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Allison Okamura

An interview conducted by
Peter Asaro

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Q: Tell us where you were born and where you grew up and went to school.

Allison Okamura: Sure. I'm Allison Okamura. I grew up in Riverside, California, in the U.S.A. Well, I guess I was born in Fontana, California, but grew up in Riverside. I – so college and grad school: So I went to college at UC Berkeley where I was a mechanical-engineering major and did my master's and Ph.D. at Stanford University where I was also a mechanical-engineering major.

Q: Were you doing robotics as an undergrad or –

Allison Okamura: As an undergraduate, I did not do any robotics. I did some research. I was working for a professor but it was more about education and how students learn to use computer-design programs.

Q: What was your first robotics project?

Allison Okamura: I would probably say my first robotics project was in graduate school when I worked in the lab of the person that became my Ph.D. adviser.

Q: Who was that?

Allison Okamura: That was Mark Cutkosky at Stanford.

Q: What was the project that you worked on?

Allison Okamura: So my very first project was to get a couple of robot fingers to manipulate an object. I don't know if it was really a new research; people had done it before but we were trying to analyze if you move an object from here to here with some robot fingers. And what makes it complicated is we move it and we change the contact point so the fingers have some curvature and so you have this rolling motion of the finger over the object and so calculating the kinematics of all those rolling kinematic constraints.

Q: Does that give you a lot more dexterity then?

Allison Okamura: Yeah. So the idea is that rather than have robot hands that just grab things and then move them around as rigid bodies you do this sort of local dexterous manipulation, and

so we define dexterous manipulation as one where the contact point changes over the surface of the fingers.

Q: Do you need a lot of sensory feedback to do that?

Allison Okamura: Yes, we think so. So at the time we were just pre-computing what finger movements you would need to move an object but we also looked at various ways to sense that information. We were trying to get away from the idea that you would have this distributed array of sensors that would let you know the contact point of your location, but prior graduate students in Mark Cutkosky's lab had looked at things like knowing when the – when they slip instead of roll by having little accelerometers that would sense the vibrations that would occur during slip so trying to use I guess simpler, more disperse sensors rather than some really complicated sensor net on the hand.

Q: At that point did you realize you wanted to keep going in robotics?

Allison Okamura: Yeah. Basically, I – partly the reason I went to graduate school I didn't know quite what I wanted to do and I enjoyed the robotics work that I was doing in Cutkosky's lab and stuck with it, but until then I had not really a particular concept that robotics was what I wanted to do.

Q: Was that your thesis project?

Allison Okamura: Yeah. So eventually my thesis project turned into how you get robot fingers to dexterously manipulate objects and sort of build maps and understand what the surfaces are.

Q: Who else did you work with besides your adviser –

Allison Okamura: As a graduate student? It's hard to say. My Ph.D. project wasn't particularly collaborative. That was actually in my thesis; it was pretty much an independent project. I was in a fellowship so it wasn't like there was a big grant that was funding it where I worked with other people, but then there were several other things I did during my Ph.D. that were much more collaborative. Would you like to hear about those? <laughs>

Q: Yes.

Allison Okamura: So a couple of years into graduate school I did a course project using one of the first haptic devices… so this is called the Phantom haptic device. It was from a company that used to exist called Sensable, which had come out of Ken Salisbury's group at MIT, and it was a desktop robot-like device that you would use to interact with virtual environments. You'd move it around and you could get force feedback. And so I had done a class project probably within a year or two of when the – that haptic device came out as a product and loved that. It had – it still had to do with the sense of touch but a very different kind of sense of touch, and that's actually the thing I really fell in love with even though it wasn't what my thesis was about. So because of that demonstration though a local company in Silicon Valley called Immersion hired me part time and over the next couple of years I worked part time at Immersion helping them design and analyze haptic devices which they were designing as products or for surgical stimulators and things like that. So I had this side project, yeah, working for Immersion and then even after I stopped working there I was doing some side research <laughs> with Robert Howe at Harvard who was also a former Cutkosky student who had become a faculty member at Harvard and his I believe postdoc at the time named Jack Dennerlein so I had collaborations with them to actually look at how we use – how we could add vibration feedback onto typical force feedback. So normally with force feedback you – to make a stiff wall you just apply a force back to the user but it doesn't give you that crisp interaction that you get when you tap on something, and so we were looking at how you display vibrations to the user to trick them essentially into thinking they were feeling stiffer virtual walls than what they were actually feeling. So my first journal paper was in that area, not on my thesis topic. <laughs>

Q: Were there any other faculty that you were influenced by?

