VIEW to the U transcribed
Season 3: Global Perspectives; Episode #7
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Jessica Burgner-Kahrs (JBK): That's actually an issue being a continuum robotics researcher. I'm a computer scientist by training, but then I have been in mechanical engineering for the past couple of years. I never thought that I would build a robot myself, but you cannot buy continuum robots. It's a research area, so we have to build our own ones.

I'm Jessica Burgner-Kahrs. I'm with the Department of Mathematical and Computational Sciences here at the University of Toronto Mississauga, and I'm cross appointed to Computer Science and Mechanical and Industrial Engineering at UofT.

JBK: The students have most of the cool ideas. I can help them navigate through this huge area of research and be like, "Oh, you know what? It hasn't been solved so far. Nobody has ever built a very small diameter, a very long continuum robot. How could we do this?"

I love discussing with them ideas. I just love when I see their eyes glowing about an idea and they are like, "Oh." Then, they come back, "You know what? I thought about this and I think we can do it that way." Obviously, yes, then we just go with it. It's just a collective thing, like research is not this one person in a room enclosed. It's by talking to others, collaborating with others, getting ideas everywhere. Next week we're going to the aquarium to just look at some tentacles and fish to just see how does nature do it. Just getting inspired, and that whole process is just very rewarding to me.

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Carla DeMarco (CD): Plugged into robotics research.

This is one of U of T Mississauga's bright sparks in an exciting new branch of robotics that has come to campus. Over the course of this interview, Jessica talks about being at the forefront of continuum robotics, what inspires and influences her work in the lab, her global collaborations and how she got into this field. Hello and welcome to VIEW to the U, An eye on UTM research. I'm

Carla DeMarco at U of T Mississauga. VIEW to the U is a monthly podcast that will feature UTM faculty members from a range of disciplines, who will illuminate some of the inner workings of the science labs and enlighten the social sciences and humanities' hubs at UTM.

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CD: Jessica Burgner-Kahrs is an assistant professor in the Department of Mathematical and Computational Sciences at U of T Mississauga, and in Mechanical and Industrial Engineering at U of T. And she is the director of the Continuum Robotics Laboratory at UTM, a newly established lab. The robotics research cluster at UTM is complemented by assistant professors Animesh Garg and Florian Shkurti. Jessica's research focuses on continuum robotics and in particular on their design, modeling, planning and control, as well as human robot interaction. Her fundamental robotics research is driven by applications in minimally invasive surgery and maintenance, repair, and operations.

She is a highly regarded global researcher having been recognized in 2015 with several awards including the Heinz Maier-Leibnitz prize, the Lower Saxony Science Award in the category of young researcher and Young Researcher of the Year in Germany. The Berlin-Brandenburg Academy of Sciences awarded her the engineering science prize in 2016, and in 2019 Jessica was nominated as young global leader from the World Economic Forum. She received her diploma in 2006 and her PhD in computer science in 2010 from Karlsruhe Institute of Technology in Germany. From 2013 to 2019 she was with Leibniz University Hannover in Germany, and from 2010 to 2012, with Vanderbilt University in Nashville, USA. She started at UTM in spring 2019 after moving here from Germany.

CD: So, I was wondering if you can tell me a little bit more about this work that you do and provide some examples of current projects that you're working on, but keeping it in mind, I know you're very good at explaining your work, but not everyone listening has a robotics background, so in lay person's terms.

JBK: I work on continuum robotics. For you to get an idea of what continuum robots are, you might think about what you commonly refer to as a robot. Most people first think of robot that looks like a human, I would term this a humanoid robot, or robot on wheels, like a mobile robot. Human like robots are mostly also just resembling the human arm. Those are commonly used in industry, for example, for assembly tasks. Then, mobile robots, you might even have one at home, a vacuum cleaning robot. Those are mobile robots. So, in my research I take a completely different approach. So, I'm inspired by, for example, worms, elephant trunks, tentacles, snakes, tongues, because I'm building robots that have no rigid links or joints.

