Is a Mathematician a Robot



Chris Budd





Gresham College





The rise of the robots!

Are robots about to become an integral part of our society?







Robot comes from the Czech term *robota* 'forced labour' in K. Čapek's play *R.U.R.* 'Rossum's Universal Robots' (1920)



Now robots build cars



and robots can drive cars too



But how close are we to Asimov's vision?

Strong artificial intelligence

Strong Artificial Intelligence Is the ability of a computer to exhibit general intelligence



Decided by the *Turing Test*



Weak artificial intelligence is the ability of a robot to (be trained to) do a specific (albeit complex) task.

Machine Learning

Examples: speech recognition, fraud detection, car driving



"Machine learning is the branch of artificial intelligence that allows computer systems to learn directly from examples"

Royal Society Report, 2017



"Machine learning is a core, transformative way by which we're rethinking everything we're doing."

Sundar Pichai, CEO of Google

Big example: Playing games with machine

Early example of artificial intelligence

Chess Playing Computers Turing, Shannon 1949



"Although of no practical importance, the question is of theoretical interest, and it is hoped that...this problem will act as a wedge in attacking other problems—of greater significance." Followed strategies which mimicked the way that grand masters play chess, only much faster (200 Million positions a second)

- Type A: Exhaustive examination of all possible moves
- Type B: Trees of possible moves, with careful pruning of bad moves



1997: Deep Blue computer based on this strategy beats Gary Kasparov

Enter machine learning: AlphaZero computer

Given the rule book of chess only and played against itself to learn to play like a Grand Master



2017: AlphaZero takes on Stockfish the best 'traditional' chess playing computer and beats it convincingly



Sadly it makes a whole new world of chess cheating possible!

Machine learning computers can now play Go

Artificial intelligence: Google's AlphaGo beats Go master Lee Se-dol

() 12 March 2016 Technology

< Share



A computer program has beaten a master Go player 3-0 in a best-of-five competition, in what is seen as a landmark moment for artificial intelligence.



And even poker and scrabble

Can machine learning be used for automatic recruitment?

Feed in a lot of CVs and link them to recruitment decisions?



Invention of the general programmable computer





Von Neumann

Pilot ACE

How machines learn

Digit Recognition



Breakthrough came with the invention of the neural net (1963)



$$Out = H\left(\sum_{i=1}^{D} w_i X_i - C\right)$$

$$H(x) = \begin{cases} 1, & x > 0; \\ \frac{1}{2}, & x = 0; \\ 0, & x < 0. \end{cases}$$

IDEA:

	0123456789
	0 2 3 4 5 6 7 8 9
	0123456789
	0123456789
	0123456789
2 Apply it to new data	0 1 2 3 4 5 6 7 8 9
1. Train the network on a set of data	0 1 2 3 4 5 6 7 8 9

Training:

Identify suitable weights W_i so that on the training data set the neural net correctly identifies the right digit

 $w_1 X_1 + w_2 X_2 - C$





Deep neural nets use many more layers



hidden layer 1 hidden layer 2

Convolutional neural networks (CNNs)



Excellent for image and face recognition



Types of training

1. Supervised

2. Reinforcement



Optimise the weights using numerical methods such as steepest descent, quasi-Newton, simulated annealing, Monte-Carlo Tree Search (MCTS)

Eg. AlphaZero used reinforcement learning over 700,000 games with MCTS optimisation

Some applications:

1. Computer vision



2. Investment planning Investment options for retirement PLANNING							
Traditional IRA	POSSIBLE UPFRONT tax deduction on CONTRIBUTIONS	Pay tax on withdrawals at ordinary income rates in retirement.					
Roth IRA	NOUPFRONT tax breaks on CONTRIBUTIONS	NO tax paid on withdrawals in retirement.					
Annuities	NO tax deduction for CONTRIBUTIONS	Pay tax ONLY on gains when receiving periodic payments in retirement.					
Brokerage account	NO tax breaks for CONTRIBUTIONS	Pay tax ONLY on gains at long-term capital gains rates when investments are sold after being held for more than one year.					

3. Hip Fracture Recognition and Diagnosis



Problems with machine learning

- Machine learning algorithms are very much a black box
- We must be careful when using them to make decisions about human beings

• Significant ethical issues





Machine Learning and its Ethical Dilemmas: an Introduction

14 Feb: Acquire a rapid overview of machine learning and the ethical questions that surround it, in preparation for the series of seminars planned during the semester. There will also be a guided practical session (bring your laptop) to see algorithms in action! Professor Mike Tipping will lead this seminar aimed at a broad scientific audience of students and staff. University of Bath, 3 West North, Room 2.1, 2.15 – 4.15pm. Euli details and registration >>

Wednesday Machine Learning Seminars

Come along to our series of machine learning seminars bringing together academics from all disciplines to share knowledge, exchange ideas and stimulate new collaborations across departments. Each seminar will feature one or more speakers on a range of relevant topics. All seminars are held in from 2.15 – 4.00pm in 8 West, Room 2.1, University of Bath.

- Goood amailytics meeds good data and that meeds good metadata, Professor Mandy Chessell, IBM, 28 February
- Accountable and explainable Al, Dr Sandra Wachter, Oxford Internet Institute, 7 March
- From computational metaphysics towards computational pseudo-ethics, Dr Christoph Benzmueller, Free University of Berlin, 14 March
- A series of mimi talks by University of Bath researchers using machine learning, 21 March
- o Governance: Arguing for greater transparency, accountability and means for citizen interventions, Dr Joanna Redden, Cardiff Data Justice

If you look at enough data you can make false connections



Correlation does not imply causation

You can see any thing you want in a cloud



Machines can get it wrong



Identified as a 45mph speed sign

Machines don't think like humans



Can a robot be a mathematician?

Answer 1: Yes. Computers can calculate fast!



Answer 2: Yes. Computers can do algebra



Answer 3: Yes. Robots can pass maths exams



Answer 4: No. There are many maths problems even fast computers can't solve well

NP-Hard problems

Can't (as far as we know) be solved in polynomial time

Eg. Factorising large numbers, testing for primes, travelling salesperson

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

And, can a machine learning based computer forecast the weather?



"And now the 7-day forecast ... "

Answer 5: No. Computers don't display mathematical reasoning



Hilbert program attempted to reduce all of mathematical reasoning to arithmetical operations

Kurt Goedel's incompleteness theorem showed that this was impossible



But can a machine learning algorithm be creative?

As a test play a computer the works of Mozart.

Then ask it to compose a symphony.

Could that then be played to an expert musician and found indistinguishable in imagination and invention from that created by a human being?

I wonder if I will see that day?





How close are we to general AI?

This seems as far away as ever!

