Approaches to AI

- Observation, Hypothesis of behaviour
  - Thinking Humanly
    - - Newell's GPS, Trace of human reasoning in humans in solving problems, Cognitive Science
  - Acting Humanly
    - - Turing test need of NLP, Knowledge Representation, Automated reasoning, Machine learning, Computer vision, Robotics
- Mathematics, Engineering
  - Thinking Rationally
    - - Laws of Thought approach, irrefutable reasoning/ Logicist approach, issue with informal/uncertain info representation, Computational Complexity
  - Acting Rationally
    - - Agents – Perceive, act/ operate autonomously, adapt to change, create and pursue goals, Rational agents to achieve best outcome
    - Laws of Thought + Skills needed for Turing Test

What is AI

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Automation of activities that we associate with human thinking, decision making, problem solving, …. (Bellman 1978)	The study of memory faculties through the use of computational models (Charniak + Mcdermott, 1985)
Study of how to make computers do things at which , at the moment, people are better (Rich + Knight 1901)	The branch of computer science that is concerned with automation of intelligent behaviour (Luger + Stubblefield, 1903)

View of AI

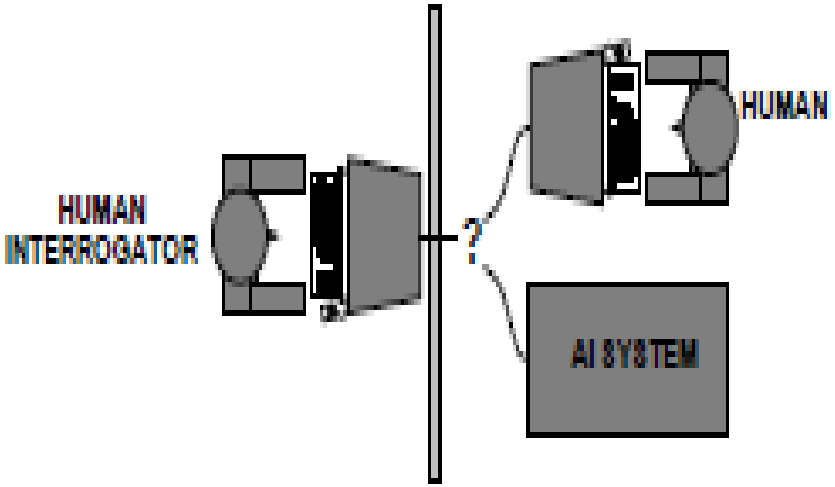
	Empirical	Computational	
Thought process and reasoning	**Thinking Humanly** Machines with minds (Understand (through introspection, psychological experiments – brain imaging), form theory, program) Input –output to match human behaviour - GPS traces reasoning steps	**Thinking Rationally** Perceive, reason, act computation model (Laws of Thought - codify right thinking, irrefutable reasoning processes) Correct conclusions, given correct premises through patterns of argument structures Field of Logic	
Behaviour	**Acting Humanly** Performing intelligent functions	**Acting Rationally** Computational intelligence	
	Success in terms of fidelity to human performance	Success against an ideal performance	

Approaches to AI – Acting Humanly

Turing (1950) “ Computing Machinery and intelligence

Can machines think? Can machines behave intelligently?

Operational test for intelligent behaviour – imitation game



Predicted that by 2000, a machine might have a 30% chance of fooling a lay person for 5 minutes

Anticipated all major arguments against AI in following 50 years

Suggested major components of AI:

Knowledge, Reasoning, Language, Understanding, Learning

Problem: Turing test is not reproducible, constructive or amenable to mathematical analysis

Turing Test

Turing Test: A computer passes the test if a human interrogator , after posing some written questions, can not tell whether the written responses came from a person or from a computer

Programming a computer to pass a rigorously applied test needs

NLP – Natural Language Processing	– to enable it to communicate
Knowledge Representation	- to store what it knows or hears
Automated Reasoning	- to use stored information to answer questions and to draw new conclusions
Machine Learning	- to adapt to new circumstances and detect and extrapolate patterns

Total Turing Test: includes test for subject's perceptual abilities and requires

Computer Vision

Robotics

Approaches to AI – Thinking Humanly

Cognitive Science

1960s – Information processing psychology replaced prevailing behaviourism

Requires scientific theories of internal activities of brain

- abstraction of knowledge? Circuits?
- how to validate -
  - predicting and testing behaviour of human subjects? (Cognitive Science)
  - direct observation of neurological data? (Cognitive neuro science)

Approaches to AI – Thinking Rationally

Normative/prescriptive rather than descriptive

Aristotle: what are correct arguments/ thought processes?

