PK: Welcome all … [background]

NA: Research in India, I'm not sure if you could ask for more. What is research? The objective is to discover and there are at least two ways to do that. One is, to climb the mountain coz it exists, and the other is, you have something to bring home and it's on the mountain and you have climb it to bring it. You are not doing it coz it's fun to climb but coz it's fun to have something that is on the mountain and you need to do that. So one is very application motivated and the other is idiocity motivated, pure curiosity. There are both kinds of people in research world. You will see people who create problems, solve them and then long after they have solved them people discover that that problem is actually real and whatever they did, does eventually indeed have a solution, has a use, the use wasn't clear when the solution was discovered or when the research was done. On the other hand there are people who don't worry about why the world is the way it is, how it works the way it does, but they have a problem at hand and they want to solve the problem. Now the problem might be simple in which case they will come up with a solution and get their job and then they will be happy. Or the solution is not the obvious and they dig into it why this, how to, how to do this, how to do that, they break their head, finally they may end up somewhere but the more challenging it is the more likely there is depth to it and therefore they will have to dig to deeper, they will have to think more, they will have to learn more from different sources, may be learn from nature, may be learn from traditions, learn from this and that and mix things up and hypothesize solutions, test if they work and in the cycle eventually they will find a solution. And that very likely would have a lot of innovation in it coz all the thinking that went into it was for a reason. So the solution that they come up with to their problem is now … they have a solution at least and it involved research but their satisfaction is coming from having solved their problem, and in the process may be they also enjoyed the thrill that comes with seeing things differently and thinking news things etc. so now coming back to India, as I was saying, both kinds of people are there wherever you go you will find both these types, there are pure curiosity types and pure engineer types and there is room for both. Now if you are the later type where you are looking for problems to solve then being in India is a boon coz there is

no dearth of problems. If you don't have your own, ask your neighbour, they will just go on and on and on ☺ so that is not something we are short of and if we are short of them then that's also good news. We don't have problems to solve, mundane problems, then we can go to super mundane problems. Think about why black holes are there etc. but until then we have employment. So now, if you go out and step on the road immediately you see traffic problems. It's not that when you are crossing a road, just first look to the right and then look to the left that formula will kill you coz when you look to the right there is a guy coming on the wrong side and will hit you. The way you save yourself on the road is not by following the same rules as you would follow somewhere else. So transportation is a problem. When you go jogging or when you are just walking, you may not be assured of getting good air to breathe so there is that problem, there is a problem of food you are eating is full of chemicals, pesticides on it, fertilizers etc. so there is no end to problems. The problem are there not coz they have to be there, there is number of sources, it could be [disconnected]

NA: so, the summary is that we have enough problems and now let me say where AI comes in, I actually don't have to say much. It's obvious how, in fact there are already ways in which AI is being used to help with traffic regulation and control. Eg. Catching violations, there are devices already that will tell you if a food item is same as it claims to be or it's adulterated. There are many other examples, even after working in India for such a long time, the trivial example of train ticketing and today of course face recognition, etc. so the problems are there, AI is there and the combination is there and not all solutions are obvious, not all solutions are trivial, they are not the kind where you just look at the problem and there is research needed and research may be at the bachelors project level, masters project level, or it's a PhD thesis. So the summary is that in India no matter how many PhD theses you may want to write there is enough fuel for it.

PK: So let's take some questions.

Q. If you have a research problem in mind, how do you validate if the problem statement is worth research? What is the difference between Engineering and Research?

NA: if you think that the problem is there, which is true that's the reason you are looking into it and the solution is not there which also is true coz otherwise you would not worry about this. The question then is why is the solution not there? Is it coz people haven't thought about it, which is also possible, it happens a lot. Or is it that people have tried and haven't hit upon a solution. If that's the case, why is it that people haven't been able to do it. Is it coz the problem is very difficult, then what is it that makes the problem difficult, there must be something when you start looking into it and you don't get the answer and you don't get the answer and you don't get the answer still then there is some depth to it, you may give up or you may realise that yes, there are these basic questions that need to be answered for you to come up with a solution. Now those questions themselves may lead to other questions and soon you will know that this is not your trivial type of activity, again I am replacing your question with qualitative answer, but the amount of efforts it takes for you to do it and then someone else also tells you, your advisor tells you, your colleagues, your senior colleagues tell you that boy, this is really neat, this is really cool, what you are doing and then you realise that some of the questions are half answered by some people which are called research papers or so and so says it's a research topic, it's not clear to me that there is a definitive quantitative answer to this but if you feel this is deep coz its taking you a lot of questions leading to many other questions, so if those questions are partly at least categorised as research done some day or still open research problems and your respected colleagues and seniors tell you that this is worth a PhD or masters then it's a validation of the undertaking. [disconnected]

