Paul Werbos: Quantum Turing Machines

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Robert J. Marks:

Every computer today can be looked at as a Turing machine. What are quantum Turing machines? That's our topic today on Mind Matters News.

Robert J. Marks:

Greetings. I'm Robert J. Marks and I'm your Belletristik host today on Mind Matters News. We're going to talk about Turing machines. Now, there are so-called specific task Turing machines, to give you a little background, and there's also general purpose Turing machines. One of the most famous specific task Turing machines cracked the Nazi Enigma code that helped win World War II. Alan Turing was on the team that cracked it at Bletchley Park in England. And this is depicted in the movie, I think the name was Imitation Game, with Benedict Cumberbatch starring as Alan Turing. The Enigma code breaking machine was designed to solve one problem, specifically crack the Enigma code. So the question was, Alan Turing asked, the father of modern computer science, could there be a general Turing machine that could be programmed to simulate all specific task Turing machines? In other words, a Turing machine that could do anything, any algorithm that you wanted.

Robert J. Marks:

Alan Turing introduced this machine in 1936, and the Church-Turing thesis says any problem that can be performed on a super duper modern computer could also be performed on a general Turing machine. It could take though a billion times as long, but we're still constrained by that. Quantum computers promise to incredibly increase computing speed and do Turing machine sort of operations. To talk about that is our special guest today, Dr. Paul Werbos. Paul is the inventor of error back propagation and he served 30 years as the program director at NSF, where he steered some of NSF's programs into quantum research. So, Paul, welcome.

Paul Werbos:

Hey.

Robert J. Marks:

Yeah, let me... I want to ask you about David Deutsch.

Paul Werbos:

Sure.

Robert J. Marks:

Because he was the guy... was he your PhD advisor?

Paul Werbos:

No. Karl Deutsch was my thesis professor.

Robert J. Marks:

Karl Deutsch. Okay.

Paul Werbos:

Karl Deutsch.

Robert J. Marks:

Lots of Deutsches in the world, I guess.

Paul Werbos:

Yeah, they keep coming up.

Robert J. Marks:

They do. No relation, I suppose, but David Deutsch, he first proposed the quantum Turing machine. Did you know Deutsch at all? I think I have them confused. The two Deutsches.

Paul Werbos:

Two Deutsches.

Robert J. Marks:

I'm confused.

Paul Werbos:

And I run across other Deutsches sometimes, but yeah. So I mentioned werbos.com. I have a new link on what is a soul and a new link on sustainable, intelligent internet. And we need a new type of internet, sustainable, intelligent internet. And on that website, I have links. One of them is to the quantum view of reality. Actually the mind, brain, and soul link, I talk a little bit about reality, too. Souls are a reality. And, come to think of it, in that link, I talk about reality and I talk about David Deutsch. I say that David Deutsch by all rights should be a face that everybody on the earth knows as much as they recognize Einstein. I began that YouTube talk on reality with four faces.

Paul Werbos:

First is Albert Einstein. And I believe in Einstein's view of reality, I didn't used to believe it, but I've learned a lot about how the math works. I believe that Einstein was basically right, even though it didn't seem like it about his basic principles. He did make mistakes like everybody. And right next to him is David Deutsch. I put Einstein and David Deutsch on top. David Deutsch has two great things. So great, everybody should know his name and his face. One of the things is the modern version of the multiverse theory of physics. How the universe really works according to David Deutsch. I believe that David Deutsch's theory of quantum physics is the best solid mainstream description anybody has of how the universe works.

Robert J. Marks:

Let's talk about that for a minute. I think that there's a bunch of different models of quantum mechanics. One is the Copenhagen model. And another one is the multi-universe sort of idea, which means that every time there's a quantum collapse, that two realities split off and you have these different realities. And I think you're referring to David Deutsch as one who believed in the multi-universe, is that right?

Paul Werbos:

Multiverse.

Robert J. Marks:

Multiverse.

Paul Werbos:

Multiverse.

Robert J. Marks:

Thank you.

Paul Werbos:

In fact, if you go to YouTube today, you can search on "Deutsch multiverse" and you get some really neat YouTube videos. So I have to be careful, everything in science, there are always these caveats. Okay? So Deutsch has a version of how the universe works. Some of it actually started with a guy I met named Hugh Everett and John Wheeler, and I have some corrections to fix up Deutsch's model to make it a little more reliable.

