Introduction to Research
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Lecture – 45
Research in Electrical Engineering

Prof. Prathap Haridoss: Hello. So, it's our pleasure to have with us Prof. Deepa Venkitesh from Department of Electrical Engineering.

Prof. Deepa Venkitesh: Yeah.

Prof. Prathap Haridoss: Here at IIT, Madras. She has been in the department for 7 years now.

Prof. Deepa Venkitesh: 7 years now yeah.

Prof. Prathap Haridoss: And, before that she was as faculty for about 8 years in Mumbai.

Prof. Deepa Venkitesh: Mumbai University.

Prof. Prathap Haridoss: Mumbai University.

Prof. Deepa Venkitesh: Yeah.

Prof. Prathap Haridoss: So, that is where she is been for. So, about 15 years as a faculty, that's a lot of experience as a faculty and she has worked on Photonics, Non-linear optics, Fiber lasers and Optical Signal processing. So, wide range of areas and these are you know technologies that we are we often interact with for lot of our communication processes. So, we are really glad that she could join us. So, we will get an idea of aspects of research associated with Electrical Engineering. So, Deepa in Electrical Engineering it 's of course, field of engineering that is being around for a very long time.

Prof. Deepa Venkitesh: Correct.

Prof. Prathap Haridoss: So, are there areas of research that a PhD or an MS student might still encounter, which are considered you know traditional areas of research in Electrical Engineering where there is a lot of literature available that they can refer to and has been around you know, for maybe I don’t know 10-15 years, may be much more than 20-30 years, but still considered something that people have to work on and there is a scope there to work on.

Prof. Deepa Venkitesh: So, thank you first of all inviting Prathap. As far as Electrical Engineering is concerned, it’s a highly interdisciplinary branch. So, as you rightly pointed out there is lot of material available in tradition. Traditionally Electrical Engineering was to do with power electronics, power systems, you know high voltage engineering and Electrical Engineering or Electronics Engineering as it is called it was in our department it is all both together. It’s machines power, electronics, VLSI kind of work. And, research is continuing in that area.

So, for instance in today's context you know, you have lot of solar things coming up and you have local generation of power happening. So, each consumer is now producer of electricity also, so going from the power grid which is a traditional, very traditional area. Now, you have inputs to take from those traditional areas, where earlier it used to be small hydro electric projects which used to feed in power into the system. Now, you would have smaller consumers sitting there and feeding so. Think lot of inputs can come from that area. Similarly, VLSI, microelectronic it is all tradition which is already there, you start from there and then you start growing. Same for photonics, photonics is in area which it’s a counter part of electronics as we called, right. Where things in electronics you control electrons and photonics you control photons.

Prof. Prathap Haridoss: Photons.

Prof. Deepa Venkitesh: So, traditionally it is optics, right.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Traditionally you called that it optics and then you start from the principles of optics and then you see how it applies to an engineering perspective. So, yes, there are different traditionally sensitive areas, if you take about for example, Communication, single processing is one of the very, very profound or the very basic subject, which gets applied in multiple different areas, it could be speech processing, it could be image processing, it could be processing for optical communication, it could be a processing for wireless communication.

So, these are traditional areas, definitely they do have a strong hold in Electrical Engineering as on today. But, you know we will see that it will things will change when as far as research is concerned, right. So, in that sense like physics or like chemistry, Electrical Engineering is not that you call it as a chased subject where you keep following one specific area and you keep expanding on that, it's highly multidisciplinary.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: So, somebody said if you know mathematics well and if you know the physics of it, then you have pretty much well equipped to do Electrical Engineering.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: And, where do you get those mathematics and physics, you got to get your basic.

Prof. Prathap Haridoss: Basics.

Prof. Deepa Venkitesh: Right.

Prof. Prathap Haridoss: Great. So, now I mean in the same token. So, you know like with various engineering disciplines, with a passage of time you know generally new areas come up.

Prof. Deepa Venkitesh: Sure.

Prof. Prathap Haridoss: And, so in Electrical Engineering is there something that is come up much more recently let's say, the last 5 10 years that people focus on a lot.