Allison Okamura: So I guess collaboratively on research I don't recall but I had great mentorship from Oussama Khatib and Ken Salisbury at Stanford.

Q: Do you still work in the haptics as well?

Allison Okamura: I do… so now I do basically nothing with robot fingers manipulating things and tons of interacting with virtual environments or giving users haptic or touch feedback.

Q: Did you do some other grasping projects after your thesis or –

Allison Okamura: No. I didn't really work on anything else with grasping. We – I guess there are some things that are related like sort of in the medical robotics scenario, palpating surfaces and trying to develop models of them, but it really wasn't the sort of dexterous manipulation like having an object within a hand that my thesis was about.

Q: Where did you go after your Ph.D.?

Allison Okamura: So after my Ph.D. I went straight into a faculty job and I was in the mechanical-engineering department at Johns Hopkins University and that was in 2000, and I was an assistant professor there and then associate professor and then full professor.

Q: What were some of the projects you worked on while you were there?

Allison Okamura: So I got hired in there and part – the reason I went there was because they had a National Science Foundation-sponsored engineering research center about computer-integrated surgical systems and technology and that was a big center headed by Russ Taylor who is really one of the fathers of the field in medical robotics. He had moved from IBM to Hopkins a few years earlier and he and some other faculty had started this incredible center, and I knew nothing about medical robotics and it was a pretty new field at the time but was interested in doing a type of robotics I thought would help people. So through the center we worked on things like – at that time the Da Vinci Surgical System was very new as a clinical product and the Johns Hopkins Hospital had a Da Vinci surgical robot and the clinicians knew that I knew something about haptics and so they came to me and said, "Can you work on haptics for the Da Vinci robot?" and that defined a large swath of my research for the next decade to now. And so we worked on if you're tele-operating – the Da Vinci Surgical System is a tele-operated robot so you move a master controller and then the slave or patient-side robot follows your movements. And we looked at what are the different ways in which you could provide touch feedback to a human operator and in some cases we were constrained by using a clinical robot; we can't go in and change the control system. So we looked at what sort of things you could add on top like maybe create a visual display like bar graphs that would tell you how much force you were applying. And in other cases we used not a really fancy surgical robot but – back to the Phantom haptic device – a pair of Phantoms, one the master, one the slave, to tele-operation within our lab, and in that case we could actually change the fundamental control law. And so we looked at how do you provide haptic feedback in a way that's stable and in addition not just haptic feedback that tells you about the environment forces but haptic feedback for guidance so could forces help the user to make movements that will help them complete a task. So a lot of that was done in collaboration with Greg Hager who was a professor in computer science at Hopkins and a huge mentor for me. He had I think relatively recently been hired away from Yale to work at Johns Hopkins and he was a computer vision researcher and so we did some work together in this case primarily not with a tele-operated robot but a cooperatively manipulated robot where the human and robot share the tool and that – Well, there's a whole family of robots they call the steady-hand robots primarily I believe designed by a guy – a robotics guy who's appointed in urology, Dan Stoianovici, and Dan Stoianovich (sic) had designed these robots and what Greg Hager was doing was using computer vision to look at what was the environment like and what were paths that someone should follow and then I was using the robot to provide haptic feedback to get people to follow those paths, and we called that work virtual fixtures. So just like a ruler is a

physical fixture that helps you draw a straight line, move a certain way, the robot motors can generate forces to help a user follow a virtual fixture.

