Report on the 2015 Jubilee Professorship Lectures by Madhu Sudan
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It was a pleasure and an honor to visit India from December 27, 2015 to January 9, 2015 as the 2015 Jubilee Professor of the Indian Academy of Sciences. Lectures in the visit varied from in-depth expositions of current areas of research aimed at experts in the field to public lectures exposing the role of Mathematics in applied fields such as Computer Science and Communication. The visit also coincided with the 100th anniversary of the birth of the father of Information Theory, Claude Shannon. The premier institutions, IIT Bombay and TIFR, co-hosted a workshop honoring this event, and I was delighted to be able to join these celebrations. Below I will briefly discuss the various lectures I gave, followed by a report on the interactions with the scientists as well as budding scholars.

Summary of lectures

The series of lectures, organized by the kind efforts of Profs. R.K. Shyamasundar and N. Limaye of IIT Bombay, included a series of lectures on "Property Testing and Affine Invariance" at IIT Bombay, a lecture on Communication Amid Uncertainty at TIFR as part of the BITS: Bombay Information Theory Symposium honoring the 100th anniversary of Claude Shannon, and a Public Lecture on "Reliable Meaningful Communication" hosted by IISER Pune, and a Public Lecture on "Mathematics, Proofs and Computation" at CBS in Mumbai.

Even though the intended sophistication of the audience varied across the lectures, I would like to stress that the topics themselves are each worthy of public lectures, or in-depth detailed ones. The topics capture natural problems that anyone working with computers or phones encounters (though often they don't think about these issues) and as a result the questions easily capture the imagination of rising scholars. The solutions to these questions involve clever mathematical modeling and inspired use of mathematical tools; but are not necessarily the "hardest" mathematics to understand or appreciate. The combination is what I tried to capture in the spectrum of lectures. Let me now jump into some details.

Property Testing and Affine Invariance:

A common challenge in modern use of computers is that one has massive amounts of data and one is seeking to know if there is some pattern in this massive data. For the common person, such challenges emerge in trying to separate spam emails from the rest of their emails – can one find the pattern in the spam – is there one? For advanced scientists such problems take other forms: For example a geneticist exploring the genes of a series of individual exhibiting a particular disease may ask, is there a pattern exhibited by the genes of the people exhibiting this disorder? Given any task that one may wish to solve efficiently using computers, Theoretical Computer Science is the field that attempts to discover the fastest algorithms to solve the given task. The tasks mentioned above form a special subclass of general tasks, since they ask questions of the form "is there some pattern that explains most of the data"? These are tasks where we expect not to look at all the data in order to discover the pattern; and indeed we may even hope that we can determine quickly if there is a pattern to be discovered even before having enough information to determine the exact pattern. This is the subject of an active area of research, called Property Testing, within theoretical computer science. This series of talks introduced this topic to

researchers from Mathematics and Computer Science at IIT Bombay, and delved into some specific technical topics within.

Communication Amid Uncertainty:

Communication between digital devices (computers, cell phones) follow very rigidly prescribed rules that specify what each transmitted bit means and how to act based on these bits. This leads to very compact communication schemes that use the communication medium very efficiently. On the other hand it is also very unstable. A slight change in one of the communicating devices or protocols leads incorrect interpretation of messages and systems either crash or have to be updated before resuming their normal services. Is this instability inherent? A contrasting setting is communication among humans where the rules of interaction are not rigidly laid out and yet humans manages to communicate (though not as efficiently as computers do). What are the mathematical foundations behind communication with such "soft" rules? In this talk, given to researchers from Electrical Engineering, Computer Science and Mathematics at the TIFR, I explained some of our research exploring these questions. The central thesis behind this line of work is that natural communication aims to model and resolve uncertainty of the communicating agents about each other. We explore how this attempt to deal with uncertainty trades off against the desire to be efficient.

Reliable Meaningful Communication:

In this public lecture given at IISER Pune, I explore the challenge of reliable communication. This is a problem that was faced by engineers and scientists in the 1940s at the advent of the digital age. Communication and Storage media are never 100% reliable, and the challenge to the researchers was: "How can information be stored more reliably than the medium permits?" I described the seminal work of Claude Shannon from 1948, and quickly covered some of the challenges posed by the increase in volumes of data being stored and communicated, and some of the algorithmic solutions to these challenges. The main goal of this talk was to describe how mathematics, sometimes quite simple, can play a crucial role in the development of technology.

Mathematics, Proofs and Computation:

In this public lecture given at CSB in Mumbai, I described the history of logic and proofs, and how it has brought mathematics and computer science together. The point to be stressed here is that the relationship between computing and proofs, is not that computers can assist in the search for proofs, but rather that the very concept of a proof is a computational one. What makes a proof different and more useful than just the theorem statement is that proofs make the task of verification "easy" and "easiness" is a computational notion – a mental task is easy if it takes few steps and this is exactly the notion of computational complexity. In the talk I described how this connection to computation has remained a source of great inspiration to computer scientists and how it takes us to the famous "P vs NP" problem, and to modern variations of this question.