Robert J. Marks:

Now, Wheeler is the one that came up with the it from bit sort of thing. Is that the same Wheeler?

Paul Werbos:

Yeah, yeah. He's a creative guy.

Robert J. Marks:

Boy, I guess so.

Paul Werbos:

Creative guys sometimes do more than one thing in their life. John Wheeler of Princeton certainly did a lot of different things in his life.

Robert J. Marks:

Yeah, that's him. Okay, go ahead. I'm sorry.

Paul Werbos:

So Everett, Wheeler, Deutsch, and my fix is to Deutsch, there is a theory... there's a version of the multiverse theory of physics, which I believe is by far the best mainstream version of how the universe works in existence, but I still believe Einstein was right anyway.

Robert J. Marks:

Okay.

Paul Werbos:

And I believe that I can believe both of those things because Einstein himself once said, "Quantum mechanics probably works because it's a good statistical description, a good statistical approximation of things that are actually more like my kind of theory down underneath."

Robert J. Marks:

Okay. That's the so-called hidden variable model, I believe.

Paul Werbos:

Some people phrase it that way. Yeah.

Robert J. Marks:

Okay. The hidden variable. Wasn't that addressed negatively by, I think it was, Bell's inequality?

Paul Werbos:

I can tell you the name. I know these guys. I knew some of these guys. Okay. So we live in this horrible world of fake history. And by coincidence, I had strange luck always to see the real history. So when we talk about Bell's theorem and were hidden variables disproven, the story is worth a few minutes. It started with Einstein. Einstein, Podolsky and Rosen said, if you guys, if your Heisenberg theory is true, I predict the following kind of thing with correlated photons, and I don't believe that we should do the experiment. And that's a very rational thing, but then nobody did the experiment. I think Bell had some papers of ideas and there were various theorems. And finally, one of my classmates at Harvard was part of a group of four people who really changed the world. Their names were Richard Holt... Clauser, Holt, Shimony, and Horne. And CHSH is their paper. If you look up CHSH, you'll probably get to one of their papers.

Paul Werbos:

Now, as it happens, they had like four important papers that year. And I got to see all of them. When I looked today on the web, I only see one paper that's cited a lot. I think the other papers were really important, too. But basically the paper that really impressed me when I talked to my classmate over tea was the paper he showed me they'd just done where they proved a theorem. They said, if you have two entangled photons, if Einstein's kind of theory is true, the results will be in one region, but quantum mechanics predicts a different result. We can discriminate which is true by doing this experiment.

Robert J. Marks:

Yeah, just a little bit of background. The hidden variable model - see if I get this right, Paul - the invariable model says that, yes, we have this model of quantum mechanics and we treat things as probabilities, but there's something happening deeper underneath that is going to explain it. And this was the theory which was adopted by Einstein and Rosen and them. Is that pretty well the idea behind the hidden variable?

Paul Werbos:

Okay. So this is where words get screwed up in science.

Robert J. Marks:

Okay.

Paul Werbos:

And discussions of reality and consciousness and God - my God do people do weird things with words. My first language was mathematics, not English. And if I rely totally on English, I would be totally confused.

Robert J. Marks:

Paul, you're bilingual. That's good.

Paul Werbos:

Yeah. Yeah. I had a friend from Nigeria. I was saying, "I speak English as a second language," and that made a big difference. But yeah, hidden variable. I don't use the term very often because people have really played games with those kinds of words. But I do know what Einstein's point of view really was. And I do know that Einstein changed his views from one year to the next, but the core vision of Albert Einstein, which I've slightly altered, I call hardcore Einstein realism. And in my old age, I have come to the conclusion, yeah, I believe in hardcore Einstein realism, but somebody would say, well, what the hell is it that you believe? I don't believe every word Einstein ever said. He said some pretty funny words.

Robert J. Marks:

What is Einstein realism?

Paul Werbos:

Okay. So in that webpage, mind, souls, brains, I have a link to a YouTube talk on reality. Actually you could probably search on Werbos reality on YouTube probably would get there. I don't know. And in that talk, talking about reality, I start with a question you might appreciate, Bob.

Robert J. Marks:

Okay.

Paul Werbos:

How can you believe in hardcore objective reality like Einstein or Ayn Rand or Lenin, and also believe we have a soul and a spirit and a spiritual destiny and they are real?