- various forms of logic notation and rules of derivation for thoughts
- through mathematics and philosophy to modern AI

Problems:

Not all intelligent behaviour is mediated by logical deliberation

Purpose of thinking? what thoughts one should have?

Approaches to AI- Acting Rationally

Rational Behaviour – Doing the right thing

Right thing? That which is expected to maximize goal achievement, given the available information

Does not necessarily involve thinking (ex: blinking reflex), thinking is expected to be in the service of rational action

Aristotle

Every act and every inquiry, and similarly every action and pursuit, is thought to aim at some good.

Approaches to AI – Rational Agents

How we

Think, Perceive, Understand, Predict, Manipulate a world far larger and complicated?

AI: understand and build intelligent entities

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

An agent is an entity that perceives and acts

$f: \mathcal{P}^* \rightarrow \mathcal{A}$ An agent is a function from percept histories to actions

For any given class of environments and tasks, agent (class of agents) with best performance are sought

Computational limitations make perfect rationality unachievable

- design best program for given machine resources

AI – Other disciplines

Philosophy	Logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality
Mathematics	Formal representation and proof, algorithms, computation Un-decidability, intractability, probability
Psychology	Adaption, phenomena of perception and motor control Experimental techniques
Linguistics	Knowledge representation, grammar
Neuroscience	Physical substrate (hardware) fro mental activity
Control Theory	Stability, homeostatic systems (that main equilibrium) Optimal agent designs
Operations Research	Planning, sequence of actions,

AI – history

1943: Mcculloch & Pitts : neurons Model
1950: Turing " computing machinery and intelligence"
Early AI programs, Samuel's checkers program,
Newell and Simon's logic theorist, Gelmeter's Geometry Engine,
1956: Dartmouth meeting "Artificial Intelligence adopted"
1965: Robinson's complete algorithm for logical reasoning
1966-74: discovery of computational complexity, NN winter
1969-79: Knowledge based systems development
1980-88: Expert systems boom
1988-93: AI Winter
1985-95: NN return, resurgence of Probabilistic, decision theoretic methods

2020: deep learning

Foundations of AI / Disciplines Contributing to AI

- Philosophy:
  - Can formal rules be used to draw conclusions?/ How does the mind arise from a Physical Brain?/ Where does knowledge come from?
  - Useful reasoning can be carried out by artefacts/machines
  - Reasoning is like numerical computation,
  - Distinction between Mind and Matter –
    - Rationalism (power of reasoning in understanding world), Dualism (a part of mind exempt from laws), Materialism (Mind operates according to Laws)
    - Empiricism (world understanding is through senses), Principle of Induction (general rules are acquired by exposure to repeated associations between elements)
  - Logical Positivism
    - all knowledge can be characterised by logical theories connected to observation sentences corresponding to sensory inputs
    - Confirmation Theory: acquisition of knowledge from Experience – Theory of Mind as a Computational Process
- Aristotle:
  - Actions are justified by a logical connection between goals and Knowledge of the actions outcome, deliberation about means, but not ends. We assume the end and consider how and by what means it is achieved. If we came upon impossibility, we give up the search. If appears feasible, we try to do/act
- What to do when several actions will achieve the goal or no action will achieve it completely?
  - Utilitarianism: rational decision making

Disciplines Contributing to AI

- Mathematics
  - What are the formal rules to draw valid conclusions?/ what can be computed?/ how do we reason with uncertain information?
  - Fundamental Ideas -> Mathematical Formalism -> Formal Science
  - Logical Representation
    - Formal Logic
    - Propositional/Boolean Logic
    - First Order Logic
    - Theory of reference – how to relate objects in logic to objects in real world
  - Algorithm
    - algorithms for logical deduction
    - Incompleteness theorem- limits of deduction - no proof for some TRUE statements
    - Computable Functions, decidability, Tractability (Computational Complexity) - NP complete, NP Hard problems
  - Probability
    - Possible outcomes, uncertain measurements, incomplete theories
    - Uncertain reasoning – updating probabilities in the light of new evidences (Bayes Rule)

Disciplines Contributing to AI

- Economics
  - How should we make decisions so as to maximize payoff?/ how should we do this when others may not go along?/ how should we do this when the payoff is far in the future?
  - " Economies can be thought of as consisting of individual agents maximizing their own economic well being. Economics is about how people make choices that lead to preferred outcomes"
  - Utility – Preferred outcomes
  - Theory of games and economic behaviour
  - Decision theory – Probability + Utility
    - Framework for decisions made under uncertainty
  - Game theory
    - No unambiguous prescription fro selecting actions (could be random)
  - Operations Research
    - How to make rational decisions when payoffs from actions are not immediate, but result from several actions taken in sequence
    - Markov decision processes: class of sequential decision problems
  - Rational Agents – Economics + OR
  - Satisficing: " Models based on satisficing – making decisions that are good enough rather than laboriously calculating an optimal decision – gave a better description of actual human behaviour"

