Rashmi Mohan: This is ACM ByteCast, a podcast series from the Association for Computing Machinery, the world's largest education in scientific computing society. We talk to researchers, practitioners, and innovators who are at the intersection of computing research and practice. They share their experiences, the lessons they've learned, and their visions for the future of computing. I am your host, Rashmi Mohan.

The world of technology does not often lend itself easily to being associated with art except when it comes to computer graphics. This niche area aided us in bringing our images to life on the screen, progressing to giving us immersive, enriching experiences that transform the manner in which we interact with the digital and real world. Our guest today is a pioneer in the world of computer graphics. Neil Trevett is the vice President of Developer Ecosystems at Nvidia and the president of the Khronos Group, a nonprofit consortium publishing open standards in a variety of areas related to computer graphics. He has worked tirelessly to bring about standardization in the graphics world, giving developers the ability to extend and expand the capabilities of their visual systems. His work involves bringing interactive 3D graphics to the web, creation of the GLTF format for 3D assets, and most recently founding of the Metaverse Standards Forum. Neil, welcome to ACM ByteCast.

Neil Trevett: Oh, it's a pleasure to be here. Thank you for inviting me.

Rashmi Mohan: Absolutely. Neil, I'd love to start with the question that I ask of all my guests. If you could please introduce yourself and talk about what you currently do, as well as give us some insight into what drew you into the field of computer science.

Neil Trevett: Sure. Well, as you've kind of hinted in your introduction, I currently have three jobs right now so that are related to, I think the topic of graphics and standardization. Well, my day job, as you mentioned is at Nvidia. I've been at Nvidia close to 16 years now, and I work at Nvidia to try to help developers make good use of GPUs for graphics and compute. But throughout my career, found myself getting increasingly involved with standardization. Again, as you mentioned first with the Khronos Group. I've been the president of the Khronos Group for over 20 years now, and now the Metaverse Standards Forum, which is much, much younger, just a few months old, but I got into computer science right from the get go at college.

My joint major was in computer science and electronic engineering, and I really loved your introduction because I did get into 3D graphics because I loved and still do, I still love the kind of visual aspect of graphics. I wish I could be a visual artist, but my hand to eye coordination is terrible. I love doing photography, but computer graphics, the immediacy and the visual impact was just addictive to me from the get-go. So I've been fortunate, basically my whole career has been in 3D graphics.

Rashmi Mohan: That's wonderful. To think about it, it sounds like you have an innate interest in art, and to sort of extend that into the world of computer science or blend that with technology is quite a unique sort of experience. Not all of us have that sort of blend of our passion and what our day job brings us, so I'm really happy to hear that. What was that journey like, Neil? Most of us go to college and do computer science. What really sparked that interest in graphics? Was it mostly the interest in art, or was there a specific incident or a specific teacher or any sort of moment that you felt, "This is exactly where I need to go?"

Neil Trevett: It was when I first went to college and started studying computer science. No, it wasn't clear what no specialization I would end up in. I did have this interest in the visual arts, but in the end it was computer graphics. It attracted me in two ways, not just the visual aspect that we talked about. It was also an amazing challenge. Then this was back in the early '80s, that's dating me, but the gaming, 3D gaming wasn't yet really pervasive at all and people were just trying to figure out the very beginnings of computer gaming back in the '80s. But lots of interesting challenges were coming up in the kind of real-time nature of gaming and the interactions of users with a gaming system. Now, all these were a cutting edge back in early 1980s. So the combination of then the visual appeal, plus the engineering challenge, both from a hardware point of view and a software point of view, and my honors degree was in computer science and electronic engineering. So hardware and software, it just seemed like the perfect place to try to bring hardware and software together.

Rashmi Mohan: That is a great blend, and really a wonderful use of your skills as you're developing them in the courses that you take. You mentioned GPUs or graphics processing units. I know that those were first developed by Nvidia not too long ago, in 1999 from what I read, and now are just sort of the industry norm and the applications of GPUs as well has sort of exploded. But I was wondering if you could take us through the evolution of computer graphics as you remember it.

