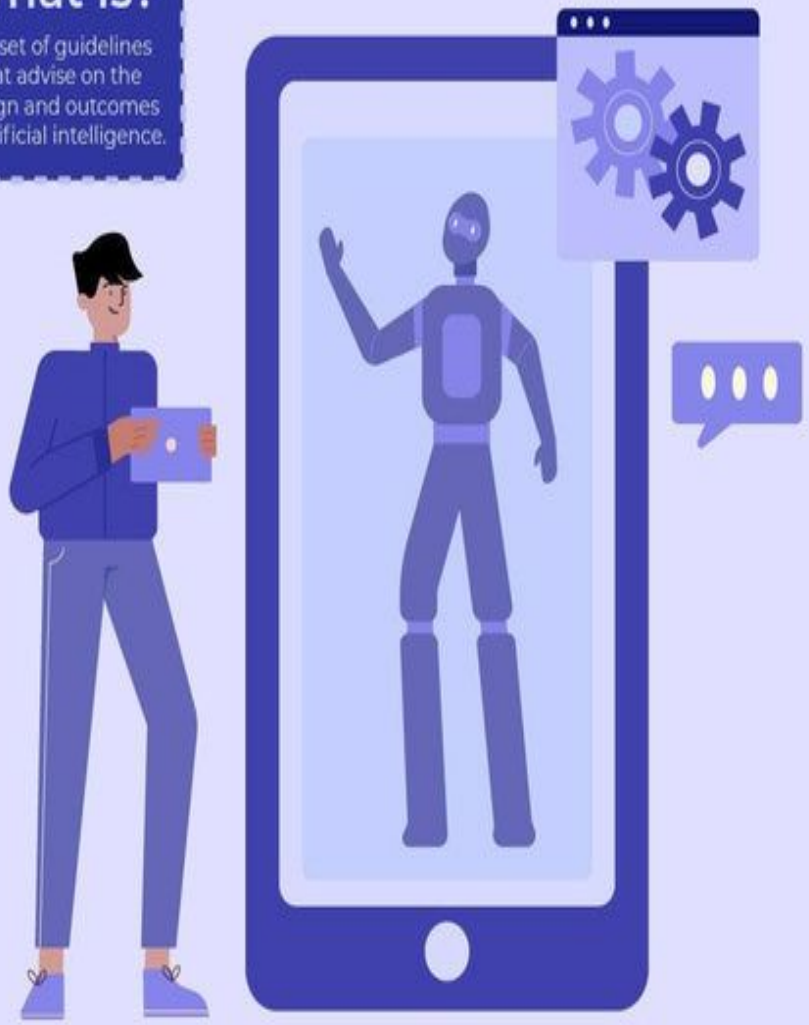
- The following points are taken as drawbacks of Artificially Intelligent systems:
  - AI do not come up with new and novel solutions
  - Existing AI systems try to reproduce the expertise of humans, but do not behave like human experts
  - Lack of common-sense
  - Reasoning: the human intelligence performs better in this respect

AI Ethics

6 key principles of ethical AI development

What is?

Is a set of guidelines that advise on the design and outcomes of artificial intelligence.



1 TRANSPARENCY

Is a design choice that can help take a look at backend functionality, increase accountability, and enhance public trust in AI decision-making.

2 ACCOUNTABILITY

Accountability in AI decision-making means it is possible to trace AI outcomes/decisions to an individual or organization or to a step in the AI design process.

3 MITIGATING BIAS

Bias amplifies within an AI-enabled system and leads to discriminatory outcomes for a group, despite a developer or designer not having intended it.

4 FAIRNESS

Is one of the most relevant and difficult elements of ethical AI development. It is a normative concept and has numerous definitions.

5 SECURITY

Safety and security while using an AI system are non-negotiable for preserving public trust in AI. As technology advances, so do the threats to security.

6 PRIVACY

Privacy in AI refers to individual autonomy regarding sharing information about oneself with others and the public at large.


