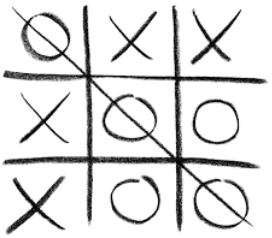
Noughts and Coding: The Rise of Machine Learning
An essay by Amy Hill

Noughts and crosses: A recreational game or a tool for the rise of robots? For those who have never had to entertain bored children at a restaurant, noughts and crosses is a simple game played on a three by three grid that involves getting three of your pieces (either noughts or crosses) in a row, horizontally, vertically or diagonally. The simple pastime has three outcomes: win, lose or draw *(see picture on the right for an example of a noughts and crosses game, which has been won by noughts)*. The optimum solution is obviously to win, but you lose nothing from a draw. So how was a simple game used to demonstrate the power and importance of machine learning? And how did one man, a lot of matchboxes and beads and a free weekend prove the importance of trial-and-error methods in the rise of artificial intelligence?



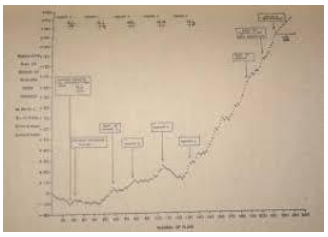
Before we delve into the wonders of how a pile of boxes can replicate some of the most intelligent AI robots on the market today, let's define a couple of terms. A machine can be defined as "an apparatus using mechanical power and having several parts, each with a definite function and together performing a particular task". An engine is "a thing that is the agent or instrument of a particular process". Machine learning is "the use and development of computer systems that are able to learn and adapt without following explicit instructions, by using algorithms and statistical models to analyse and draw inferences from patterns in data". Artificial intelligence is "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages". Using these definitions from, Oxford Language Dictionary, we can now explore the wonders of MENACE.

In 1961, Donald Michie devised a machine that could play noughts and crosses. Although his idea could be set up for the engine to work as the first or second player, he focused on it in the first player role. His machine was called MENACE (Machine Educable Noughts And Crosses Engine) and was made of 304 matchboxes *(the picture on the right shows Michie's initial MENACE machine)*. On each box, one of the 304 distinct options of grid the opening player can encounter during the game, is drawn on the side. In this version of the game, only distinct grids are used to reduce the number of boxes used; avoiding rotations and reflections. In each box is a set of coloured beads *(the picture on the left shows an example of the bead colours and the positions they represent for the final move)*; each colour represents a position on the grid. Each box starts with an equal proportion of beads, naturally these proportions quickly change as the machine learns and grows. There are more beads in the boxes for earlier moves because there are less options for starting moves than finishing moves. For each of the moves done by the machine, a bead is picked at random for the corresponding matchbox. These beads are kept out of the box until the end of the game. If the MENACE loses the game, it is "punished" and the bead is taken out of the boxes used in that game. If it draws with its opponent, another bead of the same colour

is added to each of the boxes to reward it. If MENACE wins, three extra beads of the same colour are put in to give it a greater reward. Over one weekend in 1961, Donald Michie played 220 games against his machine. Anyone have a spare 304 matchboxes, quite a few beads and some patience? I fancy a game of noughts and crosses…

Before we discuss Donald Michie's results from his busy weekend becoming a game master, let's discuss the man behind the machine. Born in Burma (now Myanmar) in 1923, he attended Rugby school and later won a scholarship to study the classics at Balliol College, Oxford. Wanting to contribute to the war effort in 1943, he signed up for a Japanese course. Well, things didn't quite go to plan with the information on that course and he ended up taking a course on cryptography. Michie showed a flair for the subject. Bletchley Park *(seen pictured on the right)* quickly recruited him to work for "Testery", a department that worked on the German teleprinter cipher. While at Bletchley Park, Donald Michie worked with the likes of Alan Turing, Jack Good and Max Newman. After the war, he returned to Oxford where he received his doctorate for mammalian genetics in 1953. Until 1965, he took the position of director in the department of Machine Intelligence and Perception at the University of Edinburgh. In 1985, he went to Glasgow to found the Turing Institute, named after the cryptographer Michie had worked with at Bletchley Park during the war. Right, after that little biography, let's get back to MENACE.

