**EPISODE 93**

[INTRODUCTION]

**[0:00:10.5] SC:** Hello and welcome to another episode of TWiML Talk, the podcast where I interview interesting people doing interesting things in machine learning and artificial intelligence. I'm your host, Sam Charrington. And we are back.

First things first, happy new year everyone and welcome to 2018. I had a great holiday, but I've definitely been itching to get back to the show. As most of you know, at the end of last year we held a listener giveaway to celebrate hitting one of our biggest milestones to date, one million plays of this podcast.

Thanks to everyone who entered. We sent out an email to entrance a few days ago so please be on the lookout for that. If you haven't heard from us yet, just reach out to us at team@twimlai.com so that we can get you your swag. Next up, the details for our January meet up are set.

Next Tuesday, January 16th, we'll be joined by veteran TWiML guest and Microsoft researcher, Timnit Gebru. Timnit joined us just a few weeks ago to discuss her recently released and much acclaimed paper using deep learning and Google Street View to estimate the demographic makeup of neighborhoods across the United States and I'm excited that she'll be joining us to discuss her paper and the pipeline she used to identify 22 million cars in 50 million Google Street View images.

I'm anticipating a very lively discussion segment as well and which will be exploring your AI resolutions and predictions for 2018. For links of the paper or to register for the meet up or just to check out previous meet ups, visit twimlai.com/meetup.

Finally, a bit about today's show. I'm joined by Davide Venturelli, science operations manager and quantum computing team lead for the University Space Research Associations Institute for Advance Computer Science at NASA Ames. Davide joined me backstage at the NYU Future Labs AI Summit a while back to give me some insight into a topic that I'd been curious about for some time now, quantum computing. We kickoff our discussion with a review of the core ideas behind quantum computing including what it is, how it's applied and the ways it relates to computing as we know it today.

We then discussed the practical state of quantum computers and what their capabilities are as well as the kinds of things you can do with them. Of course, we explore the intersection between AI and quantum computing, how quantum computing may one day accelerate machine learning and how interested listeners like you can get started down the quantum computing rabbit hole.

Now, on to the show.

[INTERVIEW]

**[0:02:57.1] SC:** All right everyone, I am here at the NYU Skirball Center backstage just as we're finishing up the NYU Future Labs AI Summit, and I have the pleasure of being seated with Davide Venturelli who's the science operations manager for the Research Associations Institute for Advance Computer Science at NASA Ames.

Davide, welcome to the podcast.

**[0:03:19.5] DV:** Thank you. Thank you very much.

**[0:03:21.2] SC:** It's great to have you on the show, and I am really looking forward to this conversation, because you are doing a ton of work in an area that I know very little about, but keep hearing a lot about, and that is quantum computing. So before we get in to me peppering you with questions, why don't you just tell us a little about your background and how you got into quantum computer yourself?

**[0:03:44.3] DV:** Yes. I'm a physicist. I'm a theoretical physicist, and I did study quantum mechanics like every physicist does. Back when I was a PhD student in 2008, 7, there was hype inside the physics community about quantum computing, but it's nothing like what we have today. What I did, I did study quantum information science and studied nanotechnology, and of course I have seen in front of me unfolding the opportunities of actually not only validating the theories on pen and paper, but now experimenting with real-world quantum machines.

I joined the Quantum Artificial Intelligence Laboratory in 2012 as one of the founding members, NASA, Google and USRA, University Space Research Association decided to create this group to investigate the near term impact of quantum computing for computational problems of national interest, and that was what I've been doing in the last five years. We managed projects in collaboration with government academia and with, of course, the principle stakeholders, the private sectors as well to understand really if the next 5 to 10 years there could be an acceleration of computing because of quantum technologies.

**[0:05:14.4] SC:** Great. I guess the place to start is on quantum technologies and quantum computing, like I imagine that it is something that many in the audience have heard of but don't fully understand. Not just what the big ideas are, but what are the foundational ideas upon which it's built and I'm hoping maybe you can walk us through some of that.

**[0:05:38.4] DV:** Yes. The idea comes from the 80s when one of the gods of physics, Richard Feynman, made the observation at a conference, pretty casual observation that if we were able to create a computer which worked with the laws of quantum physics, then simulating quantum systems would not be very difficult. While today, it's very, very difficult to do that. We need super computers and blah-blah-blah.