Prof. Deepa Venkitesh: Absolutely, absolutely. One thing that you see, the solar we were talking about, right. So, now, how do you do this distributed grid? How do you do the smart grid? How do you do distributed generation? How do you feed it into the grid that is in case of power electronics? So, let me also tell you that in general Electrical Engineering we have 5 disciplines, major disciplines we used to classify. One is Communications related area, which is to do with wireless communications that involves lot of hardware to make those antennas, to make the wireless systems and more than hardware a lot of software and mathematics. For example, if you are trying to send a signal from the transmitter to the receiver, the data rates have to are going up so you need to model your channel very well, you need do an adaptive control of your signal, you need to give a feedback adapter, it is a lot of mathematics probability too that goes in.

So, there is a large influx of you know highly efficient mathematics and signal processing going in that area, that is in the what we call as a Electrical Engineering. One in our, one in our IIT setup, but it's basically communication signal processing and related areas. The second area is Power Systems and Power Electronics. So, as I mentioned earlier the distributed power scenario is one thing, power quality power, when you have distributed system of you know, every consumer starts feeding in power into the system. Now, how does electrical TNEB, for example, ensure the quality of power, right.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: So, now there is a software approach to that, there is hardware approach to that, so those are the advances in that area. Same way in renewable power for example, wind solar how you integrate it to the grid, those are issues. And, I think many of you might know the solar DC project.

Prof. Prathap Haridoss: Direct.

Prof. Deepa Venkitesh: You know.

Prof. Prathap Haridoss: Direct DC.

Prof. Deepa Venkitesh: Direct DC consumption where, how do you make your lights? Lights, of course, LED's work on DC; How do you make your fans, your refrigeration? everything on DC so that you don’t, you can avoid the ac DC conversion lost, that is a very big project and that is of highly socially relevant project also. So, that’s a lot of effort is going in that area. So, that is to do with power systems, power electronics machines. Another important thing in that area is you know, different users will have different requirements, for instance, you are powering your satellite the requirement could be small voltage, but high current application, right. So, how do you do those DC-DC conversions from, you could be drawing the power from the grid or you could be drawing power from solar, but, one DC to another DC of different requirement, how do you do that?

Prof. Prathap Haridoss: All right.

Prof. Deepa Venkitesh: Even robotics, any area that you pick in of engineering you would need that DC-DC converter. So, that’s another very important area. You know applications specific DC-DC converter designs. Then the third one, third major area of Electrical Engineering is micro electronics and VLSI. Micro electronics, I don’t have to say that is the you know, the granularity has going down, you are following more slog, you are going from nanometer to sub nanometer kind of device dimensions. So, you have all the associated math and you have all the associated physics, along with the fabrication technology for that.

So, you will have. The other important area that is come up there is Microelectronic and you know MEMS what we called as, Micro Electro Mechanical Systems. Now, that is evolved into nano electro mechanical systems, where the device dimensions are very small and you will be able to control or switch certain devices.

Plasmonics is another new area, where metal interfaces can enhance certain properties of light and so that is another area. Silicon photonics is another area, where you know you can just like how you had the electronic integrated circuits you could have photonic integrated circuits where your mother board. So, the biggest problem today in a computer mother board is how fast can you transfer from your CPU to your memory, right. Now, if you can do everything in optics, where your transfer happens in optics, your processing happens in optics, that's the whole area of optical signal processing. You do not have to go into the electronic domain.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Like being the fastest, you can do it at that speed, right. There is lot of development happening around bio medical devices, how do you make simulators for making a surgery efficient or making giving practice to the doctors and things like that? So, definitely yes, all these areas so the controlled an instrumentation and that's where we talked about bio medical engineering. Then of course, we talked about photonics where the other smart city scenario right now people are talking about putting as many sensors as one can and then develop sensor network.

