Episode 1: Quantum Insights: Navigating Tomorrow's Tech Landscape

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Welcome to the podcast series by the HCLTech Enterprise Technology Office, exploring the trends in emerging technologies.

Pranav Kaushal: Hi everyone. Good morning, good afternoon, good evening. I am Pranav Kaushal, Strategist, Open Innovation, Office of CTO at HCLTech. I welcome you all to HCLTech's Enterprise Technology Office podcast. This podcast is focusing on quantum technologies and the role that they have to play in our future. This podcast is focused on how quantum ML is paving the way for the next-gen tech revolution. I am joined by Dr. Venkat Subramaniam from IBM, Sanjay Muthiyalu and Abhinav Khare from HCLTech. Let's start with a brief introduction and a bit about your roles. Dr. Venkat.

Dr. Venkat: Hello and thank you so much for having me on this podcast. I'm Venkat Subramaniam and I'm the IBM Quantum India Lead. Today, I'll talk about some of the work that we are doing in Quantum ML. Thank you so much.

Ravikumar Sanjay Muthiyalu: Hello, everybody. Thanks for having me on board today. This is Sanjay Muthiyalu here. I am a Chief Technologist with HCLTech; I have around 24 years of experience in the industry, largely dealing with emerging technologies and helping customers adopt emerging technologies across the board, be it DevOps, machine learning, or AI. In that context, I am very excited to spearhead this initiative from the digital business services unit of HCLTech. Thank you.

Abhinav Khare: Hi, everyone; good afternoon, good evening and good morning, based on where you are. My name is Abhinav Khare and I am happy to be part of this discussion today. As we discussed, my key role in HCLTech is around technology exploration. And today, we are here to discuss quantum computing and quantum machine learning applications that are potentially being explored.

Pranav Kaushal: Panel members. Quantum has been making a lot of recent news and it seems enterprises are trying to get their hands on the tech. What is HCLTech really doing to propagate quantum technologies?

Abhinav Khare: Here at HCLTech, we've been working on exploring this technology for a while now and we've sort of accumulated various efforts into sort of a brand name, which is HCLTech quantum labs and there are various things that we are doing under this lab. So it's like a fluidic lab; it's not a physical lab that we've set up. It's highly collaborative and we collaborate with various people inside HCLTech based in different locations. Some of the key things that we are doing is building the quantum ecosystem because we realize this is an ecosystem strategy, sort of an exploration strategy for us and then there are multiple players that need to come together to really contribute to the exploration and move towards the adoption. We're collaborating with academia, we're collaborating with startups, we're collaborating with various technology partners. So yes, we realize that and we're building the quantum ecosystem under the lab. Then, our customers also realize the importance of this technology, and then we are constantly having conversations about how they could start their journey in the exploration journey that they want to go to and what use cases. And those early conversations are happening. Hence, we have sort of a consultative approach for our clients, where we are helping them answer these early questions and helping them with their exploration journeys.

We also realize that we need to be ready for technology and then we need to have an adequate skill set to address future demands. So, we have a focused effort in the lab where we're sort of running an academy where we're trying to skill our fellow HCLite and equip them with the technology and know-how and nuances of the technology. Then, there's a small team inside the lab that is focused on assets and solutions creation. So, we're building various industry solutions and assets that we will release in the market soon as and when the development process begins. There's a lot of incubation activity going on. So focus on certain solutions and asset creation. And last but not least, the lab is also engaged in a similar exercise to what we're doing today in terms of establishing thought leadership for HCLTech in this space. So yeah, quite a bit happening in and around HCLTech Quantum Labs. Happy to delve into more details as we go along with this topic today.

Pranav Kaushal: IBM has been one of the pioneers in quantum tech development and Abhinav also mentioned Quantum ML and shifting focus towards it in our customer engagements and customer conversations. Dr. Venkat, could you please highlight IBM's focus on Quantum ML?