Q. How to do survey for doing research? Or in other words how do you do the literature review?

NA: First thing is exactly the problem you have encountered, you state it in some way and then see some of the obvious ways of phrasing the problem, the words, the technical terms, the English words, if you just search for them,

that's the first thing to do. Chances are you will get them quickly. Now the real survey comes when you want to know whether somebody has solved it, how many different ways are there that they have solved it. So you trace people's activities by these various words that lead you to the research. The greater challenge comes when you are looking for the equivalent of synonyms, in other words if you have some sub-concepts in the formulation of the statement of the problem and you want to know whether some other people have done some work on this concept or sub concept, even if they have not worked on the problem itself. But since your solution is going to be made up of pieces and those pieces have been worked upon, then you want to know that also, so that you can construct your solution from the solutions of the pieces of the problems. Remember that the solution to your problem doesn't have to be entirety, you can have a formulation for it and that is a set of sub problems. If you get solutions to the sub problems, you can assemble them for your solution from the sub solutions. So now you are looking at various sub problems, that have been worked upon and this is recursive now. You look for a problem, then look for sub problems and that again can be from straight forward key words or some concepts that you think will be encountered as you look at the sub problem. So survey to summarise is, you look at straight forward definitions and then elaborate versions of it, both in terms of technical terms and the derivative of it where you have the implications of those problems to sub problems and then you search for sub problems.

PK: Given that you are looking at ITRA here and the organisation for funding research and all that, so what kind of research do you think are the top three, if students have to explore on, and lets keep the AI discussion slightly after this, coz many students will be interested in knowing whether AI can be applied and all that. At broad level most exciting problems according to you.

NA: Most exciting problems are the most serious problems that we are facing today. Coz if you come up with a solution for those, the excitement that will be generated for having solved it, excitement can be in terms of being recognised for it, it could be in terms of making money from it, it could be in terms of pure simple satisfaction. To be specific, let's ask the question about the seriousness of the problem, so look at the problem of water, problems in agriculture, for

example, the farmer doesn't know what to sow, why? Coz the farmer doesn't know what the weather is going to be like at the time of seed germination. Let's say the farmer sows the seeds today and the forecast is, it is going to be dry or wet and if doesn't turn out to be the case then the decision that was made at the time of sowing may turn out to be wrong. Similarly suppose there is forecast which says that in three weeks the humidity and the moisture levels will be such, then the farmer will prepare to buy seeds of the right kind, rice or bajra. And if the forecast is wrong, then he got the wrong seed. The farmer may not know anything about the pest that is about to arrive, and as a result is not ready to face the attack. Coz if the pest is not checked and given the right amount of time then it will destroy the crop. So these are some examples of forecast. Similarly there are weeds that are to be taken out, there is soil mapping to be done. A soil has its own makeup and for a given type of plant, you need a certain mix of minerals, certain amount of moisture in the soil. Fertilizers simply compensate for what is missing by adding it externally but if you don't know what is missing, you will just throw the fertiliser on the field, it may include things that the soil needs and that the soil doesn't. What it doesn't need is poison. It's just there. That's one dimension but then … [disconnected]

Q. For early career researchers, would you recommend incremental work or 'low-hanging fruit' that can be comparatively easily translated into publications and career progression as opposed to potentially higher impact research that could have more challenges and run the risk of hitting a wall?

NA: extremely good question. I congratulate you for asking this question. This is a problem that all of us face. But let me tell you one thing, if you have a solution that is coming to your mind, which is out of the box, which is on the one hand extremely inviting and you get that feeling of thrill like Oh, what about this approach, and it may give you goose bumps, you shouldn't be looking back, at all. What is likely to happen is the following, suppose you take this completely out of the box approach, the reason it is out of the box is, it is very different from anything that you have seen in the approaches that you have encountered to this problem, very different. Now if you have studied other approaches to the problem, but you have this out of the way somewhat

crazy thought in mind, this is how you want to approach, chances are that even if you make small progress, not solve the entire problem, you solve part of the problem using this completely new approach, it is probably going to be more valuable than having solved the problem incrementally, just giving a twist to something that already exists. There will be thousand other people who could have done this but since you have taken this new approach, and solved the problem partly, there will be other people who will be thinking slightly differently from you and might extend your solution further. And in that case what you did, even though partial, was much more impactful than doing small increments. Second, you take it all the way or most of the way it's certainly great coz it will be generating so much more activity than if you do it otherwise. On the other hand, you don't come up with out of the box approaches coz you say ok, on Fridays I will come up with out of the box approaches and rest of the week I will do incremental work, it doesn't work that way. Out of the box things are like precedents or break throughs, and you don't plan break throughs, they just happen. And there are many examples of this. You are doing something completely different and somehow, you get drawn in some way that you don't understand in a different direction and it looks very exciting, so if you are struck with this crazy out of the box idea, if I were you I would, never never think to not pursue it in favour of pursuing something that is more likely to give you something back. And the fear, as you call it, hitting the wall should not stop you from pursuing exciting new directions.