Robert J. Marks:

Well, I think that boils down to your philosophy, whether you're a... there's lots of theories which divide that question and which give you different answers. One of the things that we're looking at right now is, at the Bradley Center, is a so-called mind brain problem and whether the mind is the same as the brain. And there's lots of emerging evidence through something called Leibniz experiment and near-death experiences, et cetera, which kind of illustrate that there're parts of the mind which are not resident in the brain.

Paul Werbos:

Yeah. I agree with that theoretical bottom line that you just stated.

Robert J. Marks:

Okay, well, that's good. Okay. Go ahead.

Paul Werbos:

It took me a long time to face up to reality and to face up to the fact that reality is not as simple as it seems.

Robert J. Marks:

Well, also, the thing is in mathematics, as you know, Paul, there's lots of things which are unknowable. You can prove things that exist, and you can also prove that they're unknowable, and you wonder if this applies to things such as consciousness in terms of a global understanding of what is going on.

Paul Werbos:

Boy, would I love to talk about that a little further, but bottom line is the talk starts simple with Albert Einstein and goes from there to David Deutsch, and hardcore Einstein realism, I don't even know if Einstein used the term hidden variables. I know he used terms like Lagrange Euler equations and Minkowski space, so there's that view of reality. But David Deutsch's theory is much more a mainstream theory, and one of the pieces of work I am proud of, frankly. I am the one who developed the mathematics which best connects Einstein's assumptions with what we see in the David Deutsch statistics. So at one point, Einstein said, "I think you could deduce the Schrödinger equation from the statistics of my fields." And Norbert Wiener tried to do it. And he failed. I read his papers, it just didn't do it. He tried hard.

Robert J. Marks:

Really? Norbert Wiener, for our listening audience, is the founder, in fact, he coined the word cybernetics, right?

Paul Werbos:

Yes, that's right. He's a very respectable guy. He couldn't solve this problem. And that's why I decided, maybe I won't do this for my PhD thesis. Maybe it's a little too hard and it doesn't guarantee I'll graduate. I'll work on it after I graduate. So I did, and I finally figured out how to solve it. It took a long time. The papers are very heavy mathematics. They're not very well known. Some of them are new. But the bottom line is I think that David Deutsch's approximation is the best that we have in mainstream science. It has been tested in quantum computing applications much more than all of these philosophical interpretations you read about. There are a million philosophical interpretations about what quantum mechanics should be, but David Deutsch's version of quantum multiverse technology, that's the one that has been used in the experiments, billions of dollars all over the world, trying to make quantum technology work.

Robert J. Marks:

Oh, everybody's in a race to do quantum computing.

Paul Werbos:

Right. So the quantum computing is based on David Deutsch's theory of quantum Turing machines. And that theory has been tested empirically at a level that these philosophers would not even dream of. The empirical work that's gone into quantum information science, huge, it's by far the best empirical theory we have today of how quantum mechanics really works.

Robert J. Marks:

Here's a question that I have for you, Paul. And I don't know the answer to this. Turing's Enigma machine did one operation, right? It was designed to crack the Enigma code. In quantum computing, if you take a graduate class or an undergraduate class in quantum computing, you're introduced to things like Shor's algorithm, which does cryptology, and Grover's algorithm, which do search - these remind me of special purpose Turing machines that are designed to do one operation. And the thing I don't understand is Deutsch's... Is his proposal to simulate a general purpose quantum computing Turing machine?

Paul Werbos:

Yes. There are two pieces of work that I cite. Deutsch has done many things in his life, but whenever I've got to be brief, there are always two things I cite from David Deutsch that everybody should know about. And one of them is the multiverse stuff. He has a book and videos. And the other one is the quantum Turing machine. He has one well cited, many other papers, proving the universal quantum Turing machine. So the concept of a universal quantum Turing machine that's more universal than the old Turing machine, his theorem, his mathematics, his concept, and his design, his vision. So, David Deutsch is a truly great person, but I need to be careful.

Robert J. Marks:

Okay. Well, why do you need to be careful?

