Alan Turing:
A modern computing legacy

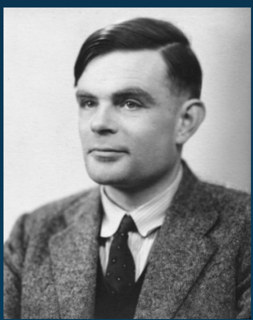

Photo credit: Wikipedia

Inside this guide:

The world would be a different place if not for Alan Turing. A mathematician and cryptographer, Turing's work at Bletchley Park heavily contributed to the Allied war effort and had profound consequences in shortening World War II. His pioneering 'stored program' computer underpins every computer today, and he has influenced early thinking on artificial intelligence, came up with mathematical approaches to problems in biology and medicine, and played a part in designing and programming the early computers built in the post-war era.

Turing – who had been convicted of homosexuality, which was then a crime – is thought to have committed suicide in 1954. In 2012, the centenary of Alan Turing's birth, this guide celebrates the computing pioneer's life and looks at how his futuristic work, from artificial intelligence to thinking machines, is seen in a modern context.

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The computing pioneer's life and works

Photo credit: Science Museum/SSPL

If mathematician Alan Turing were still alive today, he would have reached his 100th birthday on 23 June. To celebrate the centenary, the Science Museum in London is staging an exhibition on the work of the British computing pioneer, whose ideas helped drive code-breaking and computer programming, but stretched into many other areas.

Turing was only 24 years old when he came up with the idea of the 'stored program' computer, which underpins every computer today. He influenced early thinking on artificial intelligence, came up with mathematical approaches to problems in biology and medicine, and played a part in designing and programming the early computers built in the post-war era.

In September 1939, Cambridge graduate Turing was recruited to work on World War II code breaking at Bletchley Park, in part to try to crack the Enigma codes used by the German High Command. He helped develop the electromechanical Bombe machine, which acted as if it were several Enigma machines wired together, for the decoding. His work is thought to have helped shorten the war by two years.

The Enigma machine pictured was lent to the museum by Mick Jagger, who produced the 2001 British movie Enigma, a wartime thriller set at Bletchley Park.

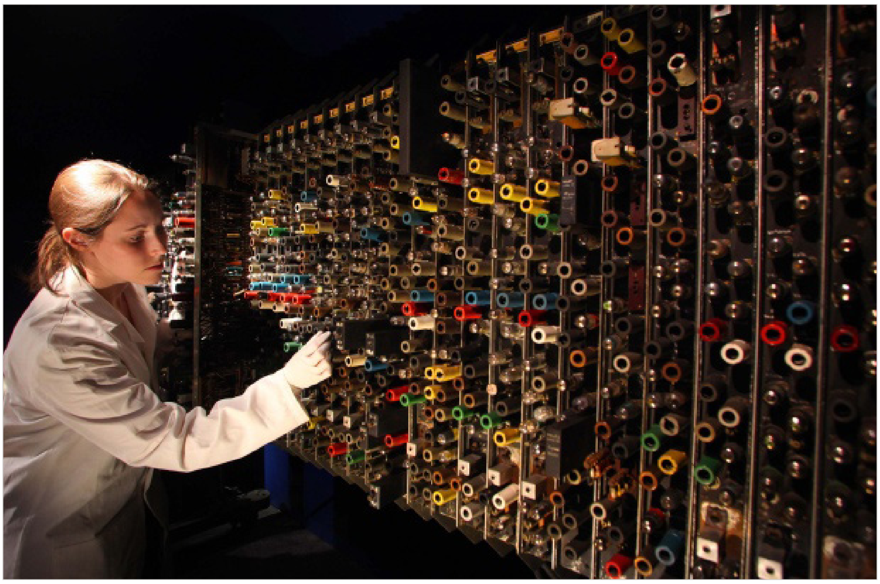

Photo credit: Science Museum/SSPL

After the war, Turing worked on developing a computer at the National Physical Laboratory in Teddington. He left the project in 1948, but a trial version of the Pilot ACE computer (pictured) was completed in 1950 from Turing's fundamental designs.

Described by the Science Museum as "the most significant surviving Turing artefact", the Pilot ACE (Automatic Computing Engine) was one of the first electronic universal computers.