Q. A follow up question, also as an advisor, how do you balance the 'need to publish' for your students with the 'need to have high impact'?

NA: We have encountered this many times. What happens is that even if you encounter an approach to be not as promising as it looked the first time it will still solve some problem, some solutions to some sub problems that would be different. So the incremental value will still be there. Its hasn't happen when no incremental value was obtained even though it did not prove to be as earthshakingly novel as you thought. So I don't think that, the ceiling is high but the floor is not that bad also. So when I see a student doing this, I say all the power to you, spend more time more time more time and as you group

this ideas in this new direction, there is every chance that some of those ideas, even if they did not deliver what you wanted them to deliver, they will deliver something that was at least as meaningful as the classical incremental work.

Q. How much is a PhD important if one wants to ultimately join R & D arm of an organisation?

NA: So PhD becomes possibly very useful if you are facing problems that require some theoretical tools, coz when you do PhD, in the American system at least and now all over the world, earlier in some of the systems it wasn't as critical to read lot of courses, read a lot of books, by requirement not by choice, by choice of course people did. But it's now almost universally mandatory for you to take courses. Which means, whether you like it or not you are pumping a lot of information into your brain and keeping it there, so that knowledge. When you have all these things sitting in your head, the combinatorics comes in to play. You can combine one idea to idea two to idea three, so there are more combinations. So if you have only two ideas there are very few combinations, but if you have 200 ideas/pieces of knowledge there are more mixtures. So you can do more mix and match and therefore come up with newer combinations. Suppose you are encountering not incremental problem, coz if you are a Btech, or not even a Btech, let's say you are a high school person, and you join a factory, there is no doubt in my mind that as this person grows in the organisation he/she will make solid contributions, the tool will be changed this way, that way, based upon the feedback from the users or the researcher himself, so there will be incremental changes but to replace the bird with airplane will not happen without basic insights, fundamental insights that yes flying doesn't mean [disconnected]

Q. What is the process of making a research idea into a research problem? How does a student decide what problems are worth pursuing?

NA: as we started out saying, there are two ways, your research can be motivated by a real problem, in which case there is not much to worry about coz you want to solve the problem and whatever it takes you will do. The problem that you are referring to arises when you are doing problem for the sake of problem. Coz you want to get a PhD and that's why you are doing

research. So now you have to somehow satisfy the requirements to get the PhD. And that's ok too. Coz you want to build your abstraction skills, your analytical skills, analysis skills etc. now a very common practise that I have seen is that you go to a problem, you go to a paper and you ask this question to yourself. How do I minimally tweak this thing so I can cross the threshold of being acceptable as a different thesis? This is a very common view point. What is the minimal I can do so that it looks different enough and acceptable for a PhD. That's not the way to do quality work. That is not the way to do something that you will be proud of in the long run. The same thing you could do when you read the paper, you abstract it and ask yourself what is it doing? Forget about whether the value of 0.7 or 0.71 or whether this threshold is here, how many variable are there etc. you ask the question, what is the fundamental issue here that is being addressed by this approach. Once you do that you ask yourself if I were faced with the same problem, just like this person was, what would I do? Now this is above the level of all the details. You remove the experiment section for example what was the problem, [disconnected]

You take a paper and if you want to make some changes to it coz somebody has taken an approach to it and you want to make difference to it, then the general rule to maximise the impact and quality and therefore acceptability of what you do is, to keep abstracting the paper out leaving the details behind and coming up to some level where you say these are the three four five main parts of the problem, convert it into block diagram and now look at the block diagram and you ask yourself, would you solve the same problem this way, would you draw the same block diagram. Or it doesn't happen to be a block diagram it could be some other abstraction and if you can think of ways of doing it differently, well-motivated of course, why is it you want to do it differently, then if you start coming down and convert that into a real solution, you will have a different details solution and a different paper which will not be incrementally different at the low level but significantly different coz you went all the way and looked at the problem in your own way and you came up with your own block diagram, own abstraction and now you have simply detailed it more.

