

## A Humble Journey



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When I received the mail from Dr. Baldev Raj to write an article for the INAE Newsletter related to my childhood, education, mentorship, challenges met, etc., it got me thinking: Am I really the right kind of person to project before the upcoming generation? There are many people out there who are far more intelligent than I am, and who have shown much greater promise during their formative years than I have. In contrast, I never was a first-ranker in school or college. True, I had a reasonably good education in the Ramakrishna Mission School at Narendrapur, West Bengal, and in the Bengal Engineering College where I did my Bachelor's degree in Electrical Engineering. But I was never considered an "ace" student. I was more interested in things other than studies: I painted, I played many games, and I was deeply involved in students' activities. Friends did not see me studying much, and were pleasantly surprised when I managed to sail through the exams. The secret lay in a peculiar aspect of electrical engineering: It is possible to derive things from the first principles sitting in the exam hall, even though you may not have any clue what the right answer could be.

At IIT Delhi, where I did my Master's and Ph.D. degrees, it was the same story. I got involved in all sorts of activities. At the IITs, the intensely competitive atmosphere of inter-hostel championships extracts the best out of anybody who has some prior exposure to a cultural or sports activity. I was in a postgraduate hostel, where the number of such people was very small. So I had to take part in almost every activity. I was into music, arts, dramatics, and most of the sports. After starting to do Ph.D. work I added two: I started to learn the violin and Judo (what a combination!). So, again, I had very little time to do research.

I framed a strategy: I requested my supervisor Prof. S. C. Tripathy to allow me to choose my own topic of research. He consented. So I went to the library and spent hours looking up what new is happening in the horizon. I chose a topic on which my supervisor had no prior exposure. In the beginning he was not willing to let me work on that. But I somehow managed to convince him that it was a "doable" topic. So we reached an understanding: I would do the work independently and would periodically report to him the progress. In case the work fails, it will be entirely my responsibility and I would not blame him for the failure. Since the planned work was in the twilight zone between power systems and power electronics, he only advised me to get a co-supervisor from the area of power electronics. So I requested Prof. J. K. Chatterjee to be a co-supervisor, with the same understanding.

Thus freed from the problem of being micromanaged, I took responsibility of my own time management. I was in the thick of students' activities, and would schedule my research work as per my convenient timings, balancing the two priorities. This gave me very valuable training and experience in time management. I consider it an important factor behind the success that I have achieved. Most of my colleagues at IIT or IISER complain that they do not get adequate time to do research due to "teaching load", and they are so very busy doing these, that they get no time to think about the society at large. I have never had any problem in being involved in social work while doing science of the highest standard—thanks to the training in time management I acquired at an

early stage of my life. My involvement in extra-curricular activities also gave me exposure in handling people and situations.

The risk I took in choosing a new field somehow worked out. After the initial groping in the dark, I began to obtain new and promising results.

After two-and-a-half years of work, an advertisement for Lecturer's post at IIT Kharagpur was published in the newspapers. I applied casually (since an M.Tech degree was specified as the minimum qualification), without ever hoping to get it. I had no publication, and no Ph.D. degree. They had to judge on the basis of only the interview. Miraculously the interview went very well (they asked just the questions whose answers I happened to know), and I got the job. That was 1986.

I still remember the first day I entered the campus of IIT Kharagpur to join service. I stood silently before the large façade, overtaken by emotion, wondering if I really deserved this honour. I had spent my student life playfully, never spending much time on studies, and now I was faced with the challenge of teaching the best pupils and doing research of the highest standard. I was not sure that I was up to the mark. That day I made a pledge to myself. I gave myself a period of 10 years to prove my worth. At the end of the 10 years, I would make an honest assessment: If I proved myself fit to be a faculty member of an IIT, I would remain there. If I fail to make a mark, I would quit IIT and will move to some less demanding institution.

Thus started my journey at IIT Kharagpur. I felt indebted to IIT because it had allowed me to use its name as my place of affiliation. We did not have much else, and for us, it didn't matter. I just had a table and a chair in a room shared with another faculty member, and no lab of my own. At that time IIT had shortage of faculty accommodation and I got just a room in a guest house with a shared toilet. We were fine with it. Nowadays I see the younger colleagues behave as if they have done a great favour to the Institute by joining it, and now it was the duty of the Institute to satisfy their requirements. They keep talking about what the Institute has given them and what it should give them. Such thoughts never crossed our minds. IIT had given me a foothold to prove myself and that was enough. I was more concerned about what I was giving back in return, rather than what the IIT was giving me.

I had that concern about my role in the society also. The poor country was giving me a fat salary, and all the time I was asking myself if I served enough to justify it. So I tried to do something extra in the free time that I had in the weekends, by involving myself in science popularization work and such social service.

The first two years were tough, as I had to study a lot in order to teach. In addition, I had to work for my Ph.D. Fortunately I was not much dependent on guidance, and could work on my own. Every vacation I visited Delhi to report the progress to my supervisors. Finally I wrote up the thesis and submitted in 1987.