Neil Trevett: Yeah, it's actually been an interesting journey. It feels a little bit like the Forrest Gump movie, where I've just been fortunate to be at some of the key evolutionary points in 3D graphics sometimes as an observer, sometimes involved. So almost my first job straight out of college was 3D graphics startup company in the UK, which is where I'm originally from. It was called 3Dlabs, and we were quite a few companies working in the new field of 3D graphics. Silicon Graphics here in Silicon Valley had the visibility and the high-end hardware, the workstations that many people I'm sure used back in the day in many types of 3D applications.

3Dlabs and other companies. We were trying to best build chips much cheaper than workstations to bring 3D graphics onto PCs. And through the '90s that was the main focus, helping 3D graphics onto the PC. And now of course as you say, GPUs are everywhere. And then at Khronos, I was fortunate to have the opportunity to initiate the OpenGL ES project, which ended up bringing 3D graphics onto mobile phones, and that continues to be used by billions of

people every day. And then also at Khronos, again, a lucky opportunity to be involved with bringing 3D to the web with the WebGL standard, which is another kernel's standard that leveraged OpenGL ES. So in all of these generations of platforms, incorporating 3D, building on the past work of the previous platforms and GLTF is what used widely on the web as well. That's the 3D asset format that you mentioned. And now with the Metaverse Standards Forum and the work at Nvidia and Khronos, the opportunity now is to make sure that 3D with open standards is brought to the new platform, which is going to be the Metaverse.

Rashmi Mohan: It's amazing. I feel like I have to break that answer down into four parts for me to really dig deeper into each one of them. You mentioned OpenGL ES, right. And that was pretty groundbreaking at the time when it was created. And to recognize the need for you to bring that to mobile devices, to bring OpenGL to mobile devices was pretty insightful. Do you remember how that came about?

Neil Trevett: Yes. And think everyone, myself included know who's involved with OpenGL ES and owes a big debt of gratitude to the granddaddy of open standards in 3D, which is OpenGL itself. OpenGL ES was a subset of OpenGL now suited for mobiles. But Silicon Graphics and Kurt Akeley, who was CTO there, took the very amazing decision back when Silicon Graphics was at the height of its market power. They had a proprietary graphics API called Iris GL, and Silicon Graphics took the decision to make it into an open standard, which became OpenGL, and they invited the other hardware vendors and other workstation vendors to participate in the governance and the management of OpenGL, and that was really the beginning of much of the 3D industry that we know today. It was 30 years ago almost to the day, OpenGL. It was 30 years old just a few months ago.

And having the opportunity, because I was working at 3Dlabs at the time, I was watching and helping and supporting OpenGL as Silicon Graphics were launching it. I watched firsthand the power of an open standard to encourage and enable, and foster cooperation between engineers and companies that normally would maybe be competitors, seeing a common good and seeing that if everyone was to invest in an open standard that everyone had a say in evolving. It was good for them, it was good for the whole industry, it was good for the participants helping the standard grow. And that was the start of my journey in open standards. Just seeing what a powerful force, the right standard at the right time could be for the good of the industry, and for the good of the participants helping to build that standard.

Rashmi Mohan: That lends so well into my next question, because I was going to ask you that. I mean it's not common. A lot of us work in industry, but not a whole lot of us participate in the manner that you describe in terms of doing work in open standards or contributing to open source. And definitely, we'll talk about the distinction between those two. But I would love to also understand, your day job from what I understand is to foster and encourage developer ecosystems and tied to the companies that you work for. But are there principles from that,

that you apply at work that also lend themselves well to the work that you do for the Khronos Group?

Neil Trevett: Yes. I think that there's a big overlap. It is not 100% obviously, any company that's developing products, particularly in a competitive field like computers and computer graphics, they're going to have a mix of proprietary technologies and proprietary APIs and frameworks to enable their customers to use their products. But very often that those same companies will want to use open standards too, because open standards can be very effective to help build a business. Suddenly a business doesn't have to invent everything that is incorporated into their products. They can use open standards to interoperate with other companies to build on the work the standards community has invested in open standards and really get the networking effect. So for 3D graphics on the pc, it's a very obvious win-win-win. If a graphics company selling was forcing people to use a proprietary API, in many cases now that would be a friction point to their business.