JBK: And that's why they're called continuum robots, because they can continuously bend, twist, elongate, contract and they resemble sort of a snake like, tentacle like motion behavior. At the same time, the robots that I'm building are much smaller than the robots you're thinking of. My robots are very small in diameter, but long. So, the smallest robots we have in our labs are just a millimeter in diameter. They look like medical needles, but at the same time move around like tentacles. We also have bigger ones that resemble more like a worm, so that's continuum robotics, and there's a lot of challenges associated with continuum robotics because to achieve a continuously bending behavior is actually not a straight forward.

Like in most human like robots, we just resemble what the human has, like a bone, which is a rigid link and a joint, and then we assemble those two have a similar motion. But for continuum robotics, we need to use softer materials, materials that can flex, materials that are elastic, and how to achieve this is actually a very interesting design problem.

CD: Can I just ask, so you said that typically they're one millimeter in diameter.

JBK: That's the smallest we can do.

CD: Okay, but how long can this extend for? Because you said about like making them be able to extend.

JBK: Well, so the robots we have in the lab right now, they can be 20- to 30-centimeters long.

CD: Like a ruler that you use in the school?

JBK: Yeah, like a ruler, yes. So, yeah, we would like to build also longer continuum robots, but that's also mechanically very hard because they have to withstand their own weight. And so, that's one of the actual projects that we are working on, building a very long but then continuum robot. That's still not really solved. And apart from that, not only design is challenging, because I'm a computer scientist, I'm not actually an engineer. Even though I've been working in engineering for the past years, much fundamental research is needed in order to understand how these robots move. How can we achieve a motion that is snake-like, or tentacle like, given that the actuators for our continuum robot are limited?

JBK: We cannot use infinite many motors to actuate the robot to pull on tendons, for example. So, we are limited in terms of the actuators. So, we have to think about how can we pull on tendons and how can we arrange tendons such that

JBK: the robot bends like a tentacle? And that is then touching on modeling, like we do a lot of mathematical, mechanical modeling work, mathematical equations to describe, "If I pull here, what happens to the tip of the robot? Is it moving to the right or to the left? If I want to elongate, what do I have to do mechanically in order to achieve this?" And that's a lot of tedious math work that we're doing, and then building on that is like planning motion.

So, now that we can describe what happens when I pull or push on some parts of the robot mechanically, then we can also build algorithms that have the robot elongated while it's moving and also follow a desired curve, a desired path. This work is associated more with the human robot interaction, is now that we can build robots that can snake around, how can a human control these robots intuitively? Because when you think about those commonly known robots like a robot with wheels, you can relate to it when you're driving your car to the left, to the right. It's somewhat intuitive. Same was an arm like robot. You can look at your own arm and when you move your hand, move your elbow, move your shoulder joint, you can relate what the robot would be doing.

With a continuously bending structure, now, imagine like a long snake. It's harder to tell what is it going to do, and like having a good way for a human to effectively control such a robot in teleoperation. Having a device in your hand like a little joystick that you could move around such that the robot does what you want, and so that touches on human robot interaction. There's not much research in this regard as well.

CD: How were the robots powered? So, is it battery operated?

JBK: Yeah, so that's interesting to explain. So, the continuum robot itself is very small. We talk about this one millimeter needle like thing. Think about a 20 centimeter long needle that moves like a tentacle. On the backend is the mechanical actuators. There is motors that are actuating little gears, that are rotating, and then there is like translation and rotation happening on the backend. That is what we call the actuator and actuation pack, and that's attached to the robot, but significantly bigger than the robot itself. So, the robot is tethered, mechanically linked. And then, we are usually just using regular current coming out of the plug. You could use batteries though.

CD: And maybe ideally a solar power?