THANK YOU FOR
YOUR ATTENTION

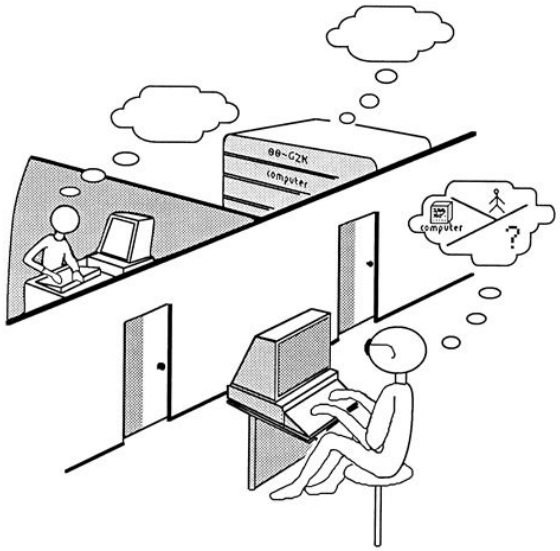
Can Machines Act/Think Intelligently?

"If there were machines which bore a resemblance to our bodies and imitated our actions as closely as possible for all practical purposes, we should still have two very certain means of recognizing that they were not real men. The first is that they could never use words, or put together signs, as we do in order to declare our thoughts to others… Secondly, even though some machines might do some things as well as we do them, or perhaps even better, they would inevitably fail in others, which would reveal that they are acting not from understanding, …"

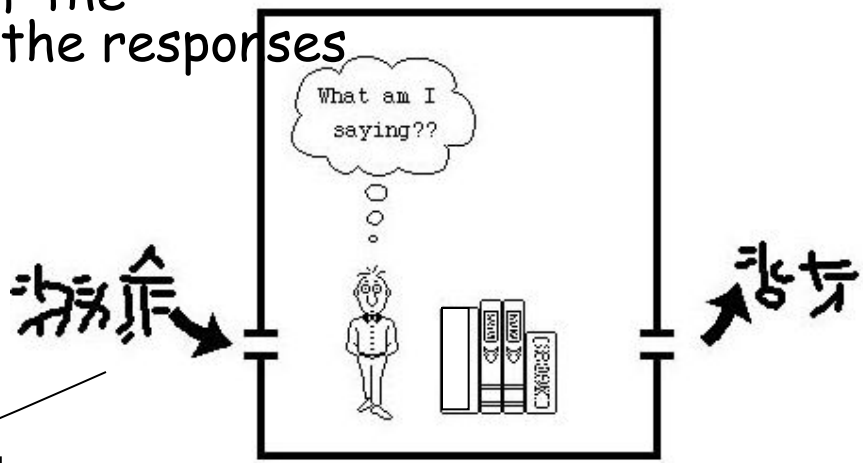
Discourse on the Method by Descartes (1598-1650)

Can Machines Act/Think Intelligently?

Turing Test: Acting humanly



- http://plato.stanford.edu/entries/turing-test/
- Test proposed by Alan Turing in 1950 was designed to provide a satisfactory operational definition of intelligence.
- The computer is asked questions by a human interrogator. It passes the test if the interrogator cannot tell whether the responses come from a person or not
- No physical interaction
- Chinese Room (J. Searle)



The computer would need to possess the following capabilities:

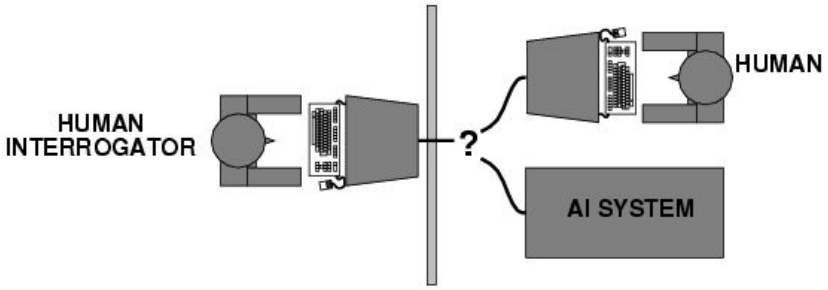
- **natural language processing** to enable it to communicate successfully in English (or someother human language);
- **knowledge representation** to store information provided before or during the interrogation;
- **automated reasoning** to use the stored information to answer questions and to draw new conclusions;
- **machine learning** to adapt to new circumstances and to detect and extrapolate patterns.
- **computer vision** to perceive objects, and
- **robotics** to move them about

Thinking Humanly: The cognitive approach

- "Can machines think?" □ "Can machines behave intelligently
- The interdisciplinary 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.
- There are two ways to do this:

GPS : general problem solver

- ❑ Introspection—trying to catch our own thoughts as they go by
- ❑ psychological experiments.