It's much more enabling for the broader market if you can enable software developers to write once and to run across different hardware vendors, then the hardware vendors get access to more software. The software developers don't have to keep rewriting their code, and in the end of course the developer gets more end users and the end user now isn't so confused. And so, that grows the market overall. So the right standards at the right time now can be a really positive thing for building business. But of course companies need to innovate too. In a normal company, there's a mix between proprietary and open standards. And a smart company now will use the right ones at the right time to maximize their market reach.

And so my own role at Nvidia, I'm fortunate Nvidia lets me invest a lot of time in the open standards in the computer graphics domain. Nvidia uses many of the standards that the Khronos Group does, not all of them. And I'm not pulled in two different directions because Nvidia using some of the Khronos standards is good for Nvidia's business. And that's where I focus my efforts at Nvidia, as well as engaging with the larger open standards community. So there's a consistency to my role whether I'm at Nvidia or Khronos and again, I regard myself to be very fortunate to be able to do that and very grateful to Nvidia to let me do that. And hopefully everyone is winning.

Rashmi Mohan: I think you're also being very modest in that I feel like you also have these very special skills to be able to spot the opportunities to participate in the open standards, and also be able to meaningfully contribute towards the company and the goals that they have. But one of the things that you mentioned, Neil, which I thought was very interesting, well you were talking about the interoperability.

This is something I know I was doing research on the work that you've done and you do talk about this quite frequently, but I was curious when we talk about

companies that want to innovate and want to build something proprietary that they can potentially monetize and help grow their business, how do you recognize when a new standard is needed? So you come up with, you germinate an idea, you build it out to a certain amount, it sort of probably builds a little bit of momentum, but is there a tipping point when somebody recognizes and says, "You know what, I think we need something more generic here."

Neil Trevett:
Yes, that's a great question and it's very easy to try to, once you get into the standards groove, it's a big mistake to try and standardize everything and you should be very thoughtful about what should be standardized and maybe a certain thing shouldn't be standardized, it should be left proprietary. Timing is important, too. So my rule of thumb is, first of all, for a technology to be a candidate for potential standardization, it has to be a proven technology. It can't still be evolving. If it's evolving, you'll never going to get people to agree on what it is, because it's changing too fast. And probably companies still are getting commercial advantage from in innovating and coming up with the next revision of whatever that particular technology is. And so, you are not going to get agreements between the various companies as to what should be standardized.

We kind of jokingly say, "Don't do R&D by standardization committee." It's a very painful process. Don't do that. So, the right time to do standardization is when the technology is proven and quite pervasive. Everyone's kind of doing their own version of it, but the technology is basically understood, and the companies are no longer getting commercial advantage from doing that technology in slightly different ways. It's just become a frustration now, because everyone's kind of doing something similar but in frustratingly different ways, and people are beginning to recognize that those differences are holding back the market, and it would be much better if we could standardize, get rid of that friction point and move on to the next wave of innovation, the next wave of technology where innovation is still going at pace and you can compete with the next wave.

With standards, you can consolidate what's proven and accepted throughout the industry, and that's the superpower of standards because a standard is a specification that lets two things communicate with each other, be it hardware, software or a client and a server device, the specification plus conformance tests. So, you know everyone is implementing it correctly and reliably. It enables multiple implementations of that technology in an interoperable way, and that lets that technology fan out pervasively across the industry, again to everyone's benefit.

Rashmi Mohan:
That is pretty amazing. I do have a question, though. So at the time when maybe a standard is created, companies recognize that, "Hey, we really need something that's more sort of a genetic and something that's standard across the industry." Is there a step there then they're actually, you're also spending time to adhere to that standard. So it's almost like a step back. I don't know if

I'm expressing myself well, but it feels like in order to, I've been moving at a certain pace and building something out, but now we are standardizing it, and it might not always be exactly the way I built it out, and so I'll have to actually spend some time adhering to this more genetic standard.