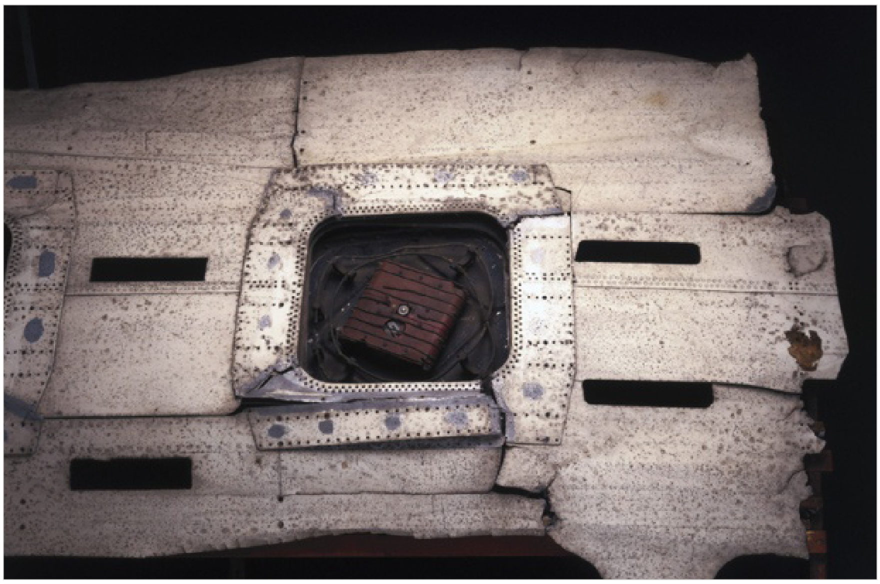

Photo credit: Science Museum/SSPL

The Pilot ACE computer was used to investigate a series of fatal air crashes involving Comet aircraft in the 1950s. The cause of the crashes was subsequently found to be metal fatigue.

This piece of fuselage (pictured) is from a Comet that crashed in 1954 into the Mediterranean near Italy, killing 35.

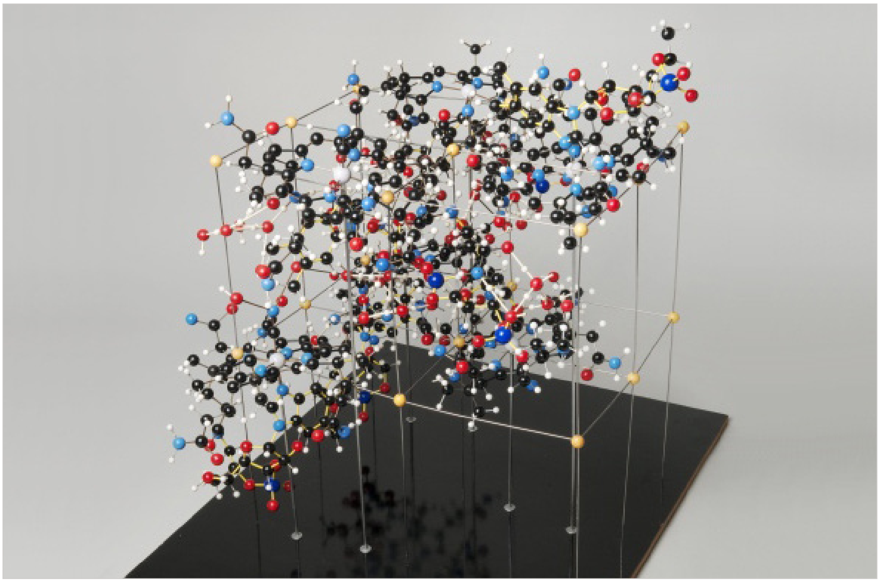

Photo credit: Science Museum/SSPL

Chemist Dorothy Hodgkin used the Pilot ACE computer in research into the structure of vitamins, using it to help devise this model of vitamin B12 (pictured), presented to the Science Museum in 1959.

Photo credit: Science Museum/SSPL

Turing went to work at Manchester University in 1948, after leaving the National Physics Laboratory. In 1949, his protégé Dietrich Prinz worked with philosophy lecturer Wolfe Mays to devise the electrical relay-operated symbolic logic machine pictured above. Built from RAF spare-parts, the machine is a device for testing logical propositions.

Turing was fascinated by thinking machines, and in 1950 wrote a paper published in Mind that contained what would become known as the ‘Turing Test’, a way to measure machine intelligence.

