AN INTERVIEW WITH DR. AMAY BANDODKAR

From left to right, top to bottom: Dr. Jonathan Bennett, BSS Faculty Advisor; Melody Lee, 2022 BSS Essay Contest Winner; Vish Ravichandran, BSS Editor-In-Chief; Lucia Wang, BSS Publication Editor-In-Chief; Dr. Amay Bandodkar, Assistant Professor in the Electrical and Computer Engineering Department at North Carolina State University; and Hrishika Roychoudhury, BSS Editor-In-Chief.

What are you currently working on in your research?

Right now we are focusing on two aspects: wearables and implantables. In the field of wearables, we all know about Apple Watch and all these wearable devices that are out there. Almost all of them monitor parameters, like say heart rate, how many steps you have taken, and approximately calculate how many calories you have burned. But in addition to this, there are a whole host of chemicals that are important to monitor. For example, can these wearable systems monitor the glucose levels, or can they monitor the stress levels that a particular person may be experiencing? To understand human physiology in a more comprehensive way, one would also want to monitor biochemicals that the body produces.

What we are trying to do is develop the next generation of wearable devices that will also integrate chemical sensors so we can understand the human body in a more holistic manner. For example, trying to develop sensors that can monitor glucose or can monitor other chemicals like lactate (because it is a good indicator of physical stress). In addition to that, we're trying to monitor small proteins that are present, which could be an indication of inflammation or, say if a person is taking medication, what is the effect of that medication on the human body. If we can monitor these in real time, in a continuous manner, it will be quite useful to understand the human body.

In implantables, presently we are focused more on the neuroscience applications. So we are trying to develop these really tiny devices that can go inside the brain of an animal to study how the brain circuitry functions. It is kind of really amazing that we have made so much progress in the field of biomedical sciences and understanding the human body, but when it comes to the brain we barely know how the brain functions. So there are a lot of question marks when it comes to understanding how the brain reacts to particular conditions, and why it sends certain signals under certain conditions. These are all questions that neuroscience people have, without the tools to answer these questions. We are trying to develop tools that can help us answer these kinds of questions.

The key aspect of being wearable or implantable is, how can we make these systems as small as possible. For brain implantable systems, we have to make it small so that it can actually go inside the brain. For wearables you could say, even if the system is big, who cares, you can just put it on the body. But nobody likes to put big, bulky things on the body. We want to make it so small that you won't even realize that the device is on your body. So that's that's the ultimate goal; how do we play with the materials of the device, how do we play with the electronics that are involved, and then the designs that are involved to make them interface with soft tissues in an intimate fashion. Because if you look at conventional electronics, they are made of rigid materials, like silicon, metals, all these things are rigid materials and two-dimensional. On one hand you have these rigid materials, but the human body — be it the skin, the brain, or any organ – it is really soft, delicate and three dimensional. How do you take two dimensional, rigid materials and the soft material like tissues closer without causing any damage to the tissue? So, we play with the mechanical properties of these devices and the material properties to make them soft and stretchable, such that you can easily wrap them around the human body or any organ, without causing any damage.

What do you think the potential impact of wearable technologies is and where do you think these technologies are heading?

So far for general applications, it could be that I want to monitor my overall health status, and what kind of a quality of life I'm leading. But if you look from more of a medical applications point of view, let's consider the case of a patient in the ICU. Right now, a lot of instruments are connected to the body to measure oxygen levels or heart rate and all these things. But if they want to do some blood analysis, they have to take the blood sample, send it to the labs, and do the analysis. It may take several hours, and depending on which country you're in, it can take several days. But if you can have small patches that stick on the body and they are monitoring your vital signs as well as numerous biochemicals, then that will be very useful because you are going to be getting information in real time, as compared to doing studies and monitoring them once or twice a day. This will be extremely important for critically ill patients. These devices can be used for sports applications as well, for athletes trying to see if they are improving their performance. For people with high stress levels in school or at work, if you want to measure the stress levels and you want to change your life schedule accordingly, these systems can be used for such applications as well. The applications are numerous.

What first got you interested in the fields of electrical and computer engineering and working with biosensors? Was there something that specifically sparked your interest, or did you always know that you wanted to pursue these fields?

My story is not as romantic as it might be for some people. In my case, what happened was I was doing my undergraduate in India, and my department happened to organize a conference on biosensors. I really wanted to get into research. I did not have any preference of, "Oh, this is what I will do with that", it was just a coincidence that they had the conference. I attended the entire two day conference and I was really amazed by the importance of biosensors, and the kind of innovation that people were doing in that field. You can develop the world's best medication. But to give that medication to a particular patient, you first need to know that the patient has a particular condition. The biosensors are the first set of devices that one requires to get that information. So this is basically what got me interested in biosensors. While working on sensors as an undergraduate, I started realizing how important wearable biosensors would be, because the conventional systems were always, "Oh you take the sample, and then you may have a handheld device like a blood glucose meter or something." But a wearable system would really solve a lot of these problems where you have just discrete data points. That's where I got really interested in whether we can take the concepts of conventional biosensors and apply them for wearable applications. To do that, you would need to bring in expertise from electrical engineering, materials science, chemical engineering, and biology. Thus it was a pretty interdisciplinary kind of research, and that's something that really excites me because almost on a daily basis, I talk to people with expertise in electrical engineering, then later I talk to people with expertise in biology. It's really amazing when you get that opportunity to work at that interface of multiple fields.