This observation changed the world, because the idea of processing informations with the fundamental laws of nature as APIs, as elementary building block of the algorithms really got every physicist excited. Some early discoveries on the fact that the mathematics of quantum mechanics is fundamentally more powerful than the mathematics we employ when we process information in standard digital computers really got everyone excited.

**[0:06:47.6] SC:** Can you give us some examples of that?

**[0:06:48.5] DV:** Yes. People have discovered in '96 that you can search a database, an unstructured database where basically all the information is not arranged by any sorting. Normally, to search that such database you do not have any smart way to do it, because you just have to randomly make queries. If you're unlucky you will find what you're looking for as the last attempt of your query, and that means that the problem has a linear complexity, meaning that if you have N-items, you need N-trials to get to the item you want in the worst case scenario.

Now, if you had the quantum database and the ability of doing quantum queries and you exploit all these effects of superposition, interference, entanglement, you are able to find the item you want in a square root of the number of items. This means that instead of, for example, hundred quarries, you need only 10. This quadratic speedup is a very interesting phenomenon which shows by itself that quantum computing is more powerful than classical computing, because there's no way you can beat this without quantum mechanics.

But what people is really after is exponential speedup. So the opportunity to device algorithmical strategies that are able to accelerate exponentially problems. There are some examples, in cryptography, in chemistry where we know how to exponentially bypass the bottlenecks of computation so that problems that could be solved today in billions of years, it would be solved by a quantum computer in seconds, but this is not the case for a lot of things that we want to solve and we are investigating, and it's so difficult to investigate these algorithms without having a quantum computer that in some sense we want to build quantum computers to understand whether it was worth to build them in the first place.

**[0:08:59.5] SC:** So is it fair then to say — What I took away from that is that quantum computers isn't the idea of kind of going piece by piece in replacing the various components on a current system board with quantum versions. It's not like shrinking down the physics is. It is a fundamental new way of thinking about compute that's built around the —

**[0:09:24.4] DV:** It's a new paradigm. It's not incremental improvement. It's really a different fundamental way to process the information. Of course, quantum effects are already very well taken care off by the Silicon industry in the integrated circuitry already, but today they kind of bother you, because you want to shrink things, you want to make them faster. Now, what we're talking about is assigning a functional role to the quantum effect and actually assigning logical states and variables to quantum states, and then very finely, very delicately orchestrate their quantum dynamics so that we do mathematical operations on our logical assignments. This is a new paradigm. It is operating on probability distributions, which are weird, because they're not over real numbers. They are over complex numbers. So there are imaginary units involved. It's very interesting mathematically.

Funny enough, for the listener of this show, you don't really need to know physics to become a quantum algorithm person. It's actually linear algebra. So as long as you accept why quantum mechanics works, you can study it in an after — Well, if you have the mathematical background, you can study it fast and you don't know why it works. It doesn't matter, but you can start writing algorithms because it's just metrics multiplication and things like that.

**[0:11:07.2] SC:** What are some of the — You kind of rattled off some quantum primitives that upon which this math and these computers are built. Can you kind of give us the next level of detail into some of the most important ones?

**[0:11:21.0] DV:** Of course, the main paradigm which is explored today is to use binary variables, so bits basically, but generalized in the quantum world. So the idea of using quantum bits of queue bits. So you do identify a physical system, it could be a super conductor or a circuit, or it could be an atom, it could be an electron, it could be a photon, anything, anything which is sufficiently small, cold, protected from the external environment, follows the laws of quantum physics, even cats in boxes apparently. As long as you're able to find that, then you look at the states of the systems and then you identify what you call zero and what you call one. For example, it could be —

**[0:12:05.8] SC:** Aren't there more states in a quantum system?

**[0:12:08.4] DV:** Yes, but you choose two of them.

**[0:12:10.7] SC:** Really? Okay.

**[0:12:10.7] DV:** You say, "Okay. This electron can have spin up or spin down," for those that know physics, or this photon can have polarization in one way or in other. This super conductor can have a clockwise current or a counterclockwise current. Then you look at how you can act on the system. Similarly as you do in chemistry, if the system is quantum, you can manipulate their state. Like in chemistry, you can do chemistry reaction, but this time you need to be very controlled. If it is an atom, you need to shine a laser. If it is a circuit, you need to apply a magnetic field and all these kinds of things.

When you do that, you know how your state will change. The fun fact is that it is totally true in quantum mechanics that you can have a state which is not zero, not one, it's kind of a super position of the two and is represented by this abstract vector in a complex number subspace where you represent zero and one at the same time.

