ARTIFICIAL INTELLIGENCE: HYPE AND SUBSTANCE

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THE BEGINNING

1936: Turing machine model
  ▪ Simple model for universal computation

1940s: Modelling of brain as a large collection of connected neurons
  ▪ Opened up possibility of simulation by computing devices

1950s: Birth of computers
  ▪ These could do unheard of computing tasks

It was believed that computers will soon outperform human intelligence
1960s-1970s: FOUNDATIONS, EXPECTATIONS, AND DESPAIR
Significant funding was directed to AI research

Neurons were modelled as a threshold gate (also called perceptron):

\[ \sum_{i=1}^{n} w_i x_i > w? \]
The weights $w_i$ and $w$ are discovered via training:
- Take some set of inputs and the correct output on them
- Use it to find out weights that satisfy the above input-output behaviour to the extent possible

This process is called **supervised machine learning**
NEURAL NETWORKS

- A single layer of threshold gates did linear classification and gave some interesting results
- Multiple layers of these gates were expected to handle more complex classifications, however, learning the weights was not feasible
- Threshold gates with multiple layers were called neural networks
A general technique, called backtracking, was proposed to solve any search or optimization problem.

- Searches the space of potential solutions, and if stuck, goes back a step and tries another direction.
- A number of reasonably non-trivial problems were solved using this.
Another general technique, called genetic algorithms, was proposed to solve optimization problems.
- Mimics evolution: start with a small set of poor solutions, apply crossover and mutation to evolve the solution set, select better ones and repeat.
- Was applied in several engineering optimization problems.
DOING HUMAN TASKS

- Natural language was modelled using *semantic net*
  - Concepts connected with relationships
  - Programs like ELIZA could carry out realistic conversations with humans using this
- First robots were constructed who could move and see
  - Limited to basic obstacles
UNMET EXPECTATIONS

- Tools developed failed beyond a point
- Backtracking could not handle blowup caused by exponential search spaces
- Genetic algorithms also could not scale up
- Neural network models failed to deliver on complex tasks like vision
- Natural language models could not even go beyond simple sentences

Developments in Complexity Theory showed that many tools are trying to solve NP-hard problems and so cannot do it efficiently.
1980s AI AS KNOWLEDGE REPOSITORY
Expert systems were designed to store the knowledge in specific domains and use it to solve problems

- For example: medical diagnosis
- Required storing and operating on large amount of data

Deep Thought, developed by IBM, became a grandmaster of chess

- It examined half a billion positions before making a move
**DISCOVERY OF BACKPROPAGATION**

- **Backpropagation** is an efficient algorithm to train neural networks with any number of layers
  - Training equals finding out weights at all gates so that the network does well on training set
  - Only simple tasks, involving a few hundred gates, could be done due to constraints on computational power
MORE DISAPPOINTMENTS

- Ambitious project to build fifth-generation computers failed
  - These were supposed to converse, reason, and analyse like humans
  - A lot of funding was invested in building special purpose hardware for it
- The era of personal computers started, which shifted focus from mainframes
Using Advances in Hardware and Algorithms

- Deep Blue, advanced version of Deep Thought, beat Chess World Champion Garry Kasparov in 1997
- In 2007, a CMU designed autonomous vehicle drove 90kms in traffic
- These were achieved by improving existing tools and significantly increased computing power
  - Moore’s Law states that computational power doubles every 1.5 years
  - Significant developments took place in approximately solving NP-hard problems as well as exactly solving in special cases
Satisfiability (SAT) is perhaps the most fundamental NP-hard problem
- It models finding solutions under constraints
- Example: find a complete pairing of $n$ boys and $n$ girls given that some pairs are compatible and some are not
  - Let $x[i,j]$ denote Boolean variable coding pairing of boy $i$ with girl $j$
  - Constraints:

\[
\bigvee_{i,(i,j)\text{compatible}} x[i,j], \quad \bigvee_{j,(i,j)\text{compatible}} x[i,j] \quad \text{No boy or girl unpaired}
\]

\[
(x[i_1,j] \land \neg x[i_2,j]) \lor (\neg x[i_1,j] \land x[i_2,j]), \text{i}1 \neq \text{i}2 \quad \text{No boy paired to > 1 girl}
\]

\[
(x[i,j_1] \land \neg x[i,j_2]) \lor (\neg x[i,j_1] \land x[i,j_2]), \text{j}1 \neq \text{j}2 \quad \text{No girl paired to > 1 boy}
\]
Fast solvers were developed for special types of formulas
- These types covered a large number of problems encoded as SAT formula
  - Transformation needs to be done carefully
DEEP LEARNING REVOLUTION

- In 2011, use of GPUs to perform backpropagation, and availability of large amount of annotated data, allowed efficient supervised learning using neural networks of multiple levels
  - GPUs were originally designed for game play, tweaked for very fast matrix operations
  - Data was collected over internet and annotated by users
  - This is called deep learning
Deep learning outperformed all other AI techniques in many domains.
- These techniques include Hidden Markov Models and Support Vector Machines
- It is becoming pervasive now!
DEEP LEARNING IN VISION AND SPEECH

- [2011] Superhuman performance in a visual pattern recognition contest
- [2012] ImageNet competition for image classification won by a significant margin
- [2015] 49% improvement in speech recognition by Google
- [2017] Autonomous cars are able to process live pictures and sound in real time
DEEP LEARNING IN BIOLOGY

- [2012] Won Merck Molecular Activity Challenge to predict biomolecular target of a drug
- [2012] Won MICCAI challenge on analysis of large medical images for cancer detection
- [2015] Deep Patient could predict onset of liver cancer, schizophrenia, etc.
DEEP LEARNING IN GAMES

- [2011] IBM Watson beat two best human players in Jeopardy
  - Used WikiPedia as main source of information

- [2016] Google’s AlphaGo beat the reigning world champion in Go

- [2017] New version of AlphaGo, without any initial data, beat the older version after training
  - This was based on Reinforced Learning, where a network is trained with feedback from live examples instead of annotated data
CONVERGENCE

- Computational speed continues to follow Moore’s Law, making more tasks feasible
- Methods based on deep learning continue to expand to newer domains and give better performance
- Newer methods like reinforced learning are also developing rapidly
- SAT-solvers continue to improve
- Old methods like Bayesian learning and clustering have also made rapid advances

These are being applied together and computers will outperform humans in more and more tasks
Some predictions say that computers will become more intelligent than humans by 2050
  ▪ Reminiscent of the hype in 1960s

It is not at all clear how to make the same algorithm do a large number of different types of tasks intelligently

  ▪ So such claims need to be taken with a pinch of salt
THANK YOU