Paul Werbos:

Okay. Because David Deutsch's vision of what is a universal quantum Turing machine. There's an analogy to Turing's vision of the universal Turing machine. Yes? And you and I both know that Turing's vision of a universal Turing machine is not really the most universal thing you can do because it assumes binary type variables. And we know there's a thing called neural networks. And in fact, there's a paper I cite a lot by Siegelmann and Sontag. There are other papers, and people debate which is the best paper. I don't want to get into that kind of fight. But I often cite the paper by Siegelmann and Sontag, and the basic idea just in the classical world, forgetting the quantum world, in the classical world the full power of analog neural network type architecture, it's like a whole level beyond what a Turing machine can do. So I think of the Turing machine as aleph-zero, the simple infinity, the countable infinity. And I think of the theorems of Sontag and Siegelmann and other people as aleph-one computing, a continuum which is a much bigger infinity than aleph-zero.

Robert J. Marks:

Yeah. The aleph-zero aleph is for example, the counting numbers, it is a smaller infinity than the number of points on the interval from zero and one.

Paul Werbos:

Right.

Robert J. Marks:

This was pioneered by Georg Cantor if I remember.

Paul Werbos:

Oh yeah, yeah. It's the counter sequence. So now, bottom line, there is a paper in the journal Quantum Information Processing by Werbos and Dolmatova.

Robert J. Marks:

Could you spell that last name please?

Paul Werbos:

D-O-L-M-A-T-O-V-A. So in that paper, which has a very interesting history and has an updated version, I say, look, Deutsch showed, add quantum entanglement, add the big cats, the Schrödinger cats, and you go from one way of aleph-zero to aleph-one. That's basically what David Deutsch did with the Turing machine.

Robert J. Marks:

I see.

Paul Werbos:

Do it another way you go from aleph-zero to aleph-one. Do both of them, you can get to aleph-two or aleph-three.

Robert J. Marks:

Well, aleph-two, by the way, I've heard described as all of the scribbles and shapes that you can draw on a sheet of paper. And I believe that aleph-three or higher is something which is beyond our comprehension. It's like a fourth spatial dimension or a fifth spatial dimension.

Paul Werbos:

But believe it or not, I hate to say it, it's not beyond my comprehension.

Robert J. Marks:

Okay, good.

Paul Werbos:

Because there is this paper. In fact, maybe I should even be more precise. The updated version of the paper I posted at werbos.com/triphoton.pdf, T-R-I-P-H-O-T-O-N dot PDF.

Robert J. Marks:

Okay.

Paul Werbos:

And basically that includes a roadmap for how to get past the quantum Turing machine to basically four more levels beyond that.

Robert J. Marks:

And what do you think you can do with these higher level Turing machines that you can't do with Turing's original machine?

Paul Werbos:

Well, I might call these Post-Turing, but what can we do? To begin with, a lot. Also, it's the hardest math I've ever worked on in my life. And that is saying something,

Robert J. Marks:

One of the things classically a Turing machine can't do is things like the halting problem. If you could come up with an aleph-one or aleph-two sort of machine to solve the halting problem, that would be an incredibly big deal.

Paul Werbos:

So, just two months ago, I put out a plan for how you could build what I call a quantum annealing of things and what you can do with it. And I view that as an example of a third generation quantum technology. Everything the U.S. government is funding today is pretty much the first generation. It's all the quantum Turing machine. It's all the first generation. We had a leader for the quantum information sciences coordinating group who was looking beyond the first generation, and he invited me to a big meeting in Baltimore in 2015. He was going to announce these new directions, but he died mysteriously. And there were only four people who are left of the plan he had to talk. One Indian, one Chinese, me and a contractor.

Robert J. Marks:

Okay, Paul, you need to hire some personal protection here, don't you?

Paul Werbos:

No joke. So at any rate. So at least since then, so far as I know the U.S. government has pretty much focused on the quantum Turing machine. The more advanced generations, there is stuff in other countries, but not in the U.S.

Robert J. Marks:

Austin Egbert, who's our director, pointed out that you talked about quantum annealing. This is something being, I think, pursued by a company called D-Wave. Are you up on that?

Paul Werbos:

Absolutely.

Robert J. Marks:

Okay. Are you impressed with what they're doing?