JBK: Solar power would be amazing, depending on the application. Some of the exciting current projects that we are doing is that we're looking into building parallel continuum robots. Not just having one continuum robot, but having several that collaborate, that attach to a common platform. Because they are so tiny and elastic they cannot hold a lot of weight, which can be a disadvantage. When you got them somewhere, they sneak into a place hard to reach, you also

JBK: want them to do something reasonable. So, if they could collaborate with each other, attached to a common platform, attached to a camera, or a laser, then they could probably do better. And so, we are investigating how to achieve this, how to build those, how to model those.

There's even more issues with that. Another exciting project that is associated with my NSERC Discovery Grant is on using machine learning to better model those robots. And what I'm trying to do is, all our mass models are good, they can reasonably find out what would happen with the robot if we do X and Y, but we always have certain limitations. Sometimes we need to neglect friction in the robot, or all sorts of things, like material properties sometimes are not completely covered in those models because otherwise they would compute for too long. But we need to be able to compute reasonably fast to control the robot efficiently. Usually, we need to solve, the model was like a kilohertz that is a thousand times per second.

We need to be able to solve it. Yeah, that's really challenging. So, that's why the model is as good as possible giving the computation constraints, and I'm hoping that with machine learning techniques we could take a different approach. We could collect data on the robot motion, just have the actuators move the robot around. We take camera images, and then we feed this into a machine learning environment and let the machine learning figure out what a good model is. Let the machine learning predict. This project is just starting and we're trying to reason about can, we actually inform the model better by using machine learning? Can the machine learning find out something that we haven't thought about? And so, that's an exciting project that we're undertaking.

CD: And so, I know that your research has a particular health focused application, and so I'm wondering has health or applications of technology for health always been of interest to you, or was this just a natural path or progression as you started to work in continuum robotics?

JBK: It was actually natural. Like, when I was a teenager I said I want to become a surgeon. All my family, they have always had health related jobs, at least all the females. And so, I was like, "I want to do something with medicine. I want to become a surgeon." But then when I was 17 my, one of my uncles, he died from brain cancer. He would've probably died anyway, I don't know. But one particular problem was that his radiation therapy that he got didn't hit the tumor right. It was just slightly off. And so, when I live through this and losing him, I was like, "Wow, as a surgeon or as a doctor, if you do something wrong, somebody can die." And I was like, "Maybe I shouldn't become a surgeon. Maybe I should use my passion for technology to help surgeons do their job better."

JBK: So, I was always interested in mechanics, always interested in computers, and then, I studied computer science. I was always focusing on medical robotics and computer assisted surgery, because I figured algorithms can help to, for example, deliver radiation therapy better. That was my initial goal, but then I discovered robots during my undergrad and I was like, "Wow, I should do something with robotics. Surgical robotics is so cool. It can help surgeons do their job better." That being said, I have always been an enthusiast for elephants. I love elephants ever since I was a kid. So, watching an elephant trunk and seeing what an elephant can do with its trunk was also fascinating me.

And so, I just, naturally, I guess brought these two together, and now, I'm building robots that resemble what an elephant trunk can do on a much smaller scale to help surgeons do their job better. And when you think about those medical needle size robots, they could actually sneak through your nose and help neurosurgeons do brain surgery. Or they could traverse through natural orifices, like do kidney surgery, or you do just a very small incision in the abdomen to do laparoscopic surgery, but using a robot, or sneak through the bronchi to reach the lung. There's so many things that these robots can do, and whenever I show them to surgeons, they are so fascinated and tell me, "Wow, if I just had a robot like this in the OR I could do this, or I could take this route that I never thought about I could because my instruments are all straight."

So, it's so fascinating to me to not only do the fundamental research that I'm doing, but also look at the application and potential that these robots have in healthcare.

CD: I imagine, I don't know, but when you started out on this path, there mustn't have been very many women in computer science.

JBK: Well, in computer science, I studied at the Karlsruhe Institute of Technology in Germany. We started with 660 students and I think we were at 10 females, and not all of them finished.

CD: I was just, again, listening to this podcast the other day, but they were talking about how computer science historically has been very male dominated field.

JBK: Yeah. I think at that time they said 10% of the student population would be female. I think it didn't get much better. I never noticed. I was just doing what I love doing.