Now, when you look at it, it will be zero or it will be one with some probability, but if you don't look at it, then it's both. You can operate on it like if it is both until you look at it. The algorithm, the job of the programmer is to figure out the way to operate on this ensemble of queue bits in such a way to orchestrate the probability at the end to be the solution of the problem you want to solve, but that's a complex job, because if you have N-queue bits, what you are really describing is a state which has an exponential number of degrees of freedom and you need to basically describe it due to the power of N-complex numbers and there's no way you can simulate this in a machine. You need a quantum computer to experiment most of the time.

**[0:14:10.0] SC:** It sounds like one of the fundamental realities of quantum computing is this chicken and an egg problem, like how do we get beyond that.

**[0:14:18.2] DV:** Yes. You're totally right. We are getting beyond that. We decided — I don't know, the chicken or the egg, what we decided, but we decided that it's worth. It's worth to do it, and we're starting. There are companies, IBM, Rigetti, Google, Intel. They're all building chips and they're making them available to research community and people are trying to use them in the short term to learn about quantum mechanics, to validate the theories that their own pen and paper have been devised in the last 30 years. Now we are really using quantum computers as tools for improving our knowledge of quantum information processing.

**[0:15:00.2] SC:** Yeah, IBM, Intel, some of these companies that you've mentioned have been talking about this forever, like in kind of research mode. I think the thing that really caught my attention recently was I think it was their Build Conference. One of Microsoft's recent technical conferences, I think it was a keynote, like their main announcement, Satya Nadella came out and had some researchers and they kind of brought out this — I'm not even sure what it was. It looked like a GPU to be honest. They brought out this board that was their first attempt at a quantum computer, or something. You tell me, what exactly that was and what's its significance.

**[0:15:37.5] DV:** Yeah. Microsoft as well as IBM, as you said, like everyone had some quantum computing expertise since the beginning of time, meaning since when the field has a name and for good reasons. Good physicists kept an eye on the idea since the beginning and these companies hire the very good people.

Now, what changed now is that people are confident that we can achieve great results very fast, great results in terms of science. Not necessarily in applications yet, because — Microsoft, for example, is interesting, because they decided to — They always had a very good group on architectures and quantum operative systems and quantum compilation methods. Now they decided to expand and go experimental as well. Their approach is long-term. They want to do topological quantum computing, which is a complicated mathematical theory which is allowing this type of computer to be automatically protected against the noise of the external world. So it would be amazing if it ever works.

However, as far as we know, nobody has ever even created a single queue bit. So everyone is really looking at what they are thinking of doing, because even the announcement of a single queue bit would be interesting.

**[0:17:06.3] SC:** Let me just hit pause on that. The queue bit is the fundamental unit of this computer. It's the bit in contemporary computing.

**[0:17:15.8] DV:** Absolutely. Yes.

**[0:17:16.9] SC:** And we've done produced one yet.

**[0:17:18.2] DV:** No. In the approach that Microsoft was, they didn't. To give you a sense, IBM has 16 queue bits operational allowing researchers to use them.

**[0:17:32.9] SC:** When you say 16 queue bits, does that mean —

**[0:17:36.1] DV:** 16 bits.

**[0:17:37.1] SC:** Just 16 bits. Not an array of 16 —

**[0:17:38.8] DV:** You can do nothing with that. No. You cannot even solve a Sudoku with that. It's nothing. Okay? Google has 9, but 22 under testing, 49 announced. Then Rigetti has about 8. Now, D-Wave has 2,000. You'd say, "Oh my God! D-Wave is so far ahead."

**[0:18:00.7] SC:** Who's D-Wave?

**[0:18:01.5] DV:** D-Wave is a Canadian company which kind of schooled the world in the fact that you can try to build a quantum computer, and they did it before everyone, and that's even why my group exists, because Google decided to buy one of these machines and then —

**[0:18:18.4] SC:** A D-Wave machine? One of the D-Wave machines?

**[0:18:20.9] DV:** Yes, to host it at NASA, and that we operated.

**[0:18:25.2] SC:** Is this analogous to main frame computers where it takes an entire room to —

**[0:18:29.5] DV:** Yes. It's a huge black box which operates —

**[0:18:33.4] SC:** For 40 bits.

**[0:18:34.6] DV:** No. It's 2,000. But 2,000, there's a catch there. First of all, this is a huge machine. It operates with a cryogenic temperatures, so at 13 milliKelvin. We're talking about less than the temperature of space. It requires vacuum. It requires helium. It's a complex machine, but it implements one strategy of computation, which is quite unknown, meaning that not so well-studied, which is called quantuam annealing, which does not have all the requirements of the other kind of computation. But at the same time, it's unclear the power of it. They decided indeed to create it, to experiment.