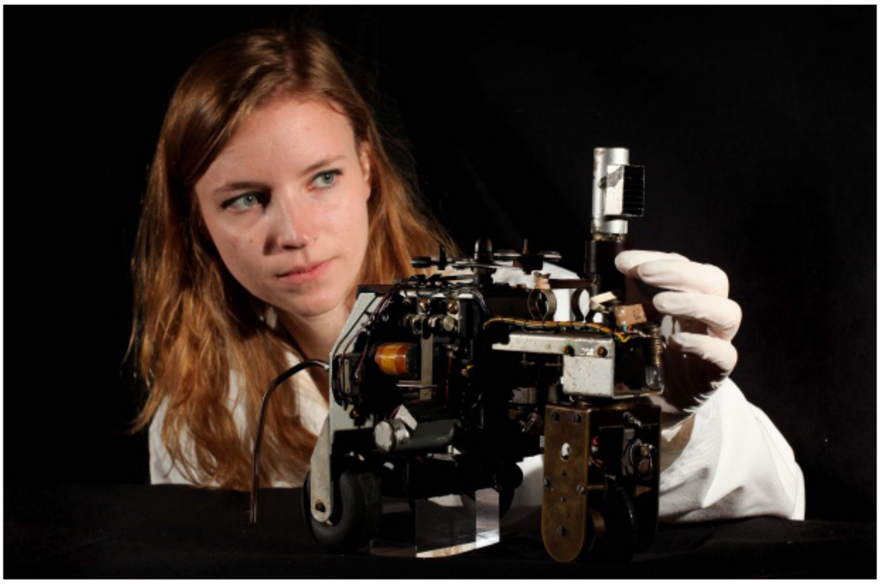

Photo credit: Science Museum/SSPL

In August 1951, Turing visited the Science Museum and saw a cybernetic ‘tortoise’ invented by neurologist William Grey Walter. The ‘tortoise’ could travel around floors and avoid obstacles, and was attracted to light.

At the time, Grey Walter’s neurological institute was also involved in trialling the use of female hormones to reduce libido in homosexual men. Turing, who knew Grey Walter through the cybernetics Ratio Club, was himself was given the choice of prison or chemical castration in 1952 after being found guilty of gross indecency. Turing opted for the course of ‘treatment’, but was found dead of poisoning in 1954 next to a half-eaten apple.

Then-UK prime minister Gordon Brown apologised for Turing’s treatment in 2009, calling it “horrifying”.

“It is no exaggeration to say that, without his outstanding contribution, the history of the Second World War could have been very different,” said Brown. “He truly was one of those individuals we can point to whose unique contribution helped to turn the tide of war. The debt of gratitude he is owed makes it all the more horrifying, therefore, that he was treated so inhumanely.

“While Turing was dealt with under the law of the time, and we can’t put the clock back, his treatment was of course utterly unfair, and I am pleased to have the chance to say how deeply sorry I and we all are for what happened to him.”

‘Codebreaker - Alan Turing’s life and legacy’ runs at the Science Museum from 21 June to 31 July, 2012.

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GCHQ releases two Turing papers

GCHQ has released two mathematical papers written by cryptographer Alan Turing after keeping the works secret for over half a century.

The intelligence agency believes the handwritten papers were produced by Turing during his time at Bletchley Park, the World War Two code-breaking centre, GCHQ said in a press release released on 19 April.

“We are delighted to release these papers showing more of Alan Turing’s pioneering research during his time at Bletchley Park,” said a GCHQ spokesperson. “It was this type of research that helped turn the tide of war and it is particularly pleasing that we are able to share these papers during this centenary year.”

> *It was this type of research that helped turn the tide of war.*
> – GCHQ spokesperson

GCHQ judged the papers ‘sensitive’ until recent reassessment. One of the papers, the informal ‘Paper on Statistics of Repetitions’, seeks a means to tell whether two enciphered messages with different plaintext and an overlap of characters used the same encipherment key during the overlap.

The second paper, ‘The Applications of Probability to Cryptography’, was possibly written between April 1941 and April 1942, as it contains the reference ‘Hitler is now of age 52’. The paper uses probability analysis to look at four problems: ‘Vigenère’, ‘A Letter Substitution Problem’, ‘Theory of Repeats’, and ‘Transposition Ciphers’, said GCHQ.

The papers were kept at Bletchley Park until February, and were then transported to the National Archives at Kew, a National Archives spokesman told ZDNet.