Neil Trevett: Yeah, that's a good question. I mean, there's a number of aspects to that question. Yes, building standards takes time and successful standards come into existence are successful because enough companies that are going to use those standards care and believe that they're going to benefit, and that industry is going to benefit it. It does take some resource, and it can take longer to create an open standard with multiple companies agreeing to it than just doing something proprietary quickly in doing it yourself. But that extra time and those conversations to build a standard, that's not a bug, that's the whole point. That's the feature that you want.

Building consensus on a standard that everyone can benefit from is the foundation for cooperation and interoperability. So, you do need a quorum of companies that's going to be willing to put that investment in. But once you've done it though, you can begin to benefit in many ways. And another aspect to your question is, it doesn't hold you back well because I often get the question, if I have to use an open standard, aren't I being brought down to a lowest common denominator, I don't have any opportunity for differentiation or advancing. A well-designed open standard very carefully chooses its level of abstraction and a well-designed open standard will only define the minimum you need to interoperate, if it's an API like Vulkan or WebGL or OpenGL ES.

It's just the calling protocols that are defined in the API, not how you implement that API. So the Vulkan API, which is the new generation 3D API, doesn't dictate at all how you implement your GPU. So, all the GPU vendors know that are supporting Vulkan on their hardware. They're fully enabled to innovate in their GPU architectures however they want as long as just the final result and the calling protocols of the API are on it now they can do all the innovation they wish to now at the implementation level. The other way we make sure that open standards don't hold back the industry again, well designed standards are often extensible.

So if you really need some functionality in an API like OpenGL or Vulkan, if you want to, and you want to move faster than the group on a particular point, you can do your own vendor extensions to meet your own market and customer needs. And in the end, it actually turns into a pretty good pipeline. Often the vendors are doing vendor extensions out ahead of the specification. Some of them will fail, some of them were really just very specific to a particular vendor, but very often they prove out the new wave of technology that then gets adopted back into the mainstream open standard. So, a well-designed standards ecosystem will encourage and enable that kind of vendor innovation through extensions.

Rashmi Mohan: I really like how you described that, and the distinction that you brought to the fore. I think that makes a lot of sense. But this also begs the question of, what is the right team to form to be able to develop an effective open standard? How do you know that you have the right composition of expertise, whether that is domain related, or it is somebody who knows how to build standards and knows how to corral the troops, if you will, towards an effective generation of the standards. So I'm just curious, what is that recruitment process?

Neil Trevett: That's interesting. In my experience, the effective working groups, of course you need domain expertise and you need expertise where people have been genuinely implementing the technology that gives you the insight to keep the standard, to keep it real. Again, a standard shouldn't be doing R&D, it shouldn't be in inventing new technologies. It should be taken established, proven practice and figuring out how to reframe that functionality in a way that everyone can benefit from. So you need people that have been implementing that technology. They're the folks that are going to have the insight. But the other vital ingredient from our experience is you need the users of the standard to be around the table as you design it, to make sure that the requirements and use cases are based in the real world needs as well.

It's very easy, it's an easy trap for a room full of implementers, with no users, no developers in the room to go off in a direction that no developer is going to find attractive and you end up with a standard that just doesn't meet the needs of the developer community. For an API, again, like OpenGL or Vulkan, it's the developer community are your customers. And so you need to make sure you are talking to your users, your customers as you design the standard. And if you don't have enough of your customers or end users in the room, that is a definite warning sign. Almost all successful standards I've seen have had a good mix of implementers and users of the standard.

Rashmi Mohan: That is such a crucial point. You're absolutely right, because I think it's like with any business, I think listening to your customers and getting regular feedback is probably the best way to guarantee some adoption as well as success. But talking about users like obviously one of the largest, I would say user base for some of the standards that you've defined, from what I understand are game developers. And from what I hear, the market is so competitive that I wonder, do people want to lock in their audience and build sort of proprietary experiences? How have you, I don't know if that specific set of users in something interesting that you might have experienced with the game developers?