 

NASA and Google and USRA decided to support the project, and then after this, Lockheed Martin bought the machine, Los Alamos bought the machine. Now, they're doing quite well.

**[0:19:26.8] SC:** How much does one of these machines cost?

**[0:19:28.4] DV:** Street price is from $10 million to $15 million. You need to ask them for the latest quote. I don't know.

**[0:19:32.9] SC:** I don't know want to know [inaudible 0:19:33.4].

**[0:19:36.9] DV:** But actually I want to advertise in this show, everyone can use this machine. USRA has a program, a collaboration program for which 20% of the machine time can be outsourced to any researcher, which is submitting a proposal. It's just a five pages proposal. The website where to find it is www.usra.edu/quantum/rfp, request for proposal. USRA, Quantum D-Wave, if you Google it, people can find it.

**[0:20:13.9] SC:** We'll have links in the show.

**[0:20:14.5] DV:** We have about 80 people, 80 groups, 80 research groups from all kind of universities around the world which are running on the machine or they proposed. Some of them are running. Some not yet, but it's a very successful project.

**[0:20:28.2] SC:** Wow! Is all of the research that's happening on this machine about how to build more machines like it or are people doing — How far are we in terms of doing things with it? Can we add one plus one yet with this machine?

**[0:20:45.1] DV:** Yeah, we can do more than that, but not much more like that. No, you are totally right. Let's say 90% of the really invested research is of the fundamental research. We need to improve our understanding, get different mindset and figuring out how to improve these machines themselves. At the same time, I say that programming this kind of machines, using these kinds of machines can often lead to new ideas in classical computing, because you need to change a mindset to frame the problem in a different way in order to be attacked by the quantum computers.

There are a lot of anecdotes of people coming up with a quantum algorithm that is beating every possible classical algorithm, every classical algorithm that was created before, and then the classical guys came back, say, “Wait a second. I can improve my algorithm,” and then they improved it and [inaudible 0:21:42.9] the the quantum began and so on.

**[0:21:44.6] SC:** Any examples that come in mind?

**[0:21:46.5] DV:** Yeah, but it’s very nerdy example. There’s a recent result on QAOA, which is baptized by us, the quantum alternating operator ansatz algorithm, which is shown to basically have a particular [inaudible 0:22:07.0] which seemed to be better to what was before known on a problem, which [inaudible 0:22:13.9]. It’s basically connected to satisfiability. But the point is like a very specific problem. It seemed that this algorithm was beating it and then the people — Then the classical computer scientists came back and they improved their own algorithm. This is the latest example.

In general, I mean it’s fun quantum computing, because there’s so much room for improvement in our understanding that it’s really fun, for instance, chemistry. Chemistry is the holy grail of quantum computing, because we can simulate molecules much faster, and people were writing on the back of the envelope calculations 7 years ago, 6 to 7 years ago, on how fast a quantum computer would solve, for example, the molecular ground state of interesting molecules, such as thioredoxin, I remember, which is a fertilizer. It’s interesting. People were trying to calculate it and saying, “Oh, okay. It would still take some billions of years.” “Ah! Not very interesting, because — Okay, with a classical computer, it’s impossible. It would take trillions of years. Quantum computer would take billions. Okay. It’s not very worth doing it.”

Then new postdocs looked at the problem and say, “No. Wait a second. It’s not scaling as N to the power of 11. It’s scaling as N to the power of 9, because I can do these mathematical tricks.” Then new postdocs and PhD students looked at the problem and say, “Wait a second. Why don’t they do this transformation before and they represent the problem Gaussian Waves instead? Blah-blah-blah. Then they’d put it down to few years?” They say, “Well, it’s still not very interesting.”

Then in a matter of like few months, other groups improved, improved, improved and now we're talking seconds. On that particular project —

**[0:24:03.9] SC:** On trillions of years, to seconds.

**[0:24:05.5] DV:** — on a specific molecule that people investigated, the initial estimates based on quantum mechanics understanding where it's so improvable where they brought down N to the power of 11 to N to power of 3 and make the things much more attractable.