CD: So, we do hear a lot about robotics in daily news and as it relates to science, and so I'm just wondering if you can say what you foresee on the horizon for surgical robotics or what kinds of innovations you would like to see come to fruition.

JBK: Well, as someone that has been in robotics since 13 years, what has been changing is that the big robotics conference, the big international ones, at the very first one that I was attending, we were probably 1600 people. Now, we are 5,000 people, so there is more researchers focusing on robotics and the field has been becoming much more diverse. While it has been industrial robotics for a very long time, it's now becoming more human centered. Initially, robots and industry have been not close to humans, right? They have been enclosed in a cage and doing their job, laser spot welding or car assembly. Whereas now, robots are more with humans, collaborative robots, robots with surgeons doing a surgery where the surgeon is still in full control.

The surgeon would still operate having a console and having input devices at its fingertips that mimic what the robot is doing, and what the surgeon does is directly commanded to the robot. So, actually the robot is just the hand of the surgeon within the patient. In the future I think on probiotics we're going to probably be able, due to all the recent advancements in machine learning, to probably automate this process a little bit more. I'm not saying that we're going to have an autonomously operating robot surgeon. I'm still thinking that a surgeon would be in charge, but that the robot can do some tasks autonomously. For example, tedious tasks like suturing, like tasks that are repetitive, that would help a surgeon, for example.

Those things could be automated in the future and we are probably close to getting there. Other things is whenever a task is very hard and challenging for a surgeon, talking about reducing invasiveness, like thinking about having a continuum robot entering the body on a nonlinear route. Like, through the nose to the brain, removing a tumor in the center of your head, needs a lot of accuracy, a lot of precision, which probably is beyond what a human can do. And so, we need some level of autonomy in order to make this possible while the surgeon is observing what the robot is doing.

JBK: Think about the robot arm as carrying little camera and like a little gripper, or little scissors in order to remove the tumor, the surgeon would still define, "Remove it here, I see the tumor should be removed here." It might be informed by additional sensing means, ultrasound, optical coherence tomography, [inaudible 00:18:01], whatever. But the robot could do some part of the job and the surgeon would do the other part of the job. I see them being like working hand in hand. So, that's definitely something that I foresee for the future that's going to happen in surgical robotics. In general, in robotics, we see more autonomy, but not to an extent where a robot could already behave like a human. This is still a very long way for research, I think, to get there.

Robots can definitely do certain tasks autonomously as long as they're repetitive. That's what they have been doing for the past 40, 50 years. But like that robot that you could just buy to your house that would just come out of the box, start talking to you, take care of your kids, clean-

CD: I just want one to clean.

JBK: Yeah, I want that, too. Who doesn't want that? Just that cleaning, like cooking. I don't think it's going to happen soon. It's still a long way. Well, but surgical robotics has been around for a couple decades for now. A very prominent example is the da Vinci Surgical System from intuitive surgical, it's the lion in the room. It's the biggest surgical robotics company. It's a robot with like three or even four arms that are used for laparoscopic surgery, lateral incisions done in the abdomen. The robot enters through there and then you have little grippers at the tip that can move, and the surgeon sits in a console observing the view of the camera in the human's abdomen, and is operating the two or three arms to do gallbladder resection, all sorts of laparoscopic surgery.

This robot has been around. It is a robot per definition, but the surgeon is in full control. The robot is just replacing the human hands. It's not what is commonly thought of as a robot doing something autonomously. Even if you think of the car welding robots, or assembly robots, they are doing the job repetitively, but a person takes a robot to point A says, "Okay, this is the first point, safe." Then it says, "Open the gripper, safe." Then hold onto an object, moves it to a different point, says, "Safe this point." Then, the robot is just repeating these steps over and over again. As soon as anything changes, the robot has to be taught again.