The two papers have not been digitised, and only currently exist in handwritten form. People wishing to read the papers need to travel to the National Archives at Kew with the reference numbers of the papers, and two forms of ID — a picture ID, and proof of address. People who do this will probably be given a reader ticket number, which will then allow them to request the papers for viewing.

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Am I a man or a machine? My role in the hunt for AI

How taking part in a Turing Test to find the first thinking computer made Nick Heath realise he is more like a machine than he thought.

I just spent two hours trying to act like a person.

Should be pretty easy - after all, I've had 34 years' practice. But it turns out that acting like an authentic human being is far trickier than it sounds.

I was one of four people chosen to be human testers in this year's Loebner Prize, the annual event where artificial intelligence software tries to pass the Turing Test, invented by the brilliant British mathematician Alan Turing in 1950 to identify a machine that can think. The 2012 event took place at Bletchley Park in the UK, where Turing worked as one of the codebreakers who helped the Allies win World War II.

The contest has been run for 22 years, and in that time the chat software hasn't managed to fool a third of the judges, which is the threshold that Turing set for identifying an intelligent machine.

During the event each judge has simultaneous instant message conversations with a remote person and software designed to chat like a human - and then has to decide which is which. The contest has been run for 22 years, and in that time the chat software hasn't managed to fool a third of the judges, which is the threshold that Turing set for identifying an intelligent machine.

My only way of convincing the judges that I was a fully paid-up member of the human race was through what I typed into a chat window. If I failed to make my answers relevant or my prose distinctive, I risked being written off as a chatbot, mechanically spewing out canned responses with little regard to the question.

The Loebner Prize, and to some extent the Turing Test itself, has been criticised by AI academics for lacking rigour and structure, and is considered by some to be more of a sideshow than a serious proving ground.

But even if the prize's intellectual credentials are in doubt, the event poses a fascinating question: how do we distinguish between human and artificial communication? It's a distinction that I found far trickier to make than I first thought.

As soon as the judge's "Hello" or "Hi" popped up on my screen, I was faced with a dilemma: do I go with a stock greeting or is that too predictable and exactly what some faceless bot would choose?

Because every word you type is broadcast online and people are milling around the human test room reading your messages over your shoulder, I found that the tone of my communications was more guarded and less natural.

Throughout the conversations I kept questioning my own responses. I repeatedly asked myself whether I was being spontaneous enough and whether I should signal my humanity by dropping in a colourful fact or quirky turn of phrase.

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But often the easiest response to the judges' barrage of questions, including, "What was India like?" or "How did you find the journey here?" was the sort of generic blah that could emerge from a machine gluing together relevant subjects, verbs and objects.

As the contest continued, it struck me that, contrary to my preconceptions, much of what people say to each other isn't a pure expression of human individuality, but a sprinkling of fresh thoughts on a bed of reheated phrases and sentiment. A style of discourse that many people would describe as robotic.

While my conversations with other humans sometimes felt laboured, it was the bots that provided the truly crazy flights of fancy. What generally gave the chatbots away wasn't predictable comebacks or stilted tone, but their off-topic and outlandish replies.

> *One bot insisted that it was a cat, while another offered a judge condolences on the death of his pet dragon.*

One bot insisted that it was a cat, while another offered a judge condolences on the death of his pet dragon. At times the bots' whacked-out patter read like a bad parody of drug-addled conversation.

Typically within 15 minutes of starting the half-hour discussions, the judge would despair of the nonsense from my digital counterpart, telling me, "The other guy is terrible" or "You're clearly the human". In short bursts the bots were fine - and could answer certain questions plausibly, without lapsing into nonsense.

One of the judges told me that if you edited together snippets of the conversations with the bots they would look perfectly plausible but, unedited, the whole artifice comes crashing down.

Admittedly, the bots are at a disadvantage. I could immediately tip off the judges to my authenticity by mentioning the tour of the venue that preceded the contest or the garish colours of organiser Hugh Loebner's Hawaiian shirt. Also, it takes only one slip-up by a bot to ruin an otherwise perfect dialogue and reveal its true identity.

Perhaps, as suggested by Brian Christian, who wrote a book inspired by his experience at an earlier Loebner Prize, a fairer test would be to have the humans remotely logging in over the internet.

Being a human tester at the event opened my eyes to how much human dialogue is predictable, but also to how a truly human-sounding chatbot needs to overcome far greater challenges than just coming off as robotic.