Paul Werbos:

Well, it turns out that I have, I think a whole YouTube talk on quantum annealing, and it's certainly in the website that I sent you, where I just this year came up with a plan. Now, in my original vision, in the triphoton paper, I describe five generations of quantum computing, some of which are pretty hard to understand, frankly. And then what I did this year was I said, okay, why don't we try to do something simple. A friend of mine had an application in mind that had to do with astronomy. He said, "Can't you do better than this application?" I said, "Maybe I could use D-Wave. That's only third generation, but that third generation could be used to solve your problem in looking at the sky." And I got very excited by it. In fact, I even was talking to a friend of ours, Don Wunsch in Missouri. I was even trying to talk to his people, "Hey, maybe we should try to get some IP, because I have an idea how to use a D-Wave to solve this astronomy problem."

Robert J. Marks:

I get a brush of greatness claim here. Don Wunsch was my PhD student, so.

Paul Werbos:

Ah, okay. Well he's... The future of NSF may depend a lot on him actually.

Robert J. Marks:

He does great, incredible things. I'm proud of him like a father.

Paul Werbos:

Great. Okay. Well, he is facing some pretty heavy challenges, but he also has some exciting opportunities. When I think about whether we will build back better, a lot of my hopes do involve Don, but God is he facing a lot of heavy stuff.

Robert J. Marks:

Well, again, I think as we talked in previous podcasts, when you come up with innovation, there's always an inertia, a resistance to that.

Paul Werbos:

That's an understatement. And have I learned about that. But let me come back. So I was really excited and then I studied D-Wave more. I studied the other stuff more than D-Wave. D-Wave was, eh, it's just third generation. I was more interested in the fifth. But I decided, okay, if we have a quick and dirty application that's really exciting, let's get the IP on how to use D-Wave. And then I got a friend from Canada and he spoke to the D-Wave people, and I got a literature survey on D-Wave like you wouldn't believe. It's a gigantic literature from all directions. But basically what I found out is the D-Wave annealing is not true quantum annealing. D-Wave has real markets, it has real clients, it has useful tools that will forever be useful, it's got a big market, it's an important player, but at the center of its box it does not have what I call a true quantum annealing box. So what I have posted this year are directions for how do you build a true quantum annealing box, and how can you use it for applications D-Wave hasn't even thought of yet?

Robert J. Marks:

Let's go down a little rabbit trail here and explain what annealing is.

Paul Werbos:

Good.

Robert J. Marks:

As I understand it, the term comes from metallurgy and the idea is how you cool down a molten metal to get optimal properties. And if you cool it down just right, slow enough, you get the really good metal. If you do it too quickly, it's bad. The great example I've heard of is ice cubes. If you start with water and you freeze ice cubes real quickly, you get cracks in your ice cube. Whereas if you slowly lower the temperature, you get nice, clear ice cubes.

Paul Werbos:

Beautiful.

Robert J. Marks:

Isn't that nice explanation?

Paul Werbos:

It is beautiful. And in my explanation for why D-Wave is great, but they don't have what they need for the greatest power. They have a real market and a real product, but you can do a hell of a lot better. And the reason why they're not doing the best you could do is the people who design their system don't really understand what you just said.

Robert J. Marks:

Okay.

Paul Werbos:

Okay? They don't understand what you just said. With true annealing, and one reason I was able to figure this out, is I knew about annealing, right? You're not the only one who's alert about it. I knew what real annealing is.

Robert J. Marks:

We should say, in machine learning annealing corresponds to adding a lot of noise in the beginning and then slowing down the noise. The more noise, the greater the temperature, the greater the shaking noise. So that's the translation. Go ahead, Paul.

Paul Werbos:

Okay. The truth is I have learned about annealing from three sources. One of them is the stuff I just learned about D-Wave in the past year. The other one was the metallurgy and solid state physics stuff that I knew about from other engineering applications. It's not only metallurgy. It's also solar cells, to be honest, I learned about it from solar cells. And in addition, there is what you just mentioned. There's something called a metropolis algorithm. So people who do numerical algorithms know about a kind of annealing algorithm use for this metropolis kind of stochastic search. And that's the one I know the least about it, ironically.

Robert J. Marks:

Okay. Let's back up. Let's back up a second. What's the big deal about quantum annealing, which in my cursory understanding involves things like quantum tunneling and stuff, but what is the effect of quantum annealing and why is it such a big deal? And why is D-Wave interested in annealing? We all know about quantum computers and the fact that you do all of these operations in parallel, but what about the quantum annealing and why are we interested in that?