Q. How to tackle situations where the potential solution to a problem breaks down midway?

NA: those of you who have done search algorithms, what is typically a search? You try something, you search here, search there, search here, there, oh blind alley! you go one step back and try an alternative that you stacked up. Now if you have finished these, you go one level back, look at the stack there, until you find a path that takes you to the goal. That's the usual search paradigm. And to say that no you won't have a tree and you won't have a set of stacks that you left behind that's very unlikely coz you never go directly, there are always alternatives in the search. If you did not have alternatives then you are gifted coz you know exactly what the solution is and you are heading there straight. In which case you will also see that there's a blind alley ☺. So you won't go there. So I think despondency is the worst thing that can happen, you say ok, it doesn't work in that direction, why did I do this, I did it coz I wanted this thing, but then you have intermediate states from where you are trying to extend, you just go back and search for other solutions. If that doesn't work go back one more step and so on.

PK: that's a brilliant suggestion, one of the thing that we have been looking at also was to maintain some level of journal or diary of problems, you spend a year reading papers and coming up with ideas but at the end of the day your paper is only 10 pages. You have to keep some way documenting problems that you were thinking through, ideas that you have, which is such an important thing, that's when you have a way to go back on the tree otherwise the tree is gone.

Q. Apart from the benefit of getting ideas from courses, why should or shouldn't an MS graduate go for a PhD and pursue academic research, as opposed to joining a company's research wing and pursuing research there? These days we see places like Google Brain doing impactful research, which university research groups have conventionally been doing.

NA: You have done breadth first search and depth first search, in breadth first search you try different things without having that much idea of which direction you want to go then. In depth first you make a commitment even if it

is to betray you later but you still make a commitment you did vertically. Masters, and not going for PhD is like this going deep, like depth first search. But if you want to get many different types of expertise and have it in your bag so that tomorrow when you need this or that, you at least you know them all and you know what is involved, what kinds of solutions this particular direction might take, so you might do non-linear optimisation, you might do linear optimisation, you might do genetic algorithms, you might do random algorithm, and all these things you know what is roughly involved. What is good about it and bad about it. So if you have this thing, then you will probably not do all of them, if you are going deep into one direction and therefore, you will not probably know what you are missing, when you are trying to look for a solution deep down here. So it's a diversified portfolio in finance, you put your eggs in these baskets.

Q. The majority of the papers that are coming out now focus on pure deep learning. I am speaking from the perspective of papers in the area of NLP. Somehow I feel that these models, although being useful, will not be able to capture the intricacies of the human language. Does any other research area have this similar kind of problems?

NA: this is a concern that many people have. When you do things like deep learning, what it does is, it says that don't worry about the detail, I am a black box, you give me this, I will give it to you as a result. You don't worry about the details. The question is, are you using what's inside the box as the focus of your activity or you want to use it as a tool and you really have a bigger network, bigger edifice, this is just a small part of it. It's like there are times when many people who are discouraged from using calculators, why, coz people said, if you use calculator, your brain will go dead, coz you will not be exercising that aspect. However if you do the calculations and if you get answers to the calculations it's actually true that you do bigger things, you have larger formulations, these are just small parts of it. So the question is, it is not deep learning of calculators, what is it that they are making easier? And if whatever they are making easier is your playground, then it is a bad thing. Coz you are replacing your old thesis with a black box. Then it doesn't work. On the other hand if you are thinking of a much larger problem and this calculation is

taking 5 months for you, then you rather have something to get this problem out of the way and you come back to the real larger problem. So if you say my NLP is a deep learning problem then clearly all the intricacies of the natural language that you are referring to are buried into the box and you will never have access to them and you will be out of it coz this is what you wanted. The nuances of the language which are now lost because they are now part of the box but if you can fragment the box into pieces again might be deep learning such that your structure is still the same and the parts are replaced by boxes which you could care less about. If that's the case then you can play with your ideas much more efficiently and quickly coz you have taken away the labour of designing the branches and your area of interest is still captured in the structure that you have attacked.

PK: lets take some broader level questions like AI, many students had sent questions earlier to me, what kinds of things do you suggest students to explore or first to gain skills and then what kind of problems can be solvable or even attempted within the context of India using AI? Basically how do you gain skills to do AI and how do you apply these skills, what kind of problems do you see, food, and traffic all that you said earlier?