So, even though it looks it's autonomous but it's only autonomous in the setting, like moving from that to a true autonomy, that's still not achieving-

CD: Well, I'm just thinking what you mentioned earlier about like say in the case of putting in sutures, I could see it's this repetitive action, but if the patient were to move, does the robot intuitively know to change?

JBK: That's a whole different story. Being able to perceive what's happening, particularly within a human body, like you have a camera, you can use the camera in there, but reasoning automatically from these images, what's going to happen? It's a whole other area of research, computer vision, and how to reason from those images. A lot of machine learning can be used in that regard, but reasoning from what do you see to what's happening in your patient case, if you would be lying in the OR, something else might happen as in me. My tissue might look slightly different. The lighting might be slightly different. My gallbladder might be a little bigger than yours.

JBK: There's so much variability that complete automation is just hard from that respect. When you think to industry car assembly, the parts are always the same, whereas a patient is always a one-piece production, so it's much harder.

CD: I was reading a profile about you and it was in the UTM student newspaper, *The Medium*, and it said that you love working with students and building robots in your continuum robotics lab. So, I was wondering when you're working with the students, do you let them drive some of the initiatives for the robot making in the lab? I was very curious about how long does it take to make a robot?

JBK: Well, absolutely. I love working with students. It's just, I guess becoming a more senior faculty member you can do the work, the exciting work, less and less yourself. Like, it's not me physically building these robots anymore, physically doing the research anymore. It's more discussing with students, developing new ideas, brainstorming together, motivating them, sparking new ideas. Absolutely, the students have most of the cool ideas. I can help them navigate through this huge area of research and be like, "Oh, you know what? It hasn't been solved so far. Nobody has ever build a very small diameter, a very long continuum robot. How could we do this?" Just this thought process with them together is so much fun to me because I love discussing with them ideas.

I just love when I see their eyes like glowing about an idea and they are like, "Oh." Then, they come back a couple of weeks later, or a week later, "You know what? I thought about this and I think we can do it that way." Obviously, yes, then we just go with it. I don't know if I would say rarely, but it's rarely my own ideas. It's just a collective thing, like research is not this one person in a room enclosed. It's by talking to others, collaborating with others, getting ideas everywhere. Next week we're going to the aquarium to just look at some tentacles and fish to just see how does nature do it. Just getting inspired, and that whole process is just very rewarding to me.

In terms of how long it takes to build a robot, it's a very iterative process. We have experience in building some kinds of robot that we could probably do faster now, but it starts with a general design idea. Then, we build a first simple prototype to see if a certain principle works. Then, we use 3D printing a lot to build a more sophisticated prototype. Then, we see what doesn't work. We iterate, redesign, build again, reiterate. One of our most successful robots that can extend, and contract, and also bend in various degrees of freedom, it's the third prototype we have now. We've been working on this since 2014, and also, we are still researchers. We don't have an assembly line, no fabrication facility. It's all us trying to do as best as we can. It's not our mandate to build a product, but still like it can take everything from a couple of months to a couple of years.

CD: I really find this interesting just because I'm doing my Masters in Information Studies, but one of my concentrations is User Experience Design. You're exactly explaining the design process because even though I know you're a researcher in robotics, but you're explaining like how people do hash out their ideas. They make the prototype, they have to keep doing the iteration based on what was the flaw in the last version. So, I imagine maybe when you started out on your career path you didn't necessarily factor in this whole design part of it, right?

JBK: That's actually an issue being a continuum robotics researcher. I'm a computer scientist by training, but then I have been mechanical engineering for the past couple of years. I never thought that I would build a robot myself, but you cannot buy continuum robots. It's a research area, so we have to build our own ones. It's just as simple as that. There are none, so we build it.

CD: Then you really have the whole world open to you because since it hasn't been designed yet, you're kind of making it up as you go along.

JBK: Yeah, that's what is so satisfying about it. It's just really being on the forefront of research. We're not doing something that many bazillion people are doing. It's a small research field, continuum robotics, soft robotics. It's a growing field, but it's really cutting edge research, like you can't buy this yet, which makes it so exciting. Also, for students, because they feel like they can really have an impact with what they're doing.