Q: What are some of the innovations and breakthroughs you've had in terms of really successful modes of haptic feedback?

Allison Okamura: Yeah. So on the virtual-fixture side, which is of using haptics for guidance, I think that concept had been developed earlier, actually, in the thesis of the guy that started the company Immersion named Louis Rosenberg, a former Stanford grad student, and as he had developed the concept of virtual fixtures but that hadn't really been analyzed from a control theoretic standpoint. And so I think one of the more important things that we did was understand the control systems for virtual fixtures; when were they stable, how would the movement of a user converge as well as user studies to say you could make the virtual fixtures very hard or very soft and the idea is that well, you wouldn't want to make them super hard because that would mean that the robot knew exactly what it should do and should be autonomous, <laughs> but then if they were too soft they wouldn't help the user so methods for picking your – how strong the virtual fixture should be to help people do a task. So from the control theoretic aspects to show stability of performance and then were there human factors, ideas about how they should be tuned. Yeah. <laughs>

Q: Did you ever work more directly within a Da Vinci company or did you just –

Allison Okamura: I did. So we did eventually actually get – so I worked with them closely in a few different ways so at Hopkins they… I guess essentially donated portions of a Da Vinci surgical robot and then we were able to kind of wrap our own controllers around it so we were no longer constrained to use a clinical robot. And so they collaborated with me both into getting that set up as well as helping us understand some aspects of the robot so that we could do the analysis that we needed to do, and a lot of that was through Chris Hasser and Intuitive Surgical initially and later through Simon DiMaio who is currently I believe their director of applied research and then most recently – very recently Tony Jark who I think is – I'm not quite sure what his position is. <laughs>

Q: Some of your other designs or principles have been reintegrated into those designs?

Allison Okamura: So I don't believe anything has gone directly into the product but some of our IP has been of interest or licensed by the company.

Q: Do you have some –

Allison Okamura: Yeah. So some examples – so this is still on the haptic feedback side – so in addition to just giving force feedback in real time whether it's through the hand or graphically we've – we're building these graphical maps of tissue stiffness so you could palpate and explore and it would estimate the mechanical properties of the tissue and then kind of draw you a map of how stiff the tissue was where so you could help find a hard lump in soft tissue that could indicate cancer so that's on patent. Again so this just gives us another major thing that I worked on at Johns Hopkins – or I guess I should mention the – so the haptic – the visual fixtures and haptic feedback side I'd say the major players there were my grad student, Jake Abbott who's now a professor at University of Utah, and Panadda Marayong, a professor at Cal State Long Beach. A very large portion of my work started a few years after I got to Hopkins with steerable needles and this also came out of the Engineering Research Center for Computer Integrated Surgery 'cause we were interested in very minimally invasive procedures and needles are very minimally invasive. And so my graduate student, Bob Webster at the time, who's now a professor at Vanderbilt, and I as well as other faculty including Greg Chirikjian and Noah Cowan we worked together to develop – as well as Ken Goldberg who is a professor at Berkeley – methods for creating these very thin flexible needles and getting them to steer through tissue to targets. And that was a very big collaborative project that had multiple rounds of National Institutes of Health funding and still continues in my lab to date.

Q: This gets into the snake robots a little bit.

Allison Okamura: Right, the snake-like robot. Yeah.

Q: But it's on a very small scale.

Allison Okamura: Right, and it doesn't locomote at all like a snake so it's not usually classified with those. I guess it's classified though as a continuum robot in that it has the sort of continuous kinematics in the way that a snake does but instead of being something that – kind of local that's by itself it's pushed into the body from the outside so there's always an actuator that's outside the body that inserts and spins the needle and through the flexibility of the needle and interaction with the tissue you can get it to steer around obstacles and get to targets. That was a cool project because it has this medical application that was very, very relevant but it could use all these principles for mobile robots and planners that people use to get mobile robots to drive around the ground you could use to now get a needle through the body.