Dr. Venkat: Sure, yeah, thank you. We know that quantum computers have the potential to boost the performance of machine learning systems. We also know that they may eventually power efforts in wide-ranging fields, ranging from drug discovery to fraud detection. So, what we're doing is foundational research in quantum ML to power tomorrow's smart algorithms. I'll give you some examples as we go along, but I'll start with this one. In 2021, IBM researchers found mathematical proof of a potential quantum advantage for quantum machine learning. In this, the IBM team solved machine learning problems, which are hard for classical methods. Specifically, a quantum computer was used to solve a classification problem where the quantum computer was able to see patterns, where a classical computer only saw random noise. And this is of huge significance because we'll talk about other examples, but this is huge because it tells you that quantum computers work in a space, mathematical space, a higher dimensional space, where they are able to make better sense of the data that we have. So, our ultimate goal for our research is to solve real-life business problems using Quantum ML. Yeah, thank you.

Pranav Kaushal: Thanks, Dr. Venkat and IBM is definitely working on a lot of research areas and we ourselves refer to those research papers sometimes. And so, some of these areas, like you mentioned, are probably looking into the emerging advancements or emerging trends in the technology. So, understanding from a market sentiment standpoint, right, Abhinav, you mentioned that you keep on exploring and capturing emerging trends across the industry, right? So what are the key trends in quantum ML that you are seeing that are coming up?

Abhinav Khare: Thank you. Yeah, I mean, if we specifically talk about quantum machine learning, it's basically driven by the need to have better models when there are certain constraints and then when we are exploring quantum machine learning, so we're looking to resolve those constraints of the let's call it traditional or classical machine learning approaches that we have today. And the trends align with the sorts of needs we see. So, if you look at the current machine learning schema, we're looking to upgrade to consume huge data sets, a humongous set of data, which is considered a constraint when we are developing models today. We're usually working around with some samples, data samples and then we're trying to build models and then training them and retraining them. And so, with quantum computing, we really see the potential of building models with a huge and humongous data set. With that premise, the second trend is, of course, how can we improve the efficiency of optimization problems by achieving the speeds at which the algorithms are executed? That's the second trend. We are looking at better efficiency. Then when we look at efficiency and the obvious progression in trend is looking at better accuracy into sort of, if you look at simulation algorithms, how can we achieve better simulations and models are more accurate and the constraints of the data sets where you have, you're working on more the data, the accuracy is potentially more so. I think these are the three key trends that are sort of driving the adoption or putting the momentum of really looking at quantum machine learning as the next step towards evolution in this area. I hope that helps.

Pranav Kaushal: Thanks Abhinav and it coincides and converges with Dr. Venkat's point of view that quantum ML or quantum systems better understand the data sets. So, quantum ML has a lot to gain and it is clearly evident from the trends you have suggested. Sanjay, you keep interacting with many customers as a part of your role. And so, according to you, what are the low-hanging fruits in terms of industry use cases or applications around quantum ML that you have seen?

Ravikumar Sanjay Muthiyalu: Definitely. Thanks for bringing that up for now. As Dr. Venkat alluded, there is a lot of promising work going on in this space. But first, it's important to understand and acknowledge that quantum machine learning cannot solve all problems. Classical machine learning has its own space along quantum machine learning, at least for now. So quantum machine learning... is best suited to address those problems that involve complex data patterns and optimization tasks whose computational needs grow exponentially with the number of parameters involved, right? So, in this context, from a modeling perspective, a few archetypes are emerging for quantum machine learning, right? This is across industries. Some examples are those problems involved in simulation, problems involving factorization and linear algebra and there is another category for optimization and search that spans across industries. Now, within specific industries, we see that there is a lot of interest in the BFSI, pharmaceutical and chemical industries, where there are use cases like dynamic portfolio optimization, feature selection for credit scoring, complex derivatives pricing, etc., in the BFSI industries, which is the banking and financial sector. Within the pharma vertical, there are simulation-led use cases for drug discovery and protein folding. Again, there is a lot of interest there. So, many research papers are being published and so on and so forth.