After finishing the Ph.D. and communicating a two-part paper out of this work, I decided to change the area of work. My reasoning was: If I continued to work in the same area, others would think that I have failed to come out of the cradle of my supervisors. So I started looking for a new area of research. The criteria of choice were as follows. Firstly it should be a problem in which little work has been done so far. Secondly, it should have the promise of being important in future. Thirdly, it should be doable within the resource available at IIT Kharagpur at that time. Those days we did not get much of a starting grant, and had to set up experiments at a corner of a teaching laboratory. So I could not choose an area that places great demand on experimental or computational resources.

With such constraints it was difficult to home on to a subject of research. I kept looking at various problems, doing a bit of work on this and that to keep the paper-clock ticking. Finally, around 1990-91, I found what I was looking for.

By then only two papers had reported peculiar nonlinear phenomena including the occurrence of chaos in power electronic circuits. The problem satisfied all the criteria I had set. Around that time I got my first Ph.D. student. So I decided to explore the area. By the time the student submitted the Ph.D. thesis in 1995, we managed to publish a couple of IEEE papers out of the work.

To me, that was not enough. My self-imposed deadline of 10 years was nearing, and as yet I had not achieved anything that would satisfy my conscience. I was not yet worthy of the IIT.

But there was something strange in the results we had obtained. By then I had read up much of bifurcation and chaos theory, but still I failed to explain the instabilities (or bifurcations) we observed in power electronic circuits. These bifurcations did not fall into any of the categories known till then. In the papers I had just reported what we observed and left it at that. I had a gut feeling that there is something big in it, and decided to explore it myself.

At that time I got the BOYSCAST Fellowship of the DST, and went to work with the physicists and mathematicians of the University of Maryland for four months. There I got to learn the tools and techniques used by the insiders of the field. I used these to explore the problem I had in mind. I discovered that the bifurcations I observed in power electronic circuits belonged to a new class called border collision bifurcation. Prof. Yorke's group at Maryland had investigated piecewise smooth maps as a mathematical possibility, and had observed similar type of bifurcations. At that time no physical example of such bifurcations was known. The bifurcations we had observed in power electronic circuits were in fact the first examples reported in physical systems.

This discovery posed a great many new questions. What is the class of physical systems where this kind of bifurcations can occur? Can the observed bifurcations be properly explained on the basis of the available theory? These questions demanded answers, but the period of my leave came to an end and I returned to the IIT. I continued to work on the problem alone, working feverishly as my self-imposed deadline was nearing. I had married in December 1995, and had to leave my wife at home during my trip to Maryland. After the return also, I was not being able to give her much time as I was returning home past midnight almost every day. I am indebted to her for the understanding and cooperation at that important juncture of my life.

Over the next few months I managed to prove that all switching systems would give rise to piecewise smooth maps on discrete-time modelling, and hence the new type of bifurcations should be observable in all such systems. Now, systems which have some kind of switching action are quite common in science and engineering. This meant that the theory of border collision bifurcation will have very wide-spread application. But the problem was that the mathematical theory developed until that time was in a very premature stage, and much work had to be done in order to give it a shape that can be applied to physical problems.

Prof. Yorke invited me the next summer to visit Maryland to work on this problem. During that two-month period we initiated the work, but could not progress much within that short period. I completed the work after coming back to India. The papers coming out of this effort proved to be of enormous impact. One paper was published in Physical Review Letters, one in Physical Review E, and three in the IEEE Transactions on Circuits & Systems.

My conscience was cleared. I had proved myself worthy of being in the faculty of IIT, and decided to stay on.

Many people have expressed surprise why I did not continue the collaboration after these pieces of work. The problem of working with famous people is that others tend to assume that the basic idea came from the most famous person among the authors. At some stage it is important to come out of the shadow, to establish oneself as an independent researcher. That can be done only by publishing papers of similar quality on your own, or with your students.

When I established myself as a leader in the field, younger researchers of different foreign universities started seeking my help in solving problems, and that resulted in further collaborative works. But I made sure that in these collaborations I am the senior person involved, and the others benefit from my ideas, not the other way round.

Recognition took some time to come by. Until 1998, I was ignored in the successive promotion exercises, and remained in the lowest cadre for more than 12 years. I did not mind that at all, because in my own assessment, I was yet to prove my worth. True, it hurts when you see contemporaries promoted while you are left behind. But I had confidence in the system: If you are good, it is impossible to ignore you for long. So I kept working silently. Finally when my work was recognized, I did not have to look back. The Bhatnagar prize and the fellowships of the INAE, IASc, and the INSA came the year my name was proposed, and I never had to wait a year.

I feel it is important to make an objective and critical assessment of oneself all the time, and to keep alive a sense of dissatisfaction with oneself. The moment you develop a high opinion about yourself, you are likely to become a victim of your own ego, and would not be able to produce much in life. It is important to be your greatest critic.

It is this dissatisfaction with me that drove me to leave IIT Kharagpur in 2009. By then I had won most of the awards and laurels that one covets in life, and there was very little to achieve further. Life was becoming too cosy, devoid of any challenge. In this situation, most people would stop being productive and would spend the rest of life basking in the past glory. I found that unacceptable. So I moved to the newly established IISER to force myself into the challenge of building a new institution, learning and teaching subjects I never studied as a student, where I will have to take up new research problems. I am finding it challenging, and am finding enjoyment in the challenge.