Q: But it's still a more collaborative control than operating it or –

Allison Okamura: Oh, actually – so we initially did that autonomously. Well, for practical clinical implementation I think that that was not the initial way to go for the cool robotics

approach was to make it autonomous so with Noah Cowan's group and with a student, Vinutha Kallem, designing controllers and another student, John Swensen, and Greg Chirikjian and his student, Wooram Park, analyzing the kinematics and then Ken Goldberg and his student at the time, Ron Alterovitz, doing the path planning and then my group doing the mechanics and the sort of low-level robot design, yeah, it was a very big collaborative project to be able to get this thing to go autonomously. Now I had a very recent Ph.D. student who just graduated named Ann Majewicz who's now at UT Dallas as a faculty member. She actually posed all of this autonomous stuff that I should kind of look at, how does a human operator control such a robot, and you might think tele-operation would be easier but it's kind of like parallel parking a car or parallel parking a tractor trailer in 3-D. <laughs> And so you have to have we think haptic assistance to sort of help people and guide people the right way to tele-operate the robots. That's very hard to do, just a human doing it with our own hand.

Q: What are the big challenges of getting a mechanism like that to –

Allison Okamura: Yeah. So I think the challenge fundamentally was actually the insight, is to get beyond having a bunch of little linkages with motors on them that had to all go inside the body 'cause that just wasn't practical, was to understand and analyze the kinematics of such a robot. So basically we just had one motor to insert and one motor to spin outside the body and a very, very flexible needle with an asymmetric tip. So I think the big thing was the insight that you could actually steer needles that way but then understanding the kinematics and predicting how the needle would interact with tissues so you could get it to a target, integrating medical imaging. So my student, Troy Adebar, is working on now how you actually get an ultrasound image and find the needle in it and wrap a controller around the medical image, which doesn't come at the same rate as we're typically used to using with cameras and such so – yeah.

Q: Has this technology been used clinically?

Allison Okamura: Yeah. So it has not been used in humans yet as a robot <laughs> but we've done animal studies with it.

Q: Have you worked with startups or do you plan to do a startup?

Allison Okamura: So I have no current plans to do a startup. We haven't spun off anything out of our lab. There's definitely been interest at times but we – I guess especially when – with sort of more clinical – with medical robotics and medical applications the path to get something applied clinically is huge and so we prefer to do the initial research, start off in new areas, patent it and get other folks who are more clinical engineers to bring it into the medical domain but that said – none of this has gotten to use in patients yet – human patients.

Q: Have you worked with any other companies or medical –

Allison Okamura: We've worked a little bit with a company called Burdette Medical Systems which makes interventional devices like needles although mostly my former grad student, Bob Webster – Robert Webster at Vanderbilt, has worked more closely with them to – and they are probably the closest to commercializing the steerable needle and related stuff. So other multiple companies have licensed the patents to it but as far as we're aware yeah, no one's used it in humans yet. <laughs>

Q: Where did you get the funding –

Allison Okamura: National Science Foundation and National Institutes of Health have been our primary funding, a little bit here and there from DOD primarily through SBIRs and STTRs and more recently some from DARPA, very little direct from companies although I've had a small – tiny grant from Intuitive Surgical. I've actually sent more money to Intuitive Surgical by having them as a subcontractor on my brand <laughs> than the other way around.

Q: <inaudible>

Allison Okamura: Yeah.

Q: How did you wind up back at Stanford?

Allison Okamura: Oh. Yeah. So I was at Hopkins for 11 years and well, I guess the – fundamentally the reason is my husband was also a professor at Johns Hopkins and he didn't get tenure and since I was from California, his family was originally in California, we – yeah – had the chance to move cross country. Being with family was a huge benefit so despite the fact that I had these amazing colleagues and collaborators at Hopkins yeah, we moved to Stanford in 2011 and the stars aligned and there was… the need for someone in my area there.

Q: You're continuing that same work for now?