In the chemical space, there is an ability to leverage QML to identify new chemicals, especially in the area of battery optimization. And this is driving a lot of research out there. Now, again, these are the, I would say, use cases that have the potential to create some near real-time value. Within the market intelligence space, we also see customers conduct promising research into customer segmentation using QML on data sets, which is not traditionally possible with classical models. Now, on a slightly... larger horizon, the logistics and transportation verticals have a lot of promising use cases that they're working on, like flight route optimization, airport gate optimization, intelligent traffic management, etc. There is also a lot of interest that customers have expressed with HCLTech in terms of last mile and first-mile optimization. The ability to optimize the last mile of a particular logistics journey or sometimes in the first mile. For example, grocery vendors and traditional retailers where they can plan their milk pick-up journeys to ensure that there's the optimal freshness of the milk. So that's one area. Again, but over the five to ten-year space, I believe there will be a convergence of large language models and QML disciplines, which will probably drive the next generation of use cases. I hope that gives you a broad spectrum of use cases we're seeing in the industry.

Pranav Kaushal: Yeah, of course, Sanjay and the applications that you have mentioned are very well known in the industry and there are a lot of different technologies or different tech that have already been applied to solve these challenges or solve the problems that are currently existing in these areas. So, a question to Dr. Venkat from a research standpoint. What will be the key drivers for adopting and accepting quantum ML in these areas? Because quantum itself is a very new technology, it's a bit difficult to understand and people don't exactly jump onto quantum straight away.

Dr Venkat: Yeah, actually, see, I think the surprising answer to this is that it is education. Education is the key driver for the adoption of quantum machine learning and as Sanjay mentioned, even selecting the right use cases, selecting the problems that are right for quantum, even that involves some level of understanding right. Both developers and business, we need to educate businesses and business leaders in terms of what quantum can do for them because that's very important. So, in IBM, we've been running these multiple challenges courses and programs, like the global summer school 2023, which just happened, and the goal here is to empower quantum researchers, developers, and business leaders. With foundational knowledge that bridges theory and practice, because what you want is for people to start using quantum in the right way to solve the right problems, so even in quantum machine learning, we offer courses for learners where we provide an in-depth understanding of quantum ML concepts and applications the other side of this is access to all the top-tier institutions in India. Since then, IIT Madras has joined the IBM Quantum Network. But the goal here is that more and more people should use these systems and start solving real problems, what is possible with quantum, which will lead to adoption and acceptance. Thank you.

Pranav Kaushal: I think you have struck the right chord there; education is something that is important and making everyone understand in, let's say, layman's terms, what exactly quantum is capable of doing and it's not rocket science, that it's difficult to understand. So, we have touched upon a few things from a market standpoint and talked about quantum ML in existing classical methods and how it is evolving. So, let us try to understand it from a deeper perspective. So, Abhinav, could you give an overview of the evolution journey of classical AI ML to quantum ML to the stage where we are right now?

Abhinav Khare: Yeah, interesting whenever we internally have a discussion around, when you look back in history, so it's sort of an interesting evolution. So if we really go back and then think about when all of this started, I'm not sure about the time perspective or date perspective, but, in around the 1950s, Alan Turing tests happened and then things started getting exciting. Then, we started the machine learning journey from there, where we ventured into building the regression and correlation-based models, classification and clustering, etc. So that's really when this all sort of started evolving. Then, we saw movement to supervise and unsupervised learning and so on. And then, if you look at a some kind of a milestone perspective, some time from then, let's say in the 1980s, we saw machine learning algorithms developed that supported vector machines. Then, we're looking at principal component analysis, deep learning and neural networks. All of these started making an impact and their journey into being active and being explored. An interesting intercept that happened in early 2000 or maybe 1999 when we saw the foundations or saw quantum computing being potentially leveraged in similar areas of machine learning. In time, I'm talking about when D-Wave announced. And then I also came up with making it available through, I think, in 2016, making the quantum computers available over the cloud, providing access to the compute power, and potentially exploring how it is possible to do machine learning activities over quantum computing. Then, we saw one thing made accessible, then we Taw research sort of happen around quantum data representation and how you could experiment, how the data could be fed into quantum systems and faster processing and so on. Then, a natural sort of progression to this was to develop quantum versions of the algorithm. We saw support vector and principal component analysis sorts of algorithms being developed on quantum machine learning or quantum infrastructure. We've seen this happening in the last half a decade. And the evolution continued.
Once this sort of became successful, then we saw QUBO, quantum unconstrained binary optimization and QA and OA, quantum approximate and optimization algorithm. These were the sort of next versions of algorithms which were developed, models were developed on this and recently, which I'm aware of is we've seen Cambridge quantum computing coming up with QNN and quantum transfer learning and QNLP and so on and so forth. This is something I think it's very recent last year or so. So, if you look at this, it shows the journey of machine learning; we talked about the adoption and finding ways where it is applicable, but it's not applicable everywhere. If you really look at this journey and it's also part of our sort of academy initiative that we are running, we make people aware of this journey as well. So, it is naturally running parallel to the, let's say, classical machine learning approaches and when the quantum infrastructure is coming, the adoption is parallelly happening and research is going on. These are such exciting times; I think that's all I had around this question. I hope this provides some insights.