Paul Werbos:

Okay. So again, we have to be really careful with words in this business, because D-Wave sells a box which is useful and it does something. And in my recent paper, when I had to be really precise, I called it DQUA, D-Wave type quantum annealing. And what I'm proposing is a different technology, which I'm calling true quantum annealing, TQUA. And there are three generations that you can build. The basic concept of true quantum annealing, my kind of quantum annealing is basically following the vision that David Deutsch applied to digital computing. And so maybe I should explain a little bit about what David Deutsch's vision is.

Robert J. Marks:

Okay.

Paul Werbos:

It starts with a cat. Everything really important may start with a cat.

Robert J. Marks:

Like Schrödinger's cat, right?

Paul Werbos:

Exactly that cat. And I've spent a lot of years learning about that cat. It's a very important cat.

Robert J. Marks:

But we're not sure whether it's alive or dead. Okay.

Paul Werbos:

Yeah. Yeah, there're some politicians like that, but...

Robert J. Marks:

Zing. Okay.

Paul Werbos:

But I'll resist. It's a big and real subject. It's not a joke. It's real. But going back to this cat, most people probably need a refresher on what the real story is with Schrödinger's cat. Schrödinger, de Broglie and Einstein all believed the beauty of their new quantum field way of thinking over the old particle based Lorentz physics. Lorentz believed in particles and matter, and all there is is force fields in Einstein space. De Broglie, Schrödinger and Einstein were pretty much at the same school. And then came this Heisenberg guy, and Schrödinger, Einstein and de Broglie couldn't believe half the things that Heisenberg said. And at some point they realized the Geiger counter is sort of a quantum mechanical phenomenon, stochastic, quantum mixed state thing.

Paul Werbos:

And so Schrödinger proposed this experiment. He said, okay, put a cat in a closet, point a gun at its head, have a Geiger counter control it with a timer so that it runs for three hours and set the numbers so that quantum mechanics predicts precisely a 50% probability that the cat's brain gets shot out, and a 50% probability nothing happens. That's the basic experiment. Oh, and experimenter leaves the room, locks the door. Schrödinger said, the reason why you're crazy, Heisenberg, is because your crazy theory predicts the following: it predicts that as soon as you turn on this machine, the cat gets put into a mixed state, so that half the cat is alive, half the cat is dead and it still doesn't make up its mind. Even after the timer stops, it's sitting there half dead, half alive, and it doesn't change until the human opens the door and looks at it. And by the act of looking at the cat, you make it be alive or dead. Isn't that dumb, said Schrödinger.

Paul Werbos:

And that was also where Einstein's EPR experiment came from was this sort of idea. However-

Robert J. Marks:

EPR is?

Paul Werbos:

Sorry. Einstein-Podolsky-Rosen.

Robert J. Marks:

Oh, okay. That was their thesis about hidden variables. Okay.

Paul Werbos:

People call it Bell's theorem because it was done by CH and SH about Einstein. They liked Bell, he was their friend.

Robert J. Marks:

Yes.

Paul Werbos:

He wrote a nice popular book, and it was a good book. But the actual theorem is different from any theorem that Bell ever published. It's a totally different theorem. And the implications are very different and very important. But yeah, they did the experiment and the cat, well, is it alive or is it dead? The bottom line is Einstein lost his debate on the EPR experiment. The experiment disagreed with his intuition, but that doesn't mean he was wrong in his whole theory. That's why you have to get rid of part of his ideas, but not all of them.

Paul Werbos:

The key thing: In that experiment, David Deutsch has a different explanation for what happens. He said, "Okay, you shoot the Geiger counter, you can put a cat in a mixed state. You can generate a Schrödinger cat. You can generate a macroscopic object in a mixed state. You can split the universe into two parts and it's alive in one and dead in the other. And when you open the door, you connect yourself to the cat so there are two of you and the universe has split bigger. So there's one of you that sees a dead cat and there's another one of you that sees the live cat. And that's the multiverse."

Robert J. Marks:

Man, if that's true, Paul, there's a lot of parallel universes, man.

Paul Werbos:

Absolutely. I didn't believe that for many years. I was an ultra conservative. I read the work of a famous guy named Tony Leggett who argued that somehow there must be a way out of this. Maybe quantum entanglement breaks down with distance, and there have been thousands of experiments on those, and they all prove there are macroscopic Schrödinger cats. And that was David Deutsch's idea. He said, "If you can put a cat in a mixed state, you can put a computer chip in a mixed state. And if you have enough leverage, instead of making two copies of the same chip in different states, you can make a million copies."