Disciplines Contributing to AI

- Neuroscience
  - How do brains process Information?
  - Brain is the seat of consciousness.
  - Brains consist of neurons, massively parallel neuronal structures
  - Cognitive processes - Brain Causes Minds- “a collection of simple cells can lead to thought, action and consciousness”
- No theory still on how an individual memory is stored.
- Psychology
  - How do animals think and act? Experimental/behavioural observations methodology
  - Scientific/ introspective/ though processes
- Cognitive Psychology
  - Brain as information processing device
  - Knowledge based agent:
    - The stimulus must be translated into an internal representation -> the representation is manipulated by cognitive processes to derive new internal representations -> these are in turn retranslated into actions
  - Perception and communication
  - Cognitive Science with Computer modelling “ A cognitive theory should be like a computer program: it should describe a detailed information-processing mechanism whereby some cognitive function can be implemented

Disciplines Contributing to AI

- Computer Engineering
  - How can we build an efficient computer?
  - For AI to succeed we need intelligence and artefact (computer)
  - Calculator - Electro mechanical, Programmable Computer, HLL
  - ABC/ENIAC – electronic computers
  - Design of Difference (for maths) and Analytical Engine (addressable memory, programmable)
  - Main frames
  - Minicomputers
  - Microprocessors
  - Desktops
  - Single core systems
  - Internet
  - Multicore systems
  - Graphic processor units
  - Mobiles
  - Smart sensors

Software: operating systems, HLLs, multi tasking, databases, virtualization, frameworks, distributed processing, internet protocols, …

Disciplines Contributing to AI

- Control Theory and cybernetics
  - How can artefacts operate under their own control?
  - Self regulating feedback control systems
  - Control theory – study of biological and mechanical control systems
    - " purposive behaviour arises from a regulatory mechanism trying to minimize error – difference between current state and goal state"
  - Computational Models of Cognition – Cybernetics
  - Stochastic optimal Control – design of systems that maximize an objective function over time

Disciplines Contributing to AI

- Linguistics
  - Hoe does Language relate to thought?
  - Verbal behaviour – behaviourist approach to language learning
  - Syntactic structures
  - Computational Linguistics/ NLP
    - Understanding language requires understanding of subject matter and context, not just understanding of the structure of sentences
  - Knowledge representation is tied to Languages

History of AI

- Gestation of AI
  - Models of neurons, networks of neurons, learning rules, Neural net computer
  - Turing test, idea of machine learning, genetic algorithms
  - Study of automata theory, neural nets, study of intelligence – for 2 months for Artificial Intelligence project:
    - " every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it"
  - The logic Theorist: reasoning program
- Early Enthusiasm, Great Expectations
  - General Problem Solver (GPS) designed, Geometry theorem prover, programs for checkers
  - LISP AI programming Language
  - Timesharing for scarce computer resources
  - Advice taker – designed to use knowledge to search for solutions to problems
  - Anti-logic outlook
  - Resolution theorem (theorem proving algorithm for first order logic general purpose methods of logical reasoning)
  - Question answer and planning systems development based on logic and resolution
  - Robotics: logic + Physical activity
  - Micro worlds: problems that appeared to require intelligence to solve, calculus integration problems, ANALOGY program to solve geometric analogy – blocks world – set of solid blocks placed on a table top. Task: rearrange in acertain way using a robot hand that can pick up one block at a time.

History of AI

- A Dose of reality
  - Early programs used syntactic manipulations without knowing subject matter/context
  - Intractability of many AI problems: programs solved problems by trying out different combinations of steps until the solutions is found – computational complexity, scaling up issues, combinatorial explosion
    - " A program can find a solution in principle does not mean that the program contains any of the mechanisms needed to find it in practice"
  - Limitations of basic structures being used to generate intelligent behaviour. Perceptron limitation (later multi layer neural networks and back propagation caused resurgence)
- First decade of AI: problem solving: general purpose search mechanism trying to string together elementary reasoning steps to find complete solution – weak methods
- Knowledge based systems/ Expert Systems
  - Use domain specific knowledge for larger reasoning steps, handle easily typically occurring cases
    - " to solve a hard problem, you have to know the answer already"
  - DENDRAL: knowledge intensive system to solve the problem of inferring molecular structure from mass spectrometer information.
  - MYCIN: to diagnose blood infections. 450 rules gathered from experts. Rules included uncertainty
  - SHRDLU: system to understand natural language based on syntactic analysis
- PROLOG, PLANNER, FRAMES development of knowledge representations, reasoning languages