CD: Are all the projects though that your students are working on always a health focused one?

JBK: No. Actually many projects are focusing on fundamental issues. Building a long continuum robot is not necessarily application related. Even though it has an application in not only healthcare but also non-destructive inspection tasks or space. So, there could be certain applications. We have this in mind that it's not just general fundamental research, but some aspects are just not understood, and we just need to work on the basis.

CD: How long have continuum robotics been around?

JBK: That's actually an interesting question. Funny fact is that the very first continuum robot has been built by the same guy that built the first commercial robotic arm at Stanford. So, there has been a type continuum robot. It's not perfectly continuum, if you consider the definition, but it's close enough. So, 1965 at Stanford University, a couple students designed a bending segment using pneumatics, and then there has been snake robotics in the 80's. But the problem was that at that time we didn't really understood how to model those robots effectively, so we could build them but not control them. And so, it was like not as sophisticated type of research, whereas since the end of the 90's, 2000's, that really when the continuum robotics research kicked off more.

JBK: Because we had advancements in modeling, advancement, also because computation became more sophisticated, and ever since then that's a slowly growing field, and I think over the past decade that I have been working on it, it kind of exploded.

CD: Yeah, I just think that's so cool to be at the forefront though. Yeah. How did you get interested in continuum robotics in the first place?

JBK: Well, I have gotten in contact with continuum robotics at a robotics conference in 2009, while I was still doing my PhD. In my PhD, I used a common serial arm type robot that you would use in industry to use a laser to cut human bone on the skull. It's a weird PhD project, but it went well. I built the first robot system that could cut the skull using a laser. That was amazing, but it was a huge robot. The robot was bigger than the patient. Anyway, I was at this robotics conference presenting on that work, and I saw a talk of Robert Webster. He's one of the pioneers in continuum robotics, and I was so touched by seeing this tentacle robot. It was very small diameter, because I was like, "This makes so much more sense in healthcare, to have a small robot that can enter the body."

JBK: Eventually, I became his postdoc. So, I moved to Nashville, moved to Vanderbilt University and I was working with him for two years, and he really sparked my passion for continuum robotics, and I haven't stopped working in continuum robotics ever since then. So, it's now nine years.

CD: Wow, that's amazing.

[interlude music fades in]

CD: Coming up: Global Perspectives.

Jessica talks about her international impact in robotics and the ongoing collaborations she has around the world, as well as what inspires her designs, her broader impact in the lab with students, in her field, and now, at U of T Mississauga in this branch of robotics.

[interlude music fades out]

CD: What do you feel is the biggest impact of your work?

JBK: We are definitely taking the field of continuum robotics to the next level, right? It's a young field. I have made a couple of contributions with all my students, like we have some papers that are very well-cited, have been very well received. I have taught the very first graduate course on continuum robotics when I was still at Leibniz University in Hannover, and I'm going to teach the course here as well. So, I'm working on a textbook on continuum robotics. It's going to be the first one, like this is going to have an impact to the field, I'm sure. Also, I just

JBK: returned from Germany where I graduated three of my former PhD students, and this is a different impact that you have as a researcher.

As I am standing on the shoulders of giants of my PhD advisor, of my postdoc advisor, I am now also leaving a trace through the people that I worked with, that I mentored. Having my own academic children is also a big impact that I'm going to have. Also, every undergrad that sits in my robotics course, their first interaction with robotics is at UTM in the introduction to robotics, and this has an impact.

CD: I'm so glad that you said that because I think sometimes people don't think about that part of the impact of their work. They do think about the contributions to their field, but I think the knowledge mobilization and the mentoring of the students and all of that is huge.

JBK: I think it's even the bigger impact.

CD: Oh, yeah, like how many people you're influencing to either go on to do more academic work in this area, or apply what they learned in your lab. They're very transferable skills.

JBK: Or, just being also a woman in robotics that is showing you can be a successful woman in robotics. Just being a role model also for all girls showing a roboticist doesn't have to be male. That's a different impact that you naturally have just by being a role model.