Neil Trevett: Yeah, it's interesting, and I think it's a fundamental property of the universe that you're always going to get a spectrum. In whatever the field of human endeavor is, including the computer graphics market or the computer market in general. Any company can decide, do they want to use proprietary interfaces and technologies and try to lock in their customers, or do they want to be open? It's a spectrum, and it's not a criticism either that there's some very successful

companies, their business model is trying to use proprietary technology wherever they can. And if they do that successfully, it can be a very successful business. But of course, there are many other companies who want to use the networking effect of open standards, not having to do everything themselves and through the networking effect, potentially get access to larger customer base and larger markets. There will always be different companies all the way along that spectrum, different points, people trying out different business models.

I think that that applies both to the platform vendors and the technology vendors, the GPU vendors, and also people selling applications, too. The same spectrum applies at each level in the food chain. Some applications will be much more open, others will be more closed, it's all good, and it's the way of the world that the Darwinian mechanics will kick in and will select out the successful business models all the way across that spectrum. But it's the role of the standards community towards the open end of that spectrum to give the companies that want to use open standards to get that networking effect, to give them the choice of effective and well-designed open standards, so they can live on that end of the spectrum if their business model needs it.

Rashmi Mohan: Yeah, that's great to hear. I mean there's room for everybody and I think it sort of depends on how you want to drive your business forward, whether it is with the goal of being interoperable and if that's what's really going to bring you the momentum, then it makes more sense for you to align with a standard that is industry-wide. ACM ByteCast is available on Apple Podcasts, Google Podcast, Podbean, Spotify, Stitcher, and TuneIn. If you're enjoying this episode, please subscribe and leave us a review on your favorite platform.

So one of the other areas, Neil, that I heard you talk about or write about quite a bit is pervasive 3D in e-commerce, right? And e-commerce is obviously something very close to my heart. I do a lot of online shopping, but I was wondering if you could maybe walk us through what do you envision as 3D in e-commerce, and how do you think it is changing the world as we know it? I know the GLTF file format is something that you've been very integral to developing and now is being adopted pretty widely. So, I was just wondering maybe if you could give us an insight into that journey, and what you think, just maybe a little bit of a future vision into that.

Neil Trevett: It's interesting now, GLTF that has an interesting genesis story, because we started work on GLTF, over 10 years ago now. And we were looking at all of the other media types, images and video and audio, and over time, they were all getting their what I call their social media moment. And it comes from having a compressed pervasively available file format. So, MP3s arrive and I'm going to show my age again now, and Napster.

Rashmi Mohan: I recognize it. So you're all good.

Neil Trevett: Okay. And now it's Spotify, right? And the rest, the JPEG arrives and you get Instagram and Facebook, and then videos arrive and you get YouTube and TikTok and all, but there hasn't been that social media opportunity for 3D. Back in the beginning of GLTF, we thought well perhaps one of the missing pieces is 3D doesn't have the equivalent to JPEG. There's not a file format that has been specifically designed to be easy to process and display, even on a mobile phone just like pictures and videos and is pervasively available. And that was the reason we started to design GLTF. And we've been fortunate that the industry has widely adopted GLTF. And so now, GLTF is fulfilling that role of being a file format that that's very widely adopted and supported in on many platforms on the web, on and in native applications.

Many tools generate GLTF, many applications absorb GLTF. So, it's been an interesting and fun journey. The 3D commerce is one of the first real beachhead applications that I think will bring 3D into a wider audience, because the commerce that's in general, and the online commerce is a huge business. And there are many studies out there that show that if you can display a 3D model of an object that you know are offering for sale, you do get more customer engagement and customer satisfaction, and less returns than just a JPEG. It's actually quite a big margin, too. It is very interesting because you can see more details, you can interact with the model, it becomes quite a compelling business booster for the online commerce folks. So there's a lot of sustained interest to figure out, "Okay, we know 3D is effective selling tool and we want to use it," but then they discover it's very difficult to have millions of products being generated by hundreds of different tools flowing through hundreds of different companies with storefronts, with different engines that are being used to display these 3D objects.