Thinking Rationally
Codify "Right Thinking"

logic

- The development of formal which , provided a precise notation for statements about all kinds of things in the world and the relations between them.
- There are two main obstacles to this approach.

❑ It is not easy to take informal knowledge and state it in the formal terms required by logical notation.

❑ There is a big difference between being able to solve a problem "in principle" and doing so in practice.

Acting Rationally

rational agent

- Acting rationally means acting so as to achieve one's goals, given one's beliefs. An **agent** is just something that perceives and acts.
- It act to achieve best outcome or when there is a uncertainty the best expected outcome.

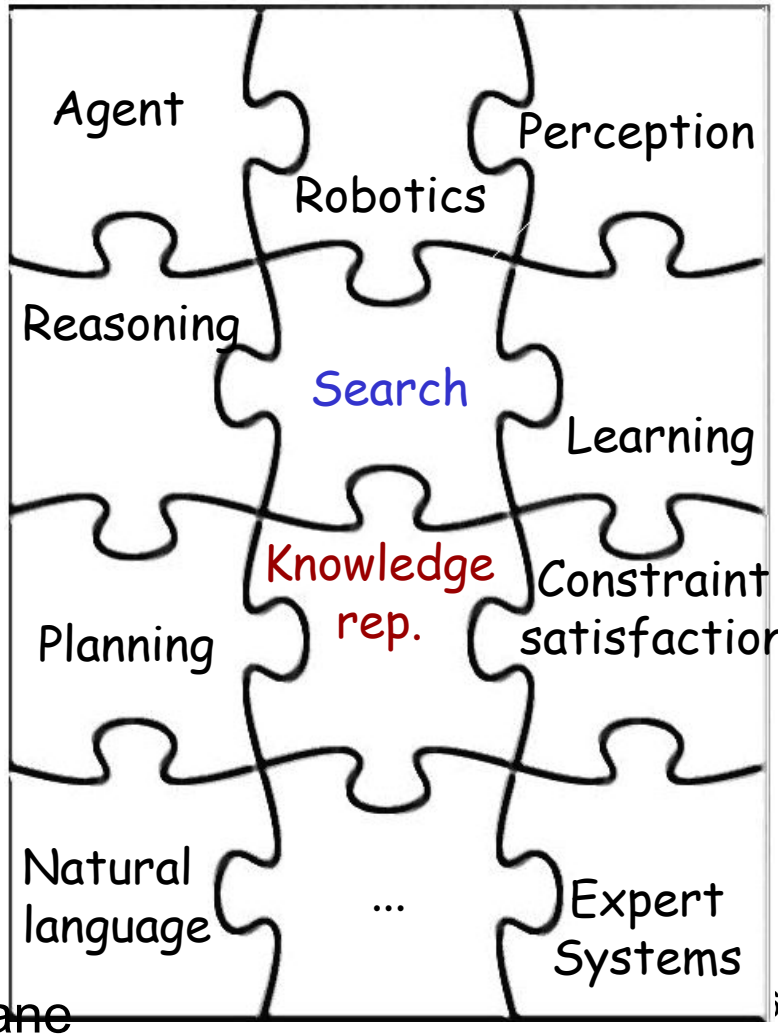
low of thought : correct inferences

Academic Disciplines relevant to AI

- Philosophy Logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality.
- Mathematics Formal representation and proof, algorithms, computation, (un)decidability, (in)tractability
- Probability/Statistics modeling uncertainty, learning from data
- Economics utility, decision theory, rational economic agents
- Neuroscience neurons as information processing units.
- Psychology/ Cognitive Science how do people behave, perceive, process cognitive information, represent knowledge.
- Computer engineering building fast computers
- Control theory design systems that maximize an objective function over time
- Linguistics knowledge representation, grammars

Main Areas of AI

- Knowledge representation (including formal logic)
- Search, especially heuristic search (puzzles, games)
- Planning
- Reasoning under uncertainty, including probabilistic reasoning
- Learning
- Agent architectures
- Robotics and perception
- Natural language processing



The State of The Art

- Game Playing: Deep Blue defeated the reigning world chess champion Garry Kasparov in 1997
- Autonomous Planning and Scheduling: NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
- Autonomous Control:ALVINN computer vision was trained to steer a car to keep in lane. No hands across America (driving autonomously 98% of the time from Pittsburgh to San Diego)
- Logistics Planning: During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program (DART) that involved up to 50,000 vehicles, cargo, and people
- Language Understanding and Problem Solving: Proverb solves crossword puzzles better than most humans
- Diaganosis:Medical diagnosis based on probabilistic analysis have been able to perform at level of an expert in areas of medicine

Consider what might be involved in building a "intelligent" computer….