CD: This new season of the podcast is focused on global perspective, so looking at UTM researchers who have global impact, or do work, or have collaborations around the world in the course of their work. I wondered if you could speak to this impact in your global research with your ongoing collaborations that you have in the U.S. and in Europe.

JBK: Well, so I have a natural global perspective, I suppose. I'm German. I was raised as a European. I graduated in a European project with Italian and French researchers that regularly met. I worked in the U.S. for two years. I was a faculty member in Germany. Now, I moved here to Canada. This year, I have also been elected among the young global leaders in the World Economic Forum, which is global young personalities that have been identified as having an impact on the future of our world. Not sure why they pick me, but they picked me.

CD: It's amazing.

JBK: But we share so many principles like generosity, authenticity, respect, and impact, and that is such an honor to be among so many great minds internationally and meeting with them. Being able to exchange ideas and discuss global challenges that we are all facing, but also robotics is an international endeavor. At the International Robotics Conferences, as I said earlier, we are meeting with several thousand researchers two times a year to discuss how robotics is being moved forward. Now, it's not necessarily all countries being represented, that's something that I think we need to change in the future. Most of the southern hemisphere countries are not as well represented.

JBK: But yeah, I have several collaborators in the U.S. and in Europe, students from all over the world. Research is, I think, so naturally international in robotics per se.

CD: Have you ever had any major setbacks in the area of your research that required a rethink or re-examination of your approach?

JBK: Constantly. I guess that's the nature of research on a regular basis. As I said, for the design, like we reiterate over designs if things don't work. We are a team, so we brainstorm and just try something else, but also on a higher level, like research proposals that don't get funded and you're like, "Damn, this is really great idea. I really want to work on this, but I don't get funding. What am I going to do?" Or, research papers that just don't get accepted because the reviewer is like, "No, I don't get it. I don't like it. I think it's not good." It's always hard getting a setback or being rejected, but you can only grow from it. Get over it, and I guess it gets easier over time for me to get over those things.

But it's always hard to have a grad student whose paper got rejected from a conference, because they were really excited about their work. I was excited about their work, but then it just got rejected because a reviewer didn't really understand, or maybe the writing was just not as great yet, or there was just other work that has been even better. Keeping the students still motivated and trying to explain to them why the rejection is not necessarily a bad thing, but they can grow from it, make this paper better and get it into another conference or to another journal. I'm telling this to myself when my research grant wasn't accepted, that eventually, I would grow from this.

JBK: This is just a constant learning thing. As a researcher, you have to deal with this, but you know what? I always think I wouldn't have ended up here if something went different. So, all these setbacks, all these roads that didn't lead to somewhere were important to get me where I am today. I'm just trusting that whatever happens happens for a reason that I might not know yet. I might not see yet.

CD: And it, yeah, shapes you as a person.

JBK: Yeah, and I'm just a very positive person. There's always something else you can do.

CD: It sounds like you're such a great teacher and mentor to the students, because I think that, especially, when you're a grad student, you have to know this is kind of part of the package, right? That sometimes your papers aren't going to be accepted.

JBK: Yeah, I try to be a good mentor, giving back what I received as being a mentee, I guess. I'm just very happy to kick off robotics research at UTM with my two new colleagues, and probably additional colleagues. Having all the students in class, I just came from teaching today and having them sit in the class and being so excited about robotics and sharing my excitement for robotics with the UTM community and with U of T at a large makes me very happy, and I'm just very happy to be here.

CD: Thank you so much for coming in today and telling me about your work.

JBK: It was a pleasure.

[Theme music fades in]

CD: I would like to thank everyone for listening to today's episode of *VIEW to the U*.

I would like to thank my guest Jessica Burgner-Kahrs for telling us about her robotics research in UTM's Department of Mathematical and Computational Sciences, and as the director of the Continuum Robotics Laboratory.

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Thank you!

[Theme music fades out]