History of AI

- AI becomes Industry
  - R1 – first commercial expert system at DEC – to help configure orders for new computer systems. Saved company 40 million $ a year. 40 expert systems used by 1988
  - Dupont had 100 in use saving company 10 m $ a year

  - Plan for 5th generation intelligent computers to run Prolog
  - Research on microelectronics, chip design, user interface
  - Billions of $ industry with expert systems, vision systems, Robots, Software, Hardware for these.
- AI Winter Companies failed to deliver
- Return of Neural Networks, Back propagation to learning, parallel distributed processing
- Connectionist models of intelligent systems vs. Symbolic models
- AI adopts scientific methods
  - Symbolic computation - control theory, statistical Analysis
  - Machine learning – information theory
  - Uncertain reasoning – stochastic modelling, probability and decision theory

Applications of AI

HLAI: Human Level AI AGI: General AI

- Autonomous vehicles
- Speech Recognition
- Autonomous planning and scheduling
- Game playing
- Spam fighting
- Logistics planning
- Machine translation

Intelligence

Involves

Learning

Reasoning

Understanding

Grasping truths

Seeing relationships

Considering meanings

Separating fact from belief

…

Follows a process (?)

Set a goal based on needs

Assess the value of any currently known information in support of the goal

Gather additional information that could support the goal

Manipulate the data such that it achieves a form consistent with existing information

Define the relationships and truth values between existing and new information

Determine whether the goal is achieved

Modify the goal in light of new data and its effect on the probability of success

Repeat process until goal is achieved!

Kinds of Intelligence

Kinds of intelligence	simulation potential
Visual-Spatial	moderate
Bodily – Kinesthetic	Moderate to high
Creative	none
Interpersonal	Low to moderate
Intrapersonal	none
Linguistic	low
Logical-mathematical	high

AI view

Strong AI – generalized intelligence that can adapt to a variety of situations

Weak AI - specific intelligence designed to perform a particular task well

Reactive machines - chess playing - no memory, computational power and algorithms – weak AI

Limited memory - self driving car – decisions based on experience stored in memory – current strong AI

Theory of mind – can assess goals

Self awareness

Experiment

1. If the number of customers Tom gets is twice the square of 20% of the number of advertisements he runs, and the number of advertisements he runs are 45, what is the number of customers Tom gets?

2. Are reflex actions rational? Are they intelligent?

3. To what extent are the following computer systems instances of AI?

a. supermarket barcode scanners

b. web search engines

c. voice activated telephone menus

d. internet routing algorithms that respond dynamically to the state of the network?

4. Which of the following can be done by computers with AI at present?

a. play a game of table Tennis

b. drive along ghat roads

c. drive in traffic

d. play a decent game of bridge

e. discover and prove a new mathematical algorithm

f. write an intentionally funny story

g. give competent legal advice in a specialised area of law

h. translate spoken English into spoken Swedish in real time

AI

AI is built on

1. Automated problem solving

through efficient search in solution space – trial and error method

enormous computational complexity

space-time trade off

heuristics – domain knowledge use

Paradigms of search

Linear programming

Integer programming

Dynamic programming

Heuristic search

Evolutionary algorithms (genetic)

with huge computational power being available these became possible (1985 – 1995)

AI

AI is built on

2. Knowledge and deduction

store and retrieve knowledge and interpret and deduce/reason

have rules and use them to deduce meaning

Knowledge and understanding /realization are different

Knowledge Representation – logic propositional, first order

Deduction - logics of knowledge

Paradigms

- Knowledge based systems
- Expert systems
- Automated theorems
- Formal verification

KB is huge! Memory being available makes KB possible (1990 – 2000)

AI

AI is built on

3. Ability to learn

   can the system learn to solve a problem better? Learn to plan?

Machine learning , NN

To make computer look intelligent

   Automated problem solving

   Machine learning

   Logic and deduction

Human computer interaction

   Computer vision

   Natural Language Processing

   Robotics

AI

Fundamentals

notion of expressing computation as an algorithm

decidability/un-decidability

Godel's Incompleteness Theorem: "Any consistent formal system F within which a certain amount of elementary arithmetic can be carried out is incomplete; i.e., there are statements of the language of F which can neither be proved nor disproved in F."

computability

Turing machine is capable of computing any computable function

tractability/ intractability

A polynomial function is intractable if an NP complete problem can not be reduced to the polynomial in polynomial time.

problems for which there exist no efficient algorithms to solve them