Summary of Interactions

I would separate my interactions with the Indian scientific community into three pieces: (1) Interactions with established researchers within my discipline, (2) Interdisciplinary interactions with established researchers and (3) Interactions with students and junior researchers.

State of research in theoretical computer science

Through the course of my meetings this time with researchers from IIT Bombay and TIFR, as also from previous visits to IISc., Chennai Math Institute, and IITs at Chennai, Delhi, Kanpur and Kharagpur, I have been getting increasingly impressed with the quality of the research that is going on here. What is even more impressive is that the young people being recruited seem to be completely masters of their field (and sometimes even masters of my field)! I used to come to India with the expectation that I will be bringing the Indian researchers up to speed on the state of the art in the world. I now no longer come with this illusion. By now I expect that the young researchers will tell me what the latest developments in the field are and explain these developments from their own unique perspective. I certainly experienced this during the course of my meetings at IIT and TIFR. Indeed some of the most exciting results here were presented not by the established researchers in the field, but by their Ph.D. students, which was a very refreshing feeling.

On interdisciplinary research

Increasingly I feel that the best research in the world is happening at the boundaries and rarely, but even more excitingly, far from the boundaries of established research domains. My own research tends to fall in the area between the domains of Mathematics, Computer Science and Electrical Engineering. I have always felt that the boundaries between these areas have been impediments to faster progress in research. In my recent visit, I was positively impressed by the fact that these boundaries are indeed becoming more porous and the researchers, especially from the younger generation, are actively moving between the areas and working to port ideas from one field to the other. My hosts at IIT Bombay have always included Mathematicians and Computer Scientists. Indeed the IITB Mathematics department has even hired faculty members that are principally theoretical computer scientists. (In the US, the MIT Mathematics Department has included computer scientists since the early 80s, and by now many Math departments have computer scientists on their faculty. Indeed three of my former students hold joint positions in Math and CS departments.) I think this is a trend that needs to be encouraged since the result improves the pace of progress in both mathematics and computer science! The Shannon Centennial workshop (BITS) organized jointly by IITB and TIFR was another positive example of such interdisciplinary collaboration --- the speakers included a healthy mix of computer scientists, mathematicians and information theorists (the final category being typically considered a part of electrical engineering). It is great to see that Indian research communities are also shedding some of the past disciplinary boundaries and expanding the scope of their research. I look forward to seeing how this trend shapes up in the years to come.

Interactions with students and young researchers

Perhaps the most personally satisfying component of the Jubilee Professorship tour was the visit to the Centre of Excellence in Basic Sciences (CBS) in Mumbai. Here I was given the opportunity to first meet with the many junior researchers (in early stages of their post-Ph.D. career, and then invited to participate in the "Science Club" – an hour or so of interaction with the students at CBS. The interaction with the junior researchers already led to some interesting questions: "What should be the right composition of senior-to-mid-junior researchers for a successful research organization?", "How can we cope with, or even leverage, the special circumstances in India, to attract the best researchers?'. The

interaction with the students was even more robust. About half of the time was spent on questions and answers about the talk itself. This would have been unsurprising if the audience had been all mathematicians or computer scientists. But the majority of the questions came from the other audience and they were all penetrating questions. Nevertheless, at my urging the questions moved on to more general topics and again it led to a lively series of questions: “What if I want to switch areas – when is it too late?” “What can I do to find help on specific questions coming from independent study?” “What is the difference between research in US and India?” “What is the difference between research laboratories and universities? Do I recommend one over the other?” (These questions are being recalled from memory and so paraphrased in my words.)

I won’t repeat my answers here, but suffices to say that the students seemed to be hanging on to every word I said. From my perspective this was a very inspiring meeting. The students seemed every bit as smart and creative as the ones I remembered from my days at IIT Delhi, but they also seemed much more attuned to the idea of carrying out research. It was also very indicative of the vast pool of talent in India and further emphasizes the importance of the creation of the right infrastructures to take advantage of this talent and steer them towards the big challenges. I should also remark that I felt it heartwarming to be introduced before my talk by an undergraduate student from Physics -

Conclusions

I will simply conclude by saying I was grateful to have this opportunity, thanks to the Jubilee Professorship, to engage with this diverse mix of science education and research institutions. As I look back over the years, India has definitely made big strides in academic research in specific fields and it is impressive to see the vast talent of computer scientists and mathematicians that are now at the forefront of research in their respective fields world-wide. What still seems a bit lagging is the active connection with the industries. I have a feeling that this might be the next stage of progress and I look forward seeing this happen over the coming decades.