# Raising the Bar Sydney 2018

# Zdenka Kuncic – Build a brain

**Welcome to the podcast series; Raising the Bar, Sydney. Raising the bar in 2018 saw 20 University of Sydney academics take their research out of the lecture theatre and into bars across Sydney, all on one night.**

**In this podcast you'll here Zdenka Kuncic's talk; Build a Brain. Enjoy the talk.**

[ Applause ]

Hi everyone. It's great to be here. I'm a physicist and, you know the title of my Raising the Bar Presentation tonight is called; Build a Brain.

So, some of you might be wondering; what on earth could a physicist have to say about the brain? So, let me explain to you, you know the meaning behind what all this is about.

So, the brain -- the human brain -- has been described as the most complex thing in the universe. Now, the human brain has also been described as the most mysterious. And probably one of the most mysterious things about the brain is this thing that we call intelligence -- so the ability to, not only acquire new knowledge, but also to apply it in new and novel ways.

Now, this is particularly interesting now because, I mean the whole world is completely infatuated with AI -- artificial intelligence -- and quite rightly so. We've seen so many fascinating and remarkable achievements with AI, but as exciting and impressive as AI is, it has its limitations.

So, one of the limitations of AI is that it's really limited to quite specific tasks. So how many of you have heard of the recent AlphaGo achievements through AI? Yeah. And also, you know there's the whole Watson playing chess and beating Kasparov and all those sorts of things.

So they're very good examples of how AI has actually been really, really successful, but successful at doing very, very specific tasks.

Now, of course the human brain can do a lot of broader tasks, not -- we're not confined to just very specific tasks. And even more important than that, when we think about why AI is limited to very specific tasks, it's because of the following.

AI relies on some algorithms, and incidentally there's nothing really special about those algorithms. We've known about them for decades now. But what it does rely on, most of all, is data -- really good data, lots of it. And the data has to be really well curated. So that means, for a very particular task, you have to have -- you have to go through the data and make sure it's good enough to get the AI to achieve really good results. But that also means that whenever there's any spurious data, you know if you throw a curveball into the AI machine, it'll collapse.

So, for example, you know if I was an AI sitting here, talking to you right now, and I had some algorithm running through me and I had data being fed into me to give my talk this evening, and someone at the bar said to me, "Hey Zdenka, do you want a drink?" I would collapse because I wouldn't know what to do because it's not part of the data that I have entered in me and it's not part of the algorithms with instructions to know what to do with that data. It's completely left field.

So, this is a really good example of the differences between intelligence that's artificial and that's data driven compared to real, human intelligence.

Our brain is able to take in and assimilate and philtre and triage in real time all the data that we have around us and that data is being fed to us all the time by the things that we see, the things that we eat, smell and so on. And we're doing that adaptively all the time. AI can't do that.

So, this is what intrigues me. How is it that the brain can do that? And more importantly, I want to ask the question; can we somehow replicate what the brain is doing? Can we replicate the intelligence of the human brain?

And of course one way to think about this, and this is how I think about it because I'm a physicist, I think; well, what are the physical processes happening in the brain that give rise to intelligence? Can we think of the brain as a physical device that produces intelligence?

And one way to test that is actually to build a device that mimics the brain, a synthetic brain with synthetic intelligence. Just like we have synthetic drugs, synthetic fabrics, synthetic diamonds, can we do the same thing with the brain and produce real intelligence?

So, how do we go about this? Where do we start? Well, if we think about the real brain for a moment. So, we do know a lot about the real brain actually. And you know neuroscience has come a long way in terms of the research that it does. And one of the most important things about the human brain is its structure. It's very, very complex and it has a lot of neurons. It's about -- there's about a trillion neurons in the human brain. But more important than the individual neurons themselves, it's the way that they connect with each other and talk with each other. And those connexions, where the neurons are talking to each other, transmitting information to each other, those connexions -- there's about a thousand times more connexions between neurons than there are neurons themselves -- so, about a thousand trillion neurons. That's amazing. And all that is compactified in a relatively small space.

So we think that it's that complexity, the way in which neurons are packed together and talking to each other constantly that gives us these properties that we call intelligence.

So another particular property of the human brain that we think is really important as well, to producing intelligence, apart from the neurons and the way that they're connected to each other, which is called synapses, is also when we take the brain as a whole.

So okay, we have individual synapses, individual neurons, they talk to each other, and we describe that as being called synapses, but when you take the brain as a whole, and you have all those neurons in there, synaptic connexions together, that whole network of neurons and synapses ends up producing emergent functionality.

It's a very complex system. And just like with social networking, we have so many networks, so many individual components that are constantly talking to each other that we end up with additional properties that can't be predicted just by looking at individual neurons themselves. In other words, the whole is greater than the sum of its parts.

So, if we were to build a synthetic brain for the purpose of trying to emulate synthetic intelligence, you know coming from a real, physical device, then we'd have to actually try and achieve those two things, those individual synapses -- synthetic synapses -- and the global network of those neurons and synapses, the way in which they talk together, to get that complexity of the network and the emergent properties of intelligence.

So, can we build this kind of synthetic brain? Can we build it to try and see if we can emulate synthetic intelligence? Well, of course the answer is yes because otherwise this would be a huge [laughing] anticlimax for you all. [laughter]

So, let me explain what we've done at the University of Sydney and also with some of my collaborators internationally towards this particular goal.