You mentioned speaking with people from all these different fields on a regular basis. What is a typical day like for you at NC State?

As a new faculty with a lab that has been evolving, I will say a good 20-30% of my time is in the lab with students, seeing how they're doing, and trying to work with them to find a solution. And then the remaining time is basically split between teaching courses and also writing proposals and grants, and then networking with other professors to try to find new ideas to explore.

One thing that I want to point out is that in the field of research, a lot of the time, nobody knows the solution. For example, when I go into my classroom to teach and give my students a set of problems, I know the solutions to those problems. If the students don't know, they come and ask me: "Hey, I tried this but I could not solve it, can you give me the solution?" But when those same students come in and are working in the lab with me, they have the tendency to think, "Oh, if I don't know what to do, the professor should know the solution." However a lot of the time, even I don't know the solution. And that's the beauty of research, right? Because we are trying to explore new things. So there are a lot of failures, and this is something that a lot of the students who are new to research find really unique there. There's no textbook solutions to the problems, because if there is, then then that's not research, because then people already know how to do it. That's something that really excites me, just thinking about, "Oh, what could be the solution, and how can we come up with a solution?"

What are some questions or challenges that you face in your research and how do you overcome them?

The challenges are always dependent on the project, they are pretty unique. As I said, my research is pretty interdisciplinary. Perhaps you're trying to build an electronic system to understand the brain. So we need an electronics engineer and a neuroscientist to work together. There are certain challenges on the neuroscience part and then there are certain challenges on the electronics part. If you want to build a system, you need to find a solution that will somehow navigate both the problems, and sometimes the problems can be really in opposite directions. I can make the best electronic system, but the biology will not be able to accommodate that kind of system. If I try to make it compatible with the biology, the electronic system properties may be really terrible. So how do we find that middle ground?

Another problem is sometimes when these two completely different people with completely different expertise try to talk to each other, communications can be a problem. For example, the neuroscientist/biologist may see a problem, but the electronics person may not be able to fully appreciate the severity of the problem, because for them, the biology is a complete black box, and for the biology person, electronics is a complete black box. So it takes a good amount of time to understand what are the challenges in the other field and try to solve problems accordingly.

When it comes to solutions, as I said, we sometimes just have to do trial and error. We go, "We tried it and it did not work, why did it not work?" I always ask my students to look at it in a broad way, don't just narrow your approach to a narrow range of solutions, because a lot of time you have to go in a completely different field to find a solution. So for example, we're trying to develop a wearable sensor for a particular chemical and we're trying to figure out what would be the best way to make that sensor. We read hundreds of papers in the field of sensors to find potential solutions to our problem, but we could not. Instead, we were able to find a solution from some of the papers that were actually for drug delivery, which is completely different. We were able to get some inspiration from these drug delivery papers, and we were able to modify it for sensing applications. That is something that I always tell my students: do not restrict yourself to, "Oh, I am a sensor guy so I'm only going to read papers on sensors." Sometimes you have to go in a completely different field to bring in some knowledge and solutions.

What is your favorite part about your research?

I would say exploring new things, things that people have not done. And also, the fact that almost every day, you're faced with new, unknown challenges. So, my life is never boring. It never seems monotonous to me because every day is a new challenge, so I know there's always something new to think about. And since my lab works on multiple projects, if I sometimes get overwhelmed by one problem, then I can give it some rest. Let me think about the other problem that is there in the other project. That is something that really keeps me excited. And also the fact that being in academia, I'm always surrounded by young, enthusiastic, self-motivated students. I'm much older than you guys, but in the academia field, I'm still considered as a "young faculty". So I'm super enthusiastic right now, but ten years, twenty years down the line, I may feel like "Oh, I've been a professor a long time and its novelty has worn out". But that's not something that's going to be the case because you're always surrounded by these super enthusiastic students who want to try new things. And if I kind of get bored sometimes, just being in this enthusiastic environment boosts up my energy. So that's also something that keeps me excited about my work.

What areas in technology and software do you think are changing the most right now? What will be different in the next ten years or so?