**[0:24:24.6] SC:** Now, what are the requirements of implementing this algorithm that they've designed in terms of a quantum computer. Does our D-Wave 2000 bit thing get us anywhere near that or?

**[0:24:37.5] DV:** No. D-Wave was mentioning before, they can attack only some specific algorithms, combinatorial optimization with a specific method and it's unclear what the performance of this machine can be. We are investigating them. Early results is that it's comparable with Intel chips on the small problems. Now, we would like to investigate them on large problems so that we really could see difference, because now we're still talking about problems we can solve in seconds, so it's not really clear, the overhead, how much it counts and blah-blah-blah.

This is interesting for D-Wave, because, again, every machine they release is a little bit more powerful than the previous one also on a qualitative level. They give you more knobs. They give you more physical effects to experiment with. That's interesting.

To run the algorithms for chemistry, for database search [inaudible 0:25:33.8] or cryptography. You need computers such as the ones which are created by now, by IBM, Google, which right now are at this 9 queue bits, 16 queue bits stage, because they're much more difficult to build, because they give you much more control. They're called the universal digital quantum computers as supposed to D-Wave, which is an analog quantum annealer. That would be a different flavor.

**[0:26:01.6] SC:** If I could paraphrase, the architecture of this D-Wave computer is limited in some way so that you can only implement these quantum annealing algorithms, and it sounds like a small-ish subset. Actually, we don't really know what types of algorithms will run on —

**[0:26:20.4] DV:** Yes. They're easier to build the computers, but much more limited in their algorithmical encoding. To give you an idea, with a thousand queue bits, we can more or less solve problems, classical problems you can encode in 50 bits roughly. It could be 60, sometimes 100. It depends on the compilation.

**[0:26:41.2] SC:** Is that 2,000 bits, or the 50 bits, is this the entire state of the computer? If traditional computer has — There's state in the CPU, there are registers, there's all of these things. Is that all different in the quantum world?

**[0:26:57.5] DV:** Yes and no. Let's say — No. Your question is on point. The end to end solvers will be hybrid system which have a classical core processor, quantum processor. After all, you can decompose your problem, preprocess it, divide it in chunks so that the quantum computer just solves the combinatorial aspect of it and the other does something in parallel. We're way behind in figuring out what's the best way to solve a full problem. We're experimenting right now on very specific special purpose problems. In that case, yes, we can use only this little memory, but it's improving at every stage. The next generation machine probably would be much better than the previous one.

**[0:27:47.4] SC:** How many bits do we need to get to on the universal side to be useful?

**[0:27:50.7] DV:** Yeah. That's a good question. It depends on the approach. For example, the Microsoft approach, it could be a few hundred for the Microsoft approach, but they don't even have one. For the other approaches, like the ones which are super conducting, we likely need almost a million, almost.

**[0:28:11.3] SC:** We're a nine.

**[0:28:12.1] DV:** Yes. Discountability is there. What is more difficult is the error correction. The error correction, we have very good theories, but we need to get the fidelity of the operations to a certain level of precision, but there's no fundamental reason why we shouldn't be able to do that with good engineering. You need to understand that the quantum engineer job is a new job. Everyone which worked on this is a physicist, and a physicist do not know how to build products.

Now, engineers are getting to these games. I believe that we will have very interesting machines soon, and there's not only the big players that are startups, which come out fun off of universities. For example, ion queue out of Maryland is doing an amazing job with the ion trap.

**[0:29:06.3] SC:** Ion cube?

**[0:29:07.7] DV:** Ion queue.

**[0:29:09.0] SC:** Ion queue. Okay.

**[0:29:10.6] DV:** They're trapping atoms with lasers and manipulating them. They're very, very good at this. There's University of Bristol group in the UK which has some stealth operation on fully photonic computers, basically atom lasers.

I believe the landscape one year from now will be already different significantly from the landscape of today. That's fun.

**[0:29:39.1] SC:** We haven't gotten to AI yet. What's the intersection between — You're at the Quantum AI Lab. What's the intersection between quantum computing and AI?