- What are the "components" that might be useful?
  - Fast hardware?
  - Foolproof software?
  - Chess-playing at grandmaster level?
  - Speech interaction?
    - speech synthesis
    - speech recognition
    - speech understanding
  - Image recognition and understanding ?
  - Learning?
  - Planning and decision-making?

Can we build hardware as complex as the brain?

- How complicated is our brain?
  - a neuron, or nerve cell, is the basic information processing unit
  - estimated to be on the order of 10^{11} neurons in a human brain
  - many more synapses (10^{14}) connecting these neurons
  - cycle time: 10^{-3} seconds (1 millisecond)

- How complex can we make computers?
  - 10^6 or more transistors per CPU
  - supercomputer: hundreds of CPUs, 10^9 bits of RAM
  - cycle times: order of 10^{-8} seconds

- Conclusion
  - **YES**: in the near future we can have computers with as many basic processing elements as our brain, but with
    - far fewer interconnections (wires or synapses) than the brain
    - much faster updates than the brain
  - **but** building hardware is very different from making a computer behave like a brain!

Must an Intelligent System be Foolproof?

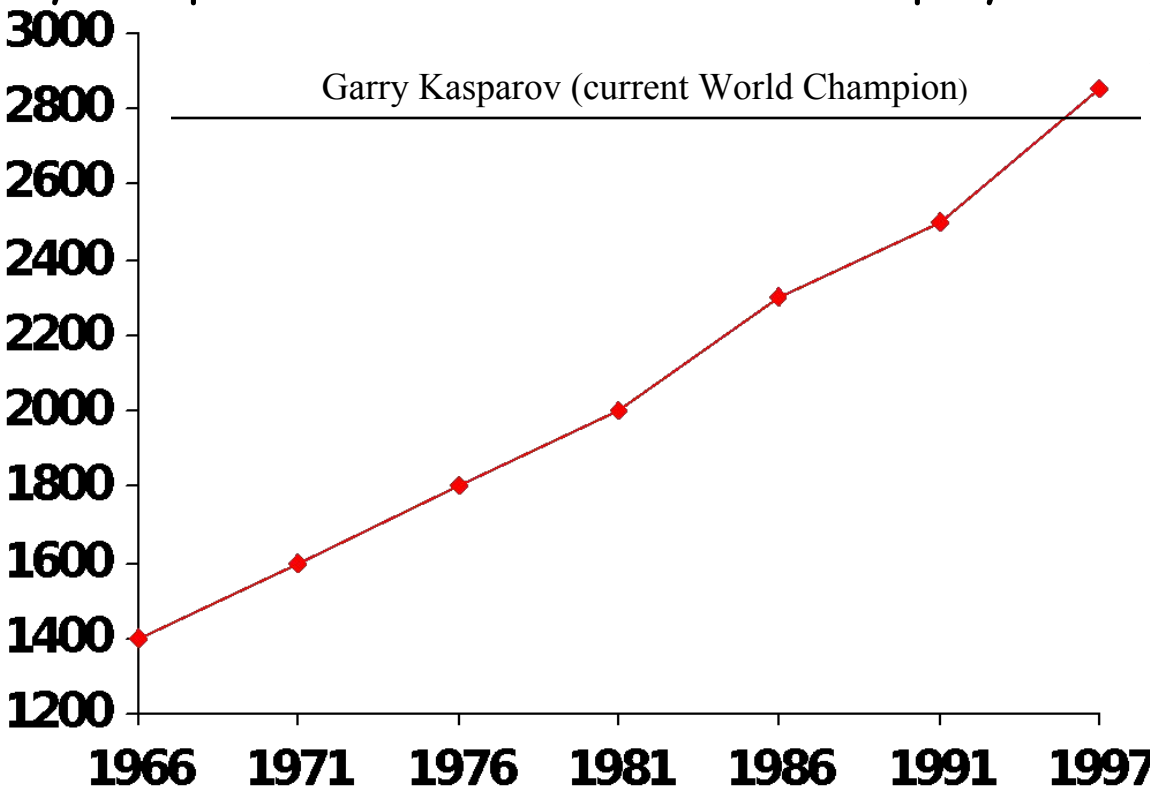
- A "foolproof" system is one that never makes an error:
  - Types of possible computer errors
    - hardware errors, e.g., memory errors
    - software errors, e.g., coding bugs
    - "human-like" errors
  - Clearly, hardware and software errors are possible in practice
  - what about "human-like" errors?