My idea of how bots communicate has been shaped by bad science fiction, shouting film names at automated cinema booking services and, more recently, Apple's pocket assistant Siri.

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But the reality of the chatbot, unfettered and free to discuss any topic, is an entity struggling to even understand the question put to it, sinking in a sea of associated meanings and grasping at whatever floats by.

I was worried about sounding like a robot when it seems that not even the bots can manage that.

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What happened to Turing's thinking machines?

Artificial intelligence is still a long way from delivering the human intelligence in robot form that has long been common in science fiction.

Less than a decade after the first electronic computer, British mathematician Alan Turing posed the question, 'Can machines think?'.

To answer that point Turing devised a test in which machines conducted conversations with human judges. If the machine's written responses fooled the judges into believing it was a person, it could be said to be a thinking machine.

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More than 60 years after his seminal 1950 paper, and following decades of exponential growth in the power of computers, Turing's thinking machine has yet to be realised outside the realms of science fiction, where the intelligent robot – from Hal 9000 to C3P0 – is common.

Instead, modern AI posses a very different sort of intelligence to our own, one that is narrow and focused on specialised tasks such as helping to fly planes or screening loan applications. In carrying out these tasks, machines can make sound judgements faster and more consistently than people, but lack the versatility of human thought. So where are the thinking machines, and will computers ever match the general intelligence of an individual?

Why what robots find hard, we find easy – and vice versa

Since the field of AI got underway in the 1950s researchers have realised there is a gulf between what humans and what computers find difficult, says Dr Peter Norvig, director of research at Google and co-author of one of the standard works on AI.

"What we thought was hard, things like playing chess, turned out to be easy, and what we thought was easy, things like recognising faces or objects, which a child can do, that turned out to be much harder," he says.

Computers excel at working out the best move in a game like chess because it has well-defined rules and established patterns of play that can be rapidly checked by a machine. The problem with getting computers to emulate human intelligence is that they need to be capable of interacting with the world, of tasks such as recognising people or spoken language, which requires them to handle variables that are constantly changing and hard to predict.

In the 1980s AI researchers realised they needed to take a different approach if machines were going to understand that real world complexity, he says.

"Part of that shift was from [focusing on] the abstract and formal rules of a game like chess to the messy real world, and going along with that is a shift from formal logic where everything is boolean, true or false, to probability where everything is uncertain," Norvig says.

Judea Pearl, professor in the computer science department at University of California, Los Angeles says that computers are now able to handle aspects of real-world uncertainty through mathematical models that apply Bayesian probability theory to as many as 100,000 variables.

"Now we understand how to cope with uncertainty, because we are armed with all the guarantees and the warning signs that mathematics gives you," he says.

Perhaps the most high profile example of how well modern computers can handle the messy environment of the real-world is how Google's driverless cars have safely navigated more than 20,000 miles of rural and city roads or the wide-ranging speech and language recognition capabilities of Apple's virtual assistant Siri.

Future breakthroughs in handling uncertainty, says Pearl, will afford AI routines a far greater understanding of context, for instance providing with the next generation of virtual assistants with the ability to recognise speech in noisy environments and to understand how the position of a phrase in a sentence can change its meaning.

But it is true that progress in the field of AI has been more reliant on advances in theory than increases in computer processing power and storage.

Norvig says: "There's a minimum floor that if you don't have the computing power you're not going to succeed, but just having more doesn't mean you're going to get somewhere.

"There are a couple of billion computers in the world and we do have enough computing power today if we pooled all of our resources to far outstrip a brain, but we don't know how to organise it to do anything with it. It's not just having the power, it's knowing what to do with it."

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And without insightful mathematical modelling, Pearl says, certain tasks would be impossible for AI to carry out, as the amount of data generated would rapidly scale to a point where it became unmanageable for any forseeable computing technology.

The importance of theoretical breakthroughs, to some extent, undermines the theory put forward by Ray Kurzweil and others that mankind is decades away from creating a technological singularity, an AI whose general intelligence surpasses our own. Exponents of the theory use the exponential growth of computer processing power as an indicator of the rate of progress towards human-level AI.

Norvig is sceptical about predictions that a technological singularity will be created before 2050: “I really object to the precision of nailing it down to a decade or two. I’d be hard pressed to nail it down to a century or two. I think it’s farther off.”

AI and robots

While we may not be on the cusp of developing intelligences greater than our own, we are likely not far off an explosion in robotics driven by advances in AI, similar to way home PCs suddenly took off in the 1980s.