Again, it's completely interdisciplinary you cannot classify whether it is a photonics or a wireless communication because all aspects of it is coming in there, right. So, you know so smart cities you want to put multiple sensors you know, these multiple sensors some of them could be electronic sensors, some of them could be photonic sensors all of them would use a wireless communication link to you know relay the information to 1 central office, then you would do the appropriate process is required. So, all these are coming up organic electronics is another area, where flexible electronics.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Right, you would have seen advertisements from Samsung or somebody who would have made a TV which is flexible, you would have your cell phones which could flexible, you can roll it and put it in your pocket. Question is how efficiently will you be able to develop? How fast will these devices respond? Can I use a make a use and throw screen for example right ? So, it is completely involving area, right.

Prof. Prathap Haridoss: So, if we now look at let's say a student prospective of you know people coming in and so on. Of course, there is an Electrical Engineering Departments in almost every colleges because it is one of the you know, traditional areas of engineering you have bachelor's degrees in Electrical Engineering being awarded, many institutions around the country. When they come for a masters or a PhD program, are there still certain I mean, are there certain challenges that they face? I mean of course, we are moving from a course based work to a research based work, that itself provides some challenges.

Prof. Deepa Venkitesh: OK.

Prof. Prathap Haridoss: But, other than that specifically for Electrical Engineering in terms of their preparation that you normally see among the student community, that is coming in for higher degree in Electrical Engineering, did you see that they face certain types of you know, handicaps that they need to overcome for which then they are involving certain mechanisms here and if so what?

Prof. Deepa Venkitesh: So, it's a very, very relevant thing that you know, this is something that we keep discussing among our research group at the faculty group and what we have always found is at the end of their undergraduate program they are probably writing a gate exam or you know, some qualifying exam to get into our system. The examination systems are always checking your ability to remember certain things or may be at best in what we call as blooms taxonomy of learning at the base levels. Where they learn something, they are able to reproduce something they are at best able to apply a formula to a given situation.

When they come into the research mold, they also need to research the final goal and the blooms taxonomy is also in creation, right, so you would want them to able to create something. Now, again broadly classifying as in any other engineering or science streams, you could have theoretical work or experimental work. So, let's talk about the challenges with the theoretical people who try to do simulations or theory. There, what we feel is the mathematics is not strong enough.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Right. There mathematics is not strong enough, as somebody said you know if you get your mathematics, if you get your physics right the rest is mathematics is what somebody say, but that rest is mathematics is not very strong.

Prof. Prathap Haridoss: Yeah, it is very.

Prof. Deepa Venkitesh: So, it is they are able to what we see as a student, if you give a stereo type problem they are able to solve. But, given a situation they are not able to formulate a problem and solve. A part of the research training is towards that I understand but, to correlate from different areas and applying the same problem is something that we are finding, the students are finding it bit.

Prof. Prathap Haridoss: Difficult.

Prof. Deepa Venkitesh: Difficult and challenging. Even in programming people know how to write a c program with same program with or may be a mat lab code as this called these days you know, use 100 lines to write something which is worth may be you know, 15 lines.

Prof. Prathap Haridoss: 15 lines, OK.

Prof. Deepa Venkitesh: So, that’s something that smart mathematical thinking is something that we would like the students to develop when they come in. And, as far as experimental skills are concerned, partly because of not their problem, you know, they are mostly not trained in handling equipment's. When I say trained, it means like we are not talking about the research level equipment's we are talking about simple things like oscilloscopes, right. Again, as I said it’s partly not due to their fault, but they even if they get a chance.

Prof. Prathap Haridoss: Exposure lack of exposure.

Prof. Deepa Venkitesh: Yeah, lack of exposure. Most of the colleges probably run 4 or 5 people on 1 equipment's, some of them might be actually using it, and some of them might not using it. So, my only advice to the student is, if they get a chance they have to go and try and run experiments and that experimental skill is something that we, it’s not even a experimental skill that experimental sense is something that thinking on feet while running the experiment, those are the things I think our students find it big challenging. Third biggest challenge everyone faces is lack of ownership.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Lack of Ownership.. Lack of ownership for a specific experiment that is done or a specific instrument. This micro electronics and photonics, the most of the instruments are you know huge facilities and I think it is more of ethical culture than anything that can be trained. You, when you are working in a place many of the students feel that it is like a college, where I go in the morning come in the evening.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Close down everything, my job is over there is somebody to take care. But, I think that has to change and they should start getting, they should kind of find a unison with the equipment, only then the results will come out.