NA: let me give you examples of kind of problems that have been solved in the recent years in this one initiate, I am sure there are other people doing elsewhere. So one of our teams has, the degree to which AI is present in these problems varies. [disconnected] here is an example of a nice computational system that's solves a real world problem. We have a team led by IISc and BITS Hyderabad and CDAC and MS Vadodra University and what they have done is they have taken the data that is gathered about rainfall when it occurs, they already know the topography, they have collected the topography of the land, let's say, given a city, they have topographical data, they have railways data, they have the buildings data, where the buildings are, drainage systems information and then what they do is, as the rain starts to fall they make predictions about at what rate the water will accumulate in which part of the city. Since they have the topography and water flows downwards so they can now predict at what rate the water will accumulate or how many feet per minute or per hour so that they can make flood predictions. There is another

project in which, if you have communication infrastructure coming apart, coz of say earthquake, these people have developed boxes which you can throw, scatter across the affected area and then will act like towers where people who are buried under the rubble but their phones are still on, in the golden hours they can communicate not via old towers which are destroyed but by these boxes. And so it is very valuable coz people can tell where they are and you can hear their movement etc. Another project where internet has been set among boats, fisherman's boats away from the shore where there is no airtel or any other service. They have devices on their boats which get connected and then together the cluster now can send information to the shore with a narrow beam. [disconnected]

There are many others where one I was telling was of setting up of internet away from the shore. So now, fishermen know when they cross international borders, they may also know what fish is selling in the market thru the communication, and their families know that they are still alive even though they left two weeks ago. So there is very important societal need that is being served by this and this is very creative work. It's not something like picking up something from the market. Then there are projects like, estimating whether there is water underground, estimating which are the best places where you don't want to build so that aqua fare is charged to the maximum degree coz where the aqua fare is most accessible you don't want to stop the water flow. Estimating the quality of water, what's in it, CO2, arsenic, mercury etc. whatever problems might be in the water, estimating those, if you do network of water distribution then you tell there is leakage somewhere and alternatively is there pilferage, that means a large leakage which could not be coz of some cracks. So these are all problems that are very real. Transportation, suppose you have these violations that happen, 2 days ago there was a whole section on TV where they talked about problems with traffic. So can we do something about this? Just imagine for a second if your thesis made, just take one violation, just one and look at the impact on India, not to mention all the Africa and rest of Asia. And of course if you solve it, it won't be one problem coz your algorithm will not be custom made for one violation, they could do much more. And so it's really very obvious how to do

research, how to find thesis topics, especially if you are problems oriented. And the other nice thing is once you pick problems and if you interest lie in fundamental questions, you will find a reason to go into your cubby hole and do some theoretical stuff coz the problem motivated you. When you solve real problems they are not verticals they are horizontals, they are all kinds of challenges that are interrelated. Its upto you which ones you want to trace.

Q. Research in company versus research in PhD, what are the pros and cons?

NA: in a company you will be mandated to produce some output. If you are doing research on this product and you go one degree off, it's ok but if you go 60 degrees off, somebody will ask you, why do you think you will come back to this, it will take you into the wild. Theoretically you will be back again but the probability goes down. If you are doing the same thing in the university, they will not say will you come back to this problem, is this interesting, is this more interesting and if it is don't worry about what you set out to do, just take this. So in one case you are following your heart and in other case you are following your [unclear].

Q. What is the better strategy for an independent researcher who wishes to do foundational research? Look for a better solution to an already well documented problem, or exploring an entirely new application/domain? [disconnected]

PK: Replies can be found in earlier answers

Q. any good online resources for future researchers?

NA: Create a balance between how people thought about learning this subject before certain year and after certain year. Coz what's happening is like many other areas of investigation AI also has its waves. So there are sociological factors that work, if you just concentrate in a narrow window you will get exposed to in-depth [disconnected]

Q. How do you read papers efficiently and what are some good method or practices?

Q. On a lighter note, do you think that AI will take over the world?

Q. Is the future of research interdisciplinary?

NA: yes. But remember interdisciplinary is a relative concept, suppose science for whatever reason had not facilated knowledge into Physics, chemistry and math and psychology etc, these are too gross divider but if the division was not along this grid but slightly different grid then what we do today would have been interdisciplinary coz discipline boundaries are somewhat artificial and so if you shift them it becomes interdisciplinary but what you shift them from was a function of some arbitrariness in the past. So interdisciplinary will be essential coz you want to investigate every part of the stakes no matter where you try.

Q. How shall undergraduates approach their preparation for PhD?

NA: I can give you a pakka answer for this. When you are reading your textbook, reading a chapter, no matter how low level or high level, don't turn the page until you feel or identify with what is being said. You feel the gravity, feel the velocity, feel the temperature, and when you feel it, when you go to the next page, before you finish the book, you will be a PhD ready material.