“Look at progress in speech recognition, machine translation, computer vision, computer planning and operations,” says Norvig, adding that the error rate in these areas is roughly halving every decade.

Thanks to progress in these sub-fields of AI, autonomous systems are being built that can interact with and learn about their environment, as well as making decisions that aid both themselves and humans.

Professor Nick Jennings is a chief scientific advisor to the UK government and heads the Agents, Interaction and Complexity Group in the computer science department of Southampton University.

“It [the field of AI] has really come back again to the idea of constructing whole intelligent things. Not in the general intelligence area, as in constructing something of human-like intelligence, but as in autonomous systems,” says Jennings, pointing to the Google Driverless Car, which brings together research in many areas such as sensors, information processing, reasoning and planning.

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Norvig predicts a boom in the popularity of robots and portable virtual assistants that utilise new UIs, such as the speech recognition of Siri and the augmented reality display of Google’s Project Glass.

“We will see a lot happen in the next couple of decades. Now everybody is carrying a computer with them that has a phone, has a camera and interacts with the real world. People are going to want to have more of a partnership where they tell the phone something and the phone tells them something back, and they treat it more of a personality.

“In terms of robotics we’re probably where the world of PCs were in the early 1970s, where you could buy a PC kit and if you were an enthusiast you could have a lot of fun with that. But it wasn’t a worthwhile investment for the average person. There wasn’t enough you could do that was useful,” Norvig said.

"Within a decade that changed, your grandmother needed word processing or email and we rapidly went from a very small number of hobbyists to pervasive technology throughout society in one or two decades. I expect a similar sort of timescale for robotic technology to take off, starting roughly now."

AI and humans – working together?

The collaboration between humans and intelligent computer systems, which can interact with the real-world and make decisions for themselves, is also what Jennings sees as the most likely future for AI.

At Southampton he is working on a research project called Orchid, where networked AI systems called agents work with humans to help make decisions. Researchers working on the project, which runs until 2015, are examining how this approach could be used in a number of scenarios, including disaster response. Orchid will test how AI agents capable of planning, reasoning and acting can help emergency services and others on the ground to react to a rapidly changing situation. The AI agents will scrutinise data from a number of sources and negotiate with other agents and humans to decide the best response, for instance which fire should be extinguished first.

Jennings feels this collaborative approach is the best way forward for AI, as while machines already outperform humans in certain areas, such as their ability to parse a trillion web pages in a blink of an eye, he says they will never surpass humans in every field of endeavour.

"As to constructing a system that is generally better than humans in all dimensions, I don't think that it's going to happen. I just think that there are things that humans are innately good at, like creativity. As a human being I feel reassured by that," he says.

Barriers to the creation of thinking machines?

There could also be limitations to the abilities of AI that people are unaware of due to our limited understanding of how the human brain works. For instance, as we discover more about the brain we could discover that some of its critical faculties are tied to its structure and size, limiting our ability to create a superior artificial alternative.

> *At some point there will be a consensus that 'Now is the time, we have all of what we need, let's work really hard to put it together', but we're not there yet. At the moment we can't put the pieces together and get to the moon, we're still flying around in biplanes.*
> – Dr Peter Norvig, director of research at Google

"We don't know what level of understanding is going to come out and what are the limitations," says Norvig. "If the human brain could have 1,000 times more brain cells, would it work at all? Would it work completely differently? Or work the same but have more?"

Norvig doesn't rule out the possibility of developing a human-level general intelligence, and says, while he wouldn't care to guess when that might happen, it is right to first focus on mastering individual tasks, such as machine vision. He draws a parallel between this step by step approach and the Space Race in the 20th century.

"It wouldn't have made sense in 1930 to say 'We haven't got to the moon yet, we've really got to get started on the whole moon project', instead we said 'Aviation as a whole has to develop a bunch of components and then when they're ready we can start putting them together'," he says.

"At some point there will be a consensus that 'Now is the time, we have all of what we need, let's work really hard to put it together', but we're not there yet. At the moment we can't put the pieces together and get to the moon, we're still flying around in biplanes."

Yet while man may still be a long way from creating a thinking machine, Pearl believes just pursuing that ideal has inspired some of AI's most impactful discoveries.

"The mere aspiration and striving to that goal has had a tremendous positive effect. It has yielded progress that could not have been achieved without that drive," he says.

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