Allison Okamura: Yeah. I'm definitely in the same line of work. There's one other thing I started at Johns Hopkins that became pretty important to me that I realize I haven't mentioned because it was kind of on a separate track and that is doing things – well, I usually think of it as rehabilitation robotics but it was really more using robotics for neuroscience research. So I collaborated with a neuroscientist named Amy Bastian who studies patients typically that have

damage to the cerebellum as well as other patient populations, and we were able to use an exoskeleton robot to help understand what is the role of certain parts of the brain in helping people control their movement. And so to do that we would examine patients that had damage to the cerebellum, look at how their movements differed from healthy people and try to decode what exactly is it with those movements and what would that say about the brain's processing of – its ability to control movement, and that's something that really took me much more into neuroscience research. And so as an example just transitioning to what we're doing at Stanford is now trying to do more work that is sort of in the neuroscience domain so applying rehabilitation robotics ideas to stroke, to some work we did in prosthetics that we started at Hopkins and want to understand how can haptic feedback be used effectively by people who are using brain machine interfaces, but we're also continuing needle steering, developing novel haptic devices for tele-operation, coming up with new medical robotic devices.

Q: Neuroscience also informs the tactile feedback to the haptics?

Allison Okamura: Yeah. So part of the neuroscience is understanding the… we're interested in… now is understanding how certain aspects of a sense of touch actually contribute to sensing and motor control. So one example is if you hold your pen and you push on a hard object you feel not only force in your arm but there's local skin stretch and so working with Will Provancher, who's a professor at University of Utah who did a sabbatical in my lab, who's also a former Cutkosky grad student, we developed these little skin-stretch tactors which could be used to substitute for force feedback or even you could take force feedback through a Phantom-like haptic device, add on a skin stretch and you would make people think that they were actually feeling more force than they were actually feeling. So kind of using these sort of haptic illusions and tricks are interesting 'cause they can also make a more useful tele-operator haptic feedback system but also it's very interesting for understanding how we process touch. So touch – feeling forces is not just about the kinesthetics in the arm but also about what you feel locally through your skin.

Q: You must have done some sabbaticals along the way as well. Have you –

Allison Okamura: Yeah. So unfortunately not too much. Yeah. I was waiting to take sabbatical until my husband got tenure and we were going to go off together, but unfortunately that didn't happen. So I wound up staying in Baltimore at Johns Hopkins for my sabbatical and I actually did my sabbatical in Amy Bastian's neuroscience lab and so that sabbatical she really gave me the opportunity to move more into this neuroscience rehab robotics realm, which is still just a third or half of what we do, but it really opened up that field to me. And I've only been at Stanford for three years now as a faculty member so I haven't taken a sabbatical there yet.

Q: Is it different being a faculty member than a student at Stanford?

Allison Okamura: <laughs> It is. I mean you get a very different perspective <laughs> seeing it from being a faculty member. That said, it's actually surprising how much has not changed. There's some great sort of mechatronics, robotics education programs that they'd put into place many years ago that are still active and done pretty much in the same way and the students still love it.

Q: Who are you collaborating with there?

Allison Okamura: So – let's see – so maybe first I'll mention at Stanford my biggest collaborative project is one of these National Robotics Initiative large projects and there's actually no one else at Stanford on that project because it's all over. It's Pieter Abbeel and Ken Goldberg at Berkeley, Greg Hager at Hopkins, Blake Hannaford at University of Washington, and Jacob Rosen at UC Santa Cruz although I think he's just about to move or has moved to UCLA. So there's this – yeah – very big group of people that we have on this National Robotics Initiative project. Grant wise – most of my collaborations that are sort of officially funded are with folks on the medical side so MDs who are clinicians that work with us on our projects but that's sort of off the books, just <laughs> collaborating. We've done some work with my former adviser, Mark Cutkosky, and Oussama Khatib also in computer science.

Q: You mentioned some of your graduate students. Are there others who are working in robotics somehow?