So, first of all, try and imagine what this might look like. And I'll give you sort of a clue as to the type of device that we've actually come up with, that replicates what we call a synthetic brain, and emulates what we call synthetic intelligence.

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So, imagine a bowl of spaghetti. Okay, now instead of the ordinary spaghetti that we all have with our bolognaise sauce and whatever, imagine the angel hair pasta -- much, much thinner. Okay? So it's much, much more messy when you pile it onto your plate. Now, shrink all that down to the size of a pea and that represents what we have as our very first synthetic brain. Sure, it's a pea-sized brain, but it still is a brain.

Now, what the actual fibres the little angel hair pastas are made up of and how they're made – it's made with a very special technique that uses nanotechnology. And the individual fibres are actually made up of materials that constitute something called nanowires.

Now, these nanowires are actually electrically conducting and this is absolutely crucial because in the brain, the neurons that transmit information in response to all the sensory input that we receive, they get activated or fired by electrical stimuli.

So, we know that whatever device that we make to try and build a synthetic brain, it has to be an electrical device. So that's what we've built.

So, we have this kind of pea-sized synthetic brain and we can zap it with lots of electrical signals and we can measure what comes out of it. And because it's very, very complex, and all the little angel hair wires, if you like, the points at which they overlap each other represent synapses. And that's exactly how neuronal synapses work as well. They come very close together and electrical stimuli cause the transmission of molecules called neurotransmitters. And it turns out, this is exactly what's happening between our nanowires when we electrically stimulate them.

So, we've created not only synthetic synapses with this very particular type of nanotechnology, but we've also created a very complex neuromorphic structure with so much complexity in it that now we're starting to see emergent behaviour that is very, very reminiscent of something that we would start to call intelligence.

One specific example of the type of behaviour that we're observing is memory, and particular the difference between long-term memory and short-term memory. I'm sure you're all familiar with, you know how you can retain certain types of information for a long period of time and others for a short period of time.

So, we have reached a point now with this synthetic brain device where we can actually control the way in which we stimulate it to get it to remember things on the short term and things on the long term in exactly the same way that we, with our human brains, respond to different stimuli as well.

What we're hoping to achieve is to be able to control this device and train it in a way that it could learn adaptively from its environment. So, think about the way in which small children are brought up and, you know they learn through making lots of mistakes and by responding to their environments -- their social environment, other environments. This is exactly the sort of thing that we're trying to achieve, putting this device -- exposing it to lots of different stimuli in a very natural way as opposed to feeding it with lots and lots of data that's been, you know created for particular, specific tasks.

So, one really interesting aspect of all this as well that brings us back to an important difference between AI and synthetic intelligence, that's starting to emulate real intelligence now, is that, with these devices -- these neuromorphic nanotechnology, brain-like devices -- we're actually observing that they consume an extremely small amount of power despite the fact that we're actually stimulating them electrically. The power that they consume is as small as the power that the human brain consumes. And this is really, really important because all of the electronics industry, the computing industry, is made up of electronic devices that actually consume a lot of power. And AI and AI algorithms that are now used to actually analyse a lot of data also use a lot of power and part of that is also because they need to draw on a lot of data.

So, does anyone here know where the data comes from that we use to -- you know, on our mobile phones and social networking apps and things like that? Anyone know where it is?

So there are really, really, really big warehouse-sized data storage centres in various places that are out of sight and out of mind and they consume enormous amounts of power.

So every time you need to use data it has to be accessed from those storage centres and that needs to be transmitted backwards and forwards.

A typical Google search -- a typical one -- would consume the equivalent amount of power to turning on a 60 watt lightbulb for about 16 seconds. And that's just a Google search.

Think about how much that scales up when you want to do something, you know more sophisticated like run an AI algorithm that needs to go through a whole bunch of data from that data centre.

So AI, yes it's very useful, but is it sustainable in the long-term? Is there a role for synthetic intelligence? Will synthetic intelligence surpass artificial intelligence? If so, how?

So, let me give you an example of the sorts of applications that we're thinking of with this kind of synthetic brain that possesses synthetic intelligence.

So, we've all heard about the sort of goals to space exploration, humans exploring and colonising space -- colonising Mars perhaps. But of course, those are very high risk human endeavours. So why not build machines, cognitive machines that have artificial brains in them, synthetic brains in them, so that when we send them out we don't have to worry about them. They're going to do their own thing. We're going to be out of communication with them anyway for periods of time, but we want to make sure that they're reliable and can adapt to unknown environments.

So, one of the goals we have for these synthetic brain devices is to actually put them into robots and have those robots be sent out into environments that would otherwise be of high risk to humans' life -- for example, putting them out into space.

Another application that we have, which we're developing right now, brings us back to the ability for these devices to actually control memory.

So we're thinking about a medical device, and in particular a medical device that could restore memory for people with Alzheimer's.

So you could imagine having a small-scale device with a bunch of these, you know pea-sized synthetic brains on it interfacing with a portion of the brain that has been damaged in some way and restoring memory for those people.

So, synthetic intelligence is a concept that is probably not as prevalent as artificial intelligence. Artificial intelligence is enjoying a lot of airwaves at the moment, and will continue to do so because it's been so remarkably successful. But the whole concept of intelligence and what is intelligence, what is the underlying physical nature of intelligence, is really not addressed by AI at all. And I think there's a really fundamental question there that can be asked by anyone, you know -- what is the physical nature of intelligence?

And with that, I would like to open it up for questions.

[ **Applause** ]

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