Prof. Prathap Haridoss: Okay. Let’s look at it from say the industry perspective. So, there is always this perception that when do a masters degree especially in MS or a PhD degree, Research based degree that we, that the person, the student is becoming a specialist in a sort of a narrow field. And, often MS, PhD projects are also may be a little ahead of their time, in terms of you know because they are really pushing the boundary of some.

Prof. Deepa Venkitesh: Correct.

Prof. Prathap Haridoss: Some areas that they are working.

Prof. Deepa Venkitesh: Otherwise you cannot publish.

Prof. Prathap Haridoss: Yes. So, in that context, to what degree does the industry show interest in what MS PhD students traditionally do in Electrical Engineering? Are there areas that even though they are advanced the industries now ready to absorb also at the same time?

Prof. Deepa Venkitesh: Absolutely, I mean Electrical Engineering by the very nature of the projects that we do is very, there are of course, there are certain areas which industry might not be interested in, let me also say that like example, Quantum Communication for example, right. Or a Quantum Computer for example, it's probably not something where an industry is not.

Prof. Prathap Haridoss: Currently interested in. Yeah, OK.

Prof. Deepa Venkitesh: No, would not spend lot of money on, right.

Prof. Prathap Haridoss: Yeah, yeah.

Prof. Deepa Venkitesh: But, there are certain areas like that. But, many areas that we are talking about for example, these grid, right. I mean, it is industry who wants the result out of this, right.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: So, definitely industry is looking forward towards many things that we are doing especially in wireless systems, some of the things that we do evolve as standards.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Right, the kind of work that people do out here, they participate in standards. But, as far as the student is concerned, I think PhD, once you get a PhD I mean, when do you get a PhD I think within a certain reasonable time if you are able to absorb a new topic let's say, industry has a certain requirement, somebody who has a PhD should be able to understand, absorb that topic and provide a solution given a reasonable amount of time. It need not be directly related to what they have actually done.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: So, in that sense when they graduate with a PhD, it is probably not necessary that it is directly related to what,

Prof. Prathap Haridoss: What their area of specialization?

Prof. Deepa Venkitesh: Specialization.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: So, I think.

Prof. Prathap Haridoss: Yeah, in that context. In fact, I mean taking that forward, what sort of positions do you see MS and PhD students in Electrical Engineering normally speaking up?

Prof. Deepa Venkitesh: Most of the students go for, MS students go for PhD and PhD students go for post doc, but having said that there are many students who are absorbed in industry also.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: They do course job. For example, we have from our photonics group 1 of our student have gone into. In fact, my student went to an industry just after PhD, he was observed in Tejas Networks for which is a communication, pure communication company. Whereas, his project was on optical signal process, it has probably 10 years into, I mean I cannot think of an optical signal processor which he had implemented in his PhD getting implemented in the industry for next 10 years, I cannot see that happening.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: But, you know, you the kind of expertise that you develop during that, he got placed in Tejas Networks. There is another student who got placed in GE, for example. I mean, there are certain core areas. Again, these are not related to directly to their PhD problem per say. There are of course, also cases where after their Masters or PhD they have their own start ups, people have started for example, Solar electronics, I mean Organic electronics. That are couple of group, group of students who have had their start ups, coming up. So, there are different possibilities one can think of it.

Prof. Prathap Haridoss: Couple of things from let's say faculties view of what is happening with respect to a student. At least, during their student life as a research scholar as a MS or PhD student and may be even their early carrier after that. How other ways in which you measure success in research? Other than you know, I mean traditionally people talk about publications.

Prof. Deepa Venkitesh: Correct.