- An intelligent system can make errors and still be intelligent
  - humans are not right all of the time
  - we learn and adapt from making mistakes
    - e.g., consider learning to surf or ski
      - we improve by taking risks and falling
      - an intelligent system can learn in the same way

- Conclusion:
  - **NO**: intelligent systems will not (and need not) be foolproof

Can Computers play Humans at Chess?

- Chess Playing is a classic AI problem
  - well-defined problem
  - very complex: difficult for humans to play well

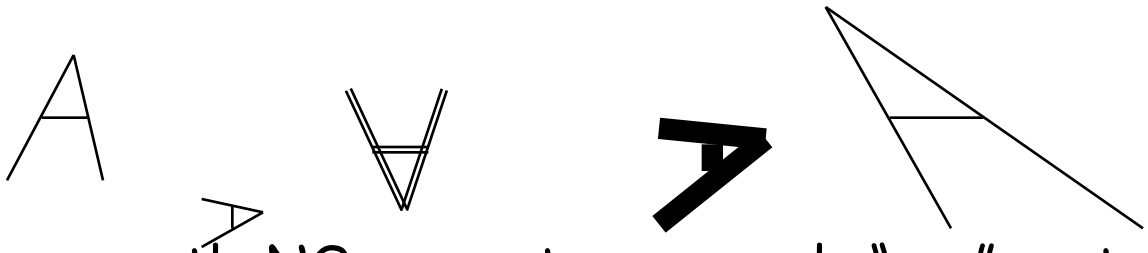


Deep Blue

Conclusion: YES: today's computers can beat even the best human

Can Computers "see"?

- Recognition v. Understanding (like Speech)
  - Recognition and Understanding of Objects in a scene
    - look around this room
    - you can effortlessly recognize objects
    - human brain can map 2d visual image to 3d "map"
- Why is visual recognition a hard problem?



Conclusion: mostly NO: computers can only "see" certain types of objects under limited circumstances: but YES for certain constrained problems (e.g., face recognition)

Can Computers Recognize Speech?

- Speech Recognition:
  - mapping sounds from a microphone into a list of words.
  - Hard problem: noise, more than one person talking, occlusion, speech variability,..
  - Even if we recognize each word, we may not understand its meaning.
- Recognizing single words from a small vocabulary
  - systems can do this with high accuracy (order of 99%)
  - e.g., directory inquiries
    - limited vocabulary (area codes, city names)
    - computer tries to recognize you first, if unsuccessful hands you over to a human operator
    - saves millions of dollars a year for the phone companies

Recognizing human speech (ctd.)

- Recognizing normal speech is much more difficult
  - speech is continuous: where are the boundaries between words?
    - e.g., "John's car has a flat tire"
  - large vocabularies
    - can be many tens of thousands of possible words
    - we can use **context** to help figure out what someone said
      - try telling a waiter in a restaurant:
        "I would like some dream and sugar in my coffee"
  - background noise, other speakers, accents, colds, etc
  - on normal speech, modern systems are only about 60% accurate
- Conclusion: NO, normal speech is too complex to accurately recognize, but YES for restricted problems
  - (e.g., recent software for PC use by IBM, Dragon systems)

Can Computers Understand speech?

- Understanding is different to recognition:
  - "Time flies like an arrow"
    - assume the computer can recognize all the words
    - but how could it understand it?
      - 1. time passes quickly like an arrow?
      - 2. command: time the flies the way an arrow times the flies
      - 3. command: only time those flies which are like an arrow
      - 4. "time-flies" are fond of arrows
    - only 1. makes any sense, but how could a computer figure this out?
      - clearly humans use a lot of implicit commonsense knowledge in communication
- Conclusion: NO, much of what we say is beyond the capabilities of a computer to understand at present