It becomes a real logistical nightmare if you don't have, not just asset formats, but you have a broad understanding of how to create assets that will run on a mobile phone, and how can you create them and how can you have engines on very different platforms like a web on a PC, or a browser or on a mobile phone or an ad platform like Facebook or Snap, all using different engines. The 3D models, even if they use a common format like GLTF, they end up looking completely different. So now your purple couch, which of course now everyone wants a purple couch, is looking more red than it should do and it will get returned and that that's a real pain for everybody. And so, 3D commerce has been this really motivated set of companies wanting to use 3D, helping the 3D industry really figure out how to get consistency in tooling and guidelines on how to use the tools, what are good guidelines for building content that can be deployed everywhere.

And now, we're onto the stage of making sure that all of the engines now, like a web browser engine or a native app on a mobile phone, they all display those 3D assets consistently to the end user, and that's essential for 3D commerce. But of course it's essential for everyone else in the 3D industry who wants to use 3D in this way to communicate real world information. So, 3D commerce

are a precursor to, they're solving many of the problems that are going to be very relevant to many more people across the industry, including the metaverse because the metaverse is going to want to consistently and accurately display 3D assets and avatars on multiple metaverse platforms. So, the 3D commerce is really a precursor to solving these problems for the wider industry.

Rashmi Mohan: It's so exciting to hear that just mean basically the marriage of a use case with such a wonderful sort of way to apply it and the genuine interest that comes from that industry as well must be so exciting because like you said, there is a lot of passion. There's a real need to solve the problem, not just for themselves but also for those to come after them. So, it's really actually very heartening to hear that. One of the other things that I noticed, Neil, is I actually went back and did research and some of your talks from many, many years ago. And one thing I noticed very pleasantly surprised and impressed was, you really started to include a very diverse set of voices while building your standards committee. I know you've presented in China and in various other sort of international destinations. What was the insight that drove that, and what do you feel bringing those sort of really different voices and just ideas from around the world brought in terms of value to building these committees?

Neil Trevett: Yeah, I'm so impressed by the research you've done. You know more about me than I do, but no, we've always wanted to include the international community because an open standard is not truly open unless it's accessible to everyone. As you say, in an inclusive way, geography should not be a barrier to the use of open standards. And over the years, as you've mentioned, we've figured out ways of reaching out into the various geographies and investing in the long term relationships that's necessary for the 3D industry in Japan or China, or other geographies to really trust, just like any business. People do business with people, not companies in the end and you need to show up and continue to show up in those other geographies to build the recognition and the trust that companies in these diverse geographies can trust the standards that this organization that they've just met is producing.

I think we have managed to build that trust in many different geographies, and of course the reward is many of the innovations, and the energy and the input into the standards that we're building. And now of course, coming from those diverse geographies and everyone then gains, including the folks here in the US. So again, it's another win-win-win. The biggest problem, we kind of joke about it, but actually it is a real problem. The biggest problem it introduces is that the earth is round, and therefore it makes it impossible to find a good meeting time that everyone can join in.

Because if you have participants from Europe, US and Asia, of course there is no time where someone isn't having to be up and on a Zoom call at two o'clock in the morning, which that's not fair either. So that we struggle with that one, continuously. The standards at the Metaverse Standards Forum for the larger meetings where we do have a lot of international participation, particularly,

we've actually begun holding two sessions of the same meeting. We hold it once in the morning Pacific time and once in the evening Pacific time with the same agenda. And so, people from different time zones can participate in a real way.

Rashmi Mohan: That's brilliant. That's a really good way to do it. I agree. I think it's a small price to pay to bring in that value of both cultural as well as unique challenges that each of these either geographies or working groups face to bring it in, to add value and help you think in dimensions that you might not otherwise have thought about. So that's great. But yeah, we've spoken about the metaverse a couple of times, Neil, but that's about as exciting and novel as it gets. So I would love to hear more about maybe one, just your interpretation of the Metaverse for our listeners, and then also what is unique in defining standards for the metaverse?