Pranav Kaushal: Yeah, sure enough. So, taking light on this area or this domain around the two different dimensions a little further, it would be great to understand from Dr. Venkat how quantum ML can achieve an edge on shortcomings of classical ML systems, which Abhinav alluded to.

Dr. Venkat: Yeah, thank you. So, Abhinav gave an excellent overview, right, of how this technology has been evolving and how classical evolved. And so, even in quantum, I think it's important for us first to understand that we are still in the early days of quantum computing. So whether it is machine learning or any other area of research, quantum computing must continue progressing along the entire stack before we can achieve quantum advantage. So, if you see today, we are advancing on the hardware technology, the algorithms are advancing and the applications are advancing. The whole stack we are advancing across this entire stack. To accelerate this, we need to work with customers to overcome some of these shortcomings. So, the best way to understand the shortcomings and where quantum fits in is to try and solve real and tough business problems, seeing patterns where classical systems only see noise.

So now let me give you one more example, so in a recent collaboration between IBM scientists and CERN scientists, this involved the detection and analysis of the Higgs boson. Higgs boson is a recently discovered particle that helps explain the origin of mass. Now, finding this large amount of raw data to find these occurrences of Higgs behavior is a tough problem for classical computers because it completely stretches them and here is a good problem for quantum computers. The goal here is to find these problems that are very well suited for quantum and while solving them, you're overcoming these shortcomings. Machine learning, whether it is classical or quantum, really offers these tools to recognize patterns in the data, just like this Higgs behavior in data sets, which are so vast and so mixed up that you need this kind of power. Thank you.

Pranav Kaushal: Just a quick follow-up question on this, Dr. Venkat. So, we are currently in the NISQ era right and there is a lot of noise in existing quantum systems that we have and it kind of medals with these algorithms and the performance of these algorithms. So, what popular modules can be used to deal with the underlying noisy hardware problem for practical applications?

Dr. Venkat: So, as you rightly said, the underlying hardware today is noisy, right? So, there are several things that we are doing to reduce these errors in the quantum computations, right? So, I will give you some examples. Qiskit has a tool for dynamic decoupling that adds sequences into the circuit to suppress noise, right? Mitigate and suppress the noise at this point because we have a few qubits to work with. So, you are not really looking at error correction, but you are looking at suppression and mitigation. Similarly, there is this package called Mapomatic, which selects the best qubits for a specific noise, Recently, IBM came out with this nature paper called the utility paper, where it was demonstrated for the first time that quantum computers can produce accurate results with error mitigation at a scale of 100 plus qubits, reaching beyond what is possible with classical approaches. So, yes, quantum computers are noisy, but at the same time, there are noise mitigation methods that are available in packages that help you improve the accuracy of the quantum computation by minimizing various types of errors which are there in the underlying hardware.

Pranav Kaushal: Thanks, Dr. Venkat. I have seen a lot of news and rounds of information happening around the error correction module that you just talked about.