**[0:29:48.2] DV:** It's a very, very good question. Our name, it might be a little misleading. We have a —

**[0:29:53.7] SC:** Is it quantum/ai?

**[0:29:55.1] DV:** No. It's a quantum AI. First of all, AI is not only machine learning. There's a lot of methods that are considered AI since even before the hype of machine learning took off. We do a lot of optimization. It's part of AI. We do a lot of planning and scheduling, which is one of my personal work where we actually have to take decisions of how robots operate on distant planets. How to take the robust decisions. That's a problem that you need to solve model-based algorithmics.

That's why there's an AI in our name, because we do pay particular attention to problems where there's not good solution yet and we need expert artificial systems to solve them. But the intersection of quantum computing and AI is interesting even beyond what we do in the quantum artificial intelligence laboratory. The intersection could be on a technical standpoint — On machine learning, there are approaches which are being investigated. It's a very new field, so we're talking about only few years of research, where you can apply some algorithms of quantum computing to gain polynomial speedups on certain aspects. For example, training the neural networks. There are approaches where you can use quantum correlations to implement quantum neural networks. Okay. I mean this requires huge number of queue bits, of course, but people are looking at this kind, and these quantum neural networks might be very good at learning quantum problems. Again, it's a little bit self-referential, but that's another approach that's been investigated.

I must say, there's an intersection on the other point of the arrow. There's a lot that AI can do for quantum computing. Okay? The payoff will come afterwards. Quantum computing will pay back in 10 years or something. For now —

**[0:32:06.8] SC:** What are some of those ideas do you think?

**[0:32:08.5] DV:** Even compiling a problem into a quantum computer is a big problem, and you need methods —

**[0:32:15.6] SC:** Kind of optimization on steroids?

**[0:32:17.5] DV:** Optimization on steroid. Calibrating a quantum computer is also a pain in — It's crazy. Again, laboratories are training neural networks and they are employing heavy heuristics to be able to do that. There is an opportunity on both ends. To imagine what quantum computing can do for AI and how to employ AI to enable quantum computing.

 

**[0:32:49.0] SC:** We're getting to the end of our time, but is there a kind of a canonical reference or a place that people can start if they want to learn more about quantum AI? Or not quantum AI, but quantum computing?

**[0:33:04.1] DV:** Yes. There are a lot of tutorials which have been published over the years.

**[0:33:11.2] SC:** Not like build your own queue bits.

**[0:33:12.7] DV:** No.

**[0:33:14.4] SC:** With a 3D printer maybe.

**[0:33:14.8] DV:** It's really not that accessible as it was a few years ago. My suggestion is to look for the reviews and the lecture notes of the most prominent professors in the field. I suggest to look at the, for example, John Preskill's lecture notes at CalTech. That's a good start. There's another very skilled evangelizer of quantum computing, Scott Aaronson. He has a fantastic blog, which is very followed, where he discussed lots of aspects of quantum computing. I'm sure that if the listener to this show are motivated, they will find their way. Of course, please feel free to contact me. My email is Davide, David with an E at the end, .venturelli@nasa.gov.

**[0:34:07.9] SC:** Okay. Great. Did you just say Davide? Am I pronouncing it wrong?

**[0:34:10.7] DV:** Davide.

**[0:34:12.2] SC:** Davide. Okay.

**[0:34:15.0] DV:** Davide.

**[0:34:17.2] SC:** I tried so hard to do the names right. Davide, thank you so much for taking the time out to chat with us. I learned a ton, but there is so much more to learn about this. I really enjoyed it. Thanks.

**[0:34:29.9] DV:** Bye-bye.

[ENM OF INTERVIEW]

**[0:34:33.9] SC:** All right everyone. That's our show for today. Thanks so much for listening and for your continued feedback and support. Thanks to you, this podcast finished the year as a top 40 technology podcast on Apple Podcasts. My producers says that one of his goals this year is to crack the top 10, and to do that, we need you to head over to your podcast app, rate the show, hopefully we've earned five stars. Leave us a glowing review and share it with your friends, family, coworkers, the barista at Starbucks, your Uber driver, everyone. Every review, rating and share goes a long way, so thanks so much in advance.

As you know, I love to meet TWiML Listeners.  This week, I'll be at the CES show on Las Vegas, so if you're in the area and will like to meet up, ping me at @samcharrington on Twitter. Last but certainly not least, for more information on Davide or any of the topics covered in this episode, head on over to twimlai.com/talk/93.

Of course, we'd be delighted to hear from you  either via a comment on the show notes pages or via Twitter at @twimlai.

Thanks once again for listening, and catch you next time.

[END]

 