Michie's machine started off losing the majority of games; a pretty unsurprising outcome, considering that he was picking out beads at random from a group of matchboxes. However, as the weekend drew on and more grids were filled with a combination of noughts and crosses, MENACE's success improved and it started to draw and win more of the games. From his system of confiscating or rewarding beads to the boxes, Michie was slowly "teaching" his machine what moves were favourable and led to better outcomes. He plotted the outcome of each game on a graph, with "Cumulative sum of excess of bonuses over forfeits" on the y-axis and "game number" on the x-axis *(see a picture of graph on the left)*. For every loss the line goes down one unit, for a draw it goes up one unit and for a win it goes up three units. (Recognise these numbers? These are the same proportions used for the addition/subtraction of beads in the matchboxes.) Although the graph dips slightly at first, the average trend is an increase in the cumulative sum. The graph occasionally dips to where MENACE lost a game or two, but these dips became less frequent later on in the experiment. Using this graph, Michie successfully proved that MENACE had "learnt" to play noughts and crosses. The group of matchboxes had gone from a random chance of drawing/winning to making statistical decisions for each move, and coming out better off as a result. So, Michie proved matchboxes could be taught to play a simple, recreational game. But what does any of this slightly odd experiment have to do with artificial intelligence and the rise of robot technology?



Artificial Intelligence was first introduced as an academic discipline in 1955. Linking back to our definition from earlier, it is all about technology being able to "think" and "act" like humans. With MENACE, Michie managed to prove that artificial intelligence was possible. He successfully showed that a machine (although mechanical, rather than electronic) could

learn human skills, such as tactical decision making, using a method of trial and error. Rather than telling the machine what moves would result in a win/draw, he allowed the machine to make mistakes and, in essence, correct itself; in this case, by adding or confiscating beads from the boxes. Using this result from a mechanical machine, doors were opened to allow electrical machines to "learn". Collaborating with Mr. D. J. M. Martin of Ferranti Ltd., the two men were able to program a Pegasus 2 computer to simulate the matchbox machine. In this case, both players are played by the computer and the reinforcement system worked slightly differently, but the aim was the same; for a machine to learn to play noughts and crosses effectively. Nowadays, the field of AI robotics has progressed far beyond recreational games. Scientists and engineers across the globe are now building and teaching robots to perform everyday human tasks, such as picking up and carrying items. For someone outside the world of robotics, watching a robot play with a toddler's toy and attempt to figure out which hole to put a shaped block into may seem rather trivial. But for the people working in the industry, it represents a long term success of 60 years of hard work. From Michie's simple representation of a machine learning to play a recreational game over half a century ago, to modern times where robots are being taught to do high precision medical surgeries. Maybe a pile of matchboxes and some beads can change the world for the better?

Bibliography:

-Definitions taken from Oxford Languages Online Dictionary
-Biographical details on Donald Michie taken from https://en.wikipedia.org/wiki/Donald_Michie and verified using https://history.computer.org/pioneers/michie.html
-Donald Michie's original report on his work can be found at https://www.dropbox.com/s/ycsycu0l01g9643/DonaldMichie.pdf?dl=0
-Research on Artificial Intelligence: https://en.wikipedia.org/wiki/Artificial_intelligence
-Picture of Bletchley Park during the war taken from https://www.bletchleypark.org.uk
-Diagram of the beads' colours and positions was taken from https://chalkdustmagazine.com/features/menace-machine-educable-noughts-crosses-engine/

Wider reading:

-https://www.youtube.com/watch?v=R9c-_neaxeU&t=18s and https://www.youtube.com/watch?v=KcmjOtkULi4 are videos by Matt Parker detailing a re-creation of MENACE he was a part of at the Manchester Science Festival
-https://www.dropbox.com/s/0f9ukxxvh0pgdui/MENACE-data.zip?dl=0&file_subpath=%2FMENACE-data%2Fsat-ending-bead-numbers.csv This provides the data collected by the team at the Manchester Science Festival at the end of their first day
-https://www.mscroggs.co.uk/menace/ This is an online version of MENACE you can play against
-https://www.mscroggs.co.uk/blog/19 This is a blog post by Matt Scrogg, who was leading the team at the Manchester Science Festival
-https://chalkdustmagazine.com/features/menace-machine-educable-noughts-crosses-engine/ This is another interesting article on MENACE, with more detail on how each game was played and recorded