Prof. Prathap Haridoss: That is certainly something we will still continue to look at. But, is there any other way in which you look at students and feel that you know, in fact, this student you know is growing as a researcher compared to somebody else that you see?

Prof. Deepa Venkitesh: Absolutely, I think that goes without saying every research guide, when do you again get your student ready for graduation and the student is able to give you ideas which the guide is not thought about. Student is independently proving certain things he is coming up with multiple ways of solving the problem. I think that is how you measure success.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: And, way to quantify that is of course, your patents, your papers, the number of citations you have had, citation of course, something that comes up over years, but the measure I think the immediate measure which is probably not very quantifiable is coming through discussion between a faculty and a student is when the student is trying to think of or giving us new ideas rather than we giving them the ideas, I think that's the measure of success.

Prof. Prathap Haridoss: In fact, on a more mundane note you know, we always say that students have I mean at least especially as a research scholar, interaction is a very important thing.

Prof. Deepa Venkitesh: Correct.

Prof. Prathap Haridoss: How well they interact with other people in the group? How well and how often they interact with the guide? In your view, you know, how often should students be meeting their guide adviser?

Prof. Deepa Venkitesh: So, there are 2 things. You pointed out 2 things, interaction with the peer group and interaction with the guide. What we have set up in the photonics group is of course, changes from guide to guide but, at least we say once in a week is the minimum. More meeting, more often than that would mean that the student is dependent on the guide and meeting less often probably student will go out of track. So, we believe once in a week is something, but what we stress on more importantly is their peer interaction. And, one of the things that forces the peer interaction is you know, it's a fairly big group, there are about 6 faculty, 6 of us who are working together in, if it's a research group like that. If people can afford to have that kind of set up.

Best thing is to have them organize peer seminars, it could be on a small topic that faculty is not typically invited for that, it could be discussion of a research paper where you know, peer learning is much more valuable. We feel especially, in certain areas which are highly interdisciplinary. So, I think it's important that the students talk to each other, give presentations to each other, get inputs from the peer the seniors. Then of course, the guide meeting with the guide at least once a week is what I would say.

And, I would also say that the students have to attend other talks, right. Other Talks from related area it could be in different department all together, but if it is having some connection to their research work it is, even if it's not a connections it is good to attend those talks to, I mean that is how they learn and that is how they kind of apply what others are doing to their own work, right. So, they should have that bigger vision or bigger view for, eye for those things.

Prof. Prathap Haridoss: Okay So, in I would say a sort of to conclude, what are you words of advice to any student who is aspiring to you know join an MS or a PhD program in Electrical Engineering?

Prof. Deepa Venkitesh: So, we have covered that mostly, one is their mathematics they need to work on.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Right, whichever area in Electrical Engineering you want to work on. If it is something to do with VLSI or I mean it is your physics and mathematics, basically.

Prof. Prathap Haridoss: OK.

Prof. Deepa Venkitesh: Well work on your physics and mathematics. Then also have this idea that research is not a time bound program, right. The adviser does not have a solution, if the adviser has a solution to the problem he does’nt need a student, the adviser can work towards every problem. So, do not expect a final answer from an adviser, it is the probably the goal is also not very clear, only the problem is clear, right. So, that will evolve. So, you need to have that patience and that kind of temperament that implicitiveness to go further.

Again, talk to others students and try to understand, what their problems are? How have they solved those kinds of problems? You know, teaching helps so, be a very trying be a proactive teaching assistant if possible, because when you try to teach certain things you will get the connect and your some of your research problems get do gets solved. There is no documentary evidence for that.

Prof. Prathap Haridoss: Yeah, yeah.

Prof. Deepa Venkitesh: But, I feel that teaching helps research and research helps teaching. So, given a chance try and teach certain things when you are in the program and yeah get your maths and physics right.

Prof. Prathap Haridoss: Ok, great on that note. Thank you so much for joining us.

Prof. Deepa Venkitesh: Thank you, thank you very much.

Prof. Prathap Haridoss: It was a pleasure to have you here.

Prof. Deepa Venkitesh: Yeah. Thank you.