Allison Okamura: Yeah, absolutely. So in addition – so I mentioned Bob Webster at Hopkins, another Hopkins student I had that was working on needle steering, Sarthak Misra who is a professor at University of Twente, and he did a lot of really big – like how do you model the needle-tissue interaction and he's still extremely active in the field. I mentioned Jake Abbott at University of Utah. A student that was working in the neuroscience area at Johns Hopkins is David Grow and he is at New Mexico Tech. Several of my former students in the postdoc side: So Katherine Kuchenbecker was a postdoc working on things related to touch feedback and prosthetics; she's a professor at U Penn. Another former postdoc who worked on needle steering is Kyle Reed who is at University of South Florida and a couple of my other students and postdocs are actually at various medical robotics companies including Intuitive Surgical, which makes the Da Vinci surgical robot. And I've only been at Stanford for three years and so there the only Ph.D. students I've – student I've graduated is Ann Majewicz and she's at UT Dallas. So I had several other students who graduated of course but they're either in postdocs or at companies.

Q: When did you become involved with the IEEE and some of the more organization of the field and –

Allison Okamura: Oh. So I know my first – very first time I got involved with a conference I guess was not an IEEE conference but I first went to an IEEE conference in I think '97; this was at my first conference paper. <laughs> And then in terms of getting involved in organization, the – there was an IEEE ICRA, I-C-R-A, conference in and around Washington, D.C., when I was an assistant professor and I think this was about 2002 or so. And so I wound up helping out with local arrangements and things and then became more involved I guess. There's sort of a subset of the robotics community which also brings in psychologists and people from other fields, which is the haptics research community, and I became very involved in sort of program committees and leadership in that. And that did used to be ASME, the American Society of Mechanical Engineers, it switched over to IEEE, and I was a co-chair of that conference for a couple of years, on the program committee for many years, and at this time I'm very involved in IEEE. I'm the editor in chief of ICRA starting in 2015 so it actually starts now because it's when the papers are being submitted and that's a three-year conference commitment. And so I've been associate editor of the IEEE Transactions on Haptics so I've been on numerous other little committees.

Q: You've maintained your identity with mechanical engineering as you've come to robotics.

Allison Okamura: That's right, yeah. I've always been in the mechanical engineering department and, yes, trained as an ME.

Q: Are you still involved in those other organizations –

Allison Okamura: Not much. So the American Society of Mechanical Engineers didn't have a ton going on in robotics and especially when they lost the haptics conference but they've been rebuilding and so I've been to – we've sent papers to a couple of conferences, but in terms of leadership I haven't really participated because most of – the most active robotics community is in IEEE so this is where it's at.

Q: What are your thoughts on women in engineering and women in robotics?

Allison Okamura: Oh. So I mean I think it's an awesome field for women because there's so many different ways to contribute and so many different opportunities. It's – there are not a whole lot of women in robotics. One of the things I love about the haptics research community is it's incredibly diverse and in part because it draws on people from other fields like neuroscience and psychology. And some of the things I love about going to IEEE haptics conferences is because of how diverse the population is. I heard a statistic today that only – in the IEEE Robotics Automation Society only six percent of the membership is women, which is – that's even lower than the percentage of women faculty in my department. So I think one of my

feelings is disappointment that there aren't more but I've seen so much improvement especially over the last decade and kind of gained a critical mass of support and dialog and discussion. Program committees now think oh, why didn't we – or why don't we have a woman on this committee. It's in people's sphere of attention and that's a good thing.

Q: And were there women roboticists or engineers who mentored you along your career path?

Allison Okamura: I have not had a direct woman mentor in robotics. I do remember Ruzena Bajcsy was – Greg Hager who was my best mentor as an assistant professor she was his Ph.D. adviser and so she was this icon, <laughs> such an amazing person, and so I knew about senior women in robotics. Interestingly, in the haptics community there are some amazing women who are somewhat more senior than me, some of them engineers, some of them not, but I've also always looked to them but my close mentoring relationships just people that were at my university and connected with on a regular basis so – yeah – have not been women, not that many of them.

Q: There are women in leadership in the Robotics Automation Society.