Robert J. Marks:

Well, that's the foundation of quantum computing, right?

Paul Werbos:

Exactly. That's what it is. It's quantum entanglement. It's herding cats. You've got a million Schrödinger cats, if not a trillion Schrödinger cats all at once, all doing different jobs and you put it together at the end and it's parallel processing.

Robert J. Marks:

Yeah. But the trick, I understand, is making it collapse to the correct solution, or in the multiverse case, making sure you're in the right multiverse. How do you assure that?

Paul Werbos:

Well, yeah, there is this... it's like de-falsification, but let me come back though to the point of, forgive me if I go back to where it was heading, what Deutsch did was he showed that our old ideas of Turing computing can be generalized by making a programmable computer which runs a million programs on a million copies of the same chip in parallel. That's the core idea. I just want to go that far right now.

Robert J. Marks:

Sure.

Paul Werbos:

The thing is though it still is like a computer. It's like our concept of a classic Turing machine. You write a program, you hire programmers. The U.S. government has hired so many programmers to try to come up with good programs to make quantum computers do something. And that's where Shor comes into it, because he came up with the first program that you could run to factor large numbers that just happened to be the critical thing you use for old-style polynomial key coding with cryptography. There's a lot these guys don't know because they live in their little ivory towers. There's a lot of stuff they don't know about this stuff. And where to begin.

Paul Werbos:

Well, we started with D-Wave. And the idea was, well, okay, instead of, what if we are not trying to run a computer program, what if we define our task differently? What if we're trying to solve an optimization problem? That's the obvious thing you would want to do with annealing. So what if you want to build a box where you still have a million Schrödinger cats running around at the same time, and you want to do the quantum mechanics such that the cat which survives is the one you want, and that gets to your final ending, decoherence kind of stuff.

Robert J. Marks:

Yes.

Paul Werbos:

Right? You want the cat you want to survive, you want the others to lose. If you know the physics, it's an obvious answer how you do that. You're using energy to represent what you want. You're mapping into a minimization problem. If you want lower energy, if you want to do annealing, in physics what you do is you shed heat to your environment and you equilibrate to a state of low energy. That's how the physics works. These guys were not physicists. And so they didn't even consider the possibility of doing it that way. So instead of shedding energy to the environment, which is what my specification calls for, they just circle around in the environment they're in and they adjust coupling coefficients, but they don't dissipate energy. It's entirely within the box.

Paul Werbos:

And they're entirely right that the minute you connect outside the box, you make life more complicated, but sometimes that's what you absolutely have to do if you want to get results. If you want a quantum computer that works, sometimes you need a cold environment. Same damn thing with a true quantum annealing. And you've got to worry about is the environment cold enough? Can you shed energy to it? But the bottom line is if you design the box to do true annealing, where you're shedding energy to your environment, it's obvious to the right kind of physicist. But I read that literature and it wasn't obvious to any of them because they were all busy doing other stuff.

Robert J. Marks:

Wow.

Paul Werbos:

I was kind of amazed when I discovered, my God, this is like the guy who leaves a $20 bill on the floor. I'll pick it up if I can.

Robert J. Marks:

So, Paul, you're going to supply us a lot of links to some of this literature so that we can put them on the podcast notes, right?

Paul Werbos:

Yeah, to true quantum annealing.

Robert J. Marks:

Okay. Excellent. Excellent. We're out of time, but I wanted to thank you, Paul, for your time you've spent with us. We've been talking to Paul Werbos. He's the inventor of the most commonly used technique to train artificial neural networks in the world, error back propagation. And he's also doing some pioneering work in quantum computing, which is going to be the future of the world if we can ever get coherence, I guess. So thanks for listening. Until next time, be of good cheer.

Announcer:

This has been Mind Matters News with your host, Robert J. Marks. Explore more at mindmatters.ai. That's mindmatters.ai. Mind Matters News is directed and edited by Austin Egbert. The opinions expressed on this program are solely those of the speakers. Mind Matters News is produced and copyrighted by the Walter Bradley Center for Natural and Artificial Intelligence at Discovery Institute.