Neil Trevett: Yes, so it's very interesting when people hear about the Metaverse standards forum, they go, "Oh, you are standardizing the metaverse. So, what is the metaverse?" That's normally the first question and the answer is, we don't know. We don't know what the metaverse is going to be in 5, 10, 20 years' time. We're at the beginning of a very chaotic, in a good sense, a very dynamic period of innovation where it's going to be very hard to know what comes next. The analogy I use is the very first web browser, the Netscape browser in 1994. If you sat someone down in front of the Netscape browser in 1994 and said, "What is the web going to be in 30 years' time?" I guarantee their guesses would not be anywhere close to reality as to what's happened. It's just impossible to know, because there's so many innovations in unexpected directions, you can't plan or predict that far ahead.

And that is precisely where we are with the metaverse today. So yes, we don't know what it's going to be in 20 years' time. But the metaverse is real, though. I think the excitement in the industry is coming from the fact that for many people what it means, what the metaverse means is, we are bringing together multiple disruptive technologies in new ways, and that is going to create opportunity and disruption at a pretty big scale. So, the metaverse often is described as the 3D evolution of the web, and I think at least in part that's true, yes. But I think it's the connectivity of the web with the immersiveness of spatial computing that includes photo realistic graphics, GPUs are in there, and using the GPUs for simulation and compute. There's XR, augmented and virtual reality, though you're not going to be forced to use those.

It's going to be an option, and some of the most immersive experiences probably will use them. But I think most people access Metaverse through their phones still. And the magic pixie dust though, which is truly disruptive, is AI and machine learning. So, that is letting our machines, our computers, do things that just seem magical, even just a year or two ago, natural user interfaces, language processing and understanding natural user interface through gesture and body tracking, scanning objects, scanning your environment and understanding them, semantically. Really uplifting the tools, so people know normal everyday people,

my mom soon will be able to build and scan 3D models because the AI will be able to help and assist the creation, text to VR. And all that innovation is happening right now as we speak almost a weekly basis. There are new innovations on how to deploy machine learning.

And so if you mix all those things up together, interesting stuff is going to happen. There is going to be a constant stream of opportunity. How can we standardize it if we don't know what it's going to be in 20 years? Well, actually it turns out to be quite simple because we know what interoperability problems we have today. If you're going to bring all these technologies to work together, then you need interoperability because interoperability is helping things work together. That's the whole essence of standardization. And so, we are finding this wave of interest in 3D standards and XR standards because people are beginning to realize that they're going to be used as a part of this overall metaverse mix. And so, we have a lot of interest in standards, in some cases we've been working on for decades. And now people, a new wave of people are interested because they're going to be used in the metaverse. So it's an opportunity for everyone, including the standards community.

Rashmi Mohan: That's fascinating the way you describe it, and it's also very exciting to think about it as, it sounds like the fact that the common denominator of interoperability has been identified and is being used as a foundation. It just seems like bringing these three or four end technologies together will be more successful, if you will. It just sounds to me that having the ability for these things to work together is the foundation of how we maybe imagine what the metaverse will be.

Neil Trevett: That's right, because if we're going to avoid just having a series of vertical silos like today, I mean the closest many people get to the metaverse today are games like Fortnite and Roblox. They're awesome, and they have many of the elements that I think people imagine the metaverse to have. User created content, real-time 3D graphics, social connectedness, connectivity, but they are verticals. You can't design an asset or an avatar in Roblox and take it to Fortnite or take it anywhere else. I think that many people's vision of metaverse is, it's not just a series of vertical applications. It is a larger platform where your investment in your work and your avatar and your cool Gucci jacket, you can take it with you across the different spaces and environments in the metaverse. And that is going to take this whole new level of interoperability. But the important thing to understand around the forum is it's not a standards organization.