That's a good question. I wish I had a crystal ball to see how things would evolve. In research, things evolve pretty fast, so it's kind of hard to say how my lab is going to look ten years down the line. I can say this: ten years ago, I was doing research that was not even close to what I'm doing right now. So, I am pretty confident that ten years from now, I'll probably be doing something that is completely different, but building up on whatever experience I've had. The way to explore new things is to build on your expertise. Whatever expertise that I'm building right now, I'll be applying it to different fields. And I can say that even presently, we are doing work on wearables and implantables, but that's not the only thing I'm planning to do. I'm trying to explore new things as well. For example, there's a lot of interest in stem cells, of growing tissues, like brains, in petri dishes. People are actually trying to do that using stem cells. We are collaborating with groups that do this really fancy work, and we are trying to develop sensors to understand how the brain actually grows from an individual cell to a complete organ. So we are trying to develop sensors for these types of applications as well. And this is something that we have never done in the past. We know that this is a new thing, and we want to see if we can build on our experience in wearables and implantables for this kind of stem cell research. We are already kind of going in new fields and exploring new things, and I'm pretty sure five years, ten years down the line, it will be completely different from what we are doing presently.

How has COVID-19 specifically affected your work and your research goals as of now?

It has certainly affected quite a lot just because of the restrictions that were imposed on the university and how many people can be in the lab. We really had to make sure that we are dividing the time to make sure that people are doing social distancing and the minimum number of students were there in the lab at a given time. It was challenging, but at the same time, we tried to make the most of it. COVID actually kind of made us more efficient because we knew that we had a short amount of time to spend in the lab, so instead of complaining, why can't we make the most of it? Let's try to make our processes more efficient. This is something that's going to help my lab a lot, because we now know that we can work in a lot more efficient way. So, we are trying to see the silver lining in the restrictions that are imposed on us.

What do you like to do outside of work? Is there anything in particular that has been fascinating you recently or that you've gotten into?

If I'm not in the lab or working, I like to go hiking. I'm really glad that I'm in the Raleigh area so there are a lot of opportunities to go hiking. That also helps me come up with new solutions and new ideas to the problems that I face in my work. A lot of the times when I'm on these hikes or walks or biking or whatever I'm doing, in the back of my mind I'm still thinking about problems and solutions. Sometimes I'm suddenly stricken with a potential solution to the problem. Then I'll send an email to my students and I'll say "Hey, I was thinking about this and, you know, maybe we should try this. It might work". And a lot of times that actually helps, so I always encourage my students to recognize that you spend time in the lab, but sometimes you need to get out of the lab to find solutions to the problems in the lab. That's really important.

If you were to go back to your high school years or your early undergraduate years, what would you like to change about them?

I'm not sure, but I do have some suggestions to young students based on my experience. I did my undergraduate in India, and the opportunities that are there in India and other developing countries are very limited. So, as a high school student, as an undergraduate student, I used to read about all this innovative stuff that's happening by researchers in India and outside in the world. But I never had that opportunity to spend in the lab, to get hands on experience because there were so few opportunities, and so few labs that could actually give these kinds of avenues for such young students. And even when I was an undergraduate, I remember I used to go to a completely different city during summer breaks and winter breaks. Instead of going home, I'm going to go to the lab, which is a thousand miles from my place, just so that I could spend some time to actually get some hands on experience. I feel, in the US, it's relatively easier to get those kinds of experiences. And sometimes, I feel students don't take the full advantage of the opportunities that students have in the US. So, I would say: make the most of it. I always say that to my undergraduate students and high school students, "If only I had these kinds of opportunities when I was in high school or an undergraduate student. I lacked those kinds of opportunities. But you guys have that, so make the most of it." In the end, you may hate it, but at least you will know that you hate it because it's only through experience that you know whether you like something or don't like something. The worst thing is, in the future, regretting not having that opportunity and saying "I wish I would have tried that when I was in my high school or in my undergraduate, at least I would have known whether I liked it or not."

Having had a few years of experience in your research career, how has your career potentially been different than how you might have imagined it to have been when initially going into your career?

A lot. I mean, as a professor, it's a lot more challenging than what I had expected it to be because from day one, people expect things from you. And as a faculty who is mentoring students, I feel responsible for how their life is going to turn out. When I was a student, I was like "Okay yeah, whatever decisions I make, I'm responsible for my own future". But now, as a mentor of students who work in my lab, all the experiences that they have, I feel like I'm playing some role in how their life is shaping so that makes me a little bit nervous sometimes. I want to make sure that I give them the best opportunities that they can have to make the most of their time in the lab. And also, in writing proposals to get the funding to do research, that's always challenging. So, yes, it's challenging for sure, but so far so good, I'm enjoying it.

If you could tell your past self or a student interested in the pursuit of research or STEM something, what would you say?

I would say: time is precious. Know what your goals are and pursue them. Do not be shy of failing. You'll fail multiple times, but in every failure, you learn things. Make the most of whatever time you have because everyone has the same amount of time in a given day. Be focused, try different things, and don't be afraid of failure.