Allison Okamura: Yeah, there really are now and so I think that's huge and that's a big change so next year we're doing ICRA and I think it kind of worked out for me 'cause I happen to be editor in chief for the next three years but the general chair, the program chair and the entire rest of the organizing committee are women. So I guess in a sense I can say that people like Lynne Parker and Nancy Amato have mentored me sort of in leadership roles within IEEE and given me opportunities and so that's definitely something I appreciate. I think it's sort of different from research mentorship but just as important.

Q: Going forward, what do you see the biggest theoretical and technical challenges for haptics and –

Allison Okamura: Yeah. So one of the issues is we don't understand enough about the human sense of touch and you might think well, that's a responsibility of the neuroscientists and psychologists, but the fact is that we – as haptics engineers we can design devices that actually help us pinpoint. We can design experiments that help us understand the human sense of touch better. So we would love to design all kinds of haptic illusions that trick people into feeling things that aren't there but to do that we need to understand people better so that – that's one issue. I think the other issue is just fundamentally device design and actuators and sensors and how do we make them smaller, cheaper, better, <laughs> all of the typical stuff, but all that kind of has to be wrapped up you're your creativity and insight and it's hard to say that being more

creative is a challenge but it is. We need to think of new ways to be – stimulate people and make them feel what isn't there.

Q: Do you see the medical domain as really the kind of application domain that's driving haptics at this time?

Allison Okamura: I think it is. There's definitely entertainment and mobile devices as well but I guess on the entertainment it – it's hard to say that that—it isn't – it hasn't actually been a huge commercial success even though people have tried. Mobile devices: I really think that's poised to be a huge area for haptics. There's just the technological challenge of getting some really interesting haptic feedback into just something low powered and small but I think the majority of haptics researchers are inspired by various medical applications ranging from rehab robots to minimally invasive surgical robots.

Q: Where is the exciting neuroscience in all of this for you?

Allison Okamura: Oh. So the – I guess on one flip side is again how do robotic devices – how can they be used as tools to help hopefully in a kind of behavioral way rather than sticking stuff in the body sort of way, figure out more about the basics of human motor control, the potential of that to help people recover from stroke or other kind of neurological diseases. The other is this whole prosthetics domain is really fascinating and not just from the perspective of the robotics and the mechanism but how that all works together with the kind of data that we can get from the brain and how we would control the system. And I guess I could also just mention in medical robotics itself it's much broader than that so I'm thinking most about minimally invasive surgical robots and robots used for interventional radiology. I think the big challenge there is how do you get devices that are very small into the body in the most minimally invasive way and be able to control them; how do they work with medical imagers; how do you make them biocompatible and sterilizable and have all the degrees of freedom that you need to have to accomplish useful tasks in the body.

Q: Also the kind of sensors that –

Allison Okamura: Yeah, the biosensors and more typical sensors that tell you about mechanical interaction. Those are all really difficult things to put in the human body.

Q: Do you have advice for young people who are interested in a career in robotics?

Allison Okamura: Ah. Well, I guess my main advice is – yeah – is do it. It – it's a huge field. There's such a huge range of what you can do. You don't have to necessarily be a math whiz – There – you can contribute – there are so many different avenues in which you can contribute. You can contribute because you're a designer. You can contribute because you're a great computer scientist and coder. You can contribute because you understand people and are interested in human-robot interaction, and as robots become more and more ubiquitous the physical and the social interaction between humans and robots is going to become super important. And so I think my overall advice is because it's such a big field find a thing that you're passionate about and not just the technology and the gadgets or the low-level programming but what will it be used for because I think more and more robotics has promised a lot to the world or maybe movies with fake robots in them have promised a lot to the world but we really have to start delivering so we need to think about what robots can really practically do for people.

Q: Is there anything that we missed or anything else you want to talk about?

Allison Okamura: Oh, I'm sure there's a ton of things that we missed <laughs> but yeah, I'm all – I think I'm all talked out.

Q: Thank you very much.

Allison Okamura: Yeah. You're welcome.