That seems counterintuitive because that there are many standards organizations already in the industry doing excellent work. Now, Khronos is mine, I'm involved with this Worldwide Web Consortium. There's the OpenGL Spatial Consortium. There are dozens and hundreds more doing or standards organizations today creating standards that are going to be relevant to different parts of the metaverse. The problem that we had was there typically wasn't a

lot of communication between them. There were some liaisons, but in general, all these organizations that are finding all this increased level of interest had nowhere to go to coordinate and communicate, and to ask the industry what the industry wanted from metaverse standards. That is just a very simple idea behind the forum. It's not another standards organization, it's a place for all of the other, existing standards organizations to come together to coordinate and to communicate with the wider industry.

Rashmi Mohan: That's great. I do have a more sort of applied question, if you will, Neil, which is really the way we are describing the metaverse. Are there things like bandwidth considerations, network availability, prohibitive costs? Are those being considered also trying to see if Metaverse is not something that is only being built for the elite?

Neil Trevett: Oh, I think, yes. That's a great question. I think Darwinian business mechanics are going to take care of that. The most successful, at least the most pervasively accessible metaverse experiences, whatever they end up being, whether it's a game or whether it's a digital twin controlling a factory or augmented reality glasses navigating you through a strange city, it's going to be more accessible, the cheaper it is and the better designed it is to survive on not needing gigabit ethernet.

The people that innovate and make their products and their technologies accessible and widely available probably are going to be the ones that stand a chance of getting most adoption, and that could lead, in the right hands to successful business, and that's where your Darwinian mechanics will kick in. I mean, you may get high-end products at the bleeding edge of innovation. That's a typical pattern, of course in the technology industry. But I think everyone's vision of the metaverse, if you do this right now, it will be as pervasive as the mobile web. Now, that's really what we want. And many, many people, of course, around the world have access to mobile web technology. We want the metaverse to be as pervasive as that.

Rashmi Mohan: Yeah, I'm very excited at the prospect of that. For our final bite, Neil, what are you most excited about in the field of technology or in what the metaverse is to bring over the next five years?

Neil Trevett: It's been an interesting journey being part of this whole metaverse cycle. I've learned not to believe the hype of the metaverse because you see market forecasts. I saw one the other day that said the metaverse is going to be, I think it was $13 trillion market in by the end of the decade. I'm going, "How can you make that kind of prediction when we don't know what the metaverse is?" So, some people are being carried away. Don't get carried away on the hype. Don't get caught up in the dystopian despair too. People say, 'Oh, it's going to be terrible because we're all going to put on our VR masks and we're never going to take them off again. We'll lose all social contact and it's going to be very

dystopian." I don't think. I have faith in human nature. I don't think people want to be disconnected from reality like that.

As I like to say, you can't buy a cup of coffee in the metaverse. Nothing is real. So I don't think we'll go to the dystopian extreme either. It goes back to what I was saying before. The metaverse though, it's an exciting place to be because it is going to create this constant stream of remarkable commercial opportunities, the combinations of the technologies that we were talking about. It's going to be an amazing endeavor for the industry over the next years and decades, just like the web has taken 30, 40 years. The metaverse will too, I think. But if you force me to say, in all the technologies that's coming together and which one is potentially the most disruptive, I think machine learning and AI. If it stays on anything like its current trajectory of innovation, things are moving very quickly and a lot of things are going to change. So, hopefully the metaverse will be a good place where we can apply that kind of technology for the good of everyone.

Rashmi Mohan: Wonderful. I have learned so much through this conversation, Neil, it's been absolutely amazing. Thank you so much for taking the time to speak with us at ACM ByteCast.

Neil Trevett: Of course. Rashmi, thank you. Thank you for the wonderful questions. It's been a pleasure to talk to you.

Rashmi Mohan: Likewise. ACM ByteCast is a production of the Association for Computing Machinery's Practitioners Board. To learn more about ACM and its activities, visit acm.org. For more information about this and other episodes, please visit our website at learning.acm.org/ByteCast. That's learning.acm.org/ByteCast.